TSN2023 NDIA MICHIGAN CHAPTER
GROUND VEHICLE SYSTEMS ENGINEERING
AND TECHNOLOGY SYMPOSIUM
<MODULAR OPEN SYSTEMS ARCHITECTURE (MOSA)> TECHNICAL SESSION
AUGUST 15-17, 2023 - NOVI, MICHIGAN

LEVERAGING ARTIFICIAL INTELLIGENCE (AI) TO ENABLE DECISION SUPERIORITY

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ABSTRACT

Recent operations in Ukraine have proven that introducing new technologies, tactics, techniques, and procedures can significantly affect the 21st century battlefield. The U.S. military is integrating the lessons learned from this and other recent conflicts into the Joint All Domain Command and Control (JADC2) warfighting concept. DoD is seeking to achieve decision superiority through JADC2 "to produce the warfighting capability to sense, make sense, and act at all levels and phases of war, across all domains, and with partners, to deliver information advantage at the speed of relevance." While this definition captures what JADC2 aims to achieve, it says little about how to achieve it. This paper uses the OODA loop and a project convergence use case (wet gap crossing) to show how artificial intelligence (AI) will enable decision superiority by reducing risk in this complex and relevant scenario.

Citation: D. Taylor, E. Kheyfets, T. Stewart, "Leveraging Artificial Intelligence (AI) to Enable Decision Superiority," In *Proceedings of the Ground Vehicle Systems Engineering and Technology Symposium* (GVSETS), NDIA, Novi, MI, Aug. 15-17, 2023.

1. INTRODUCTION

Recent operations in Ukraine have once again proven that the introduction of new technologies and tactics, techniques, and procedures can yield significant effects on the 21st century battlefield. The U.S. military is using the lessons learned from this and other recent conflicts and integrating them into the Joint All Domain Command and Control (JADC2) warfighting concept. Recent Department of Defense (DoD)-sponsored experiments, which include participation by the Services, Combatant Commands, and allies have focused on increasingly complex situations to gain insights into JADC2.

This approach looks to use artificial intelligence (AI), machine learning (ML), autonomy, and other advanced capabilities to better connect sensors and shooters, and reduce the time to bring lethal and non-lethal effects against an adversary to influence multidomain operations. Objectives such as lowering the cognitive load of warfighters and decision makers as well as decreasing the time of detection to engagement decision to gain advantage represent just some the requirements, risks, and technical challenges being addressed by the DoD.

Meanwhile, the Chinese appear to be on a similar path to develop their own version of JADC2 under the general title of systems destruction warfare. Under their premise, warfare is no longer solely focused on the destruction of enemy forces. But rather, it is won by the team who can disrupt, cripple, or outright destroy the other's underlying information networks and infrastructure.

2. DECISION SUPERIORITY

As with other past conflicts, those conducted in the 21st century will depend on decision superiority, and those who can best leverage and secure information to make the best-informed decision in the shortest time will likely prevail. Decision superiority is defined as the ability to assimilate, analyze, and act upon information acquired from the battlespace more rapidly than an adversary.

Throughout history, decision superiority has always been crucial to the winning or losing of battles and conflicts. Now, in an era where U.S. combat capacity and capability advantages are dramatically shrinking in the face of a growing Chinese threat, achieving decision superiority is more important than ever. It has also become more challenging due to rapid proliferation of technology across the globe by and to other states and non-state actors.

Advances in telecommunications, sensors, processing power, and weapons, along with the growing utility of space and cyberspace as operational domains, have fundamentally shifted the character of command and control in warfare. With this in mind, DoD is seeking to achieve decision superiority through JADC2 "to produce the warfighting capability to sense, make sense, and act at all levels and phases of war, across all domains, and with partners, to deliver information advantage at the speed of relevance." But while this definition captures what JADC2 aims to achieve, it says little about how to achieve it.

3. SHARED INTELLIGENCE

To make the JADC2 concept a reality, the various Services are analyzing what its contributions will be in achieving this vision. While many Services are focusing on creating a global targeting system that can enable the find, fix, track, target, engage, and assess functions of the kill chain, some are looking at how JADC2 can assist with achieving decision superiority to maneuver forces to positions of advantage to prevent an adversary from meeting their objectives.

The U.S. Army recently hosted the Air Force, Navy, Marine Corps and, for the first time, included international partners and allies to integrate technologies and test multi-domain operations during its yearly modernization experiment: Project Convergence 2022. The Army's third annual Project Convergence put the service's range and capabilities to the test with a series of experiments and events held at multiple locations based on various operational scenarios.

Warfighters from the United States, United Kingdom and Australia spent weeks testing approximately 300 technologies and new operational concepts to demonstrate how the services might one day fight as a joint force. These and other experiments are helping to inform the vision of the future operating environment by shaping cross-organizational collaborations, prioritizing technology investments, and refining platform and systems requirements documents.

Through these various experiments, a common theme that has emerged is that future warfighting is going to require collaboration across countries, domains, and technologies to ensure interoperability and achieve the JADC2 vision. Regardless of the scenario, the assumptions are that a near-peer competitor will be the likely adversary and will seek to achieve an Anti-Access/Aerial Denial (A2AD) environment with no guarantee of U.S. air or other domain superiority.

4.IDENTIFYING TECHNOLOGICAL CHALLENGES

U.S space-based assets, including Global Positioning System satellites, are likely to be degraded. It is also believed that AI/ML capabilities with human interfaces will make final targeting and other decisions and the ability to see, understand, act and decide first will provide the critical advantage in which side will prevail. What is also clear is the critical importance of industry, academia, and coalition partners in finding technical solutions to the various gaps and challenges that exist.

The purpose of this paper is to examine how new and innovative technical solutions can help in achieving decision superiority within the land domain using manned and unmanned systems. It will identify and address critical technical challenges and risks and potential technical material solutions. Realizing JADC2 will require critical changes across doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy, however, this paper will focus only on material solutions.

5. AI IN CURRENT GROUND OPERATIONS

Recognizing data as a strategic asset, and employing it an enterprise-wide, holistic approach in multidomain operations will serve to advance the JADC2 initiative and enable improved decision superiority across military missions. One of the most complex ground-based scenarios of note is wet gap crossing operations, which are important to enabling maneuver forces to close with and to destroy enemy forces. (Figure 1)

Figure 1: Depiction of a Wet Gap Crossing

However there are distinct logistical challenges in planning and executing these critical operations. (Figure 2) When successfully executed, a wet gap crossing operation can provide one of the most valuable fundamentals of war – speed. Tempo is the key to seize the initiative, prevent enemy reconnaissance and exploit success. Executing a safe and efficient wet gap crossing allows friendly forces to set conditions necessary for success.

A recent failed wet gap crossing by Russian forces in Ukraine highlights many of the challenges and risks associated with this complex operation. The Russians lost the better part of two or more battalions—potentially 100 vehicles and more than a thousand troops—trying to cross a pontoon bridge spanning the Siverskyi Donets River in eastern Ukraine.

In evaluating this failed scenario, this paper will address the key risks in conducting wet gap crossing operations and potential technical solutions using AI/ML and other critical technologies.

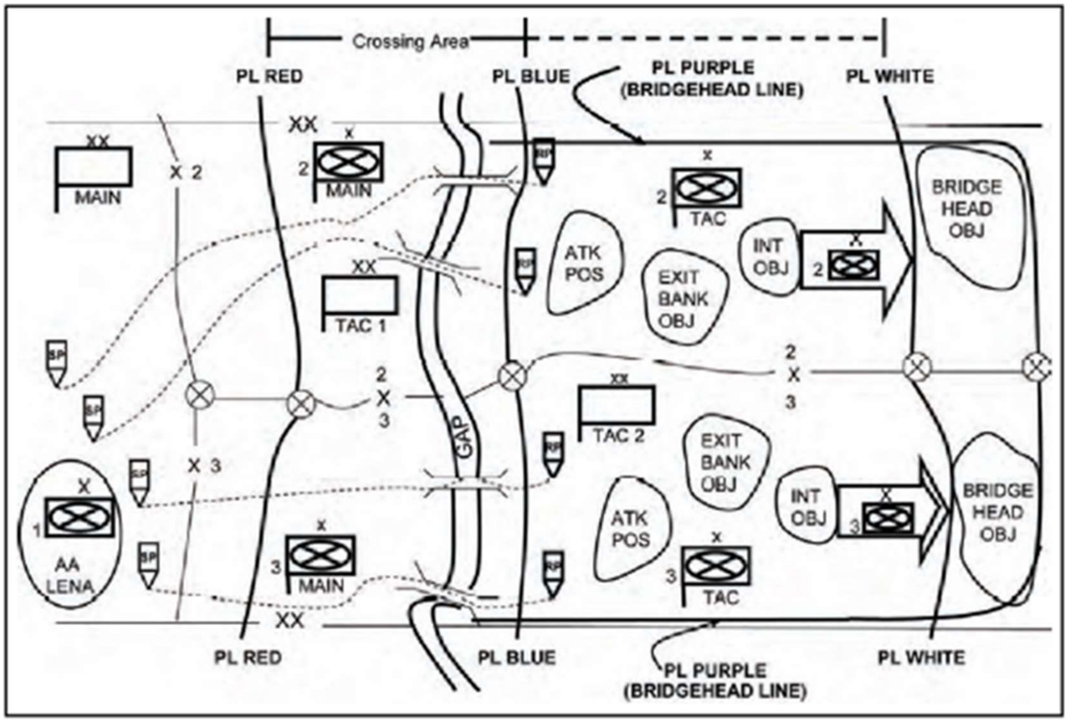

Figure 2: Typical Analysis When Planning and Executing a Wet Gap Crossing Operation

6. ANALYZING RISKS

Since most future breaching assets will likely be conducted using unmanned or optionally manned systems, large amounts of data will need to be secured and transmitted across tactical networks to synchronize reconnaissance and security, maneuver, fires, logistics, and other warfighting functions. At the macro level, JADC2 involves gathering massive quantities of data through a broad range of distributed sensors and processing it into actionable information.

Stakeholders at the strategic, operational, and tactical levels harness germane elements of the resulting information flows to best execute their missions. The entire system is stitched together with a robust set of communication links. This does not mean everyone receives all information, for that would leave everyone drowning in data. Instead, it entails allocating the right information to enable organizations to achieve enhanced effects in their specific areas of responsibility. The following are additional risks that material solutions will need to address:

- If there is a failure to achieve surprise at gap crossing sites, then the chance of casualties and mission failure in crossing is high.
- If there is a lack of command and control (C2) at crossing sites, then friendly forces are susceptible to destruction and degradation by an adversary’s lethal and non-lethal fires.
- If there are inadequate cyber protections or lack of secure over-the-air updates, then unmanned or optionally manned systems can be spoofed or taken over by an adversary disrupting gap crossing operations.
- If the ability of friendly forces to process sensor and shooter data is degraded, then the likelihood of a successful gap crossing decreases due to the lack of synchronization between maneuver, fires, and other warfighting functions.

- If joint and Coalition C2 systems are not interoperable, then the ability to synchronize warfighting functions to ensure a successful crossing operation is degraded.

7. SOLUTIONS TO TECHNICAL CHALLENGES

To apply and assess technology to the decision-making process, a model is required. The OODA Loop — Observe, Orient, Decide, Act — is a well-known and accepted model, especially in the warfighter community, given its origins. It is a concept developed by US Air Force Colonel John Boyd and serves as a model for decision-making and action-taking in various domains.

The OODA Loop describes a four-step process for making decisions and taking action. First, you observe your environment and gather information. Then, you orient yourself to that information by analyzing it and understanding its meaning. Next, based on your observations and orientation, you decide what action to take. Finally, you act on your decision.

The OODA Loop emphasizes the importance of speed and agility in decision-making and action-taking. The goal is to complete the loop as quickly and efficiently as possible so that you can adapt to changing circumstances and take advantage of opportunities as they arise.

By inspection of the above diagram, there are two critical considerations for leveraging AI to enable decision superiority:

- Artificial Intelligence (AI) processing applies to every part
- Minimizing latency among the four steps

A macro consideration manifested by the risks outlined earlier in the Wet Gap Crossing scenario is that the decisions must be made "at the edge" and not remotely from a Command Center. This significantly minimizes the latency and provides flexibility in a rapidly changing environment. AI at the edge (AIAE) refers to deploying artificial intelligence algorithms on devices physically close to the data source.

Connecting sensors directly to the AIAE unit will greatly reduce latency between the Observe-Orient steps in the OODA Loop. Sensor data will be moving from sensors the AI unit sensor inputs then to the data processing cores via high speed busses inside the processing IC or between ICs in the same unit. (Figure 3)

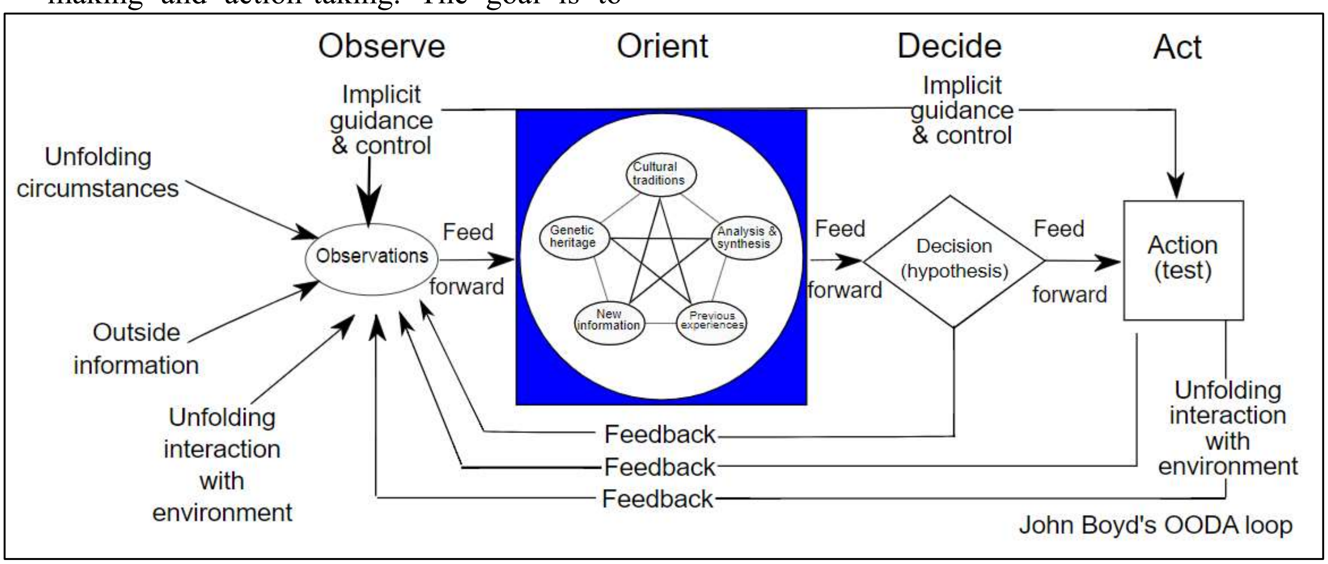

Figure 3: Applying AI at the Edge (AIAE) to the OODA Loop Speeds Decision-making Capabilities for Improved Decision Superiority

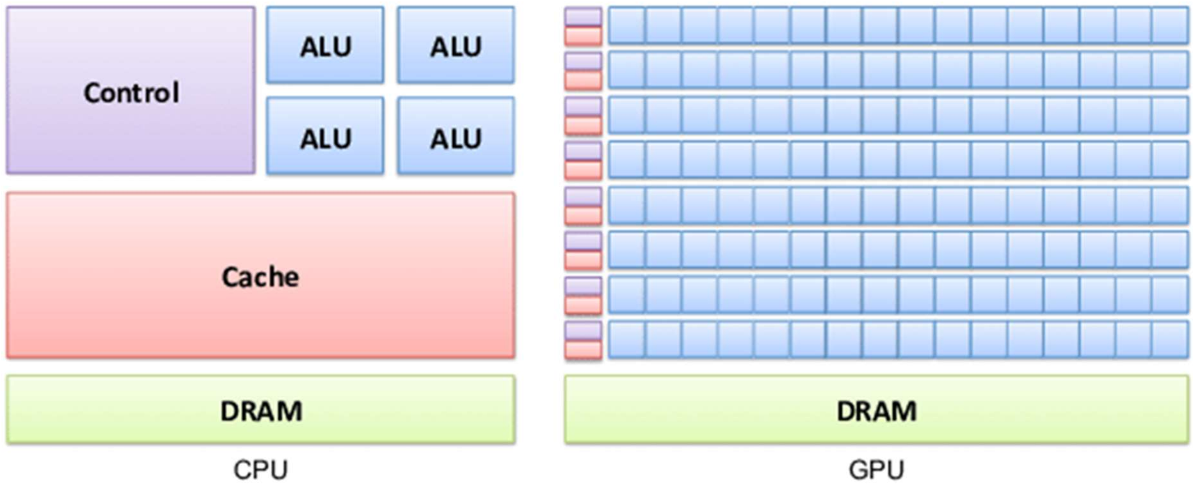

Figure 4: The Parallel Processing Architecture of a GPU Enables Faster Computation Than a CPU That Enable a Wide Number of AI Applications

Doing AI processing and decision making in the AIAE unit will significantly reduce latency between Orient-Decide steps as well. There will be no need to send out large amounts of data for additional decision making steps to the external center, and then wait for the decision to be sent back. Sending the "Act" command from the AIAE unit will reduce latency for the Decide-Act steps for the same reasons, as well.

8. ENABLING AI PROCESSING

A dominant COTS (commercial-off-the-shelf) solution for AIAE processing is a general purpose graphics processing unit (GPGPU). General purpose computing on graphics processing units refers to the use of a GPU (graphics processing unit) to perform general-purpose computations in addition to its traditional role of rendering graphics.

GPUs are designed to handle large amounts of data in parallel, making them ideal for performing certain computations much faster than traditional CPUs (central processing units). By leveraging the parallel processing power of GPUs, GPGPU can accelerate a wide range of AI applications. (Figure 4)

Advances in technology are bringing to the market small form factor higher performance supercomputers, which combine GPGPUs with CPUs and can be used for AIAE applications. GPUs are widely used for AI applications.

The NVIDIA Jetson family of modules combine AI-capable GPGPUs with multi-core CPUs creating a tightly coupled, high performance, low power supercomputer that can support AI processing capabilities and decision making applications software. Several modules with different form factors, performance and maximum power options are available in the NVIDIA Jetson family. (Figure 5)

When examining the NVIDIA Jetson Xavier NX module, for example, it is noted that the modules provides six trillion floating points operations per second (TFLOPS) performance with a maximum power of 15 Watts. Such performance is comparable to the performance of a several-hundred Watts workstation with processor and with GPU cards.

This type of computing architecture can process and apply AI algorithms for 20+ high definition video inputs with 1040p resolution at a rate of 30 frames per second, i.e. it has enough bandwidth to run AI applications servicing multiple high definition cameras in the system.

A ruggedized unit with an NVIDIA Jetson Xavier NX module can be as small as 4" x 2.3" x 3.9". With a maximum weight of 1.3 lbs and maximum power of 15 Watts, it is an

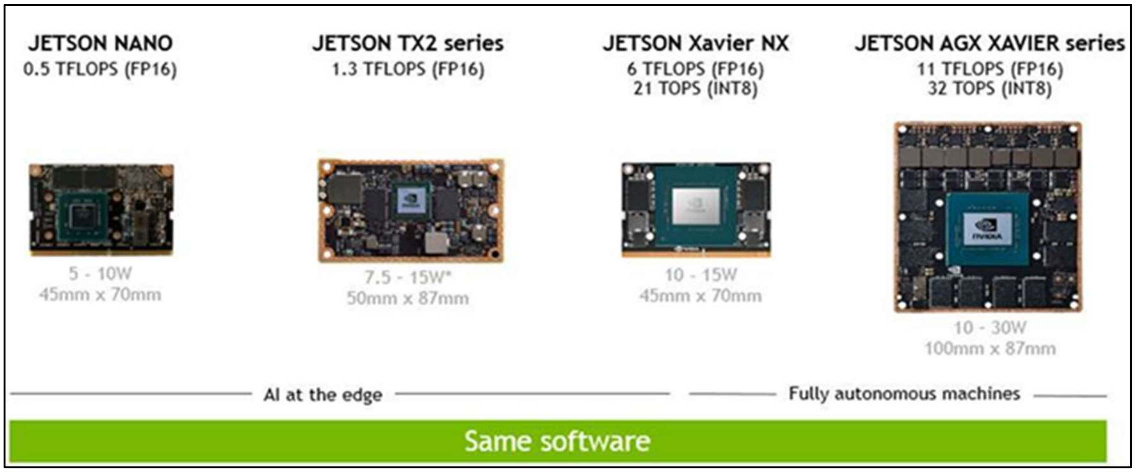

Figure 5: The NVIDIA Jetson family includes different modules with various form factors, performance and maximum power options.

ideal candidate for AIAE applications from the size, weight, and power (SWAP) and performance perspective. (Figure 6) If higher performance is needed, larger and higher power rugged solutions based on higher performance NVIDIA Jetson modules are achievable.

Figure 6: Compact, high-performance Supercomputers are Processing Vast Amounts of Sensor Data at the Edge.

These types of rugged GPGPU-based units can also support industry standard interfaces such as Ethernet (1GbE and/or 10GbE), CAN bus, Serial Ports, etc.). For example, an Ethernet interface can be used as a communication channel to other "smart" boxes and mission computer(s) in the systems, and for interactions with external equipment through wireless communications converters. If low latency Ethernet communication is required, Time Sensitive Networking (TSN) or Time-Triggered Ethernet (TTE) can be used.

Using an Ethernet network for internal communications allows the implementation of multiple redundancy levels, from physical cables to routers and packets. Implementing IEEE 1588-time distribution across the network will allow all network elements to be synchronized to a single time source.

Besides high-speed sensor processing, these units can also be used to process data coming from lower speed sensors – analog I/O, discrete I/O, serial ports, etc. Combining these functions into one AIAE unit can help to eliminate additional electronics boxes and associated harnesses in the vehicle, further reducing the size, weight and power of electronics equipment.

9. Time-Sensitive Networking (TSN) and Decision Superiority

Time-Sensitive Networking's (TSN's) capabilities—including precise timing, low-latency communication and deterministic data transmission—contribute to improving decision-making processes, enhancing situational awareness and ultimately achieving decision superiority.

By providing low-latency communication, TSN ensures that critical information reaches decision-makers without delay through the transmission of real-time data with high precision and reliability. It also facilitates the collection, aggregation and analysis of this real-time data, empowering decision-makers with up-to-date and accurate information for making informed choices.

TSN's ability to synchronize devices and systems across distributed networks is instrumental in achieving decision superiority. It ensures that data from multiple sources are aligned and consistent, providing a holistic view of the operational environment, as well as enhances coordination between different components, such as sensors, actuators and control systems, for seamless collaboration and integration.

10. OPTIMIZING GROUND VEHICLE OPERATIONS USING AI-AT-THE-EDGE (AIAE)

10.1 Streamlined Network Communication

Placing ruggedized AI supercomputers close to the sensors (e.g., high-resolution cameras, IR detectors) helps resolve challenges in ground vehicle electronics, which ultimately benefits the warfighter. For example, processing, such as object recognition/classification, target recognition/acquisition, terrain analysis, etc., close to the sensors brings the following benefits:

- Eliminates the need to move a large amount of data from sensors to the mission computers or external command centers decreasing latency and information overload
- Reduces response time of the systems to provide faster decision-making.
- Enhances capabilities of the unmanned or optionally manned vehicles/systems
- Increases system reliability, availability, and maintainability by reducing wiring complexity by eliminating the need for long, expensive, high-speed data cables between sensors to the mission computers.
- Improves systems integration and operability – all data between "AI-at-the-Edge" boxes and other "smart" boxes in the system is moved via industry-standard Ethernet interfaces.
- Improves upgradeability – all unique sensor processing is done in the AIAE units. Sensors and associated processing units (if needed) can be upgraded without the need to replace Ethernet cables and without the need to replace mission computers, which can reduce the time and cost to get new capabilities into the hands of warfighters.
- Improves scalability – additional sensors and AIAE boxes can be added if the vehicle provides wiring for a few additional Ethernet ports, making the integration of new mission equipment packages easier and faster.
- Makes ground systems more available, reliable, and easier to maintain by reducing the size, weight, and power (SWaP) of electronics systems by eliminating the need for large mission computers and heavy wiring harnesses.

10.2 Cybersecurity Protection

High performance AI-capable systems with enhanced cybersecurity protection capabilities will help to prevent cyber and spoofing attacks, and it will protect information sharing data links.

Using "AI-at-the-Edge" solutions will help to eliminate or to minimize the following risks described in Section 6 by:

- Significantly reducing the amount of data to be shared across tactical networks by processing most of the data at the source
- Simplifying data distribution efforts by allocating the right information to each data user
- Improving Command and Control (C2) communications by reducing the response time
- Improving cyber protection of the communication channels
- Minimizing the possibility of degraded ability to process sensors data – most data is processed locally and redundancy schemes can be used to address damaged sensors issues
- Synchronizing all systems in the vehicle and across multiple platforms using a single time source
- Eliminating interoperability issues between Coalition C2 systems, if all systems will use the same communications protocols and data messaging structures

10.3 Other Considerations to Optimize AI in Ground Vehicles

While AIAE has numerous benefits, such as reduced latency and increased privacy, it also presents several technological challenges that must be addressed. Some of these challenges include:

- Limited processing power: Edge devices often have limited processing power and memory compared to cloud-based servers. Therefore, developing AI algorithms that can operate effectively on low-power edge devices is a significant challenge.
- Limited storage: Edge devices often have limited storage space, limiting the amount of data that can be processed and stored locally. This can also impact the accuracy of machine learning models that require large datasets.
- Energy efficiency: Edge devices are typically based on low power solutions. Developing energy-efficient AI algorithms is crucial for minimizing the power consumption of edge devices.
- Connectivity: Edge devices may have intermittent or limited connectivity to the cloud, making it challenging to train and update machine learning models. This can also limit the ability to communicate with other devices in the network.
- Security and privacy: Edge devices can be more vulnerable to security threats, and using AI at the edge raises concerns about data privacy. Ensuring secure and privacy-preserving AI at the edge is crucial.
- Standardization: As Edge AI grows, standardization is needed to ensure interoperability and compatibility across different devices and systems.

Addressing these challenges will require ongoing research and development in the field of Edge AI as well as collaboration across industries and standards organizations. Rugged AIAE solutions based on NVIDIA® Jetson modules can help to address many of these challenges.

11. CONCLUSION

Leveraging AI/ML and advanced algorithmic warfare systems provides a significant advantage to achieving decision superiority. The military force that can effectively and efficiently secure, transmit, and process information and compress the OODA loop faster than an adversary will likely prevail. AI/ML is not tomorrow’s problem. This enabling technology is being used today and will be more and more prevalent in the future.

For the DoD, achieving the JADC2 vision begins with demanding that industry have the ability to connect every current sensor that can support battlespace awareness, making sensor data available to any potential user, at any level of operation. This data-sharing construct can create secured battlespace awareness, wherein actions in one part of the single, integrated, global battlespace can be understood and inform actions and decisions required in other areas.

Next, the concept of sensor data sharing and interoperability should be mandated in every system and program. In addition, the DoD will need to pursue a faster rate of digital transformation, prototyping, and systems of systems integration to make use of data and build better battle-winning AI/ML algorithms and hardware systems and exercise them through a campaign of learning and experimentation to succeed.

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