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ABSTRACT *(MAXIMUM 200 WORDS)*

This concept describes the potential for Artificial Intelligence (AI) employment within existing U.S. Marine Corps (USMC) intelligence systems and doctrine to streamline the deliberate intelligence staff processes required to create situational understanding at the tactical level of war. Specifically, it proposes the phased integration of AI technologies to automate increasingly complex components of the Intelligence Preparation of the Battlefield process on time horizons consistent with anticipated technological maturation.

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MASTER OF MILITARY STUDIES

TITLE:
AUTOMATING INTELLIGENCE PREPARATION OF BATTLESPACE: AN ENABLING CONCEPT FOR INTELLIGENCE

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

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Executive Summary

Title: Automating Intelligence Preparation of Battlespace: An Enabling Concept for Intelligence

Author: MAJ LaRue, John B.

Automating Intelligence Preparation of Battlespace (IPB): An Enabling Concept for Intelligence describes Artificial Intelligence (AI) employment within existing U.S. Marine Corps (USMC) intelligence systems and doctrine to streamline the deliberate intelligence staff processes required to create situational understanding at the tactical level of war. The increasing pace, lethality, and complexity of the modern operating environment, coupled with a massive increase in collected sensor data, challenges intelligence staffs to function at the speed necessary to support maneuver warfare. To provide situational understanding at the pace of modern war, this concept proposes the phased integration of AI technologies to automate increasingly complex components of the IPB process on time horizons consistent with anticipated technological maturation. In the near term, *Automating IPB* proposes a mix of expert system and neural network machine learning methodologies to achieve initial functionality. The machine learning-driven processes, will require significant amounts of relevant data to establish and improve their algorithms. This concept therefore will reach full potential only if fielded as part of a DoD-wide effort that leverages the common, interoperable command systems and vast, cloud-based data sets.

DISCLAIMER

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PURPOSE

Automating Intelligence Preparation of Battlespace (IPB) is an enabling concept for tactical and operational intelligence. It proposes how the Marine Corps may employ current and emerging AI within existing doctrine and force structure to improve the speed, precision, and certainty of intelligence staff processes critical to military planning. This concept describes the IPB functions with the greatest potential for partial or complete automation, identifies requisite AI capabilities, and anticipates material and non-material solutions for integration. Finally, *Automating IPB* is intended to provoke discussion on how the increasing use of AI-enabled situational understanding and automated probabilistic decision tools will affect command in war.

TIME HORIZONS, ASSUMPTIONS, AND RISK

Automating IPB advocates the phased incorporation of existing and emerging AI methodologies. This model anticipates 24 months from solicitation to initial operational capability with the eventual integration of emerging methodologies as they become viable.

- *Automating IPB* will achieve limited functionality using existing AI 'first wave' and 'second wave' methodologies through solicitation with commercial vendors. Current DoD vehicles[1] for commercial outreach model a 24-month timeline for prototyping, developing, and fielding such commercial hardware and software methodologies.[2] *Automating IPB* therefore anticipates at least a 24-month timeline from initial solicitation to limited initial operational capability fielding.

[1] The Defense Innovation Unit Experimental (DIUX) employs new commercial solicitation processes for competitive contracts with commercial vendors.

[2] *Artificial Intelligence Initiatives Within the Defense Innovation Unit: Testimony Before the Senate Armed Services Committee Subcommittee on Emerging Threats and Capabilities,* 116th Cong., (2019) (Statement of Michael Brown. Director, Defense Innovation Unit), 2.

- Full capability as this concept describes incorporates AI methodologies under current research and development with uncertain timelines for viability. Emerging AI methodologies such as schema learning, Explainable AI (XAI), and Machine Common Sense (MCS), will significantly expand *Automating IPB*'s capability as functional concept. The Defense Advanced Research Project Agency's (DARPA) Artificial Intelligence Exploration initiative functions on an 18-month interval to even demonstrate the feasibility of emerging AI concepts.[3]

Automating IPB requires access to vast repositories of inter-discipline and inter-agency data that is organized, labeled, and accessible. It relies on state-of-the-art AI machine learning methodologies such as neural network technology, which requires significant data to perform the learning processes that build certainty in its outputs. *Automating IPB* necessarily makes significant assumptions in key infrastructure, resource, and technology areas:

- The Intelligence Community (IC) will successfully transition to a common infrastructure[4] that replaces agency-centric systems and facilitates aggregate data accessibility across the IC.
- The DoD will field cloud-based network systems[5] that enable distributed access at lower echelons to vast labeled data repositories.

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[3] *DARPA's Seminal Role in the Field of Artificial Intelligence: Testimony before The Emerging Threats and Capabilities Subcommittee, U.S. Senate,* 116th Cong., 2019 (statement of Dr. Peter Highnam, Deputy Director, DARPA).
[4] Office of the Director of National Intelligence, *IC ITE Fact Sheet.* (Mclean. VA: Office of the Director of National Intelligence, 2019), 1, https://www.dni.gov/files/documents/IC%20ITE%20Fact%20Sheet.pdf
[5] Sydney Fredberg, "War Cloud: JEDI to Deploy Backpack Servers to Front Line," *Breaking Defense,* April 2018, https://breakingdefense.com/2018/04/war-cloud-jedi-to-deploy-backpack-servers-to-front-line/ .

- Marine Corps concepts for Information Battle Management Command Systems (IBMCS)[6] can adaptably integrate new software without introducing additional hardware requirements.
- Data labeling and validation can be integrated with routine intelligence staff training in both synthetic training environments and maneuver training exercises with minimal additional outsourcing requirements.

This enabling concept assumes risk in the areas of technology and security:

- The concept is vulnerable to training maladaptation which may occur through erroneously labeled data, human bias injection though internally-sourced data labeling, and incomplete data sets.
- Reliance on commercial solicitation increases vulnerability to threat actor compromise and malicious training data.[7]
- Human trust in the outputs as decision support tools. *Automating IPB* applies objective AI methodologies to automate a process traditionally grounded in subjective, human assessments. Removing direct human supervision at the input level risks losing the expertise and contextual knowledge required to assess AI process accuracy and recognize system change.

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[6] Headquarters, US Marine Corps. *Marine Air Ground Task Force Information Operations Concept of Employment* (Washington, DC: Headquarters, US Marine Corps, July 6, 2017), 34.

[7] Office of the Director of National Intelligence, *AI: Using standards to mitigate Risk* (Mclean. VA: Office of the Director of National Intelligence, 2019), 1, https://www.dni.gov/files/PE/Documents/2018_AEP-AI.pdf.

MILITARY PROBLEM

Strategic Context

AI capability has expanded massively since 2015, with commensurate social, economic, and security implications. AI itself is a broad concept encompassing many technologies, disciplines, and capabilities. Fundamentally, it characterizes any device or system capabile of emulating varying degrees of human pattern recognition, experiential learning, sense-making, and knowledge abstraction.[8] The AI field of Machine Learning (ML), combined with greater accessibility to data, is primarily behind this growth of capability and potential, with development accelerating at a far greater rate than previously anticipated.[9] Reinforced by new ML methodologies, AI promises to be at least as transformative to national security as aircraft, nuclear weapons, computers, and biotechnology.[10]

The U.S. and its competitors are now locked in a whole-of-government race to realize this transformative potential. The U.S., despite the conspicuous lack of policy emphasis until 2019, is widely acknowledged as the global leader in AI development due it deeply powerful private sector innovation base.[11] China, however, declared AI development and implementation a national priority as early as 2016 with its *13th 5-year Plan* and *Next Generation Artificial*

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[8] Office of the Director of National Intelligence, *AI: Using standards to mitigate Risk* (Mclean. VA: Office of the Director of National Intelligence, 2019), 4, https://www.dni.gov/files/PE/Documents/2018_AEP-AI.pdf.
[9] Greg Allen and Taniel Chan, *Artificial Intelligence and National Security* (Cambridge, MA: The Belfer Center for Science and International Affairs, 2017), https://www.belfercenter.org/sites/default/files/files/publication/AI%20NatSec%20-%20final.pdf.
[10] Ibid., 1.
[11] Darrell M. West and John R. Allen, *How Artificial Intelligence is Transforming the World*, Brookings, April 2018, https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/.

Intelligence Plan.[12] The U.S. is catching up. In February, 2019, the executive order *Maintaining American Leadership in Artificial Intelligence* for the first time provided directive policy guidance for AI as a collaborative public and private national effort. [13]

The Department of Defense followed shortly with its first Artificial Intelligence Strategy. The DoD strategy targets numerous areas for AI automation or facilitation. Most relevant to *Automating IPB* is the DoD AI Strategy's guidance to improve situational awareness and decision making.[14] The visible early efforts in this area are the Algorithmic Warfare Cross-Functional Team's (AFWCT) Project Maven that leverages AI and machine learning integration to Process, Exploit, and Disseminate (PED)[15] the flood of imagery data that DoD intelligence systems are able to collect. It the Geospatial Intelligence discipline alone, the National Geospatial Intelligence Agency estimates the amount of collected data will grow by a factor of one million over the next 5 years, and seeks to automate at least 75 percent of its PED.[16] Project Maven, however, is only the beginning for as the DoD's Joint Artificial Intelligence Center is leading data aggregation and labeling for the department while the Defense Advanced Research Projects Agency and the Defense Innovation Unit Experimental lead investment and research.[17]

The Intelligence Problem

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12 *Artificial Intelligence Initiatives., 3.*

13 US President, Executive Order, "Maintaining American Leadership in Artificial Intelligence", Exec. Order No. 13859, 84 Fed. Reg. 3967 (February 2019), https://www.whitehouse.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/

14 US Department of Defense, *SUMMARY OF THE 2018 DEPARTMENT OF DEFENSE ARTIFICIAL INTELLIGENCE STRATEGY: Harnessing AI to Advance Our Security and Prosperity* (Washington, DC: Office of the Secretary of Defense), 11.

15 US Deputy Secretary of Defense, *Establishment of an Algorithmic Warfare Cross-Functional Team (Project Maven),* Washington, DC: Office of the Secretary of Defense, April, 2017.

16 Colin Clark, "Cardillo: 1 Million Times More GEOINT Data in 5 Years," *Breaking Defense*, June 2017, https://breakingdefense.com/2017/06/cardillo-1-million-times-more-geoint-data-in-5-years/.

17 Sydney Freedberg, "Show me the Data: The Pentagon's Two-Pronged AI Plan," *Breaking Defense*, December 2018, https://breakingdefense.com/2018/12/show-me-the-data-the-pentagons-two-pronged-ai-plan/.

"Intelligence provides knowledge of the enemy and the battlespace that permits the commander to reduce uncertainty, identify opportunities for success, assess risk, outline intent, and make decisions that provide focus, generate speed and tempo, and achieve decisive results."

-MCWP 2-10 *Intelligence Operations*

The Intelligence warfighting function is responsible for solving the most ancient leadership problem in war- the struggle between the amount of information needed to make decisions and the ability to provide it.[18] As available information has increased, however, certainty in command has not. National agencies may be awash in data but combat units are drowning in it. Intelligence sections at Marine Air Ground Task Forces (MAGTFs) consume information and intelligence from numerous sources to create the basic tool for commanders to understand their environment- IPB. IPB is a detailed staff function populated with tedious analysis and recurring objective assessments. Across the DOTMLPF-P,[19] however, the intelligence warfighting function is unprepared to complete this task at the anticipated pace of modern conflict. MAGTFs must now conduct intelligence tasks in the traditional domains of land, sea, air, space, and cyberspace while adding the information environment and electromagnetic spectrum.[20] The new Marine Corps Operating Concept compounds this already significant analytical responsibility by adding intelligence support to help commanders conceptualize and conduct "maneuver in the cognitive domain."[21] The amount of information collected- from traditional intelligence sources, reconnaissance sensors, and combat data from

[18] Martin Van Creveld, *Command in War* (Cambridge, Massachusetts: Harvard University Press, 1985), 265.
[19] DOTMLPF- Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities- Policy
[20] Headquarters, US Marine Corps. *Marine Air Ground Task Force Information Operations Concept of Employment* (Washington, DC: Headquarters, US Marine Corps, July 6, 2017), 21.
[21]Headquarters, US Marine Corps, *Marine Corps Operating Concept, 2016* (Washington, DC: Headquarters, US Marine Corps, 2016) https://www.mccdc.marines.mil/Portals/172/Docs/MCCDC/young/MCCDC-YH/document/final/Marine%20Corps%20Operating%20Concept%20Sept%202016.pdf?ver=2016-09-28-083439-483, 8.

units developing their unique local situation- threatens to completely outstrip the capacity of small S-2 sections to properly synthesize with the rapidity needed to inform the increasingly complex decisions in modern maneuver warfare.

Emerging concepts such as Expeditionary Advanced Base Operations (EABO) only compound the shortfall. Distributed lethality from numerous expeditionary, self-contained units with a greater number of sensors[22] will require distributed situational understanding, placing even greater demands on limited available intelligence personnel.

A Historical Case Study: (Artificial) Intelligence is for Commanders? What the U.S. Army's Operational Intelligence Evolution Suggests About AI's Coming Impact on Combat Intelligence Processes

What full AI integration will look like- how it will affect existing institutions, processes, and doctrine- remains to be answered. Fundamentally, these AI efforts seek to address the most ancient problem of leadership in war- the struggle between the amount of information needed to make decisions and the ability to provide it.[23] For insight toward how AI will affect existing structures and methods, it is therefore useful therefore to consider the evolution of U.S. Army and Marine Corps operational intelligence doctrine in this timeless race to create certainty on the battlefield. Now known as Intelligence Preparation of the Battlefield (IPB), the four-step process is designed to delimit the battlespace, identify battlespace effects, quantify the threat, and determine probable threat courses of action.[24] It is the primary staff output through which mission variables (environmental, enemy, etc.) are analyzed to support the commander's visualization of the

[22] United States Marine Corps, EABO Concept https://www.candp.marines.mil/Concepts/Subordinate-Operating-Concepts/Expeditionary-Advanced-Base-Operations/
[23] Martin Van Creveld, *Command in War* (Cambridge, Massachusetts: Harvard University Press, 1985), 265.
[24] ATP 2-01.3 Intelligence Preparation of the Battlefield/Battlespace, Headquarters, Department of the Army, November 2014.

battlefield. It is a predictive tool, necessitating that the intelligence officer, in coordination with the staff, identify the enemy's 'most likely' and 'most dangerous' courses of action for consumption by the commander.[25] From Army and Marine Corps tactical processes to Joint operational doctrine, the predictive model is everywhere the foundation of intelligence support to maneuver and largely not given a second thought by either its practitioners or consumers. It was not always this way. The history of the IPB process and its predecessors is one of recurring oscillation between what is now the current, subjective emphasis on predictive analysis, and an objective emphasis on a description of the situation and enemy capabilities. This case study seeks to address the causal factors that drove this evolution. The current IPB is a direct result of the growth in battlefield information, a more dynamic operational environment, and above all the need to support emerging doctrine conceived by a new generation of leaders.

The American Expeditionary Force went to war in 1917 with a predictive model of operational and tactical intelligence remarkably similar to the present. Known informally as the 'Intentions Model,' it was based on the intelligence staff developing hypotheses to describe enemy probable "mission and intentions."[26] This method did not function well in wartime and did not survive introspection during the inter-war years. It was finally eradicated as Army intellectual and doctrine-producing centers became populated with First World War veterans. As one inter-war Command and General Staff College professor and veteran of the last conflict lamented, the Intentions Model introduced an artificial element of certainty where there was none, and that an analysis of enemy capabilities should include "all possible enemy maneuvers rather have it less vague and exclude a possible enemy line of action."[27] In essence, the Intentions Model delegated

[25] Ibid., 114.
[26] Edwin E. Schwien, *Combat Intelligence: Its Acquisition and Transmission* (Washington, DC: The Infantry Journal Inc, 1936), 10.
[27] Ibid., 9.

the *subjective* analysis of *objective* facts from the commander to a less experienced, narrowly focused staff officer.

The Intentions model soon gave way to the 'Combat Intelligence' a capabilities-based, descriptive system that the Army carried into the Second World War. In this system, military intelligence was the product of processed information to create an objective picture of the enemy and environment when applied to an area of military operations. Tactical intelligence began with contact, confirmed enemy capabilities, and developed closely with the friendly situation. It was used by the commander to make tactical decisions in near real time.[28] The intelligence officer, or S-2's role shifted from predicting enemy intentions as a senior analyst to integrating all the capabilities of the intelligence warfighting function. He and his section identified enemy capabilities based on his running situation map that could comprise and exhaustive list of possible 'enemy lines of action' that should be prioritize and provided to the commander as part of the intelligence estimate.[29] The commander then considered these capabilities in light of what possible enemy courses of action the threat was physically capable of carrying out. Therefore, while the capabilities model did include an element of predictive analysis, it was limited. Determining which capability the enemy was most likely to employ was not a directed task for the S-2 in preparing the intelligence estimate, but conditional based on the facts available and the intelligence officer's experience.[30]

The temptation to distil the capabilities model to hypothetical enemy intentions never disappeared. As the post-war Lovett Committee found in its study of War Department Intelligence Activities, intelligence officers continually attempted to short-cut the capabilities system to predict

[28] Robert R. Glass and Phillip B. Davidson, *Intelligence is for Commanders* (Harrisburg, PA: The Telegraph Press, 1948), 4.
[29] Ibid., 50.
[30] Ibid., 59

enemy intentions and provide commanders with specific assessments of what the enemy *would* do, as opposed to the range of what the enemy *could* do.[31] This was enough of a concern for the U.S. Army Command and General Staff College Commandant in 1948 to commission a survey of World War II general officers to determine if G-2s should predict enemy intentions instead of providing commanders with an objective list of fact-based capabilities. The answer from 35 of 35 respondents was 'no.'[32]

The capabilities system survived conceptually intact under different names through the Korean and Vietnam Wars. Then, something interesting happened- the predictive emphasis on the intentions model began to slowly reappear in doctrine. The 1973 revision of the Field Manual 30-5 "Combat Intelligence" for the first time specifically directed intelligence officers to create, and rank possible enemy courses of action by probability to identify, and expand, a most likely course of action.[33] By 1975, the United States Army Intelligence School made a decisive return to the predictive model in the new concept of IPB.[34] While the core intelligence process underpinning IPB had been present since the 1930s, the divergence from wartime experience in major conflict and unabashed enthusiasm for predictive, intentions-based, assessments warrants attention.

Were the lessons of large-scale mechanized maneuver conflict forgotten? By the middle of the 1970s, a new generation of officers was rising to prominence in the Army's Training and Doctrine Command (TRADOC) as the World War II generation began first to age out their uniformed leadership positions, and then out of their subsequent careers as civilian instructors and doctrine-writers. In 1977, General Donn Starry took command of TRADOC, succeeding General

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[31] Richard Quirk, "Seeking a Theory of Tactical Intelligence to Support AirLand Battle," Monograph, (Fort Leavenworth, School of Advanced Military Studies, 2 December 1985), 6.
[32] Ibid., 6.
[33] FM 30-5 *Combat Intelligence*, Headquarters, Department of the Army, October, 1973), J-10.
[34] Collin Agee, "Intelligence Preparation of the Battlefield: One Size Fits All?" Monograph, (Fort Leavenworth, School of Advanced Military Studies, 1991), 5.

William Depuy. Depuy was the final TRADOC commander who served as an officer during the Second World War.[35] Similarly, the project officers responsible for writing emerging doctrine that drove the 1981 transition from Active Defense to AirLand Battle were not Second World War or Korean War veterans.[36] IPB and the definitive return to a predictive model of intelligence coincided temporally with the handoff from those hardened in the Second World War to those tempered in Vietnam. However, the transition to predictive intelligence, as indicated in mid-1970s intelligence doctrine, was already underway before TRADOC changed hands. The generational change was certainly an enabling variable that accelerated the transition to a predicative intelligence model, but it was not the only cause.

The Army of 1975, compared to that of 1945, was awash in information. The increased complexity of weapons and communications systems, to say nothing of intelligence gathering capability, was significant. As Van Creveld calculated, the Army of 1963 required roughly twenty times as much information to effectively command a formation of equivalent size to its 1945 counterpart. In his words, as the complexity of units and environments grows, "the amount of information needed to coordinate their performance grows not arithmetically, but geometrically."[37] Army intelligence in the Vietnam environment met with mixed results, struggling to process the amount of information collected in time to provide intelligence that enabled commanders.[38] If existing intelligence processes, even executed by growing, increasingly automation-enabled staffs, could not keep up with the amount of information required in slow to mid-paced conflict like Vietnam, what would happen when they were applied to fast-paced maneuver environment in Europe?

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[35] John L. Romjue, "From Active Defense to AirLand Battle: The Development of Army Doctrine 1973-1982," Monograph, (Fort Munroe, Virginia: United States Army Training and Doctrine Command, June 1984), 14.
[36] Ibid., 45.
[37] Van Creveld, Command., 235.
[38] Quirk, "Seeking a Theory., 19.

It was the doctrinal renaissance of the 1970s and early 1980s that sought to answer this question- first with Active Defense, and finally AirLand Battle. Developed throughout the early 1970s and adopted in 1976, Active Defense recognized the command system requirements and pace of contemporary conflict coupled with a significant NATO inferiority in ground capability.[39] It was a reactive doctrine predicated on massing overwhelming combat power at narrow, decisive points.[40] Intelligence, therefore, had to anticipate where highly mobile Warsaw Pact formations would break through.

A more aggressive doctrine soon placed greater emphasis on intelligence to provide predictive assessments. "Air-land battle" was already evolving as a Joint warfighting theory concurrent with Active Defense and was approved as a concept in 1981.[41] Developed as a reaction to what was seen as the pessimism and political unfeasibility of Active Defense,[42] AirLand Battle was a proactive fighting doctrine that sought to regain the initiative in a potential confrontation with overwhelming Soviet mechanized formations. AirLand Battle was complex, fast paced, and sought to achieve an unprecedented synchronization of U.S. combat power to win. In simultaneous, deep attacks against high value targets in the Soviet first and second echelons, AirLand battle required precise 'time windows' where enemy capabilities and formations could be targeted.[43] The Military Decision Making Process (MDMP) was then conceived as the vehicle that would integrate complex command staff planning at the speed required to carry out AirLand Battle. IPB and a predictive model of enemy intentions were therefore essential to provide the first assumption in a series of "successive assumptions"[44] that formed the basis for the new model of

[39] Romjue, "From Active Defense," 7.
[40] Ibid., 8.
[41] FM 100-5 *Operations* (Headquarters, Department of the Army, June 1993), V.
[42] Ibid., 7.
[43] Ibid., 48.
[44] Quirk, "Seeking a Theory," 8.

operational planning. While improved sensors increased the likelihood of identifying or confirming enemy targets, AirLand battle simply was not feasible without a predicted enemy situation from which to plan.

IPB evolved less as product of environment it seeks to define than a necessity to the processes and systems it supports. Among the causal factors, it was AirLand battle that finally settled the half-century struggle between the descriptive, capabilities-based approach to intelligence, and the predictive, intentions-based approach. While IPB attempts to balance the descriptive and predictive, the bias toward subjective predictions is unavoidable.

What implications does this case have for the present? As network-centric warfare and AirLand battle drove the doctrine shift to IPB, AI-enabled intelligence and Multi-Domain Operations are the beginning of the next great paradigm shift as intelligence doctrine adjusts to its environment. AI and machine learning, in their seemingly boundless potential to assimilate and make sense of information, promise to generate descriptive intelligence at far greater speed. Perhaps it will bring a return to the commander-centric descriptive model of capabilities-based intelligence. More likely, however, is that predictive intelligence is here to stay in the relentless race to see, understand, and decide before adversaries.

THE CENTRAL IDEA

The Information Hierarchy

AI integration can reduce the cognitive burden for MAGTF Information Group (MIG) and MAGTF intelligence staff from the Marine Expeditionary Force (MEF) to Battalion levels. While each echelon performs different functions in support of situational understanding, all MAGTF intelligence personnel perform the core function of converting data to understanding.

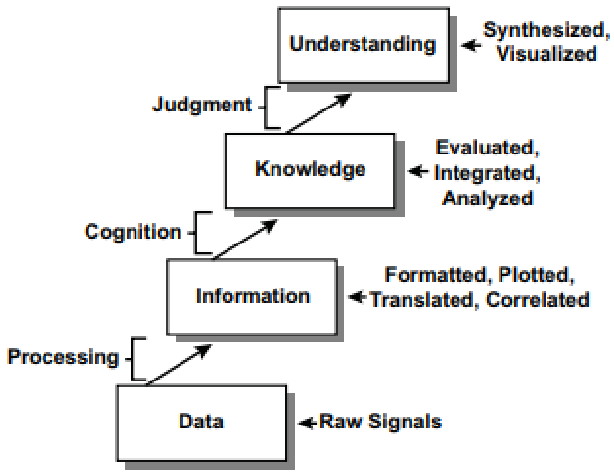

Figure 1. The Information Hierarchy (MCWP 2-10)

The MCWP information hierarchy fcan also be visualized as pyramid, with vast, raw data inputs undergoing increasingly nuanced, contextual levels of human analysis as they move up the information hierarchy toward understanding.

The Intellectual Problem: Intelligence Preparation of the Battlespace

For commanders, IPB is the basis for that understanding and the planning output that represents the intelligence warfighting function's role in the information hierarchy. IPB is conducted from the Battalion to MEF level and incorporates numerous labor-intensive product outputs to graphically represent each step (Figure 2). It is a running product that is updated and maintained continuously to support the commander's understanding in real time.

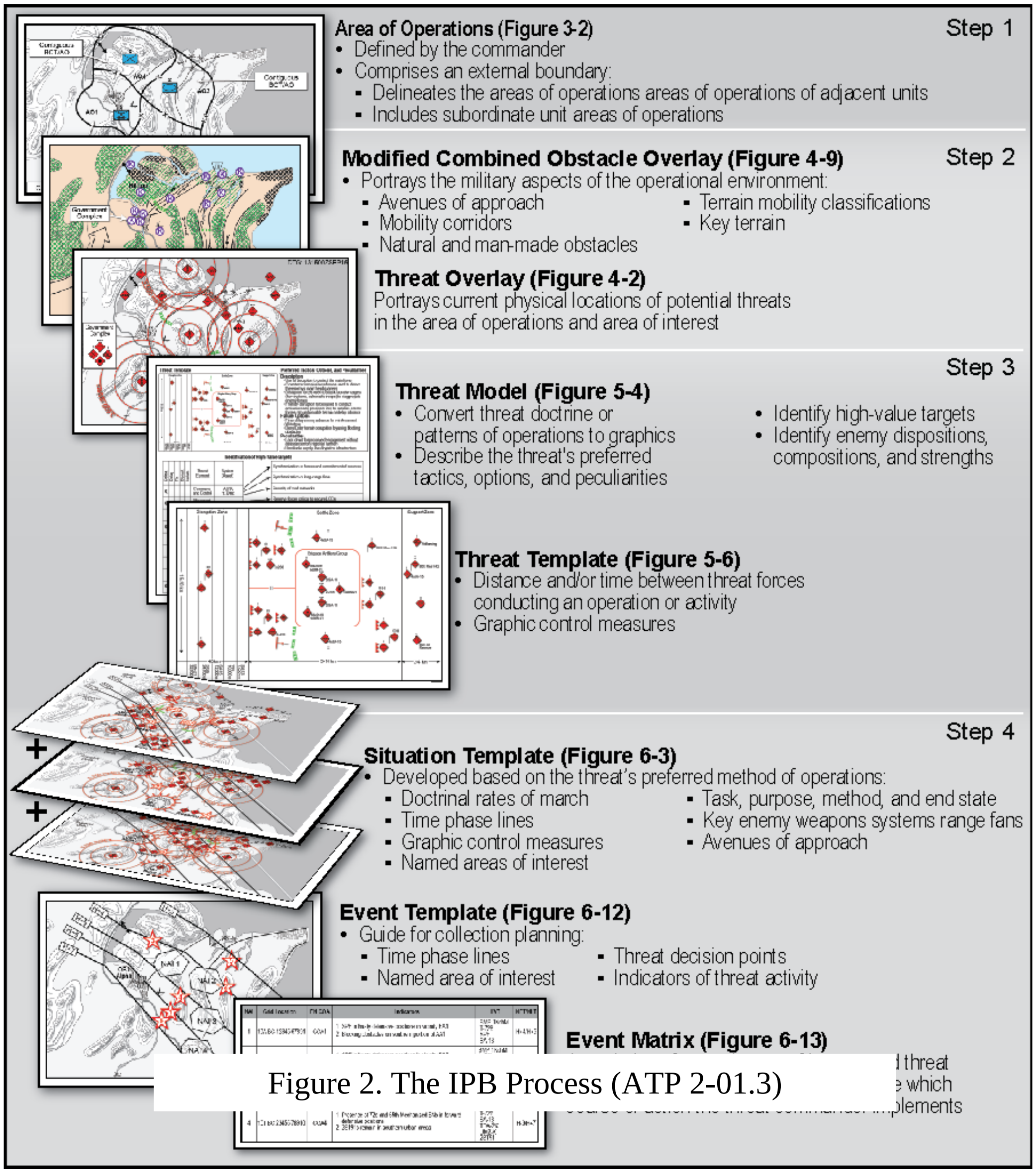

Figure 2. The IPB Process (ATP 2-01.3)

Figure 2 illustrates IPB in a maneuver warfare environment against a conventional threat in major combat operations. *Automating IPB* focuses on this conflict scenario because the risk to friendly forces is greatest, preparation time is limited, and decision-making is rapid. While IPB's knowledge outputs are judgement-based and highly subjective, it is fundamentally an intellectual problem made up of numerous component problems and their resulting products. *Automating IPB* therefore splits IPB's analytical steps into discrete sub-problems that can be solved effectively by a machine, applying or developing a specific AI methodology to solve each discrete analytical sub-problem, and aggregating the results in a solution, or in this case output, for each step. Deconstructing the sub-problems is beneficial in that it reduces variables, eases training data requirements and allowing practitioners to isolate discrete AI-enabled components if they become individually unreliable. For clarity, this concept will not deconstruct the IPB problem to an order lower than the second order sub-components (Figure 2) that support the greater process. *Automating IPB* recognizes that these products may have to be further deconstructed for execution by specific AI functions.

Automated IPB Example 1: The Modified Combined Obstacle Overlay (MCOO)

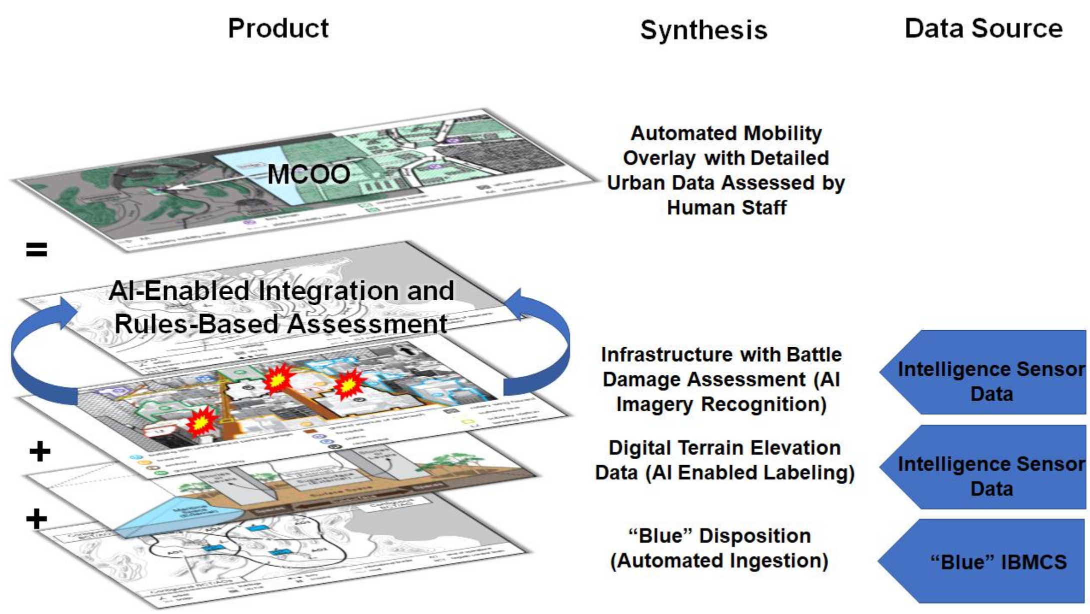

Figure 3. Automated MCOO Example

Automating IPB contends that the first and second steps of IPB can be readily automated with AI methodologies. As an example, subcomponents required to Define the Operational

Environment and Describe its Effects on Operations[45] can be completed discretely with existing AI capabilities in imagery and pattern recognition. AI in this use case would rapidly make sense of complex, multi-dimensional and multi-domain environments, allowing human analysts to apply the final subjective analysis. Using the common tactical data network (Information Battle Management Control Systems) anticipated in the MAGTF Information Environment Operations Concept of Employment,[46] AI enabled programs would ingest trusted data from multiple sources to create layered environmental information. Second wave AI methodologies would interpret and classify terrain features using Digital Terrain Elevation Data in one process while other second wave imagery recognition methodologies would interpret and classify infrastructure by type and status with a higher degree of accuracy than human imagery analysts.[47] First wave AI methodologies would then evaluate the layered data against user-defined mobility criteria to create the MCOO. While not depicted in Figure 3, other AI-enabled discrete process would then add electromagnetic, cyber, and information environment layers to the base product to facilitate a more complete understanding of multi-domain environmental effects on operations. While human analysts focus on higher-order IPB tasks, the AI processes described would continually re-assess the environment as new sensor, intelligence, or combat data is collected. This division of labor in an AI-human teamed process would play to the strengths of both, using AI to abstract information from vast data inputs while preserving human cognitive energy to create knowledge and understanding.

[45] Department of the Army, ATP 2-01.3 *Intelligence Preparation of the Battlefield,* (Headquarters, Department of the Army, March 2019), ii.
[46] Headquarters, US Marine Corps. *Marine Air Ground Task Force Information Operations Concept of Employment* (Washington, DC: Headquarters, US Marine Corps, July 6, 2017), 34.
[47] *Artificial Intelligence Initiatives Within the Defense Innovation Unit: Testimony Before the Senate Armed Services Committee Subcommittee on Emerging Threats and Capabilities,* 116th Cong., (2019) (Statement of Michael Brown. Director, Defense Innovation Unit), 5.

Automated IPB Example 2: Threat Order of Battle

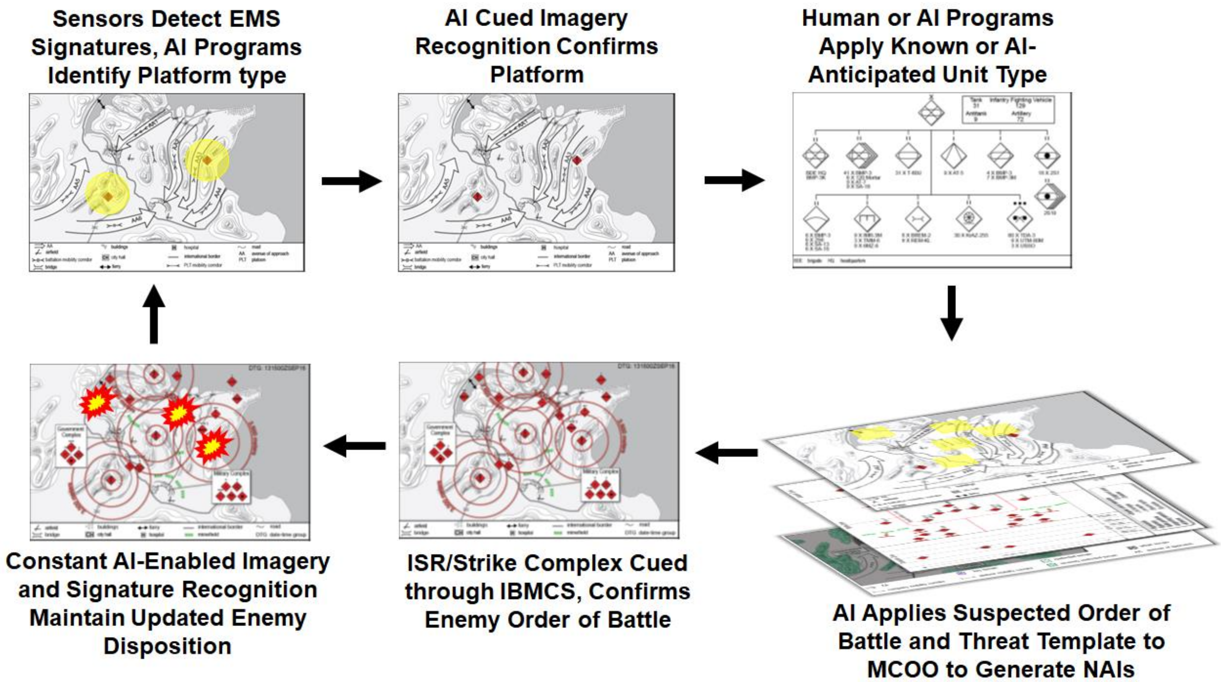

Figure 4. Maintaining a Threat Order of Battle

> "There is inherent friction between the desire to provide as complete and accurate an intelligence product as possible and the continuous requirement to support the time-sensitive urgency of tactical decisionmaking."
>
> -MCWP 2-10 *Intelligence Operations*

In the Threat Order of Battle Example, AI-enabled IPB processes are applied maintain a running threat order of battle. The Order of Battle encompasses the tactical characteristics of a threat force, including composition, disposition, and strength.[48] It is the foundation of the commander's continual understanding of the enemy, providing the basis of a capabilities-based assessment of what actions the enemy can take. It must be maintained continuously and

[48]Headquarters, Department of the Army, ATP 2-01.3 *Intelligence Preparation of the Battlefield,* (Headquarters, Department of the Army, March 2019), 5-4.

accurately, as it provides the commander's understanding of friendly effects on the threat, enabling the commander to make rapid decisions that drive tempo in maneuver warfare.[49]

Automating IPB's order of battle concept proposes a mix of first and second wave AI methodologies. While any intelligence discipline may start the process and cross-cue corroborating disciplines, Electronic Intelligence sensors identify two anomalous signatures in Figure 4. AI programs mapping the Electromagnetic Spectrum (EMS) find that the signatures are inconsistent with the EMS overlay and provide possible geolocation data to imagery recognition algorithms that analyze corroborating imagery collection. The imagery recognition function identifies the platform type and quantity, allowing subsequent programs or human analysts to match the information with suspected threat units. AI programs then apply a human-provided or AI-learned enemy doctrine template to the MCOO to generate a suggested Situation Template (SITTEMP) of anticipated enemy locations for consideration by the MAGTF intelligence staff. As an added benefit, the AI methodologies creating this suggested SITTEMP would attach probabilistic assessments of accuracy based on integrated source data for each discrete enemy unit or position. The human intelligence staff would apply the subjective analysis currently beyond the capability of AI processes to approve the SITTEMP, as which point AI processes would take over again to automatically generate Named Areas of Interest (NAIs) where other threat units may be found that confirm the enemy SITTEMP and order of battle.

The same common, Information Battle Management Control Systems that enabled the automated IPB processes to ingest friendly force data would function in reverse, feeding the NAIs to the ISR/strike complex and tasking collection against those NAIs to confirm the enemy order of battle. Furthermore, automated imagery recognition and battle damage assessments

[49] Headquarters, US Marine Corps, MCWP 2-10 *Intelligence Operations* (Washington, DC: Headquarters, US Marine Corps, 2014), 2-9.

would identify NAIs for human-approved reclassification as Target Areas of Interest for the ISR/Strike complex to create effects. As the engagement progresses, AI programs continually apply the above methodologies to reinforce the feedback loop and maintain a running enemy order of battle.

Reconstructing IPB

While many of IPB's lower order sub-components may readily be automated, integrating the process will be challenging. Mixed first and second wave AI methodologies employed by deep neural networks are showing promise in solving complex problems. The Chinese board game Go is highly complex, with 10 to the power of 170 possible board configurations.[50] Famously, Google's Alpha Go employed parallel 'policy' and 'value' neural networks that leveraged first wave search tree methodologies to plan and evaluate moves during Go play.[51] Using training data from previous recorded Go games, Alpha Go played against itself in a mixed supervised and reinforcement learning model, gradually improving until it beat the reigning European Go champion 5-0 in its first match.[52] Alpha Go Zero, a new initiative, removes the training data and allows the program to learn Go in an unsupervised reinforcement learning model with a streamlined decision making structure, with profound implications to automate complex, sequential processes.[53] These programs, while technologically and statistically impressive, function with specific rules, in specific domains, employing one type of media. The

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[50] "AlphaGo," Deepmind, April 24, 2019, https://deepmind.com/research/alphago/.
[51] David Silver, Aja Huang, Chris J. Maddison, et al., "Mastering the game of Go with deep neural networks and tree search," *Nature* 529 (2016): 1, https://storage.googleapis.com/deepmind-media/alphago/AlphaGoNaturePaper.pdf.
[52] "AlphaGo."
[53] Ibid.

current, multi-domain operational environment *Automating IPB* seeks to understand is far more complex.

Automating IPB's capstone fourth step "Determine Threat Courses of Action" is therefore more difficult than Go mastery. It requires nuanced analysis adaptation of events to environmental and cognitive factors to anticipate threat activity over time.[54] Step four requires a higher degree of subjective judgement than the earlier IPB steps and cannot be as easily disaggregated to discrete AI functions. Current AI methodologies struggle with this type of activity, which must connect multi-media temporal information and event patterns with numerous sub elements whose relationships are not readily identifiable by programs.[55]

Automating IPB therefore recommends a schema library-based approach to automating the overall process. In this type of learning, discrete first and second wave AI processes create process schemas using structure-based bottom-up modeling.[56] DARPA's recently announced Knowledge-directed Artificial Intelligence Reasoning Over Schemas (KAIROS) is an example of AI schema-based learning applied to understand and predict complex real-world phenomena from multimedia inputs. KAIROS seeks to find correlations in seemingly unrelated events by "detecting, classifying and clustering sub-events" in a manifold structure from which they may be further differentiated.[57] KAIROS will then apply generalization and composition processes to create generalized event schema.[58] These event schema can be understood as broad framing

[54] Headquarters, Department of the Army, ATP 2-01.3 *Intelligence Preparation of the Battlefield,* (Headquarters, Department of the Army, March 2019), ii.
[55] Defense Advanced Research Projects Agency, "Generating Actionable Understanding of Real-world Phenomena with AI, March 2019, https://www.darpa.mil/news-events/2019-01-04.
[56] Erdi, P, "Structure Based Modeling of Schemas," *Artificial Intelligence 101, (Amsterdam, Netherlands: Elsevier B.V., 1998), 342.* https://pdf.sciencedirectassets.com/271585/.
[57] Defense Advanced Research Projects Agency, "Generating Actionable Understanding of Real-world Phenomena with AI, March 2019,
[58] Ibid.

narratives that help the AI tool understand and predict a complex event chain as a human would. *Automating IPB* proposes this conceptual model to complete higher-order analysis (Figure 5).

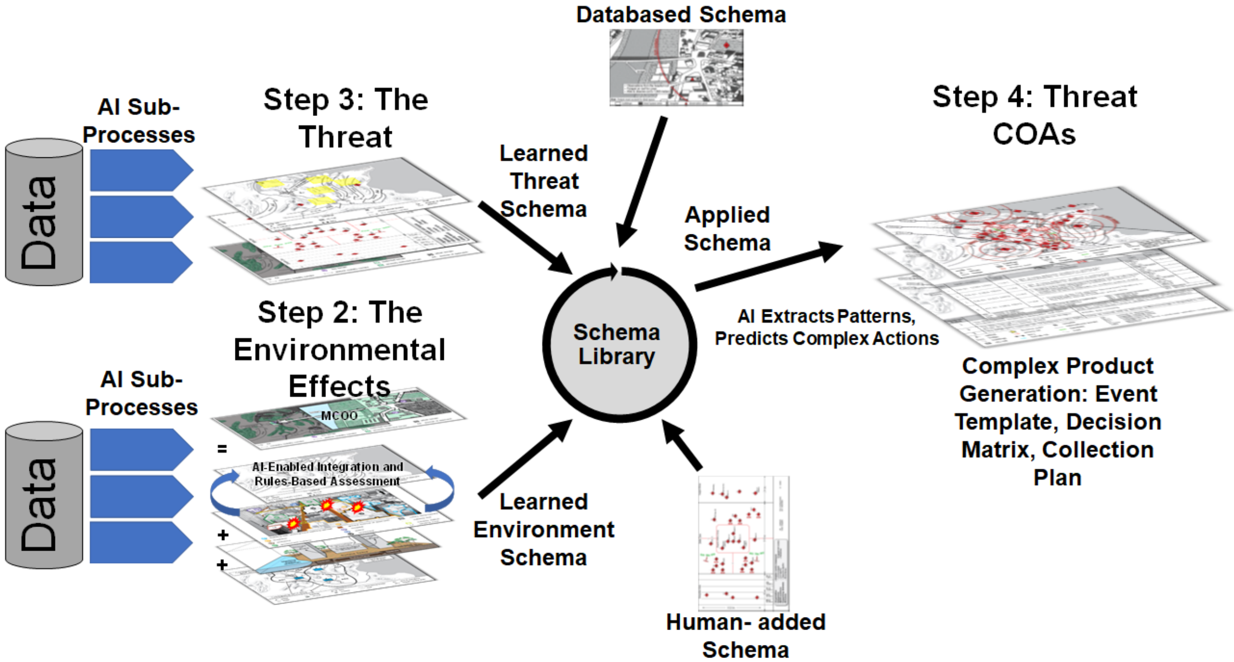

Figure 5. Reconstructing the Process

In this schema-based model, the IPB process is reintegrated as powerful neural network AI extracts patterns and predicts complex, temporal, multi-variable actions using aggregated schema contributed by the lower-order subprocesses. As processes are run, user-specified schema are added, or external schema databases are linked, the library grows and predictive accuracy is improved as the system 'plays' against itself and learns.

Like all current second wave AI process, this schema model relies on accumulated data to then generate the aggregated schema to achieve any level of predictive accuracy. In the absence of true battlefield data, *Automating IPB* proposes schema generation through training environments to both validate the concept and contribute initial threat schema to a databased library. Synthetic training environments and experimentation are the least resource-intensive, but risk perpetuating artificial biases or inaccuracies. Combined arms exercises MAGTF Training Command, National Training Center, and Joint Maneuver Readiness Center provide opportunities for real-time schema generation and experimentation incorporating realistic human variables.

This approach would rapidly generate the most complex IPB outputs with a greater level of detail in complex temporal event chains detail than currently possible. Threat Event Templates could be extrapolated over time with a high degree of precision, allow for greater certainty for friendly decision support matrices. Moreover, AI use for this process adds a significant precision to probabilistic assessments. The event chain mapping possible with this level of schema library-based AI assessment would not only provide probabilistic assessments for each instance of threat activity, but also the probability that an instance would change over time. The potential for decision support, as well as operational branch and sequel mapping, is significant.

Distributed Situational Understanding: A Wargame Vignette

A contact layer war game conducted at the Marine Corps Warfighting Laboratory from 31 October 2018 to 13 November 2018 demonstrated the opportunity for *Automating IPB* to facilitate distributed situational understanding. In the war game, Blue forces conducted Expeditionary Advanced Base Operations to deter a regional peer maritime power. Blue lacked an effective multi-domain understanding of the OE and overlapping Information Environment (IE) commensurate with Blue's expansive mission and area of operations. Blue's intelligence architecture and scheme of employment were insufficient to provide situational understanding in a severely congested physical and information environment at the pace needed to act first. Each Red tactical move came as a surprise to Blue leadership, leading to a chain of reactive Blue countermoves and, ultimately, unanticipated Red escalation without Blue forces generating perceptible cost imposition.

While a running estimate of threat military capabilities is critical and cannot be neglected, the contact layer game's most important maneuver and effects were in non-physical domains. In this sense, the contact layer developed in the game as positional warfare in the information environment. The 2016 Marine Corps Operating Concept recognizes this close inter-relationship of physical and cognitive maneuver.[59] However, it is thinly defined, and in current concepts, open source and non-traditional information environment collection activities are conducted are higher echelons that are not optimized to support the distributed MAGTF as employed in the game's scenario.

Automating IPB recommends developing distributed situational understanding through AI-enabled Intelligence Preparation of the Operational Environment. Blue forces went ashore in the contact layer with minimum structure required to execute multiple tasks and operate as distributed elements. Included was a multi-functional MEF Information Group (MIG)-Forward (FWD) detachment co-located with the Ground Combat Element) GCE.[60] This element would depend on reach-back to the MIG Combat Operations Center (COC) and function primarily intelligence synchronizing element between the MIG COC and supported GCE. Mitigating this forward element's cognitive burden through an AI enabled IPOE would reduce reliance on reach-back, susceptibility to degraded connectivity, and enable mission-style execution by providing responsive intelligence closer to the operational force.

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[59] Marine Corps Operating Concept. 2016 https://www.mccdc.marines.mil/Portals/172/Docs/MCCDC/young/MCCDC-YH/document/final/Marine%20Corps%20Operating%20Concept%20Sept%202016.pdf?ver=2016-09-28-083439-483, 8.
[60] "Marine Expeditionary Unit Construct: Command and Staff College Gray Scholars AY18 -AY19." DRAFT. Prepared for Marine Corps Warfighting Lab, Ellis Group, November 20, 2018.

Open source information carries the most immediate potential for automated exploitation to enhance distributed situational understanding. Limited open source and social media exploitation tools must be provided to non-intelligence personnel at subordinate maneuver elements. Unclassified, social media aggregate programs such as UA Livemap have already proven highly effective as an accurate supplement to, and in some cases replacement for, traditional intelligence collection to maintain situational understanding in less developed theaters such as Syria.[61] Separating these tools from intelligence personnel and processes may be necessary until authorities are resolved.

The MIG-FWD will require dedicated AI programs driven by powerful algorithms that are able to identify and triage possible indicators and warnings from broad social media and other open source data scrapes. Commercial capabilities like Dataminr are already in use to provide time-sensitive security indicators and warnings to government agencies.[62] However, more powerful aggregate sentiment mapping tools such as those employed in disaster relief would be of greater utility in maintaining running situational understanding. In disaster relief studies, researchers have been able to accurately correlate a disaster's impact path not only by social media subject matter, but also by geolocated clusters of positive and negative sentiment intensity.[63] Unsurprisingly, negative intensity clusters peak at the impact site, but both positive and negative sentiment intensities decrease as they become increasingly dispersed from the affected area. The implications for distributed military operations in the contact layer are

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[61] Sydney Freedberg, "Generals Worry US May lose in Start of Next War: Is Muti-Domain the Answer?" *Breaking Defense*, https://breakingdefense.com/2018/05/generals-worry-us-may-lose-in-start-of-next-war-is-multi-domain-the-answer/, 14 May 2018.

[62] COL Sean Larkin, "Transparency's Double-Edged Sword," *Defense One*, *https://www.defenseone.com/ideas/2016/05/transparencys-double-edged-sword/128210/*, May 11, 2016.

[63] Cornelia Caragea , Anna Squicciarini , Sam Stehle, et al. "Mapping Moods: Geo-Mapped Sentiment Analysis During Hurricane Sandy Mood Mapping for Disaster Response," In *Proceedings of the 11th International ISCRAM Conference* (University Park, Pennsylvania: Pennsylvania State University, May 2014), http://asquicciarini.ist.psu.edu/pdf/iscram14.pdf.

significant. Beyond simply identifying more or less permissive routes and environments, the MIG-FWD in this case could directly correlate the cognitive and information effects of military activity using non-intrusive collection methods.

These sentiment heat maps would be layered with more traditional IPB products to allow commanders to achieve an unprecedented understanding of their true area of influence. These tools would provide insight toward less obvious inter-group and intra-group linkages that defy traditional, geographically or ethnically focused, methods of understanding. In counterinsurgency, as in disaster relief, these tools would allow the counterinsurgent to intervene in a specific region or demographic group early enough to mitigate a downward spiral in emotional support.

Similar AI enabled open source capabilities could readily be developed as government-owned programs, authorities delegated, and integrated with scale at echelon. An unclassified capability would be operable at distributed locations with minimal infrastructure and provide sustained situational understanding to units in disrupted or degrade environments.

The MIG-FWD element with the GCE should be the first echelon where open source and traditional intelligence data are fused with more advanced AI toolsets in *Automating IPB's* proposed integrated process to facilitate shared understanding. This capability will also dramatically enable MIG ability to identify cause and effect relationships by rapidly corelating friendly actions with effects across the information environment. The MAGTF Information Operations Concept of Employment already seeks to develop the MIG with the necessary integrating structure through its organic capability to synchronize inputs from distributed Information Battle Management and Control Systems.

The MIG's projected fusion of open source data with traditional intelligence, friendly force information, and non-traditional sensors to provide holistic "Information Environment Battlespace Awareness" while conducting seven other functions will require dedicated AI integration at key points to function as available data continues to grow. Furthermore, both open source data and AI are vulnerable to adversary spoofing and deception, requiring the capacity to corroborate through traditional ISR for targeting purposes.

APPLICATION AND INTEGRATION OF MILITARY FUNCTIONS

Automating IPB proposes a scalable, tailorable integration model. It anticipates iterative modification to, or replacement of, AI-enabled discrete sub-components as new AI methodologies are realized or existing methodologies are improved. Many of its proposed sub-components anticipate integrating existing programs for functionality (i.e. Project Maven and Computer Vision imagery recognition).[64] It is therefore critical that *Automating IPB* eschews the exquisite hardware/software pairings common in current DoD intelligence and battle command systems. The MAGTF Information Environment Operations Concept of Employment's Tactical Services Oriented Architecture (TSOA) (Figure 6) templates this integration model. Within the TSOA, The Marine Corps Software Resource Center (MCSRC) maintains hardware-agile software resources that are adaptable to operational requirements.[65] The MCSRC would maintain *Automating IPB* as a functional suite of interoperable applications. Within the MAGTF Information Environment Operations concept, the *Automating IPB* suite of applications fits

[64] Deputy Secretary of Defense Memorandum. "Establishment of an Algorithmic Warfare Cross-Functional Team (Project Maven)" Washington DC April 26, 2017.
[65] Headquarters, US Marine Corps, *Marine Air Ground Task Force Information Operations Concept of Enployment.* 6 July 2017, 17.

within the TSOA system group that comprises the Information Environment Operations Running Estimate family of services.[66] MIG personnel manning the Intelligence Operations Center (IOC) at the MAGTF COC would operate the specific functions of the Automated IPB process as they would traditionally conduct IPB. Within the IOC, the Production and Analysis section's All-Source Fusion Center would synthesis, evaluate, and finish the automated products.[67] At the MAGTF COC, they would have full access to complete IBMCS and Authoritative Data Sources needed to facilitate their component of the Information Environment Operations Running Estimate.[68] The resulting information environment operations common operating picture would supply the MAGTF commanders holistic situational understanding.

In distributed operations at lower echelons, *Automating IPB* proposes integration on Intelligence Operations Workstations with cloud-based access to the Intelligence Operations Servers at the MAGTF's IOC.[69] Distributed elements would download relevant information to small form-factor tactical data servers. The supporting IOC, with higher bandwidth Tactical Data Networks, would provide access to the centralized information environment operations common operating picture fed by the greater range of national to tactical authoritative data sources.

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[66] Ibid., 19.
[67] Headquarters, US Marine Corps, MCWP 2-10 *Intelligence Operations* (Washington, DC: Headquarters, US Marine Corps, 2014), 4-14.
[68] *Marine Air Ground Task Force Information Operations*., 19.
[69] MCWP 2-10 *Intelligence Operations.*, 3-16.

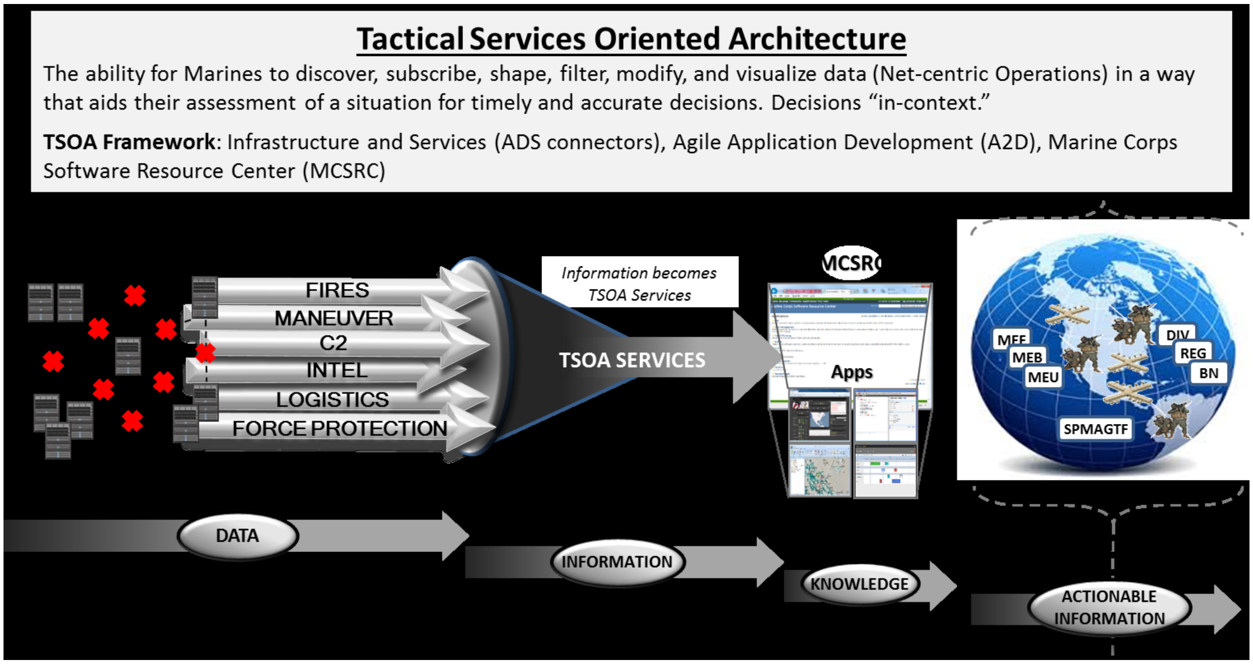

Figure 6. The MAGTF Tactical Services Oriented Architecture

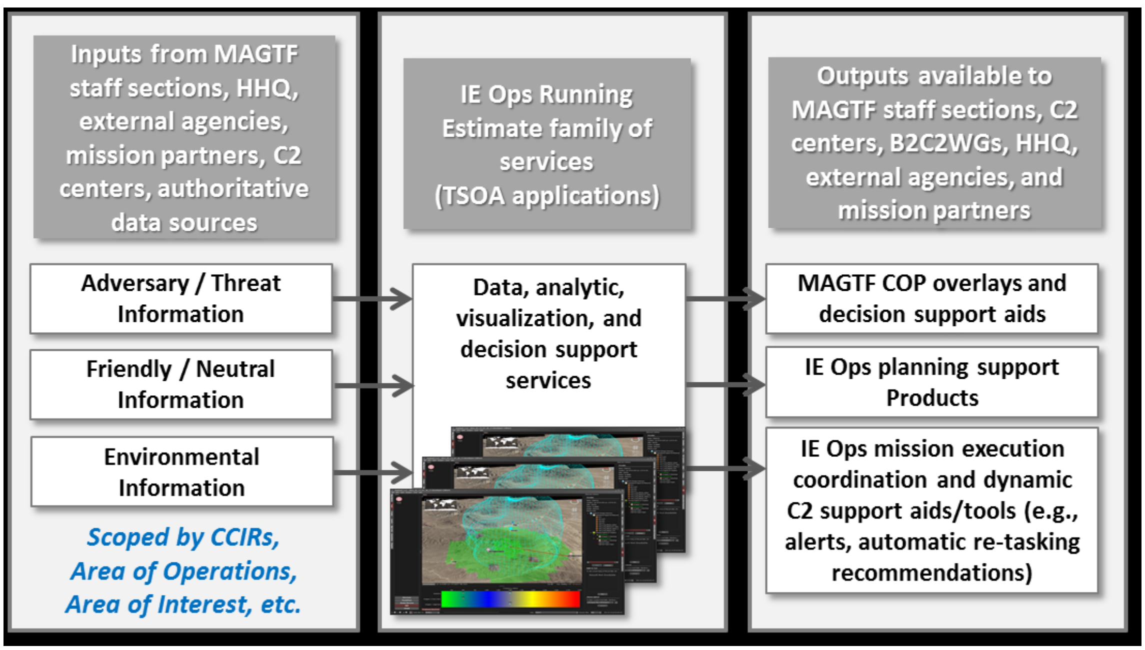

Figure 7. The MAGTF Information Environment Running Estimate

NECESSARY CAPABILITIES

Applicable AI Methodology and Integration

This concept uses DARPA's first, second, and third wave model in classifying AI methodologies. It proposes applying tailored first and second wave methodologies to specific sub-problems:

- The first wave: Expert Systems. Examples of potential use in *Automating IPB* include "if-then" tasks such as correlating electromagnetic spectrum signatures with the threat order of battle and applying radar-generated Digital Terrain Elevation Data to mobility overlays.
- The second wave: ML neural networks. Neural network methodologies have the greatest potential in *Automating IPB.* They have already proven viability for imagery recognition in both Project Maven and the nascent DIUX Computer Vision program.[70] *Automating IPB* seeks to further integrate emerging neural network methodologies in a schema-based learning model[71] that will begin to integrate the discrete subtasks executed by more limited AI.
- The third wave (anticipated). DARPA predicts third wave AI will achieve adaptive reasoning that allows AI methodologies to apply context an achieve near human-like understanding of changing situations.[72] The implications are significant in that it will create more resilient, explainable systems that will not require exhaustive training for

[70] *Artificial Intelligence Initiatives Within the Defense Innovation Unit: Testimony Before the Senate Armed Services Committee Subcommittee on Emerging Threats and Capabilities,* 116th Cong., (2019) (Statement of Michael Brown. Director, Defense Innovation Unit), 5.
[71] Defense Advanced Research Projects Agency, "Generating Actionable Understanding of Real-world Phenomena with AI, March 2019, https://www.darpa.mil/news-events/2019-01-04.
[72] Ryan Daws, "DARPA Introduces Third Wave of Artificial Intelligence Technology," *AI News,* September, 2018, https://www.artificialintelligence-news.com/2018/09/28/darpa-third-wave-artificial-intelligence/.

viability. However, third wave realization is considered unlikely in the next ten years.[73] Without a clearly defined scope of these anticipated capabilities, *Automating IPB* cannot consider third wave AI as critical to initial functionality, but acknowledges its disruptive potential.

CONCLUSION

The amount of information required to support military decision-making is increasing geometrically. As new domains, physical and non-physical, are added, the intellectual problem of visualizing this environment is evolving beyond the human ability to understand in time to act. At the tactical level of war, were time and space are compressed by the pace and lethality of modern systems, the risk is acute. Compounding the problem are outdated decision support processes and manning limitations. Powerful AI-enabled automation, however promises to upend, or at least accelerate, these structures. *Automating IPB* proposes the latter, seeking to harness AI's significant potential to support the tactical level of war. If, "from Plato to NATO the history of command in war consists essentially of an endless quest for certainty,"[74] AI is less likely to be the final chapter, at least in the near term, than it is to become another punctuation in the race for commanders gain a fleeting edge in battlefield understanding.

[73] Ibid.
[74] Van Creveld, *Command in War*, 264.

APPENDIX

AI Methodologies

- Expert Systems. Expert Systems are the most traditional form of AI, with computerized expert systems existing in common use since the 1980s. Expert systems employ direct human programming to replicate expert human knowledge in a specific functional area. They are highly logical, and function well within rules-based systems where values can be readily differentiated.[75] In spite of these strengths, they are profoundly limited in broad functionality as the search trees expert systems employ must be programmed with every possible outcome.[76]
- Machine Learning. ML is a promising AI field that has grown dramatically and widely exceeded expectations over the last five years.[77] ML benefits from large, recognizable data sets to abstract conclusions. Machine learning methodology can be broadly classified in three categories: supervised learning, unsupervised learning, and reinforcement learning. Supervised learning algorithms are trained using human-labeled examples and are most effective where historical data trends can predict future events.[78] Unsupervised learning, on the other hand, allows the algorithm to reach its own conclusions through the exploration of transactional data.[79] Unsupervised learning is therefore best suited to identify trends, outliers, and clusters. In reinforcement learning, AI algorithms discover the best solution through trial-and-error action by mixing policy (action) and value

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[75] Sukha Shubhendu and Jaiswal Vijay, "Applications of Artificial Intelligence," *International Journal of Scientific Engineering and Research (IJSER)* 1 (2013): https://pdfs.semanticscholar.org/2480/a71ef5e5a2b1f4a9217a0432c0c974c6c28c.pdf, 30.
[76] "AlphaGo."
[77] Greg Allen and Taniel Chan, *Artificial Intelligence and National Security, 1.*
[78] "Machine Learning: What it is and why it matters," SAS Insights, April 25, 2019, https://www.sas.com/en_us/insights/analytics/machine-learning.html
[79] Ibid.

(reward) networks.[80] Reinforcement learning is highly effective in gaming, navigation, and planning. AlphaGo is perhaps the most famous example of reinforcement learning.

- Neural Networks. Neural networks are an advanced AI methodology that builds from ML. They rely on ML as a supporting function to make connections between facts and draw conclusions about what the program perceives. They employ a series of analytical layers to abstract information from the data input where each succeeding layer abstracts more detail with the benefit of the previous layer output. Neural networks are capable of learning and modifying conclusions from experiences but continue to struggle in causal analysis and understanding which inputs to discard as irrelevant.[81] Neural Deep Learning is more advanced neural network that "…uses multiple layers of nonlinear processing to extract features from data and transform the data into different levels of classification."[82] The most advanced neural networks, such as that employed by AlphaGo and the neural deep learning of AlphaGo Zero, integrate expert systems such as advanced search trees with neural networks to magnify the unique strengths and mitigate the weaknesses of both methodologies.

[80] "AlphaGo"
[81] Ibid., 31.
[82]" Deep Learning," Deep AI, March 20 2019, https://deepai.org/machine-learning-glossary-and-terms/deep-learning.

Bibliography

Agee, Collin. "Intelligence Preparation of the Battlefield: One Size Fits All?" Monograph, Fort Leavenworth, School of Advanced Military Studies, 1991.

Allen, Greg, and Chan, Taniel. *Artificial Intelligence and National Security*. Cambridge, MA: The Belfer Center for Science and International Affairs, July 2017. https://www.belfercenter.org/sites/default/files/files/publication/AI%20NatSec%20-%20final.pdf.

Artificial Intelligence Initiatives Within the Defense Innovation Unit: Testimony Before the Senate Armed Services Committee Subcommittee on Emerging Threats and Capabilities, 116th Cong., (2019) (Statement of Michael Brown. Director, Defense Innovation Unit.

Caragea, Cornelia, Squicciarini, Anna, Stehle, Sam, et al. "Mapping Moods: Geo-Mapped Sentiment Analysis During Hurricane Sandy Mood Mapping for Disaster Response." In *Proceedings of the 11th International ISCRAM Conference*. University Park, Pennsylvania: Pennsylvania State University, May 2014. http://asquicciarini.ist.psu.edu/pdf/iscram14.pdf.

Clark, Colin. "Cardillo: 1 Million Times More GEOINT Data in 5 Years*." Breaking Defense*, June 2017. https://breakingdefense.com/2017/06/cardillo-1-million-times-more-geoint-data-in-5-years/.

DARPA's Seminal Role in the Field of Artificial Intelligence: Testimony before The Emerging Threats and Capabilities Subcommittee, U.S. Senate, 116th Cong., 2019 (statement of Dr. Peter Highnam, Deputy Director, DARPA).

Daws, Ryan. "DARPA Introduces Third Wave of Artificial Intelligence Technology." *AI News,* September 2018. https://www.artificialintelligence-news.com/2018/09/28/darpa-third-wave-artificial-intelligence/.

Erdi, P. "Structure Based Modeling of Schemas." *Artificial Intelligence 101. Amsterdam, Netherlands: Elsevier B.V., 1998.* https://pdf.sciencedirectassets.com/271585/.

"Deep Learning." Deep AI. Web Site. https://deepai.org/machine-learning-glossary-and-terms/deep-learning. Accessed 26 March 2019.

Defense Advanced Research Projects Agency. "Generating Actionable Understanding of Real-world Phenomena with AI." March, 2019. https://www.darpa.mil/news-events/2019-01-04.

Deputy Secretary of Defense. "Establishment of an Algorithmic Warfare Cross-Functional Team (Project Maven)." Washington, DC: Office of the Deputy Secretary of Defense, 2017.

Freedberg, Sydney. “Generals Worry US May lose in Start of Next War: Is Muti-Domain the Answer?” *Breaking Defense,* May 2018. https://breakingdefense.com/2018/05/generals-worry-us-may-lose-in-start-of-next-war-is-multi-domain-the-answer/.

Freedberg, Sydney. “Show me the Data: The Pentagon’s Two-Pronged AI Plan.” *Breaking Defense*, December 2018. https://breakingdefense.com/2018/12/show-me-the-data-the-pentagons-two-pronged-ai-plan/.

Freedberg, Sydney. “War Cloud: JEDI to Deploy Backpack Servers to Front Line.” *Breaking Defense,* April 2018. https://breakingdefense.com/2018/04/war-cloud-jedi-to-deploy-backpack-servers-to-front-line/.

Glass, Robert R., and Davidson, Phillip B. *Intelligence is for Commanders.* Harrisburg, PA: The Telegraph Press, 1948.

Headquarters, Department of the Army, ATP 2-01.3 *Intelligence Preparation of the Battlefield.* Headquarters, Department of the Army, 2019.

Headquarters, Department of the Army. FM 100-5 *Operations*. Headquarters, Department of the Army, 1993.

Headquarters, Department of the Army. FM 30-5 *Combat Intelligence*. Headquarters, Department of the Army, 1973.

Headquarters, US Marine Corps. *Marine Air Ground Task Force Information Operations Concept of Employment.* Washington, DC: Headquarters, US Marine Corps, 2017.

Headquarters, US Marine Corps, *Marine Corps Operating Concept, 2016.* Washington, DC: Headquarters, US Marine Corps, 2016. https://www.mccdc.marines.mil/Portals/172/Docs/MCCDC/young/MCCDC-YH/document/final/Marine%20Corps%20Operating%20Concept%20Sept%202016.pdf?ver=2016-09-28-083439-483.

Headquarters, US Marine Corps, MCWP 2-10 *Intelligence Operations* (Washington, DC: Headquarters, US Marine Corps, 2014).

Larkin, Sean. “Transparency’s Double-Edged Sword.” *Defense One,* May 2016. https://www.defenseone.com/ideas/2016/05/transparencys-double-edged-sword/128210/.

“Marine Expeditionary Unit Construct: Command and Staff College Gray Scholars AY18 - AY19.” DRAFT. Prepared for Marine Corps Warfighting Lab, Ellis Group. November 20, 2018.

Office of the Director of National Intelligence. *IC ITE Fact Sheet.* Mclean. VA: Office of the Director of National Intelligence, 2019. https://www.dni.gov/files/documents/IC%20ITE%20Fact%20Sheet.pdf.

Office of the Director of National Intelligence. *AI: Using standards to mitigate Risk.* Mclean. VA: Office of the Director of National Intelligence, 2019. https://www.dni.gov/files/PE/Documents/2018_AEP-AI.pdf.

Quirk, Richard. "Seeking a Theory of Tactical Intelligence to Support AirLand Battle." Monograph, (Fort Leavenworth, School of Advanced Military Studies, 1985.

Romjue, John L. "From Active Defense to AirLand Battle: The Development of Army Doctrine 1973-1982," Monograph, Fort Munroe, Virginia: United States Army Training and Doctrine Command, June 1984.

Schwien, Edwin E. *Combat Intelligence: Its Acquisition and Transmission.* Washington, DC: The Infantry Journal Inc., 1936.

Silver, David, Huang, Aja, Maddison, Chris J., et al. "Mastering the game of Go with deep neural networks and tree search*." Nature* 529 (2016): https://storage.googleapis.com/deepmind-media/alphago/AlphaGoNaturePaper.pdf.

Sukha, Shubhendu and Jaiswal, Vijay, "Applications of Artificial Intelligence," *International Journal of Scientific Engineering and Research (IJSER)* 1 (2013): https://pdfs.semanticscholar.org/2480/a71ef5e5a2b1f4a9217a0432c0c974c6c28c.pdf.

US Department of Defense. *SUMMARY OF THE 2018 DEPARTMENT OF DEFENSE ARTIFICIAL INTELLIGENCE STRATEGY: Harnessing AI to Advance Our Security and Prosperity*. Washington, DC: Office of the Secretary of Defense, 2019.

US Deputy Secretary of Defense, *Establishment of an Algorithmic Warfare Cross-Functional Team (Project Maven),* Washington, DC: Office of the Secretary of Defense, April, 2017.

US Marine Corps Concepts and Programs. *Expeditionary Advanced Base Operations.* Web Site. https://www.candp.marines.mil/Concepts/Subordinate-Operating-Concepts/Expeditionary-Advanced-Base-Operations/. Accessed 24 March 2019.

US President, Executive Order. "Maintaining American Leadership in Artificial Intelligence." Exec. Order No. 13859, 84 Fed. Reg. 3967 (February 2019). https://www.whitehouse.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/.

Van Creveld, Martin. *Command in War.* Cambridge, Massachusetts: Harvard University Press, 1985.

West, Darrell M., and Allen, John R. *How Artificial Intelligence is Transforming the World*. Washington, DC: Brookings. April 2018. https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/.