GENERAL DYNAMICS
Canada

Increasing the Operational Effectiveness of Land Combat Vehicles

Requirements for an intelligent, integrated and scalable Vehicle Electronic Architecture (VEA)

Abstract

Although many military organizations have developed system standards, there is no real solution to the network and system integration challenge on land combat vehicles. The ideal solution must enable a vehicle to fight and move more effectively while leveraging the power of all the disparate, independent systems on board. It must integrate seamlessly with and leverage the power of a networked command and control environment, and effectively integrate with the voice and data communications systems used by dismounted personnel. This can only be achieved with an intelligent, integrated and scalable vehicle electronic architecture (VEA) that incorporates hardware, software and in-vehicle and dismounted human resources for complete operational effectiveness on the battlefield.

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Operational Inefficiency in Land Combat Vehicles

The next generation of land combat vehicles must be extremely versatile platforms, capable of operations in a variety of complex situations. At any given time, these vehicles may be called upon to defend, or attack, strategic locations, provide troop transportation, perform reconnaissance, or provide logistics support. Given the continuously changing nature of an operational environment, it is imperative that the vehicle and its systems enable the vehicle's, crew, dismounted personnel, and related command and control elements to act decisively within an opponent's Observe, Orient, Decide, and Act (OODA) loop. Effective collection, dissemination, and presentation of operationally relevant information between aligned elements significantly reduce the OODA response loop and increase the chance for success. Therefore, military organizations and platform manufacturers are adding more sophisticated and capable Command, Control, Communication, Computing, Intelligence, Surveillance and Reconnaissance (C4ISR) elements to every vehicle.

As a result, land combat vehicles are getting smarter. On-board video, targeting, and alarm sensors are being added to act as the vehicle's eyes and ears. These systems are complemented by communications and data processing systems engineered to continuously receive, process, and distribute information from sensors, command and control elements, and dismounted personnel in real time. All that sensor, intelligence and command and control data is being fed to personnel on interactive displays. And everything is supported by power distribution solutions that ensure there is never a shortage of electrical power.

When all systems are working as intended, on-board sensors and data processing systems provide the crew with a continuous stream of real time, accurate situational awareness information. They enable the crew to share intelligence with dismounted personnel, and relay key mission data to command and control elements. Most importantly, they enable effective and efficient collaboration between vehicle operators, dismounted personnel, and commanders to ensure threats are identified and dealt with quickly.

But while vehicles are getting smarter they are also getting more complex. The addition of more intelligent hardware and software has made even the most basic transport vehicle a complicated collection of disparate systems that must be monitored, managed and maintained. Typically, all that hardware and its associated cabling are being crammed into a power and space constrained cabin that leaves little room for the personnel who must monitor and operate it. And because many systems come with their own operator machine interfaces (OMIs), operators must continuously deal with information overload by keeping track of all that sensor data and situational awareness intelligence on multiple displays.

This is inefficient for a number of reasons. With so many disparate systems, there is no integration of information and data to enable effective command and control processes. Operational efficiency is reduced because the vehicle must be designed to support multiple independent systems, each of which increases size, weight and power. Crew efficiency is reduced because personnel must continuously monitor multiple systems. The effectiveness of dismounted personnel is diminished because mobile systems are not integrated with in-vehicle systems. In addition, training is a challenge because personnel have to be trained on a variety of systems, each with their own specific operating processes. And, finally, security is an issue, because classified material going to the vehicle from the external command and control environment is being delivered to multiple systems.

Military organizations worldwide have recognized the fact that the addition of so many disparate systems has reduced the electronic architecture's interoperability, maintainability, modularity, scalability, and security, while increasing size, weight, power and cost (SWaP-C). Some have developed system integration standards that prescribe an acceptable level of integration for key in-vehicle systems. The Vehicular Integration for C4ISR/EW Interoperability (VICTORY) standard in the United States, and the Generic Vehicle Architecture (GVA) in the United Kingdom are two such standards. These and other standards have made significant strides towards resolving the inefficiency challenge. But to truly eliminate operating inefficiencies, tomorrow's platforms must go further. They must be designed with an intelligent, integrated and scalable vehicle electronic architecture (VEA) that incorporates hardware, software and in-vehicle and dismounted human resources for complete effectiveness on the battlefield.

Operating with Multiple Vehicle Systems

Most land combat vehicles have a variety of systems, which are designed and engineered to enable the platform to operate effectively on the battlefield, and manage and process situational awareness data, information and intelligence. These systems can be grouped into three broad categories:

Local situational awareness systems, which enable operators to see around the vehicle, such as:

- Driver Vision Enhancement (DVE)
- 360 degree cameras
- Health and Usage Monitors (HUMS)
- Vetronics

Self-protection systems, which protect the vehicle itself, such as:

- Electronic Support Measures (ESM)
- Reactive armor
- Smoke generators
- Weapon systems for targeting and fire control

Command and control systems, which enable operators and commanders to maintain vital links with personnel in the field and command centers, such as:

- Voice communications systems
- Data communications systems
- Battle Management Systems (BMS)
- Network connectivity systems, such as tactical video systems
- Multiple Independent Levels of Security (MILS)

All these systems share a finite amount of precious space and power. A typical cabin must accommodate a variety of independent computing, communications and display hardware. Each system reduces the amount of space available for crew and passenger accommodation and creates a high level of equipment intrusion into the crew area (Figure 1). These environmental conditions are exacerbated by the fact that each operator must wear a variety of standard gear in the field. In addition, personnel may also be required to wear chemical, biological, radiological, and nuclear (CBRN) mitigation equipment, further crowding an already cramped environment. Most importantly, every system adds weight, reduces the overall remaining payload, and draws power. Complicating the situation for operators is the fact that all installed systems are usually configured to work independent of each other, which makes it more difficult for the vehicle to be operated effectively in a combat situation.

Figure 1: Land vehicles must accommodate a variety of hardware in a very limited space

Existing Standards Address Some Inefficiencies

Unfortunately, this inherent inefficiency is evident in all combat vehicles deployed around the world. As a result, many military organizations have established system integration standards that eliminate some inefficiency.

For example, the VICTORY standard in the United States was created to correct the problems associated with the “bolt on” approach to fielding equipment on U.S. Army vehicles. To achieve this objective, the standard provides a framework for integration of C4ISR/Electronic Warfare (EW) and other electronic mission equipment on ground platforms. That framework includes:

- An architecture, which defines common terminology, systems, components, and interfaces
- A set of standard technical specifications for the elements identified in the architecture
- A set of reference designs

From a technical point of view, the VICTORY standard is built around:

- A “data bus-centric” design
- Sharable hardware components that will support the deployment of software additions without the need to add hardware
- Open standard physical and logical interfaces between system and C4ISR/EW components
- A set of shared data bus services
- Shared hardware and software Information Assurance (IA) components to enable systems integrators to build security designs that protect and control access to information

In addition, VICTORY provides a phased set of standard specifications that outline the capabilities needed to integrate C4ISR/EW mission equipment and platform applications.

As the VICTORY Standards Organization notes, “implementation of VICTORY allows tactical wheeled vehicles and ground combat systems to recover lost space while reducing weight and saving power. Additionally, implementation allows platform systems to share information and provide an integrated picture to the crews. Finally, implementation provides an open architecture that will allow platforms to accept future technologies without the need for significant re-design.”

The GVA developed by the Ministry of Defence (MoD) in the United Kingdom is another example of an effort to eliminate inefficiencies on ground vehicles. Rather than a standard, the MoD has positioned the GVA as an integration approach designed to ensure that subsystems on land platforms are integrated properly (electronically, electrically and physically). It does not mandate a specific architecture design because the design will vary based on the specific requirements of each platform and its role. Rather it recommends an approach that takes a whole systems view and uses open standards for system interfaces. The MoD emphasizes that it is a crew-centric approach based on a common multifunctional crew station human machine interface (HMI), which allows the platform to be controlled through screens and input devices.

Among its nine basic key principles, the GVA states that the platform engineering approach must:

- Be applicable to current and future systems
- Use open, modular and scaleable architectures and systems
- Facilitate technology insertion (upgrade, update, replace, repair, remove and addition)
- Not needlessly implement in hardware any functionality that can be implemented in software
- Take a "whole platform" systems view through a platform's lifecycle

Like many integration standards around the world, both the VICTORY and GVA approaches go a long way towards resolving the inefficiency challenge on land combat vehicles. But, there is an opportunity to go further.

The VICTORY standard, for example, does not address the need to integrate all vehicle networks and systems. It treats communications, data, and power as separate networks with common architecture elements. On the other hand, the GVA does address integration of video, data and communications systems into a common architecture, but it does not create an effective system of integrated hardware and human resources. An intelligent, integrated and scalable VEA must efficiently integrate video, communications on a common medium with the scalability to handle ever increasing bandwidth requirements of the data.

In addition, like most standards, neither addresses one of the most important integration issues, the need to keep personnel connected to all systems once they exit a vehicle. This is critical for maintaining the bi-directional flow of situational awareness intelligence and command and control communications, and ensuring that all field resources continue to work as one entity.

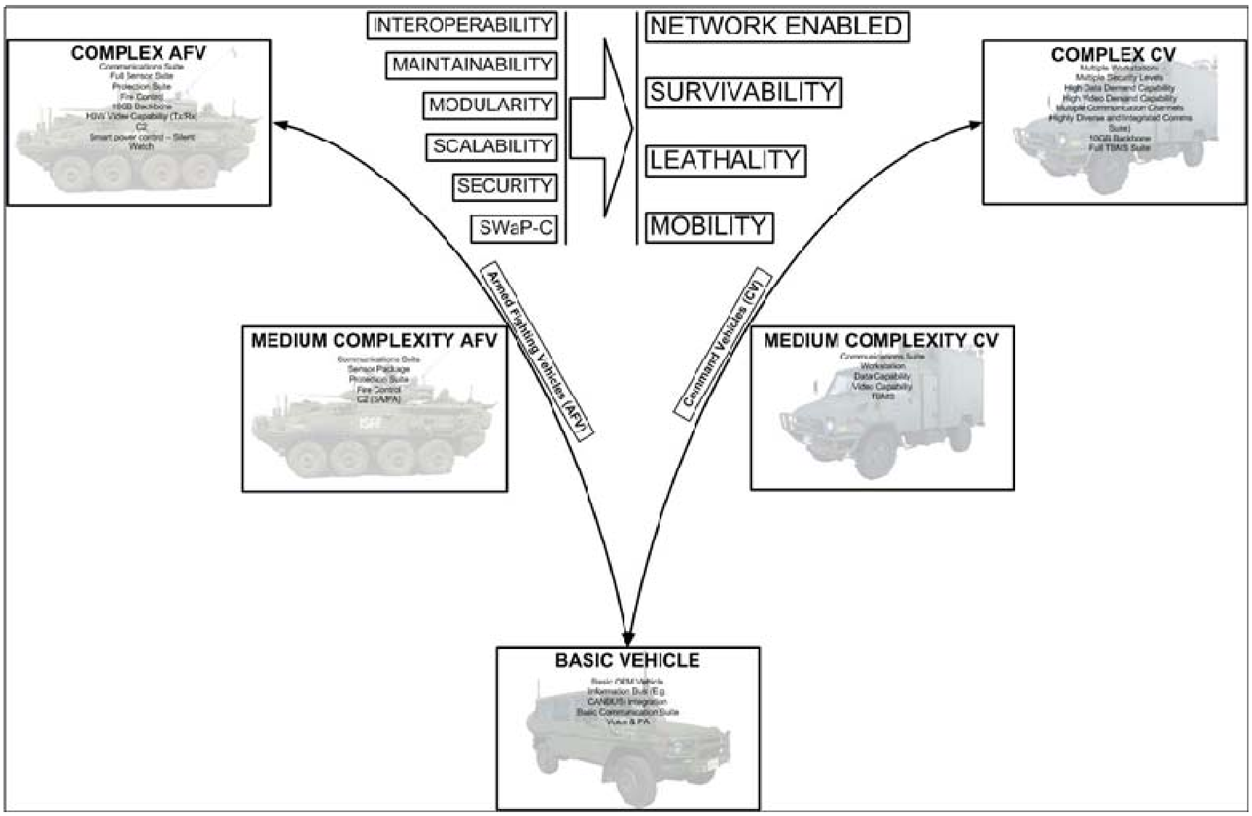
As a result, although many organizations have developed standards, there is no real solution to the network and system integration challenge that allows a vehicle to fight and move more effectively while leveraging the power of all the disparate, independent systems on board. Likewise, there is no solution available that allows a vehicle to integrate seamlessly with and leverage the power of a networked command and control environment. And there is no solution available that effectively integrates with the voice and data communications systems used by dismounted personnel once they exit a vehicle.

Complete Integration Required to Eliminate all Inefficiencies

To fully address the operating inefficiencies on land combat vehicles, electronic systems must be improved to make the vehicle and its personnel more effective in the vehicle, on their own, and within the context of a networked command and control environment. The ideal solution must integrate all systems into an intelligent, integrated and scalable VEA optimized for maximum interoperability, maintainability, modularity, scalability, and security, as well as lower SWaP-C.

Obviously, this solution should be engineered to provide reliable, robust performance at all times, and under all rugged operating conditions. It should enable all systems to work together as an integrated whole to provide crew members, commanders, and dismounted personnel with a single view of all sensor and situational information when the vehicle is in the field. Most importantly, it should be flexible enough to be adapted cost-effectively for use on all land vehicles (Figure 2).

Figure 2: The ideal electronic architecture should be flexible enough to be adapted for use on all platforms



Simplifying Vehicle Architectures

An intelligent, integrated and scalable VEA that incorporates hardware, software and in-vehicle and dismounted human resources addresses the complete integration requirements of all land platforms. Built properly, this architecture should be comprised of five key subsystem layers:

- **Base vehicle vetronics systems,** such as driver information, power management, and vehicle health and operational status systems
- **Weapons systems**, such as weapon orientation, ammunition status, and fire control systems
- Local situational awareness systems, such as onboard and remote video sensor, audio detection, terrain mapping, and weather systems
- **Protection systems,** such as Electronic Counter Measures (ECM), Silent Watch Configuration, and Global Positioning System (GPS) Anti-Jam systems
- **Command and control systems,** such as communications, target identification, MILS, and HUMS systems

Complete integration of these layers creates an intelligent, integrated and scalable VEA, which enables more effective operation of a vehicle in complex missions. It supports efficient, continuous uninterrupted processing of critical information in a secure and useful manner. It ensures all situational awareness and intelligence data is efficiently collected and processed by a variety of sensors, delivered to operators, and shared with command centers and other in-field resources. Most importantly, it enables effective C4ISR collaboration between personnel in the vehicle with dismounted resources and command elements. The net result is a common operating picture for commanders and users at all levels.

Key Requirements for an Integrated VEA

Creating an integrated VEA that successfully addresses these five aspects of a vehicle’s system requires close attention to eight key technical considerations.

Multi-function Smart Displays

To leverage the full benefits of an integrated architecture, the VEA should be configured to deliver all situational awareness and command and control information to personnel via multi-function smart displays. Each workstation can be simultaneously connected to network services, sensors and vehicle subsystems, thereby integrating information delivery to personnel, and enabling more efficient monitoring of multiple functions, such as DVE, sensor feeds, Tactical Battle Management System (TBMS), vehicle health and instruments, weapon control, weapon sighting and targeting. As a result, operating efficiency is increased because all vehicle positions (driver, commander, gunner, and navigator/rear) have the option and ability to access all information and video feeds at any time on their respective workstations and correlate information to enable more informed decisions. The integrated workstations also allow for tasks to be dynamically redistributed within the vehicle to make maximum use of personnel capabilities, or partially compensate for damage or loss of crew within the vehicle.

Multi-function smart displays also reduce the number of hardware components that must be installed in a vehicle, thereby streamlining cabin configuration and further reducing SWaP-C (Figure 3). Most importantly, they enable more flexible future growth. By supporting multiple interfaces, such as Ethernet, raw video, and digital video (standard and high definition), they can accommodate feeds from new sensors and vehicle subsystems easily without requiring integrators to install additional displays and processor assemblies.

Figure 3: Multi-function smart displays reduce the amount of hardware that must be installed in a vehicle

Integration of Systems and Cabling

To deliver information to each workstation, the VEA should be engineered based on common interfaces that enable complete system and cabling integration. Common interfaces reduce the amount of cabling required to support all the disparate systems by enabling single cables to be used for multiple interfaces, thereby reducing, SWaP-C. Also, by standardizing on common interfaces common parts can be used across multiple platforms, thereby ensuring military organizations benefit from the cost-effectiveness that can be achieved through volume purchasing.

The VEA architecture should also exploit common onboard vehicle control busses to provide a low cost, reliable solution for the most basic vehicles. Bus infrastructures such as Controller Area Network Bus (CANBus) are reliable low latency busses that provide access to automotive systems and also provide a solution for integrating key navigation and control capabilities. More advanced networking capabilities and greater data throughput can be provided with common high-speed copper-based cabling implementations.

Given the continually rising need for bandwidth to support advanced systems, such as video sensors, fiber is the most obvious choice for cabling. It can support current and future bandwidth requirements, and it can host many devices on a single fiber, thereby providing true anywhere-to-anywhere networking and reducing the need for switches and hubs. Ultimately, this reduces single point failure nodes in the architecture.

Smart Delivery and Distribution of Information

The continuously increasing number of systems on most land platforms, combined with the complexity of those systems has made bandwidth a major issue. Exacerbating the bandwidth challenge is the need for a vehicle to communicate efficiently with external resources, including dismounted soldiers, vehicle peers and other assets in the field. Therefore, it is important that the VEA is engineered to support efficient and smart delivery of incoming and outgoing information and communication throughout a vehicle.

To do this, the architecture must provide effective use of available bandwidth at all times, and as demand increases. By implementing network admission control and quality of service (QoS) management policies, the VEA can ensure critical information is processed and delivered properly with little packet loss, and it can support future demands on bandwidth by bandwidth-hungry devices, while maintaining the proposed physical network medium.

Security of Information

The success of any mission is often determined by the ability to deliver secure intelligence to in-field personnel. Therefore, the security of incoming and outgoing information must be a top priority for a VEA.

The MILS architecture is becoming a standard for military vehicle communications and data transfer. By building the VEA with common hardware platforms that are MILS compliant, the VEA can support a more controlled information flow managed by separation mechanisms that can handle both untrusted and trustworthy components. In addition, the total security solution is non-bypassable, evaluatable, always invoked and tamperproof.

Compliance creates additional efficiencies. It reduces integration efforts and costs associated with mechanical installation and interfacing. It reduces maintenance costs because it minimizes the number of boxes that may require service, and the number of spares that must be maintained in support inventory. It reduces training requirements by streamlining the number of equipment variants in a vehicle. And it reduces SWaP-C by eliminating the need for duplicate hardware to support multiple systems.

Smart Power

Of course, all vehicle architectures require electrical power. To enable the higher operating efficiencies that can be achieved with a VEA, the integrated system should be supported by smart power technology. This technology enables electrical power distribution throughout a vehicle with fewer units and a much smaller footprint facilitated by advancements in solid state circuit breakers. More importantly, these units are usually equipped with common interfaces (CANBus, Ethernet), which enable direct connection into the VEA.

As an integral part of the architecture, the electrical power distribution system can dynamically monitor, change and allocate varying levels of electrical power for all connected subsystems and loads. This enables a more efficient use of electrical power, and is tactically important for the various states in which a vehicle may be required to operate, especially technically demanding ones, such as Silent Watch.

Optimization of Antenna Footprints

Efficiency can be further achieved by reducing the antenna footprint on a vehicle. By using multi-band antennas, multiple radios of different bands can be configured to share a single antenna. This provides many advantages, ranging from installation to tactical operations. It reduces SWaP-C by eliminating the need for multiple antennas. It also eliminates the potential for signal interference between antennas.

From a tactical perspective, the primary command and control or communication hub vehicles will have a reduced antenna array. This can minimize the distinguishing features that make these vehicles primary targets.

Dismount as an Extension of the Vehicle

Full integration with an intelligent, integrated and scalable VEA should also enable easy extension of the in-vehicle network to dismounted personnel.

Today’s soldier can only be connected to a vehicle’s architecture by wearing a headset that is native to that vehicle and is physically connected to internal systems with cabling. Once a solider dismounts, the headset is removed and the connection to all systems is lost. As a result, dismounted personnel must revert to using standard radio communications systems (UHF, push-to-talk). This eliminates the ability of all assets to work as a single entity. Complicating the issue is the fact that today’s soldiers are also equipped with computing devices, which require connectivity with a vehicle’s information systems to support the effective flow of bi-directional command and control information.

With an intelligent, integrated and scalable VEA, this situation can be eliminated. Each soldier's standard kit (handset, earpiece, and computing device) can be easily integrated with the vehicle over standard wireless interfaces so that the soldier's mobile communication and information system becomes an extension of the vehicle's VEA.

Architecture Scalability

Finally, an intelligent, integrated, scalable VEA must be configured to be easily scaled for use in a variety of land vehicles, from a basic transport jeep to a full command and control vehicle. Scalability must also support capability growth within a vehicle or family of vehicles. Therefore, the VEA must support plug-and-play additions or changes to sensors, weapons communications and networking systems. This will:

- Minimize training development and the amount of personnel training required because all vehicles will have similar systems and OMIs
- Streamline supply chain management (SCM) because all vehicles will use common VEA parts
- Reduce costs and optimize purchasing budgets because common parts can be procured for an entire fleet as opposed to one type for a specific vehicle
- Reduce the risk of parts obsolescence on one vehicle because parts are common to multiple vehicles
- Minimize logistics support costs and efforts because processes can be standardized for multiple vehicles
- Improve sparing management because common parts can be used for multiple platforms

General Dynamics Canada and an Intelligent, Integrated and Scalable VEA

General Dynamics Canada has made significant strides towards the development of an intelligent, integrated and scalable VEA based on these requirements. Leveraging the concepts of integration standards from around the world, General Dynamics Canada has engineered product components that, when used together, enable the creation of an accessible, integrated, world-centric VEA solution for all vehicles.

The General Dynamics Canada approach is based on integrated communications and networking solutions, specifically engineered to enable the delivery of Internet-based applications. These solutions take advantage of existing commercial technologies and are:

- Easy to use, manage and maintain, with minimal planning
- Modular and built on industry standards to allow the use of the best equipment and software to suit specific needs
- Engineered with MILS integrated into the hardware and software components to ensure confidentiality, integrity, and availability of information

As envisioned by General Dynamics Canada, these components can be effectively integrated into the rugged, mobile environments of advanced land platforms to enable creation of an intelligent, integrated and scalable VEA.

For example, GD Canada has developed integrated smart display technology engineered to optimize computing and display systems. This technology addresses space and functional considerations, and simplifies C4ISR architectures by consolidating MILS and incorporating local situational awareness onto a single Smart Display Unit (SDU). The complete system integrates OMI, display, computer and a mass storage device in a rugged enclosure. With this solution, land combat vehicles require less line replaceable units (LRUs) to perform required functions. In addition, mechanical and electrical integration is simplified because the smart displays require one installation kit and one set of cabling.

The General Dynamics Canada SD80XX series of cross-domain smart displays can be simultaneously connected to more than one network to run software with different security classifications, and configured with optional hardware and software for Secret and Below Interoperability (SABI). These MILS-enabled units use a TEE that enables an operator to access both classified and unclassified information on the same display, either in an individual full screen mode or a dual view split screen mode.

To process bi-directional information and communication, General Dynamics Canada offers the MESHnet® line of products, which can be operated as standalone equipment or integrated to create a voice and data network infrastructure that provides:

- An open, IP-based, integrated voice and data tactical communication network
- A distributed, network-centric, self-healing, fault/failure tolerant architecture
- Scalability from individual vehicles to joint task force system-of-systems
- Open interfaces to sensors and tactical, joint, strategic and commercial networks
- Interoperability with allied and coalition partners

General Dynamics MESHnet products include:

- **MESHnet Tactical Mobile Router (TMR),** which enables the use of e-mail, instant messaging or web-based applications in self-forming, self-healing mobile ad hoc networks where end-to-end communications may not be stable and bandwidth is limited
- **MESHnet Communications Selector Box (CSB),** which provides a single access point for voice and data services, including intercom, radio and telephony
- **MESHnet Tactical Network-layer Gateway (TNG),** which provides a backbone for interfaces to external networks
- **MESHnet Power Distribution Unit (PDU),** which distributes up to 50A of vehicle-supplied 28V DC power to vehicle-mounted electronic equipment, and provides the first line of defence against transients and noise pickup on power leads

Combined, the General Dynamics Canada MESHnet product suite and SDUs enable operators to share intelligence with dismounted personnel, and relay key mission data to command and control elements. They form the foundation of an integrated VEA that enables effective and efficient collaboration between vehicle operators, dismounted personnel, and commanders at all times.

These and other General Dynamics Canada products are designed to exploit existing communications standards and interfaces, such as Wi-Fi®, 3G, CANBus, and Ethernet. They enable efficient electronics architecture integration for in-vehicle and dismounted personnel, while lowering vehicle SWaP-C. Plus, they provide immediate solutions for integration efforts based on standards around the world, including VICTORY and GVA.

Conclusion

While land combat vehicles are getting smarter they are also getting more complex. The addition of more intelligent hardware and software has made even the most basic transport vehicle a complicated collection of disparate systems that must be monitored, managed and maintained. With so many disparate systems, there is no integration of information and data to enable effective command and control processes. Operational efficiency is reduced because the vehicle must be designed to support multiple independent systems. Operator efficiency is reduced because operators must continuously monitor multiple systems. The effectiveness of dismounted personnel is diminished because mobile systems are not integrated with in-vehicle systems. In addition, training is a challenge because personnel have to be trained on a variety of systems, each with their own specific operating processes. And, finally, security is an issue, because classified material going to the platform from the external command and control environment is being delivered to multiple systems.

An intelligent, integrated and scalable VEA offers the most complete solution for eliminating operating inefficiencies on land combat vehicles. It treats the vehicle, the network, and the personnel inside and around the vehicle as part of a complete system, rather than an amalgamation of separate and distinct systems working independently of each other. This improves communications and information delivery. Most importantly, it increases the overall effectiveness of all vehicle assets and the personnel who operate them.

Ultimately, this approach takes the objectives of other standards, such as VICTORY and GVA, to the next level. It addresses the deficiencies in today's land platforms with a scalable architecture that can accommodate the needs of tomorrow's complex in-vehicle requirements today.

Acronyms

Term	Definition
BMS	Battle Management Systems
C4ISR	Command, Control, Communication, Computing, Intelligence, Surveillance and Reconnaissance
CANBUS	Controller Area Network Bus
CBRN	Chemical, Biological, Radiological, and Nuclear
CSB	Communications Selector Box
DVE	Driver Vision Enhancement
ECM	Electronic Counter Measures
ESM	Electronic Support Measures
EW	Electronic Warfare
GPS	Global Positioning System
GVA	Generic Vehicle Architecture
HUMS	Health and Usage Monitors
HMI	Human Machine Interface
IA	Information Assurance
LRU	Line Replaceable Unit
MOD	Ministry of Defence
OMI	Operator Machine Interfaces
OODA	Observe, Orient, Decide, and Act
PDU	Power Distribution Unit
QoS	quality of service
SABI	Secret and Below Interoperability
SCM	Supply Chain Management
SDU	Smart Display Unit
SWaP-C	Size, Weight, Power and Cost
TBMS	Tactical Battle Management System
TMR	Tactical Mobile Router
TNG	Tactical Network-Layer Gateway
UHF	Ultra-High Frequency
VEA	Vehicle Electronic Architecture
VICTORY	Vehicular Integration for C4ISR/EW Interoperability

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