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14. ABSTRACT

Problem: Current C4ISR and Robotic and Autonomous Systems create more data than can be exploited by human means. Commanders must harness the analytic power of Artificial Intelligence (AI) as a decision support system (DSS) in order to truncate the intelligence process for faster planning-decision-execution (PDE) cycles. Findings: An Expeditionary Advanced Base commander will make better informed decisions at a faster rate than his adversary using an AI DSS. Barriers currently exist. The Marine Corps must produce an AI concept of support for EAB Operations that nests within Naval Operating Concepts, adequately prioritize and resource AI efforts, and resource enterprise data management to maximize data analytics and machine learning for knowledge discovery in databases (KDD). Additionally, the Marine Corps must leverage U.S. Army AI experimentation and concept development for Multi-Domain Operations (MDO). Finally, the Marine Corps should determine current technology and operational areas that can be improved by narrow AI today.

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Artificial Intelligence (AI), Decision Support Systems (DSS), Observe Orient Decide Act (OODA) Loop, Planning Decision Execution (PDE) Cycle

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MASTER OF MILITARY STUDIES

Gaining a Cognitive Advantage:
Artificial Intelligence (AI) as a Decision Support System

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

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AY 2019-20

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Date: __30 Mar 2020___________________________________

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DISCLAIMER

Executive Summary

Title: Gaining a Cognitive Advantage: Artificial Intelligence (AI) as a Decision Support System (DSS)

Author: Major James D. Pineiro, United States Marine Corps

Thesis: If Marines are going to compete with near-peer adversaries, the Marine Corps must embrace artificial intelligence (AI) as a decision support system (DSS) for faster planning—decision—execution (PDE) cycles in order to gain a cognitive, temporal, and lethal advantage over the enemy.

Discussion: Information systems and surveillance technologies are changing the character of war and allowing smaller forces to distribute and influence larger areas. But current Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) and Robotic and Autonomous Systems (RAS) are manpower intensive and create an enormous amount of data that Marines must quickly exploit to provide actionable intelligence. This is problematic as Expeditionary Advanced Base Operations (EABO) call for small, distributed, and resilient forces that must make rapidly-informed decisions to survive against a variety of developing and evolving threats.

Conclusion: Artificial intelligence using data analytics and machine learning processes, exploits, and disseminates information quicker than human processes. An EAB commander equipped with an AI DSS will make more informed decisions at a faster rate than his adversary. However, significant barriers currently exist before this can become a reality. The Marine Corps must produce an AI concept of support for EABO that nests within Naval Operating Concepts, adequately prioritize and resource AI efforts, and resource enterprise data management to maximize data analytics and machine learning for knowledge discovery in databases (KDD). Additionally, the Marine Corps must leverage U.S. Army AI experimentation and concept development for Multi-Domain Operations (MDO). Finally, the Marine Corps should determine current technology and operational areas that can be improved by narrow AI today.

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Preface

The idea for this topic came out of my work as the Ground Combat Element (GCE) Branch Head, Science and Technology (S&T) Division, Marine Corps Warfighting Lab (MCWL) from 2013-2016. Following two deployments to Afghanistan, I was thrust into the world of technology and experimentation. Drawing on my combat experience, I wanted to use Robotics and Autonomous Systems (RAS), as eyes and ears, to give the commander a cognitive advantage over the enemy. However, the more my MCWL team experimented with current technology the more we began to see the limitations. I found that these systems were increasing the information burden on the commander instead of reducing it. I hypothesized, if certain RAS processes were automated, they could truncate the intelligence process, speeding-up a commander's planning—decision—execution (PDE) cycle. I believe this is the third strategic offset.

After three years I found my hypothesis had changed little, but the larger operating paradigm had. I used my time at Command and Staff College to research new technologies and concepts that align with the *2018 National Defense Strategy*, *2019 Commandant's Planning Guidance*, *Expeditionary Advanced Based Operations*, and many others. I spoke with leading voices within the Marine Corps Artificial Intelligence (AI) community of interest and representatives from Defense Advanced Research Projects Agency (DARPA) for the latest developments. I conducted an extensive literature review of John Boyd's decision loop and Department of Defense (DoD) AI publications, strategy, and supporting concepts.

I want to thank my Lord and Savior Jesus Christ for granting me the fortitude to see this through, my wife and family for supporting me through the long hours, and my thesis advisor Dr. Richard Hegmann and second reader Dr. Harry Dreany for guiding me through this process.

"All of our investments in data science, machine learning, and artificial intelligence are designed to unleash the incredible talent of the individual Marine."[1]

– 38th Commandant's Planning Guidance

Introduction

The proliferation of Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) and Robotics and Autonomous Systems (RAS) technologies is changing the character of war by allowing smaller forces to distribute and influence larger areas. However, the data collected during operations is quickly outpacing human cognition. As early as 2013 the Department of Defense noted that, "There has been a dramatic increase in ISR collection and … data collected. We continue to find that we often collect more than we can process, exploit, and disseminate. We also recognize that the PED resource requirements in terms of the numbers of analysts at the tactical level may never be enough."[2]

If exploited quickly, C4ISR/RAS data will give commanders an information advantage over the enemy. But gaining timely and actionable intelligence from these sources is manpower intensive and the data must be quickly processed, exploited, and disseminated (PED) by human means to be useful. This is problematic for the Marine Corps if expeditionary forces are going to compete and gain a competitive advantage through C4ISR against a near-peer. This wealth of information can lead to faster planning—decision—execution (PDE) cycles, but if left unmanaged it will overwhelm leaders with information and indecision. Commensurate steps must be taken to leverage new technologies to automate and manage data. If Marines are going to compete with near-peer adversaries, the Marine Corps must embrace Artificial Intelligence (AI) as a Decision Support System (DSS) for faster PDE cycles in order to gain a cognitive, temporal, and lethal advantage over the enemy.

The goal of this paper is to demonstrate that a commander's ability to observe, orient, decide, and act within his environment is accelerated using AI techniques. This paper acknowledges, but does not purport to solve, significant obstacles to technical issues that arise with radio frequency communications, information systems, and organizational change. This paper is organized into four different parts. The first part focuses on the challenges with the changing security environment and emerging technologies and how these will impact the commander. The second part discusses technological solutions, decision-making models, and how AI applied as a DSS will create a cognitive, temporal, and lethal advantage for an EAB commander. The third part illustrates the advantages of such a system in notional combat vignettes an EAB commander might well face in a future conflict. The final part focuses on obstacles to implementation and recommendations for the way ahead.

Part I: New Security Environment and Emerging Challenges

Since 2001, the Marine Corps has focused on Violent Extremist Organizations (VEO) and counter-insurgency warfare in Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and recently Operation Inherent Resolve (OIR). U.S. Armed Forces assumed a permissive environment that favored technological superiority, unfettered lines of communication, and freedom of movement in all domains. This paradigm changed with the 2018 *National Defense Strategy (NDS)* and 38th Commandant of the Marine Corps, *Commandant's Planning Guidance (CPG),* which re-designates great power competition as the nation's top defense priority and the Marine Corps as a naval expeditionary force-in-readiness in support of fleet operations.

To support this new strategic direction the Marine Corps developed *Expeditionary Advanced Based Operations (EABO)* as an enabling capability for *Littoral Operations in a*

Contested Environment (LOCE) and *Distributed Maritime Operations (DMO)*. EABO supports the Joint Force Maritime Component Commander (JFMCC) or Fleet Commander by providing an amphibious force to obtain, sustain, and advance naval interests in an Anti-Access Area Denial (A2/AD) environment as an integrated maritime defense in depth for sea control.[3] However, EABO poses some specific challenges for the force that must be considered. These challenges are competition against a near-peer in all domains, reliance on emerging technology, the tradeoff between personnel and capability, and the complications due to geographical distance and distributed operations. The overall theme is how to overcome these challenges by integrating AI technologies at key points to enhance a commander's PDE cycle.

The Processing Exploitation Dissemination (PED) Problem

If intelligence drives military operations, the Marine Corps is heading for problems. As noted earlier, data collection is outpacing the processing, exploitation, and dissemination (PED) process at the tactical level.[4] Data by itself is useless; it must be organized and contextualized to be valuable. According to the

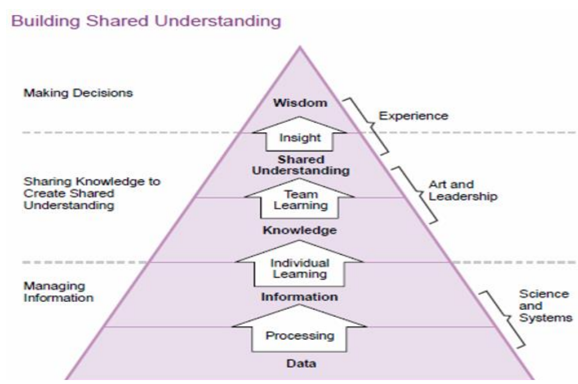

Figure 1: Cognitive Hierarchy Model
Source: Department of Defense, Joint Chiefs of Staff. *Joint Concept for Operating in the Information Environment.* Washington, DC: July 2018. 12.

Cognitive Hierarchy Model (Figure 1), data and information are critical to creating a shared understanding.[5] The Joint Intelligence Process does this through a six-stage process of planning and direction, collection, processing and exploitation, analysis and production, dissemination and integration, and evaluation and feedback.[6] The proliferation of C4ISR/RAS has expanded collections without a commensurate increase in PED. Unless steps are taken to automate information management, commanders risk information overload and decision paralysis.

Information overload is the difficulty in making decisions due to a person's inability to process large amounts of data or information.[7] Robert S. Baron's 1986 seminal study on Distraction-Conflict Theory shows that:

> Decision makers performing complex tasks have little if any excess cognitive capacity. Narrowing one's attention as a result of the interruption is likely to result in the loss of information cues, some of which may be relevant to completing the task. Under these circumstances, performance is likely to deteriorate. As the number or intensity of the distractions/interruptions increases, the decision maker's cognitive capacity is exceeded, and performance deteriorates more severely. In addition to reducing the number of possible cues attended to, more severe distractions/interruptions may encourage decision makers to use heuristics, take shortcuts, or opt for a satisficing decision, resulting in lower decision accuracy.[8]

Given Baron's conclusion, C4ISR/RAS will decrease not increase a tactical commander's decision-making. Prior research conducted by the author, while serving as the Ground Combat Element (GCE) Branch Head, Science and Technology Division, Marine Corps Warfighting Lab (MCWL) confirms this conclusion.

> In 2013 the Marine Corps Warfighting Lab (MCWL) conducted the Tactical Network Sensor Suite (TNS2) Limited Technical Assessment (LTA). A Marine rifle company and its subordinate platoons were equipped with air and ground robots, ground sensors, and a tactical robotic controller (TRC). The TRC enabled one operator to conduct ISR, controlling multiple vehicles simultaneously, day or night, beyond line of sight. MCWL named this form of ISR multi-dimensional ISR (Figure 2). The LTA showed that platoon commanders using TNS2 quickly detected threats in the defense, offense, and while patrolling, but the LTA uncovered two signficant problems: 1. Until software and robotics can autonomously analyze and correlate sensor inputs, Marines will still have to collect and collate ISR data; and 2. Under medium to high operational stresses…operators become overloaded... failing to detect and identify targets and suffering a general loss of situational awareness. [9]

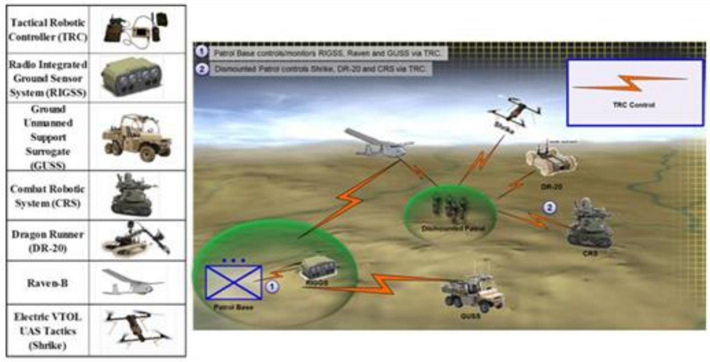

Figure 2: Multi-dimension ISR
Source: U.S. Marine Corps, Marine Corps Warfighting Laboratory, Tactical Network Sensor Suite (TNS2) Capstone Limited Technical Assessment (LTA), 2013. (Quantico, VA: MCWL 2013), 9.

The Marine Corps Intelligence Surveillance and Reconnaissance – Enterprise (MCISR-E) is addressing these concerns by incorporating a predictive analysis process through the MEF Intelligence Centers (MICs), Marine Corps Intelligence Activity (MCIA) with connectivity to the Combat Support Agencies (CSAs) and National Intelligence Community (IC).[10] MCISRE has addressed full motion video (FMV) joint PED support through Marine Corps Intelligence Activity (MCIA) and in 2017 stood-up the FMV JPED cell with a full operational capability to provide twelve hours of support, seven days a week at a cost of fourteen analysts and three mission commanders.

Although a step in the right direction, this may prove inadequate due to the heavy manpower requirement. The EAB Commander must rely on finished intelligence products produced from a geographically separated higher headquarters, transmitted over a contested electro-magnetic spectrum. Results from the MCWL's experiment MIX 16 (Marine Air Ground Task Force Integrated Exercise) confirm this conclusion: "future wars will be fought in challenging electromagnetic environments, the ability for distributed units…to "reach back" for daily intelligence assistance from a higher HQ may be limited and something that could not be relied upon." Additionally, more analysts added at the tactical and operational levels can lead to circular reporting,[11] which will only increase the information overload problem.

The EABO/Distributed Operations (DO) Dilemma

According to the EABO Handbook, an EAB must "generate the virtues of mass without the vulnerabilities of concentration."[12] Experimentation by the U.S. Army in 2016 shows that it is possible for smaller units to distribute and influence larger areas (Figure 3). The Manned Unmanned Teaming Concept (MUMT) posits that a unit employing sensors in depth, effects in depth, and supporting actions can achieve combat effectiveness and expand its area of influence.

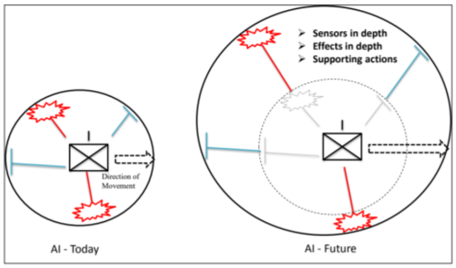

Figure 3: Expanding Area of Influence
Source: U.S. Army, Maneuver Battle Laboratory, Manned Unmanned Teaming Ground (MUM-T(G)) Tactics, Techniques, and Procedures (TTP), 2016. (Ft. Benning, GA: MBL 2016), 7.

However, DO and EABO are a zero-sum game. C4ISR and RAS technologies allow units to distribute farther, but experimentation reveals that economies of scale are lost. Increasing the force will increase the demands in all areas. As Pineiro concluded in a 2017 research paper, "When forces distribute, they lose efficiencies in supporting functions such as command and control, intelligence, and fires;"[13] and is also acute with respect to logistics. This DO Dilemma can be represented by the following revised "Triple Constraint Paradigm"[14](Figure 4). A consolidation in one area will decrease capability in the other as forces distribute. If the EAB Commander can increase her capability without increasing her EAB footprint, she can regain economies of scale. Intelligent technological integration can solve this problem.

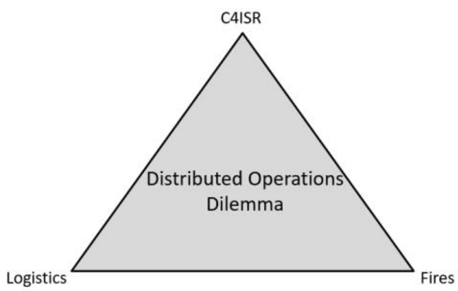

Figure 4: The Distributed Operations Dilemma
Source: Modified by the author from U.S. Marine Corps, Marine Corps Warfighting Laboratory, Enhanced MAGTF Operations Advanced Warfighting Experiment (EMO AWE), 2014. (Quantico, VA: MCWL 2014), 91.

Part II: Merging Technology, Decision-making, and Concepts

Artificial intelligence demonstrates the greatest potential for solving the PED Problem and EABO/DO dilemma, while providing adversarial overmatch to the Commander. According to the General Accounting Office, "AI can be used to gather an enormous amount of data and information from multiple locations, characterize the normal operation of a system, and detect abnormalities, much faster than humans can."[15] An AI system informed by the Joint Planning Process (JPP) can produce faster and more informed PDE cycles. If the Marine Corps wants to make EABO a reality, it cannot rely on humans alone. Instead, the future lies in operationalizing artificial intelligence to augment human decision-making.

Artificial Intelligence

The literature on Artificial Intelligence is vast and its meaning not clearly defined. The Department of Defense (DOD) describes AI as "the ability of machines to perform tasks that normally require human intelligence"[16] and Defense Advanced Research Projects Agency (DARPA) defines AI as "a programmed ability to process information."[17] DARPA recognizes three waves of AI development which, range from expert-based systems to intelligent autonomy that requires contextual understanding and explainability.[18] AI technologies are generally categorized into two areas: narrow and general. Narrow AI is commonly used today and focuses on task completion for a specific application.[19] General AI, which has not been created, is more akin to human intelligence and contextual understanding.[20]

Modern AI research originated in 1956 at Dartmouth College. Twenty-eight year old mathematician John McCarthy, with the help of colleagues Marvin Minsky and Claude Shannon organized a "2 month, 10 man study of artificial intelligence to be carried out during the summer of 1956."[21] The idea was that human learning and intelligence could be precisely explained and therefore replicated by machines.[22] This simplistic view in theory turned out to be more complex in practice.[23] The workshop produced few tangible results but did define the field and its goals, and many of the topics discussed -- natural language processing, machine learning, neural networks, etc. – still resonate to this day.[24]

Even today many researchers disagree philosophically on the definition and approach for developing artificial intelligence. What is generally accepted, however, is that AI moves beyond simple automation of tasks and performs complex functions that require analysis, learning, and reasoning. It does this using a multitude of sub processes that mimic human behavior and can augment human capabilities. Of the different areas of AI, the most critical for the EABO commander is machine learning, natural language processing, computer vision, and artificial neural networks.

Machine Learning is the focus of narrow AI and "uses algorithms to study data to detect patterns or by applying known rules to categorize, predict outcomes or actions, identify patterns and relationships, or detect anomalous or unexpected behaviors."[25] Machine learning occurs in two distinctly different ways: symbolic and sub symbolic. Symbolic uses symbols such as words, phrases, and rules like conscious human learning. Sub symbolic is devoid of rules and instead uses weight and threshold values to classify objects and learn – similar to subconscious neuron processes in the brain. Humans must train or supervise each method to ensure the AI is performing appropriately. The sub symbolic method is used to make artificial neural networks. It is critical to use both methods for military applications to maximize the system's learning potential within the constraints of human values or rules.

Artificial Neural Networks (ANN) are software programs modeled on the sub symbolic process using nodes organized into input, hidden, and output layers.[26] Similar to mammalian biological processes the input represents photoreceptors, the hidden layer neurons, and the output layer as the visual cortex.[27] Two or more of these nodes will produce a network, and the amount of the hidden layers for each node will determine the depth learning or amounts of data sets that can be processed.[28] It is this deep learning process that enables common second wave AI features such as natural language processing, computer vision, and deep learning.

Natural language processing (NLP) is the ability of a computer program to understand written and verbal human language and respond in an appropriate manner.[29] NLP allows the commander to interface and communicate with the intelligent virtual assistant similar to human means, and performs two functions for data retrieval and storage. First, the commander can query the information system without learning a programming language. Second, NLP data sources can be stored as unstructured textual data for later retrieval and continuous learning.[30] NLP is now commonplace and used extensively in smartphones and intelligent virtual assistants such as Siri, Amazon's Alexa, and Google.

Computer vision is the ability of a machine to recognize, process, and categorize images and video similar to human methods. The medical and security industries use computer vision technology extensively in the to augment professionals in disease detection and treatment and crime prevention.[31] This allows intelligent agents to analyze images for meaning and make rule-based decisions such as threat characterization and detection, pattern of life analysis, autonomous target acquisition, and "detect, sense, and avoid" behaviors for RAS autonomous operations in a global positioning system (GPS)-denied environment.[32]

Taken together a system using these narrow AI functions can conduct precision information operations[33] and extrapolate patterns and knowledge from the substantial amounts of data collected from sensors in the battlespace. This iterative process is known as knowledge discovery in databases (KDD) and involves interactive steps (selection, pre-processing, transformation, data-mining, and interpretation/evaluation) to produce usable information.[34] KDD as a Decision Support System (DSS) will provide an added benefit to an EAB Commander by reducing the manpower required for intelligence analysis and command and control (C^2) while simultaneously speeding up the PDE cycle.

Decision-making and Decision Support Systems

Studies have shown that human decision-making is imperfect and deteriorates rapidly in complex and stressful situations.[35] Human decision-making is largely intuitive and has been optimized by evolution to prevent cognitive overload by using judgment heuristics (biases).[36] Biases serve as shortcuts for rapid decision-making by making assumptions based on previous experience and knowledge. Although optimized, these decisions are not informed by the larger body of data that was negated due to heuristics. Since theses decision are based on previous experience and existing knowledge people thrust into chaotic and new situations can be unprepared. As discussed earlier, this is problematic for an EAB Commander. A decision support system can help.

A DSS can be any method a person uses to improve the quality of his decisions. A Marine Battalion Commander uses his staff and the Joint Planning Process (JPP) to provide expert judgment to improve decision quality and the commercial sector is increasingly relying on DSS and AI to process large volumes of data. For this paper, decision support systems are defined as "interactive computer-based systems that aid users in judgment and choice activities" also known as knowledge-

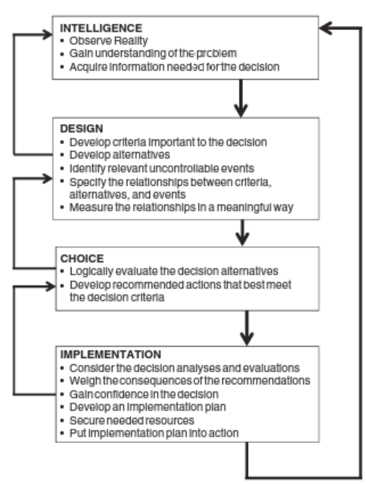

Figure 5: Simon's Theory of Bounded Rationality
Source: Doumpos, Michael, and Grigoroudis, Evangelos. Multicriteria Decision Aid and Artificial Intelligence: Links, Theory and Applications. Somerset: John Wiley & Sons, Incorporated, 2013. Accessed February 17, 2020. ProQuest EbookCentral, 27.

based systems because of "their attempt to formalize domain knowledge so that it is amenable to mechanized reasoning."[37] Most DSSs are modeled using Simon's Theory of Bounded Rationality, which recognizes human limitations in information, time and cognition for decision-making.[38] Simon proposed a four step model (Figure 5) consisting of 1. Intelligence to observe reality; 2. Design to develop and measure criteria and alternatives; 3. Choice to evaluate alternatives and recommend actions; and 4. Implementation to act on the information ending with a feedback loop to step one. [39]

The two key elements for the commander's decision-making are choice activities and reasoning. Choice activities, also known as *option awareness*, are the recognition of different courses of actions or alternatives in a situation. Option awareness provides the Commander different pathways to a solution. A DSS that can autonomously analyze enormous amounts of data may reveal options that weren't previously known. Reasoning is the ability to think in a logical way. By structuring the decision process, a DSS can draw conclusions about data in an unbiased and unemotional way. Some studies show that in realistic settings simple linear decision models even outperform experts in their field.[40]

There are differing classes of DSS and the type determines the performance and utility for human augmentation. The Intelligent DSS (IDSS) is the most relevant system for combat operations because it uses AI techniques and computer technologies to emulate human decision-making to solve an array of problems in real-time complex environments.[41] For the purpose of this paper, this will be called an Artificially Intelligent Decision Support System or AI-DSS. It is composed of a database management system (DBMS) to store data for retrieval and analysis, a model-base management system (MBMS) to capture decision-making models for structure and unstructured data, a knowledge base for selection of alternatives, and a user interface for the user to communicate with the DSS.[42] An AI-DSS combines the human strength for structuring problems with a system that supports complex decisions through statistical analysis and AI techniques in order to compress the PED process (Figure 6).

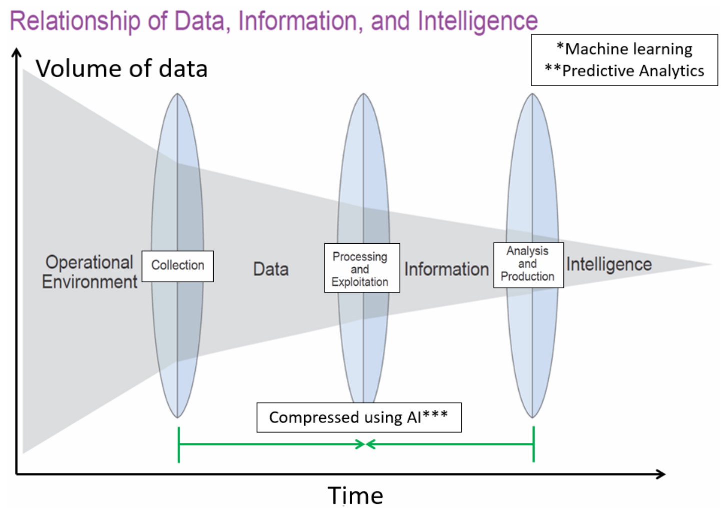

Figure 6: Compressing PED process
Source: Department of Defense, J2, Joint Publication 2-0, Joint Intelligence, 2013. (Washington, DC: October 2013), I-2, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp2_0.pdf. Modified by author.

AI-assisted OODA Loop

John Boyd, Col (USAF retired) is credited as one of the key authors of maneuver warfare doctrine and its corresponding model of mental processes. Through his work with experimental fighter aircraft, he recognized "mismatches contributing to one's success and survival, as well as the relationship between agility, tempo, and how one could exploit them to make an adversary's perceived reality diverge from actual reality."[43] To explain these mismatches he postulated a PDE cycle that came to be known as the OODA (**O**bserve, **O**rient, **D**ecide, and **A**ct) loop (Figure 7). Boyd theorized that the person

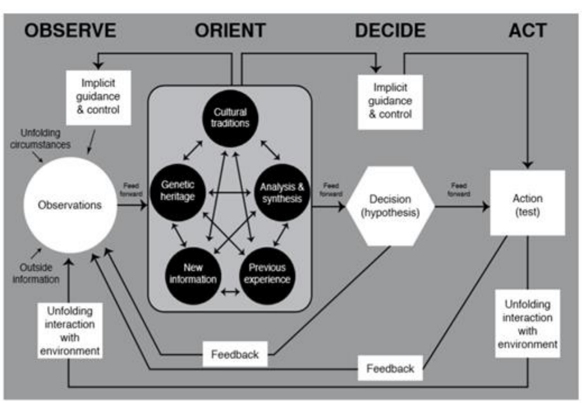

Figure 7: OODA Loop
Source: Major Ian T. Brown, *A New Conception of War: John Boyd, The U.S. Marines, and Maneuver Warfare* (Quantico: Marine Corps University Press, 2018), 119.

who could execute this process faster either by inductive or deductive reasoning would win. By integrating AI within the OODA Loop an EABO Commander can gain a decisional advantage over the enemy. As Commandant Berger states in his planning guidance, "We must reach and execute effective military decisions faster than our adversaries in any conflict setting, on any scale."[44]

Better information and options lead to more rapid and informed decisions while simultaneously reducing cognitive overload. EAB forces will be faced with supersonic and potentially hypersonic weapons that will leave them little time to make well informed decisions. The EAB commander will be forced to sense the threat with a vast array of manned and unmanned sensor platforms and rapidly determine a course of action.

The AI-assisted OODA Loop (Figure 8) visually depicts how the EAB Commander will make decisions with the aid of AI techniques. It places Boyd's OODA Loop as the foundation for a commander's PDE cycle. This reflects the commander as the center of the decision-making process and prime consumer of intelligence and decision support. The next layer is the Office of the Director of the National Intelligence (ODNI) six-step intelligence cycle used to process data into intelligence. Next, Simon's Bounded Rationality model is integrated to depict how the AI-DSS would nest within the EAB Commander's decision framework. Finally, the external agents enhanced with narrow AI are overlayed to represent the physical tools (e.g. RAS, weapon systems, AI-DSS, and graphical user interfaces (GUI)). Integrating narrow AI at key points to automate sensor operation and exploitation, PED of data and intelligence, and weapons employment reduces manpower and compresses PDE cycle time creating windows of advantage for the commander to exploit.

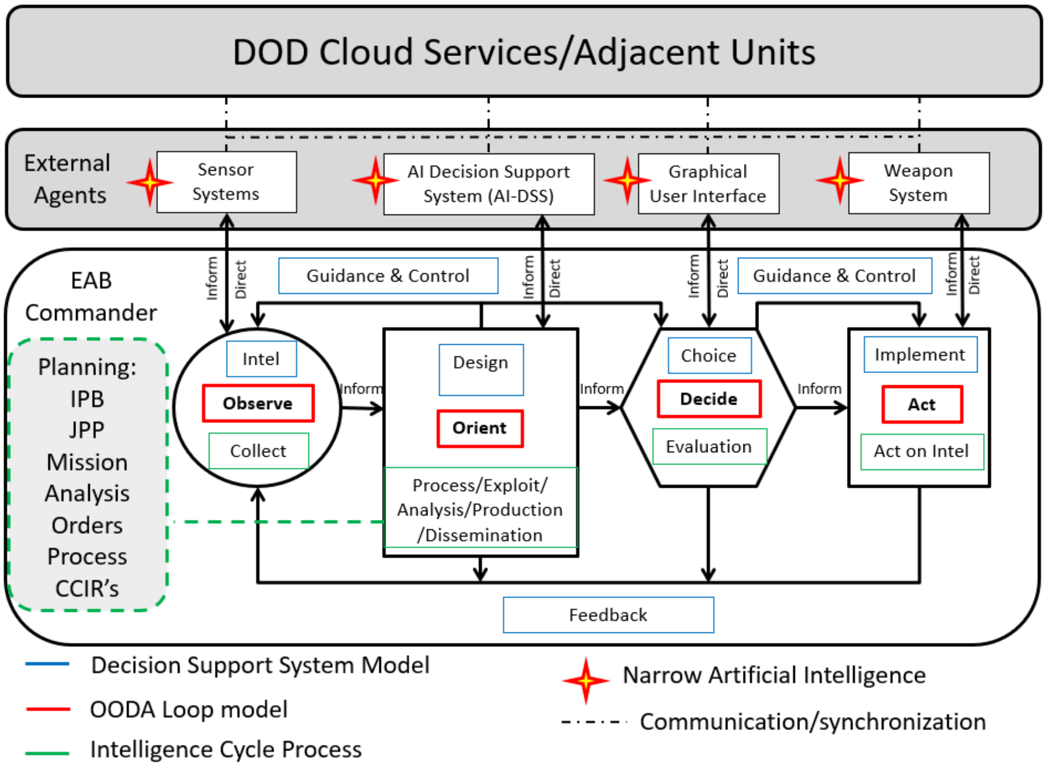

Figure 8: Artificial Intelligence (AI)-assisted OODA Loop (AI-OODA Loop)

Source: Created by the author.

Concept of Operations

Since the EAB Commander will operate in an austere, distributed, and resource-constrained environment, he must regain efficiencies lost in those areas in order to overmatch his opponent. The AI-OODA Loop will solve the problem in the following way. Prior to the mission the commander conducts her mission analysis/staff planning process to determine the Commander's Critical Information Requirements (CCIR) (Priority Intelligence Requirements (PIR) / Friendly Force Information Requirements (FFIR)) and tasks associated with the higher headquarters intent (intelligence preparation of the battlespace (IPB), area of operations, tasks, constraints/restraints, etc.

In Step 1. Observe phase, the commander is collecting data about his operating environment, enemy disposition, and friendly disposition to validate the baseline assumptions from IPB and to update his situational awareness. This is accomplished by using multi-source intelligence aided by DOD cloud services and unmanned systems equipped with computer vision and machine learning technologies that will autonomously analyze the environment for CCIR's. As these systems collect and identify CCIR's they may conduct two courses of action depending on the threat level and emissions control (EMCON) status: 1. Distribute/drawdown information to/from the cloud and/or edge AI platform (AI-DSS); 2. Limit communication and return to base for exploitation. The data collected from this process will be fed forward to Stage 2 - Orient to determine meaning and relevance.

In Step 2. Orient phase, the commander is making meaning of the vast amounts of data collected in order to make the appropriate decisions. The output of step one must be processed by human means consuming significant time and resources as the data pool grows. If this is not properly managed the commander risks information overload paralyzing her ability to determine a course of action. Research shows that people will use sub-optimal coping strategies leading to cognitive biases when faced with human cognitive limits such as information overload.[45] Step two is the bottleneck in the current process and the ideal location for an AI-DSS to alleviate information overload and PDE cycle times.

The strength of the AI-DSS is that it can autonomously and digitally integrate data from an infinite amount of sources to include multi-source intelligence, RAS, adjacent edge AI nodes, open source data, and eventually DOD cloud-based services to produce decision aids, predictive threat forecasts, or response courses of action. By monitoring these sources, AI can extrapolate patterns and meaning using KDD to detect enemy intentions and respond using a kill chain model of F2T2EA (Find, Fix, Track, Target, Engage, Assess) in Step 4 of the AI-OODA Loop. Similar to techniques used in Computer Network Defense (CND) an EABO force can detect enemy actions, associate enemy kill chain indicators to defender courses of action, and identify patterns that link individual enemy actions into the broader campaign[46] creating a land-based Intelligence Driven SLOC (Sea Line of Communication) Defense (IDSD) for local sea control. His intelligence picture is now informed with the best data available and assisted with AI generated courses of action (COA) in preparation for Step 3 - Decide.

In Step 3. Decide, the commander is now ready to determine what course of action will produce the desired outcome. The AI-DSS can recommend COAs, determine the probability of success, and recommend follow-on actions or adversary actions. Using the graphical user interface her decision can be communicated throughout the echelons and to RAS platforms creating an integrated manned-unmanned team across a distributed battlespace.

In Step 4. Act, the commander is executing the mission and using feedback mechanisms to inform his next decision cycle, which has been communicated through an integrated communications, fires, and command and control network to determine the available and appropriate weapon system. The AI OODA Loop will continue cyclically until the commander has achieved her desired endstate or the situation no longer necessitates tactical action. By leveraging AI as a DSS the commander has achieved:

1. <u>Convergence</u> - the ability at echelon to integrate rapidly, continuously, and accurately organic and external capabilities from across all domains, the electromagnetic spectrum (EMS), and the information environment;
2. <u>Optimization</u> - the ability to deliver effects to the right target, at the right time, and in the most effective and efficient manner possible;
3. <u>Sychronization</u> - the ability to combine situational awareness, fires (lethal and nonlethal), and maneuver to penetrate and exploit; and
4. <u>Speed of awareness and action</u> - the ability to recognize and visualize conditions leading to windows of domain superiority and/or challenges and to act on those during all phases of the conflict continuum;

with confidence that all data points are weighted in an unbiased way and at a faster cycle rate than the enemy.[47]

Part III: Vignette on AI-Assisted EABO

This section will tie the themes discussed previously through a vignette that explain how an AI-OODA Loop will operate in a prospective conflict. It is intended to give the reader a conceptual overview of how this system may be employed, the challenges it solves, and the opportunities it creates.

BACKGROUND: At the onset of hostilities an EAB will exist either in the Forward Line of Troops or an isolated mobile defense. As a forward island-based element, the EAB becomes the primary reconnaissance, sensor, and fires platform for the joint force. As tactical reports from ATHENA (AI-DSS) begin to flood the EAB command post, the Commander must make a series of rapid decisions. Is he under attack? Must he displace? How much time does he have? How does he respond?

TIME/YEAR: 2100L/2030
LOCATION: EAB ELLIS, SOUTH CHINA SEA
MISSION: Establish EAB Ellis and provide local sea control in the vicinity of the Spratly Islands in order to enable 7th Fleet freedom of navigation and ensure Philippine territorial security.

- 21:00:05 – (ATHENA) "CCIR - U.S. Destroyer detects four J-23 aircraft inbound to your position, estimated time of arrival four minutes."
- 21:00:07 – (ATHENA) "CCIR - Unmanned aerial surveillance has identified priority intelligence requirement one -- enemy Type 075 amphibious assault ship detected 13 miles offshore IVO NAI 1 – estimated size: battalion landing team."
- 21:00:11 – (ATHENA) "CCIR – local twitter feeds and social media are reporting potential reconnaissance elements at NAI 5 two miles east of your position."
- 21:00:30 – (ATHENA) "CCNE – HHQ is receiving open source reports of enemy activity in your area of operations and is demanding an update."
- 21:00:31 – (EAB CO) – "ATHENA, what are your recommended courses of action?"
- 21:01:00 – (ATHENA) – "Hostile act: Yes; Hostile intent: maybe
    - COA 1 (Non-lethal) – Request aerial interdiction for J-23 (ETA 2 min) from Expeditionary Strike Group. Re-task UAS 1 to NAI 5 to determine disposition of recon forces. Broadcast message to enemy forces to determine intent."
    - COA 2 (Intermediate) – Activate electronic countermeasure decoys and disseminate force displacement message. Generate IO message to deceive enemy forces of friendly intent."
    - COA 3 (Deadly Force) – Respond with deadly force. Designate enemy surface ships, reconnaissance forces, and J-23. Generate fire support message."
- 21:02:00 – (EAB CO) – "Combine COA's 1 and 2 with force displacement on standby. Prepare for escalation to COA3. Notify HHQ of the situation and continue to monitor."

In this scenario, the AI-DSS is feeding the EAB Commander's PDE cycle by integrating forward sensing and fires capability. Battlefield sensors will locally collect the atmospherics of the threat environment. Using a tiered structure (strategic, operational, tactical), the EAB AI-DSS will locally process and distribute information to higher echelons (Figure 9). Simultaneously, higher friendly C4/ISR networks will integrate the information into a joint force common operational picture. This will give the Joint Force Maritime Component Commander (JFMCC) timely, precise, and relevant information to act on. The AI-DSS will prioritize missions based on threat, recommending time windows, cueing of ISR platforms and weapons systems, and potential adjacent unit handoff.

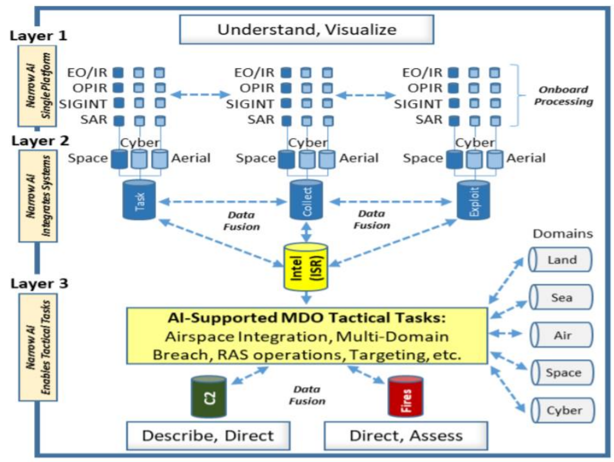

Figure 9: Layered AI Framework
Source: U. S. Army Futures Command, Future Study Plan 2019: Operationalizing Artificial Intelligence for Multi-Domain Operations, (Fort Eustis, VA: U. S. Army Futures Command 2019), 9.

Part IV: Obstacles and Recommendations

Several issues exist that are not the subject of this paper but are significant barriers to acceptance and development of an AI-DSS. Focusing energy and resources into these areas will stimulate industry solutions and assist the Marine Corps in developing the requisite policy, procedures, and tactics necessary to achieve this concept and bring the Marine Corps in line with the DOD strategy for AI.

The first issue is an AI Concept of Support for EABO. Without a clear understanding of the problem Marines are unable to make the proper investments in technology, training, and experimentation. One avenue to consider is partnering with the U.S. Army. In August 2019, Army Futures Command released the *Future Study Plan 2019 - Operationalizing Artificial*

Intelligence for Multi-Domain Operations (MDO). *MDO* is a Joint Force concept and the Marine Corps nests easily within the expeditionary echelon.[48] This study, reinforced through wargaming outlines the requirements, strengths/weaknesses, and operational vignettes for establishing an AI capability in an A2/AD environment.

The second issue is Marine Corps AI resourcing. The *USMC Annex to the Department of Defense AI Strategy* establishes an AI community of interest (COI) and AI Branch at MCWL to prioritize and synchronize the AI effort and develop a Marine Corps AI strategy. This is a good start but falls short of the resources needed to operationalize artificial intelligence. The Marine Corps must leverage the scope and scale of the U.S. Army's AI work in Multi-Domain Operations to hasten technology maturity, experimentation, and force development. MCWL AI Limited Technical Assessments should focus on how an AI-DSS could enable, improve, or completely revise the execution of tasks associated with ISR-Strike, C2, sustainment, and force protection. Opportunities exist to collaborate in 2020 with the Army Artificial Intelligence Task Force (A-AITF) for its FY20 Study Plan on operationalizing AI.

The third issue is enterprise data management. The DOD struggles to aggregate its data and assemble it into a usable form.[49] In order to fix this problem, the DOD Digital Modernization Strategy calls for enterprise cloud data services also known as the Joint Enterprise Defense Infrastructure (JEDI).[50] The Commandant also recognized the Marine Corps deficiency in data collection, management, and exploitation to facilitate better decision-making.[51] For machines to conduct KDD there must be large usable data sets to work from. The Marine Corps must structure its data in a way that enables AI-DSS's and other deep learning technologies to exploit for operational gain.

The fourth issue is trust in AI technology. According to the GAO, AI is approaching the third wave but is not without serious barriers: “An important part of third-wave AI will be developing AI systems that are not only capable of adapting to new situations, but also are able to explain to users the reasoning behind these decisions.”[52] Current deep learning methods have tremendous analytical capabilities but have at times produced unusual results. The ability to explain how Artificial Intelligence derives its answers is necessary for commanders’ to trust and use an AI-DSS in military operations.[53] Explainable AI is a concern to both DOD and the commercial sector, and the commercial sector is leading the research into possible solutions. Understanding why a good or bad decision is made engenders trust in the technology and is essential for military operations.[54]

The fifth issue is edge computing or “pushing computing power down to the source of data instead of relying on a centralized computing solution.”[55] This is necessary because the electromagnetic spectrum will be contested and machines will not be able to rely on consistent communication and cloud-based computing. The data network architecture will require restructuring in order to become more disaggregated and survivable against catastrophic loss and each edge device should be able to mesh and communicate with adjacent nodes. In practice, data connectivity will occur on a sliding scale from full to denied depending on the threat environment. This will allow an AI-DSS to conduct rapid PED on locally collected data, real-time and in support of the EAB commander’s decision cycle. Additionally, the DOD must offer cloud-based services at the tactical edge with 5G data rates[56] to fully exploit AI and RAS at machine speed with low latency. Again, this is an area of collaboration with the U.S. Army for Multi-domain Operations.

The sixth issue is that this has been tried before. In 2002, DARPA created the PAL (Personalized Assistant that Learns) program as a cognitive computing system that learns to assist users with tasks in order to make more effective military decisions.[57] One of the main goals was to reduce the need for large staffs so that the decision-making could be more distributed and less vulnerable to attack. Some of PAL's features to include multiple source data fusion into a single feed transitioned to Apple Siri personal assistant and the U.S. Army's Command Post of the Future (CPOF) program.[58] The author was not able to get detailed information on the limitations of the PAL program however, the Army recognizes the need for an expeditionary decision support system and is streamlining CPOF now. The Command Post Computing Environment (CPCE) consolidates multiple environments into a single user interface with an overall weight reduction from 1200 pounds to 300 pounds and is intended for mobile operations.[59] This is a step in the right direction and a potential collaboration area for the Army and Marine Corps.

Lastly, MCWL should study areas for narrow AI in RAS, computer vision, machine learning, and data analytics that can be immediately applied to reduce the commander's cognitive load.

Conclusion

Current C4ISR/RAS are labor intensive and create an enormous amount of data that must be exploited quickly to provide actionable intelligence to naval forces. Artificial intelligence using data analytics and machine learning can process, exploit, and disseminate information more quickly than human processes. An EAB commander equipped with an AI-DSS will make more informed decisions at a faster rate than his adversary. However, significant barriers currently exist before this can become a reality. Moving forward, the Marine Corps must produce a Marine Corps Operating Concept that nests within Naval Operating Concepts, adequately prioritize and resource AI efforts, resource enterprise data management to maximize data analytics and machine learning for knowledge discovery in databases (KDD), and leverage U.S. Army AI experimentation and concept development for Multi-Domain Operations (MDO). In addition, the Marine Corps should determine current technology and operational areas that can be improved by narrow AI today.

The Marine Corps can no longer rely on antiquated decision support systems and methods of information management for tactical decision-making. The information load on the commander will continue to increase as friendly and adversary forces leverage technology for tactical gain. An AI-DSS can solve this problem. The MCDP 6 states why this is imperative, "Whatever the age or technology, effective command and control will come down to people using information to decide and act wisely….the ultimate measure of command and control effectiveness will always be the same: Can it help us act faster and more effectively than the enemy?"[60]

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