The Boyd Loop Explanation of Artificial Intelligence for Policy Makers

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ABSTRACT

One of the most effective, yet simple, frameworks to describe military operations, whether it be ground maneuver, aerial combat, or cyberspace operations, is the Boyd (Or OODA [Observe-Orient-Decide-Act]) Loop. The Boyd Loop paradigm describes the process individuals, commanders and units use to observe the situation, orient onto the conditions that exist, decide how to act, carry out the decision, and then to repeat the cycle. The simplicity of the Boyd Loop makes it an excellent tool to use in educating senior leaders and policy makers reference the employment of Artificial intelligence (AI) and Machine Learning and into military operations. Both capabilities are increasingly being leveraged to support and facilitate command and control within military operations by increasing access to pertinent data and more importantly increasing the speed of each step of the loop in comparison to our adversary. The premise of achieving decision advantage and ultimately decision dominance depends on AI and ML enabling commanders' and units' ability to not only execute the OODA loop faster than the adversary but also find means and methods to disrupt his OODA that supports his decision cycle. Although the initial results of enabling decision making through the application of AI and ML have been positive, civilians, as well military leaders and policy makers, have nonetheless expressed doubt or caution as to their use for fear of "the machines taking over" or lack of humans in- or on-the loop to approve decisions. Similarly, the United States must make use of AI in its command and control systems as quickly as practical to keep pace with peer threats' use of these capabilities. In pursuing a military advantage achieved though AI and ML aided Decision Dominance, western leaders, especially, must recognize, mitigate, and address the apprehension over the use of AI and ML for it to be effective. The purpose of this paper is to propose a framework using the Boyd Loop to explain AI enabled operations and decision making to policy makers as well as describe the key conditions, characteristics, and capabilities needed to increase trust in its use. The paper will conclude with other potential uses of the framework and areas such as doctrine and policy development for continued development. The intent is that this paper will contribute to the body of knowledge concerning AI and ML for this conference and other venues by focusing on its incorporation into mission command by using the Boyd Loop as a methodology for educating and developing trust in its use among commanders and policy makers.

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INTRODUCTION

One of the most effective, yet simple, frameworks to describe military operations, whether it be ground maneuver, aerial combat, or cyberspace operations, is the Boyd (Or OODA [Observe-Orient-Decide-Act]) Loop. The Boyd Loop paradigm describes the process individuals, commanders and units use to observe the situation, orient onto the conditions that exist, decide how to act, carry out the decision, and then to repeat the cycle. The simplicity of Boyd's Loop and its ability to compare quantitative (relative speed of each step) and qualitative (effectiveness of the decisions) between adversarial forces makes it an inter-service accepted framework to describe various military operations from aerial combat to ground maneuver and from tactical to operational and strategic levels of war. Given its universality of in describing decisions and actions across multiple domains, the OODA Loop can also serve as an excellent tool to use in educating senior leaders and policy makers reference the employment of Artificial intelligence (AI) – "to the ability of machines to perform tasks that normally require human intelligence" (DoD Summary 2018 Artificial Intelligence Strategy, p.5) and Machine Learning (ML) - a discipline of artificial intelligence (AI) that provides machines the ability to automatically learn from data and past experiences – into military operations. Both capabilities are increasingly being leveraged to support and facilitate command and control within military operations by increasing access to pertinent data and more importantly increasing the speed of each step of the loop in comparison to our adversary. Although the results have been positive, civilians, as well military leaders and policy makers, have nonetheless expressed doubt or caution as to their use for fear of "the machines taking over" or lack of humans in- or on-the loop to approve decisions. Similarly, the United States must make use of AI in its command and control systems as quickly as practical to keep pace with peer enemy's use of these capabilities. These early concerns about how to apply advanced technologies to preestablished methods of operations are similar to the uneasiness expressed when artillery counterfire radars were first paired with automatically initiated indirect fire deliver systems without a human in the loop or when counter-improvised explosive device detect systems with automatic countermeasures were deployed. Just like previous technological advancements, senior leader and policy maker education was critical in securing endorsement for their use and building "trust" between machine action and decision maker under accepted policy guidance. In pursuing a military advantage over the pacing enemies of Russia and China achieved though AI and ML aided Decision Dominance, western leaders, especially, must recognize, mitigate, and address the apprehension over the use of AI and ML for it to be effective. The purpose of this paper is to propose a framework using the Boyd Loop to explain AI to policy makers as well as describe the key conditions, characteristics, and capabilities needed to increase trust in its use. The paper will conclude with other potential uses of the framework and areas such as doctrine and policy development for continued development. The intent is that this paper will contribute to the body of knowledge concerning AI and ML for this conference and other venues by focusing on its incorporation into mission command by using the Boyd Loop as a methodology for educating and developing trust in its use among commanders and policy makers.

BACKGROUND

The Boyd Loop

John Boyd was a US Air Force (USAF) Pilot who flew aerial combat missions in the Korean war. As the result of his experiences in combat, analysis of the aircraft involved, and actions the pilots took, Boyd developed a model for describing the cognitive and physical actions that took place during aerial combat. Boyd's model describes a cycle consisting of four primary phases- **O**bserve-**O**rient-**D**ecide-**A**ct, which has also led to it being referred to as the O-O-D-A (or OODA) Loop. In the model, the pilot **O**bserves the surroundings and situation, **O**rients to those conditions given his status and location, **D**ecides which course of action to pursue, and then **A**cts on, or executes, the decision. Speed of execution is essential; the pilot who can cognitively and physically execute the Boyd Loop fast will be at an advantage. Boyd biographer Robert Corum points out "the military believes that *speed* is the most important element of the cycle, that whoever can go through the cycle the fastest will prevail". (Corum, p. 334-5) Many authors reference speed, but we feel that in addition to speed, the accuracy, precision, and thoroughness of completing those phases is equally important. In developing it and staffing it with other professionals, Boyd's own version of the process is depicted on the next page, in Figure 1.

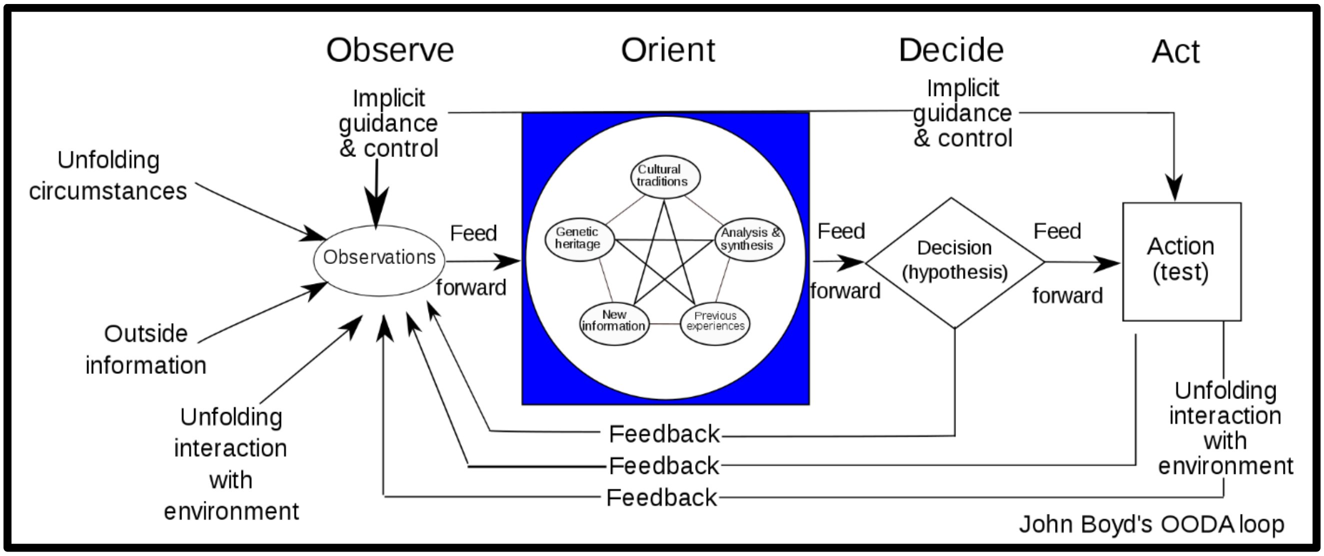


Figure 1. The Original Boyd Loop depicted by Patrick Edwin Moran

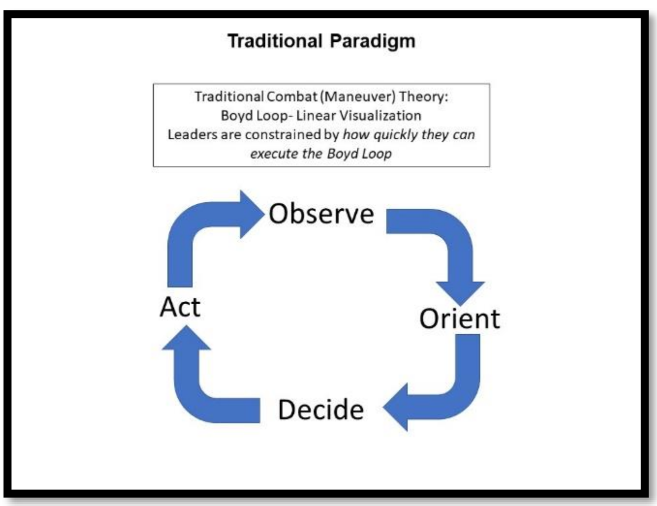
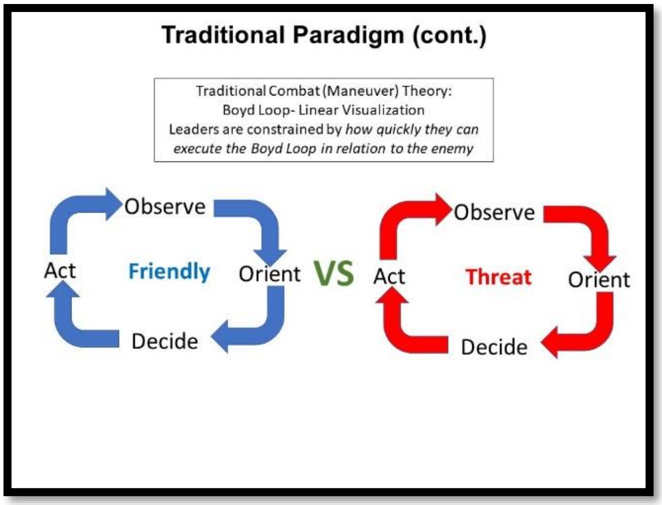


Figure 2. The Boyd Loop Simplified

As understanding of the Boyd Loop became more widespread and advocates of Boyd's theory became more comfortable with the nuances of the aspects of the four phases, the Boyd Loop is generally simplified and depicted by its four phase as in Figure 2. In addition to aerial combat, tacticians and historians have adopted Boyd's framework to describe and analyze ground maneuver warfare, as well as command and control, both the ability of commanders and staff to decide as wells as transmit guidance that controls action. In "The Art of Maneuver," Robert Leonhard expands the scientific discussion of speed by advocating that "The Boyd Loop is a subset of acceleration… By improving his staff's ability to cycle through the [Boyd] Loop, the commander adds to his acceleration and multiplies his force.



One aspect that is absent in many depictions of the Boyd Loop, is that the enemy pilot(s) or unit is executing their own Boyd Loop simultaneously to the friendly pilot. Consequently, the pilot who completes their cycles better (both in terms of speed and quality of decision and action) will have an advantage. These competing cycles recognize that each side is not standing by passively, simply reacting to Friendly actions – both OODA loops are in competition. Boyd referenced this as of the "unraveling the competition". (Corum, p. 334) As a result, a holistic view of the Boyd Loop in practice must depict the friendly execution **versus** the enemy execution of their respective Boyd Loops (Figure 3).

Figure 3. Friendly Versus Enemy Execution of the Boyd Loop

AI Integration into US Department of Defense and Policy Guiding Its Use

For understanding what is AI, a good reference is the November, 2019 United States National Security Commission on AI Interim Report for Congress which states "The term "artificial intelligence" covers a broad range of computer system abilities to perform tasks that otherwise would require human intelligence or other forms of intelligence observed in nature" (P. 53) The US DoD Summary of SI Strategy from 2019 states "We will launch a set of initiatives to incorporate AI rapidly, iteratively, and responsive to enhance military decision-making and operations across key mission areas. Examples include improving situational awareness, and decision-making…" (P.7) The US Army AI Strategy from 2019 adds to this understanding that "AI is not one thing or a single piece of software that can simply be acquired or installed; AI is a massive collection of interrelated technologies that work together to solve problems and make complex decisions. (P.4) The development of AI has facilitated faster and more accurate military operations especially in the area of command and control, especially in terms of analysis data and providing potential courses of action. Nonetheless, there is still an apprehension on the part of some military leaders to integrate AI as a tool.

The Army AI Strategy discusses this need to address this apprehension as "Bridging the Cultural Gap for AI" stating "One of the largest obstacles associated with integrating AI into the Army will be the cultural impact and potential lack of trust that the warfighting community may have about AI capabilities. These capabilities will involve substantial change to the status quo way of operating…. Regardless of specific pathways, bridging the cultural gap will require key interactions with all stakeholders, especially those in the warfighting community". (P.6)

Additionally, *The Army AI Strategy* addresses AI and its potential to assess and mitigate risk. It states "there are also areas of uncertainty that pose risks to successfully integrating AI within the Army. Perhaps the most notable among these is defensive AI used to counter adversarial AI…. For example, this may ultimately result in the need for a branch or sub-branch of OPSEC (Operational Security) to counter adversarial AI operations (P. 8) Returning to the Boyd Loop paradigm and Figure 3, the Friendly forces Boyd Loop is not operating in a vacuum- the enemy is processing through his own Boyd Loop Cycles- and this competition of "Out-Boyd-Looping" the enemy is exactly what leaders must understand about the power of integrating AI into command and control of military operations.

The Boyd Loop Empowered by AI and ML

With the development of AI and ML, and its introduction into mission command systems, military equipment, management of intelligence and operational databases, and other the depiction of the Boyd Loop in operation requires revision. Speed of the executions enabled by AI and ML not only accelerates the execution of the Boyd Loop, but actually enables the execution of multiple, simultaneous, and interdependent Boyd Loops. Individual phases of one Loop may inform other phases, as in Number 1, in Figure 4 (next page). The execution of one Boyd Loop can inform whole Boyd Loops simultaneously being executed, as in Number 2, Figure 4. Additionally, individual Phases in one Boyd Loop can inform multiple other Phases being executed in simultaneous Boyd Loops, as in Number 3, Figure 4.

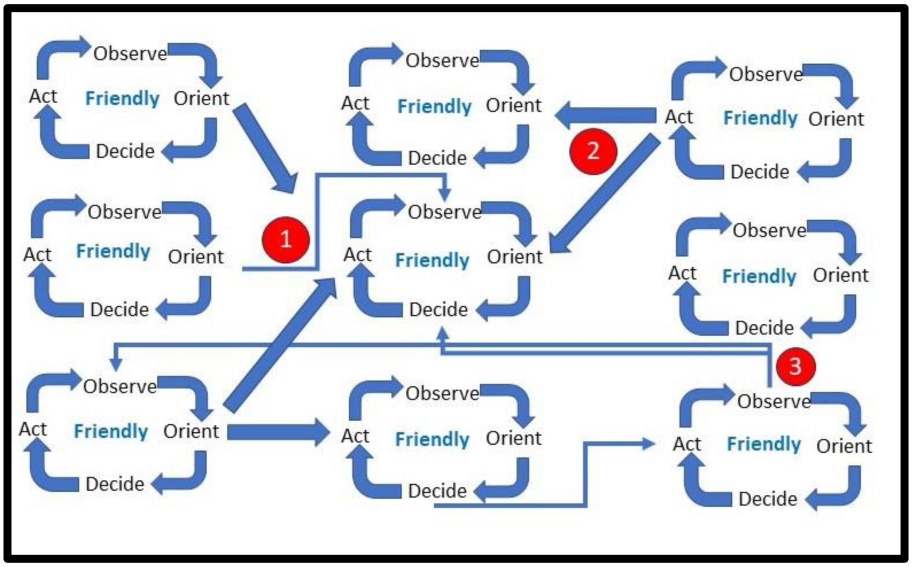


Figure 4. Boyd Loop Empowered by AI and ML

Boyd's original framework was developed for understanding aerial combat, but, as mentioned earlier, it is a useful tool for understanding maneuver warfare, especially command and control. At a recent Army Futures Workshop, over 70 AI and ML potential uses across key warfighting functions from intelligence to sustainment, were found to have applicability to increasing not just efficiency of the systems involved but also in increasing the speed, accuracy and tempo embodied in the Boyd OODA loop process. (Author's participation notes, June 2024) Multi-Domain operations (MDO or All Domain Operations)- those which include land, sea, air, cyberspace, and space are inherently complicated and are increasingly being enabled by AI and ML. Consequently, there are many examples of how AI and ML can facilitate the rapid execution and improve execution of the Boyd Loop. In the example of Number 1 in Figure 4, a unit who has observed and reported enemy movement in their Orient phase of an operation will nearly instantly inform other units to begin its own Observation phase concerning that particular enemy formation.

How the AI and ML-Enabled Boyd Loop Facilitates Attack of the Enemy Boyd Loop Execution

Figure 5 (next page) provides a framework for understanding the advantage of AI and ML to the friendly forces, just as with the traditional Boyd Loop, the enemy is not standing by passively reacting to friendly actions- they are executing their own Boyd Loops in a competitive cycle attempting to increase speed of decision and quality of action. This provides another aspect for consideration of the new Boyd Loop framework- how the AI and ML-empowered Boyd Loop can facilitate the attack on the enemy's execution of its own Boyd Loop throughout whole cycle as well as each sub-set. Through the exponential nature of AI (assistance in developing courses of action normally done by staff officers) and ML (optimized data collection and analysis), the Boyd Loop, cycles taking place in Figure 4 (above) are effectively taking place in every phase of every cycle of the Boyd Loop and is more accurately represented in execution by Figure 5. Additionally, as pointed out by MBL Analyst T.J. Sabau friendly actions directed at degrading or eliminating enemy execution of his own Boyd Loops has a binary result; it generally results in a degradation of the enemy's ability to transition from one Phase to another with varying effects depicted in Figure 5 as operational efficiency being anywhere from disrupted to excellent (or no impact to his operational efficiency). (Sabau discussion with author, April 2024). In the future, each portion of OODA loop will be supported by data and AI and ML supported analysis, course of action development and decision-making. Based on a comparison of the adversary's decision-making system, its strengths and weaknesses, action can be directed against portions of the adversary's system – attacking, disrupting or delaying his ability to Observe, Orient, Decide and Act. A disruption of any one of the subsets could place the enemy's ability to act and or reaction to friendly decision making at a distinct disadvantage and can create windows of opportunity.

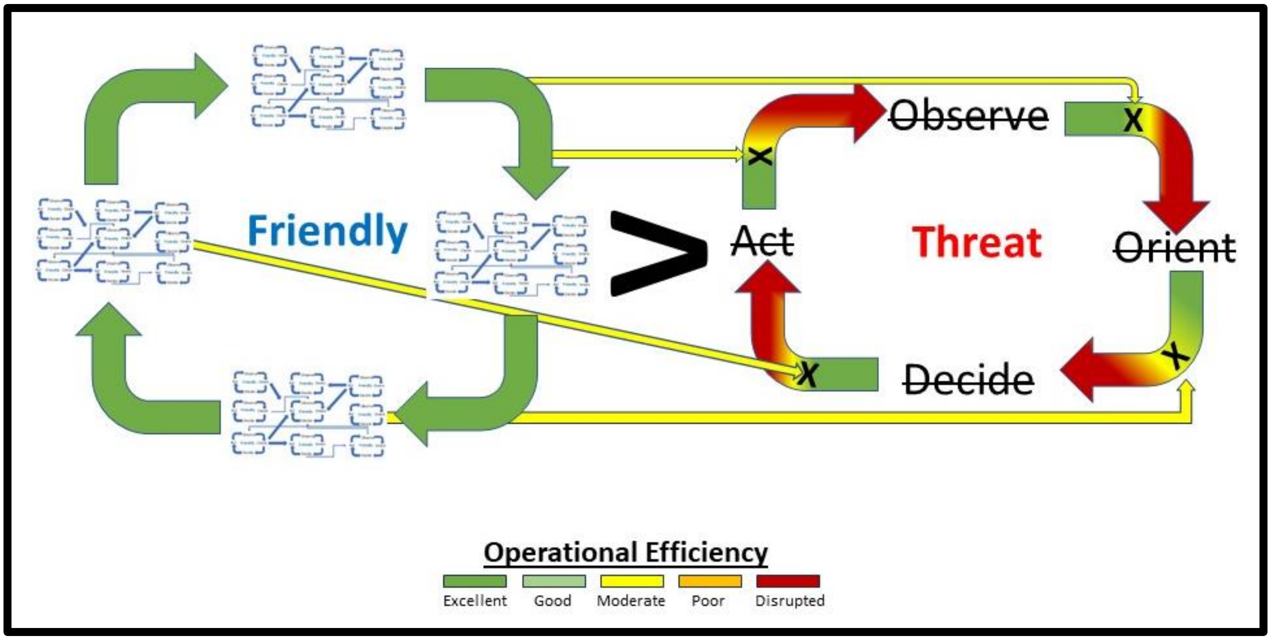


Figure 5. Friendly AI and ML-Enabled Boyd Loop Versus Enemy Execution of the Boyd Loop

AI Use Case: The System of Systems Enhanced Small Unit (SESU) Campaign at MBL

The MBL conducted the SESU campaign of experimentation from 2019 through 2023 which started as Tabletop (non-simulation based) experiments, followed by simulation experiments, and culminating with live demonstrations. This campaign of experimentation focused on the use of an AI-enabled advanced command and control web (AC2W) and how it facilitated both mission planning and execution. The background for the campaign is best summarized by the Background paragraph in the first simulation experiment (SIMEXp) background paragraph:

> [The US Army] Futures and Concepts Center and the Defense Advanced Research Projects Agency requested that the MBL assess the implications of enabling a small unit using autonomous and semi-autonomous air and ground platforms to deny, degrade, defeat, disrupt, or destroy the enemy's Anti-Access/Area Denial (A2AD) capability. The premise is that such capability could create windows for tactical and operational Joint Force Operations. The purpose of this experiment was to provide science and technology (S&T) requirements to industry partners for the development of an advanced command and control web (AC2W) enabled by artificial intelligence. This experiment hypothesized that, if an Army or Joint HQs employs a SESU formation to enable rapid transition to armed conflict, then enemy Integrated Air Defense System (IADS) will be degraded. This will facilitate Joint Force transition to full scale combat operations within a reduced standoff bubble when the Joint Task Force (JTF) is preparing for operations against a near-peer enemy. This SIMEXp is part of a larger campaign of learning and is the first of three scheduled SIMEXps. The intent is to move from pure constructive simulation to live experimentation over the next three fiscal years. (MBL SESU SIMEXp 1 Final Report, P. 4)

The SESU campaign was successful and culminated with several live-fire demonstrations of the concept. Originally, the SESU concept was focused at enabling Joint missions such as neutralizing enemy IADS and locating enemy command posts, but given the success of the AI-enabled AC2W, experiments examined its use at the US Army Division and Brigade Combat Team (BCT) echelons. Active duty US Army Soldiers from operational units participated as Military Role Players (MRPs) in all phases of the campaign. Initially Soldiers were very cautious in employing the technology. As the campaign progressed, an operational concept of employment was developed based on feedback and lessons-learned that guided each successive group of military role players (MRPs) who employed the AI-enabled AC2W technology. Based on the results documented in the Experiment Reports published by MBL, military role players in the SIMEXp gained trust in the system quicker and were more successful in mission execution. (MBL SIMEXp 1-3 Final Reports)

The SIMEXp conducted by MBL showed how the AI-enabled AC2W accelerated the friendly staff's execution of their Boyd Loop and were able to dis-integrate the enemy's execution of his own Boyd Loop. Examples of SIMEXp Final Report Findings and MRP comments concerning how the AC2W accelerated the execution of their own Boyd Loops included:

Observe- "AI Tools can be used to accelerate planning on the COA development stages of the Military Decision Making Process (MDMP)… This AI can be used to develop COAs and quickly conduct wargaming" (P. 52, SESU SIMEX 1 Final Report)

"The AC2W sensor web was effective at demonstrating the reconnaissance capability of SESU. Both performers [protype AC2W systems) use SESU systems to continuously gather intelligence, surveillance, and reconnaissance information during the mission". (P. 37, SESU SIMEX 1 Final Report)

Orient- The use of drone swarms to spoof or deceive the enemy will result in the enemy unnecessarily cueing radars and employing munitions resulting in faster positive identification of high payoff targets and engagement through the AI-enabled AC2W. (P.31, SESU SIMEXp 1 Final Report)

"Pairing the AC2W with automated/autonomous running estimates could substantially reduce the human-in-the-loop requirements for execution of the operations process (plan, prepare, execute, assess). The implications for the implementation of AC2W are substantial, especially if it can be adequately task organized depending on mission command level or target size. Successful ingestion of data to define mission parameters in support of decision-making processes can reduce cognitive burden on commanders and staffs." (P. 9 SIMEXp 2 Final Report)

Decide- "The AC2W's ability to collect and transfer large amounts of data to other systems allows analysts to provide real time intelligence to the commander, speeding up the decision making process. Ultimately, this can significantly shorten the predictive analysis process and enable the other warfighting functions (WfFs) to maximize effects on the battlefield. Ultimately, the end state is to assist in speeding up the Processing, Exploiting, and Disseminating (PED) of key information." (P. 9 SESU SIMEXp 2 Final Report)

Act- "The AC2W's ability to control and synchronize hundreds of assets to achieve surprise, mass and maintain concentration and a rapid tempo gave the commander a significant advantage during the fight." (P. 9 SIMEXp 2 Final Report)

"The dilemma for enemy forces was that if SESU swarms were approaching their larger more lethal systems they either had to keep their systems powered down and give up the airspace or engage SESU and make their position known. Once enemy radars were turned on, they could be engaged by SESU directly, or indirectly by using SESU ISR capability to send targeting information to [other assets]" (P. 42, SESU SIMEXp 3 Final Report)

Pacing enemys' use of AI andML

"*Artificial intelligence is the future, not only for Russia, but for all humankind. It comes with colossal opportunities, but also threats that are difficult to predict. Whoever becomes the leader in this sphere will become the ruler of the world*."

Russian President Vladimir Putin
1 September 2017

As near peer competition between the U.S. and China and Russia continue to extend across all elements of national power, especially in the area of military strength, the relative strength of nation's military can no longer be measured in terms of capability and capacity in relation to the potential opponent but whether one side can increase the speed and tempo of military action to such an extent that it places the adversary in a position of disadvantage. Both China and Russia have made significant investments in AI and ML military application to increase not only the speed but seek to overcome the deficient in leadership decision making by their commanders.

Russia – Development of AI capability even while embroiled in war with Ukraine

Prior to Russia's offensive actions against Ukraine in 2022, the Russian military was aggressively seeking to leverage AI and ML technology to enhance command and control, as well as layered air defenses and ground-based fires. Specifically, Russia focused on developing AI and ML tools to enhance tactical (battalion battle group) and operational (larger formations to include combined arms army and corps sized formations) employment of heir unmanned ariel vehicles, (UAVs), intelligence surveillance and reconnaissance (ISR) capabilities, and their employment and management of electronic warfare (EW). Given their lessons learned in supporting RU supported insurgents in the Donbas, along with operations in Syria in support of the Assad regime, Russian leadership saw the potential of AI and ML in combining these systems to make the battlefield more visible and transparent. This would allow them to more effectively control and mass Russian forces, particularly in terms of massing fires quickly and effectively. (Samuel Bendett et al, 65). Strategically, Russia has also sought to enhance its ability to shape the information environment through the integration of ML techniques into cyber and influence operations, these capabilities augment an existing Russian strength and further enhance their ability to influence and manipulate potential opponents and adversarial public opinion by embedding their opponent's decision-making process. AI and ML technologies have also been used to enhance RU's ability to disrupt and disable critical infrastructure. (Bendett, 66)

Over the last two years, both Russia and increasingly the Ukrainian military has sought to expand and use AI and ML as key data analysis tools to assist weapons' system operators, warfighters and commanders to make sense of the growing volume and amount of information available on the modern battlefield. Allowing them to make "more precise and capable responses to adversary forces, movements and actions" within their own decision cycles. (Benett CNAS article). In this respect, the Ukrainian through the use of western provided AI and ML analysis tools like Palantir, have been far more successful tactically in geolocating and analyzing open-source data such as social media content in order to identify Russian soldiers, weapons, systems, units or their movements. (Bendett, Russia Matters Article) This has greatly allowed enhanced the Ukrainian military's decision cycle (OODA loop) allowing them to shift forces and orient fires on key Russian formations before they moved making them more susceptible to indirect form. While having invested heavily in AI and ML technologies prior to invasion of Ukraine in 2022, Russian forces have only achieved minor tactical successes in providing autonomous capability to their uncrewed systems, specifically their Lancet loitering munitions. The Russian's have seen several strategic advantages in the information space through social media manipulation assisted by AI and ML. (Bendett, Russia Matters Article)

China – Seeking to advance "System on System" Warfare through the application of AI and ML

While Russia is actively seeking to integrate AI and ML into its fires centric character of war, China, in terms of a peer competitor, has set aside $150 billion in government funding to make China the first AI-driven nation – touching every aspect of life from health to law enforcement to ultimately a new character of warfare that focuses on "Intelligent Warfare". At its current proposed spending plan, China's AI spending program will reach 33 percent of the world's AI investment by 2027, up from 4.6 percent in 2022. (Arthur Herman).

The People's Liberation Army (PLA) is now conceptualizing a future battlefield environment dominated by artificial intelligence (AI) and autonomy. Not only does the PLA regard AI and autonomy as the future of warfare for which it must prepare; it also appears to regard them as an opportunity to offset the US military's technological superiority (Pollpeter and Kerrigan, 1). The Chinese Communist Party (CCP) sees AI and ML as essential in their modernization of all facets of the PLA which will allow them to move from current focus on *Mechanized Warfare* (focused on weapons systems and formations) through *Informatized Warfare* (focused on linking sensors, systems and people through systems) to ultimately *Intelligent Warfare* (weapons systems, formations and even process will be enhanced through the application of AI and ML) (Pollpeter and Kerrigan, 5).

As the PLA moves through the stages of mechanized to intelligent warfare, PLA military theorists, senior officials and strategist seek to incorporate AI into three key areas – autonomy of unmanned weapons, including the development of swarms of numerous drones; processing of large amounts of information through machine learning that assist in robotics but also electronic warfare; and speed up military decision-making. (Takagi)

As it relates to speeding up decision-making in hopes of establishing decision advantage over an adversary, numerous PLA military theorists argue that "…intelligent warfare will bring about an acceleration of the entire observe, orient, decide, act (OODA) loop process from intelligence collection to transmittal, processing, and decision-making" **(**Pollpeter and Kerrigan**,** ii, iv). One Chinese author asserts that development and incorporation of AI-enabled C2 "…John Boyd's OODA loop of "observe, orient, decide, act" so rapidly and effectively that they will replace humans." **(**Pollpeter and Kerrigan**,** 14)

As China moves from *Informatized* to *Intelligent Warfare,* B.A Friedman in "Finding the Right Model The Joint Force, the People's Liberation Army, and Information Warfare," there are four types of targets the PLA will seek to strike through kinetic or non-kinetic means:

> (1) the flow of information in the adversary's operational system, which likely refers to communications and sensors; (2) the essential elements of the adversary's operational system, which likely includes command and control, reconnaissance intelligence firepower, information confrontation, maneuver, protection, and support forces; (3) operational architecture of the opponent, which may refer to the infrastructure required to deploy and employ combat forces; and (4) support the PLA's aim to "slow down" the enemy system in a temporal sense, whether slowing down its decision making or its movement and reaction times. (Friedman, 8)

To achieve these goals, the PLA have built an AI and ML enabled system consisting of Reconnaissance Intelligence, Information Confrontation, Command, Firepower Strike to deliver these effects that targets the key sub steps of Boyd's OODA loop:

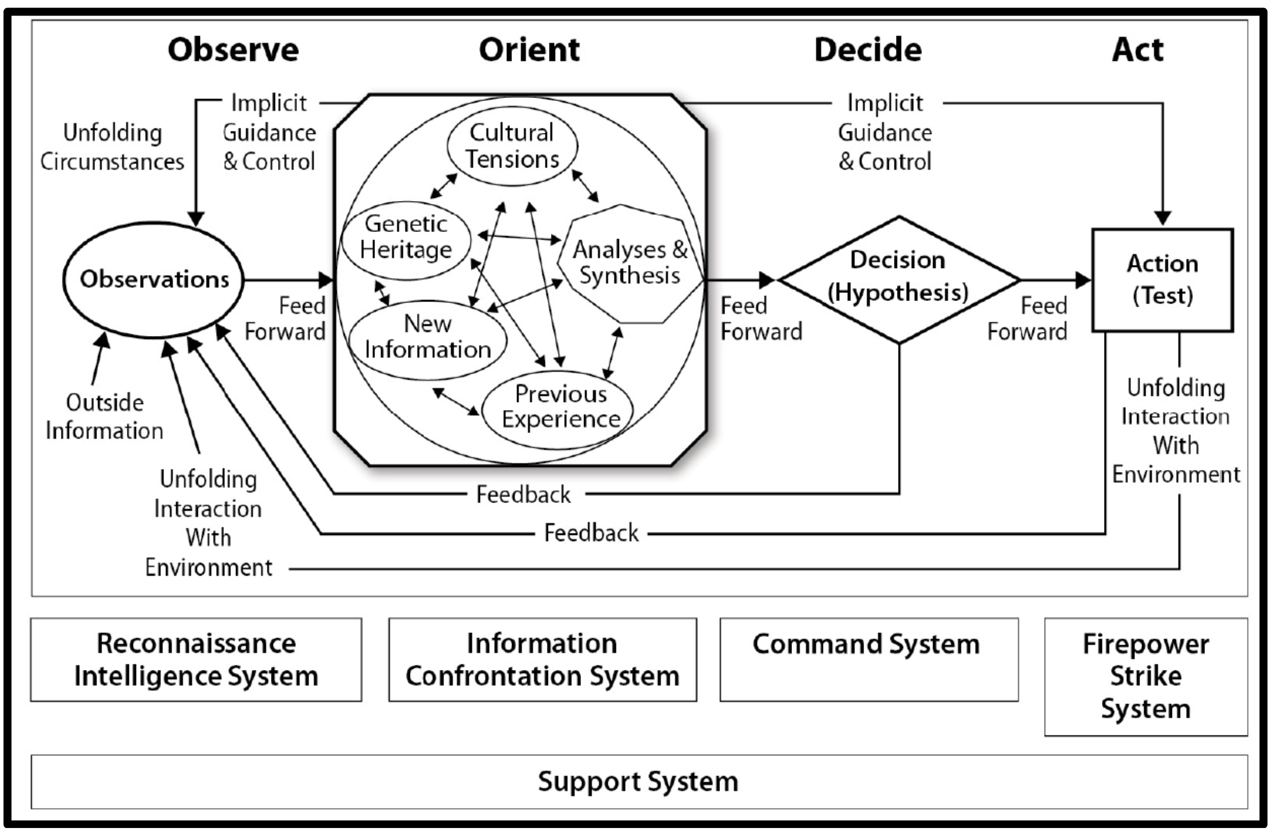


Figure 6. Chinese System Warfare overlayed with Boyd Loop (Friedman, 15)

As Friedman noted, “What is striking about the component system of staff organization is that, with the except of the support system, it mirrors USAF colonel John Boyd’s Observe-Orient-Decide-Act (OODA) Loop. This is not a coincidence, as the PLA has referenced Boyd and the OODA Loop in its texts. Rather, it should be viewed as deliberate effort by the PLA to structure high-level staffs around the OODA Loop to facilitate quicker and more efficient exploitation of information.” (Friedman, 8). The PLA sees this as not only increasing the speed of decision making and action but also the quality of decision-making through uniformity. As the PLA continues massive investment in long range precision fires and extensive anti-access aerial denial strategy, focusing on increasing the speed, tempo and effectiveness of its operational reconnaissance strike complex reinforces it strengths of centralized command and control. At the tactical level, the PLA envisions the application of AI and ML enabled decision will offset the lack of operational experience at lower levels.

Conclusions and Areas for Further Research

Although Russia and China have expended great resources to exploit AI to support military operations, the US and its allies have critical advantages in the competition to develop better AI. As noted in the previously mentioned National Security Commission on AI Interim Report for Congress “U.S. universities remain the top centers for AI research. The United States continues to attract, train, and retain the world’s best for its companies and labs; around 80 percent of international computer science PhDs that trained in the United States, including those from China, stay in the country after graduating. American companies remain world leaders in AI research and some areas of application. Our market-based economy and low regulation has created three-quarters of the world’s top 100 AI startups.”(P. 20)

AI-enabled command and control must be developed, but users and policy makers must also be taught how the AI is functioning and providing information in order for it to be trusted. It can’t be a “black box” that users are told to simply trust information being provided by the system. The MBL Final Report for SESU SIMEXp 2 stated

> “Many of these functions occurred at a rate and/or with a degree of automation that was not immediately apparent to the human staff. This speed and autonomy proved dualistic in the findings. The role players and other observers were impressed with the speed and capacity at which the AI could augment the human driven mission analysis process but were hesitant to put significant trust into the embedded AI or the robotic swarm component of SESU in part because they were incapable of understanding how it made decisions and developed COAs.” (P.21, MBL SESU SIMEXp 2 Final Report)

Uniformed and civilian leaders and policy makers must have trust and confidence in the use of AI and accelerate its fielding to operational forces. The Boyd Loop model provides an excellent framework to help them in the understanding of the uses of AI as an important tool to maintain military advantage in command and control.

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