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GROUND COMBAT SYSTEMS – COMMON VEHICLE ELECTRONICS ARCHITECTURE AND APPLICATION

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ABSTRACT

Curtiss-Wright has developed an advanced, open system approach to Vehicle Electronics, based on our vast experience in providing military electronics to many programs for ground, sea, and air platforms. This experience has provided Curtiss-Wright with a unique understanding of key architectural concepts which provide for highly successful implementation of specific Vehicle Electronics suites to meet Ground Combat System program and platform requirements. This paper describes a Common Vehicle Electronics Architecture and key architectural concepts. The Network Centric Reference Architecture incorporates Open Systems approaches and leverages Commercial-off-the-Shelf (COTS) components. Some key concepts discussed include Interoperability, Risk Mitigation, Upgradeability / Obsolescence Mitigation, Scalability, Space, Weight and Power, and Cost (SWaP-C) optimization, as well as enabling technologies. Correlation with the emerging VICTORY Architecture is shown in the Network Centric Reference Architecture. General descriptions of the building blocks are provided, and sample applications of the architecture are discussed.

INTRODUCTION

Interconnection and interoperability of systems within the vehicle is a challenging task. As operational requirements, technologies, and missions change, vehicle equipment and functions need to adapt. In traditional appliqué models, physical vehicle equipment and functionality is tightly coupled and inflexible. Curtiss-Wright has developed an advanced, open approach to a Network Centric Common Vehicle Electronics Architecture which allows straightforward upgrade, interconnection, and interoperability. This approach builds upon enabling technologies to focus on key architectural concepts in order to provide a modular and scalable Network Centric Reference Architecture comprised of a set of architectural building blocks. This allows the creation of a suite of modular and scalable Common Vehicle Electronics Architectures for particular vehicle use cases.

KEY ARCHITECTURAL CONCEPTS

Although a straightforward assumption when discussing Vehicle Electronics architectures in the context of Network Centric Operations, interconnection of these devices can be extremely complex. The very same potential value of the network described by Metcalfe's Law (*potential value creating interactions for N networked nodes is* N^2-N) can provide potential complexity and risk in the process of interconnecting the nodes. The goal of interconnecting is simple, but the implementation can be chaotic and unstable without a defined architectural approach. In order to implement successful Vehicle Electronics Architectures, a number of key architectural concepts need to be considered, specifically:

- Interoperability
- Risk Mitigation
- Upgradeability / Obsolescence
- Scalability
- Optimizations

These concepts are discussed below.

Interoperability

The goal of interoperability is the seamless integration of both legacy and new technologies from multiple vendors in a nonproprietary open systems approach to vehicle networks. Interoperability between old technologies and new technologies is a constant challenge when modernizing or implementing vehicle networks. As opposed to the traditional approach of bolt on appliqués for Vehicle Electronics upgrades, interoperability allows for staged and flexible changes to the overall system in a low risk manner without requiring significant changes to all vehicle systems. The interoperability also allows for resource sharing, flexibility, and functional reallocation based on evolving mission and platform needs, as well as mitigating obsolescence issues.

The challenge of interoperability is careful evaluation of standards compliance, the proper mix of Commercial-off-the-Shelf (COTS) products and the balance of unique or custom solutions encapsulated by standard interfaces. The systems integration task requires a thorough understanding of the specific program and platform requirements, while leveraging experience and agnostic application of interoperable technologies.

Interoperability is provided through the use of open standards. When custom or proprietary products or technologies are required, application of the architecture properly encapsulates and isolates them from the overall system thus maintaining the system interoperability, scalability and obsolescence mitigation goals.

Risk Mitigation

The architecture mitigates obsolescence risk by allowing for encapsulated and isolated changes to the system without affecting the system as a whole. This allows for staged approaches to changes which can be incorporated when technologies and components are sufficiently mature. At the same time, a flexible architecture will allow for the inclusion of prototypes and commercial equipment in the system during development and demonstration phases anticipating the qualification of rugged components. By using open standards and nonproprietary component interfaces, new elements can be integrated into the system with minimal risk. Reuse of existing components from other systems is also low risk because the component interfaces are well understood and easily integrated into a new system.

A significant benefit of risk mitigating architectural goals is reduced cost and reduced time to deploy an entire architecture, as well as an upgrade or expansion of existing architecture. Downgrade integration of proven technologies when newer technologies are unstable or scarce can be performed as well, further providing risk mitigation at an operational level.

Risk Mitigation is provided by adhering to a flexible architecture, utilizing nonproprietary open systems, and providing interoperability with legacy networks and devices.

Upgradeability and Obsolescence Mitigation

The architecture must provide clear paths to upgrade due to obsolescence and evolving mission needs. As with interoperability and risk mitigation, upgradability is provided through the open standards and interfaces, which provide both future and backward compatibility for components. Given overall platform development schedules which may last multiple years, ensuring upgradability exists in the architecture allows for straightforward technical refresh of capabilities as commercial and industrial technologies advance and are adapted for rugged applications.

Upgradeability and Obsolescence Mitigation is provided by adhering to open standards and interfaces.

Scalability

Architectural scalability provides for a common implementation which can be modified for different variants or different missions of a platform, such as commander vehicles versus personnel vehicles. In order to support multiple different platforms which leverage a common heritage and similar (or subset) operational requirements, yet have significantly different SWaP-C constraints, the architecture needs to function in a similar manner, whether for minimal installations (such as for a light vehicle) or for a high capability installations (such as for a heavy combat vehicle). This allows for common components, training, logistics, and leveraging of low risk, mature products.

Scalability is provided by using standard components with sizing and growth considerations as part of the architecture decisions.

Optimizations

A balanced approach of low-risk hardware integrated with readily available COTS technologies provides the best SWaP, low risk, and cost optimized solutions for Vehicle Electronics.

Fully COTS systems, although considered low-risk, generally have non-negligible SWaP-C; furthermore, the integration risk of multiple COTS components as opposed to one or two custom elements tends to be higher than expected, as COTS components do not always lead to tightly integrated and optimized high level solutions.

Fully custom systems may provide the best SWaP (and sometimes cost) optimization, but usually do not provide time-to-production schedule nor risk mitigation; however, in some cases some functions are not available as COTS, dictating the custom approach.

The use of various building block design elements (functional modules, reusable programmable logic) provides significantly lower risk and faster time-to-production for custom modules in a larger system.

A balanced approach of COTS standards, components, and technologies mixed with proven low-risk building-block design elements creates SWaP-C optimized modules and systems with low integration risk and fast time-to-production.

ENABLING TECHNOLOGIES

A number of enabling technologies and processes allow for open and flexible architectures, low risk modification / development, and continued upgradeability. Enabling advances in integrated circuits, manufacturing technologies, and software, include:

- Processing Power Increases
- Storage Density Increases
- High-Speed Fabrics
- Widespread Industrial Control
- Programmable Logic
- Thermal Management
- Rapid Prototyping and Advanced Manufacturing
- Software Interoperability and Standards

These enabling technologies are discussed below.

Processing Power Increases

Moore's Law, which describes a doubling in density of integrated circuits roughly every 18 months, has provided increasing processor densities as well as lower power consumption and better thermal performance. Commercial and industrial use of microcontrollers and microprocessors has provided significant advancement in processor architectures, alternatives and optimizations. In response to highly integrated PowerPC and highly efficient ARM based System-on-Chip designs, Intel (x86 architecture) has provided the low-power Atom processor in addition to standard desktop and server type processors

These Processing Power increases allow for significant flexibility in computing resources as well as use of significant processing power in embedded devices. Increased processing power allows more functionality and capability in devices to enable feasible and economical use cases.

Storage Density Increases

Also as a result of Moore's Law, the density of flash memory has increased so much that it is now a viable alternative to traditional rotating media. With compressed video stream data rates as high as 10 to 50 Megabits per second, rotating media provides a low risk method to record all video and ancillary data. For rugged applications, rotating media can be used with proper provisions; however, flash memory is becoming more economical as chip densities increase, and solid state memory is generally preferred for ground vehicles due to non-trivial vibration environments. Currently, a mix of both technologies provides sufficient recording speed and capacity to store multiple hours of mission data. With further increases in flash memory density, rotating media will no longer be the economical option for high capacity storage.

High-Speed Fabrics

With higher-speed embedded processing capabilities and advances in signaling technology, high-speed fabrics have become available, enabling true network centric systems. Although 10 and 100 Megabit per second Ethernet provides a significant level of connectivity between network nodes, higher speeds significantly reduce data and command bottlenecks. With the advent of Gigabit Ethernet, PCI Express, Serial RapidIO, as well as existing technologies such as Fiber Channel, processing and data storage systems can be connected to each other with 1 Gigabit per second or higher data rates. Most importantly, these higher data rates allow loose physical coupling and of processing, sensors, and storage, as opposed to tight physical coupling within a single physical chassis. This decorrelation of the functional architecture from the physical architecture cannot be underestimated, as it removes physical and functional cross-constraints.

As it pertains to physical chassis design, Gigabit Ethernet, PCI Express, and Serial RapidIO provide scalability and expandability of standard designs, allowing for rapid development of high capability processing clusters.

Widespread Industrial Control

In general, technologies and trends from adjacent markets can have significant impact on vehicle electronics; however, the widespread use of Controller Area Network (CAN) is of significant note.

Widespread industrial and automotive usage of CAN in rugged applications has provided a significant product base of CAN enabled devices, such as microcontrollers and microprocessors for use in real time control systems. Leveraging CAN for real-time control in Vehicle Electronics provides a low risk path towards integrating real-time systems by using proven technologies for similar or identical control applications. CAN enabled devices are low cost and optimized for SWaP, providing an additional benefit to military rugged platforms. Additionally many CAN devices are designed for significantly long life spans as required by industrial equipment manufacturers.

Programmable Logic

Another result of Moore's Law is dramatically increased densities in programmable logic. Field programmable gate arrays can be used to rapidly develop custom and building block-based digital signal processing, interface, and prototype functional blocks in complex systems. FPGAs are available from multiple vendors with licensable and free functional cores (such as protocol interfaces, signal processing, and processing), allowing designers to rapidly create a custom processing solution with the benefit of low risk reuse, rapid prototyping, flexibility, and small SWaP-C footprint.

Thermal Management

Although thermal management techniques are not enjoying the same rapid innovation experience by integrated circuits due to Moore’s Law, vastly increased computing power has had an enabling impact. Computer aided design and finite element analysis tools allow for high fidelity thermal analysis and design simulation, providing low risk chassis designs for an entire range of thermal environments and thermal dissipation requirements. Standard thermal management concepts such as natural convection cooling (~100W), conduction cooling / cold plate (~200W), forced air cooling (~1000W), and liquid flow through cooling (~2000W) can be properly modeled and applied depending on the thermal requirements of the system. In addition, other proprietary and nonproprietary cooling methods exist. The challenge for Vehicle Electronics is to choose the right balance of thermal management methods and SWaP-C, for example, one large liquid flow through chassis with the required liquid loops versus a number of smaller natural convection cooled chassis with no additional cooling hardware. The overall peak thermal dissipation may be limited, driving towards smaller thermal peak chassis (e.g. 200 W versus 500 W). Alternatively, other physical considerations may dictate that thermal peak is a minor concern with respect to available mounting locations (e.g. one cold plate available in only one location versus mounting locations available for three natural convection cooled chassis). Experienced application of thermal management techniques allows for a physically flexible Vehicle Electronics architecture, especially given the decoupling of physical and functional architectures provided by the high-speed fabrics.

Rapid Prototyping and Advanced Manufacturing

Rapid prototyping of both electronics (Quick-turn printed circuit boards available in 24 hours) and physical parts (CNC milled or SLA) allow for risk mitigation through early engineering validation, performance studies, hardware availability for systems and software integration, and manufacturability analysis. Coupled with quality manufacturing procedures, advanced manufacturing techniques such as surface mount technology, in-circuit testing (flying probe and bed of nails), CNC milling of metal parts, and use of composites and rugged plastics in molds allow for highly optimized quality production of sophisticated and complicated products for use in rugged applications. Driven by adjacent industry high-volume production, these advances in manufacturing allow a dramatic increase in the tempo of innovation when developing and upgrading elements of the architecture.

Software Interoperability and Standards

Widespread use of Internet-based technologies for multiple applications and domains has driven significant advances in software interoperability and standards. Flexible Service Oriented Architectures and other conceptual models require encapsulated and reusable software modules which are independently testable and verifiable, providing constant leverage from past and present to future applications. Common middleware layers provide abstraction between the computing platform (hardware and the operating system) and the application, allowing decoupled development and verification of highly portable applications. Virtualization software allows for complete isolation and coexistence of multiple operating systems on a single hardware system, providing a highly flexible path to incorporate multiple different applications (both legacy and future) without significant or potentially no change to hardware. Furthermore, virtualization can provide additional security benefits by separating different applications and operating systems from each other, as well as from the physical hardware though the use of a secure virtualization layer.

NETWORK CENTRIC ARCHITECTURE

A conceptual architecture provides a high-level view of how the key architectural concepts are met. The detailed reference architecture provides a better understanding of the technologies involved. Operational and functional concepts are concepts are explained.

Conceptual Architecture

The Conceptual Architecture is shown in Figure 1. It shows the Vehicle Electronics using a Network Fabric which provides connections to Operator Interfaces, Processing Elements, Storage, and other subsystems, either through native to legacy interface converters, or directly to native subsystem interfaces.

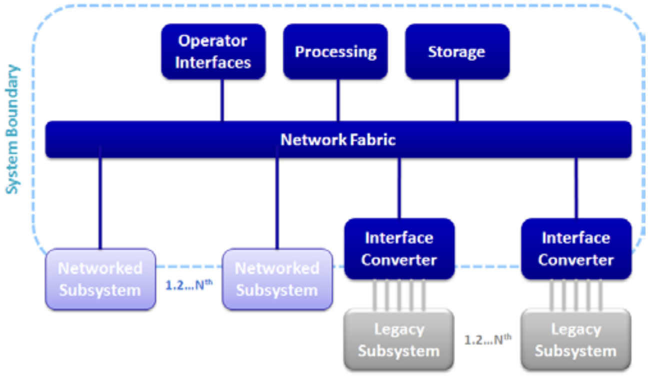

Figure 1: Network Centric Architecture Concept

Reference Architecture

Curtiss-Wright's Network Centric Reference Architecture (shown in Figure 2) for distributed computing and interfaces can meet the requirements of vehicle programs, incorporating Open Systems Architecture goals and leveraging COTS components. Key building blocks include general-purpose and specialized computing clusters, network switches, real-time controllers, network centric sensors / effectors, I/O concentrators, and legacy bridges. The distributed network centric approach substantially reduces overall procurement and logistics costs as well as obsolescence risks because computing elements are separated from the platform-specific I/O elements. Importantly, the architecture enables flexible optimization in various dimensions (Recurring Cost, NRE, Risk, Schedule, SWaP, performance, etc.) since the various building blocks for the architecture are individually selected for key platform and program requirements, while still providing the same overall type of functionality. In addition, the architecture shows synergy with the VICTORY Architecture standards (www.victory-standards.org).

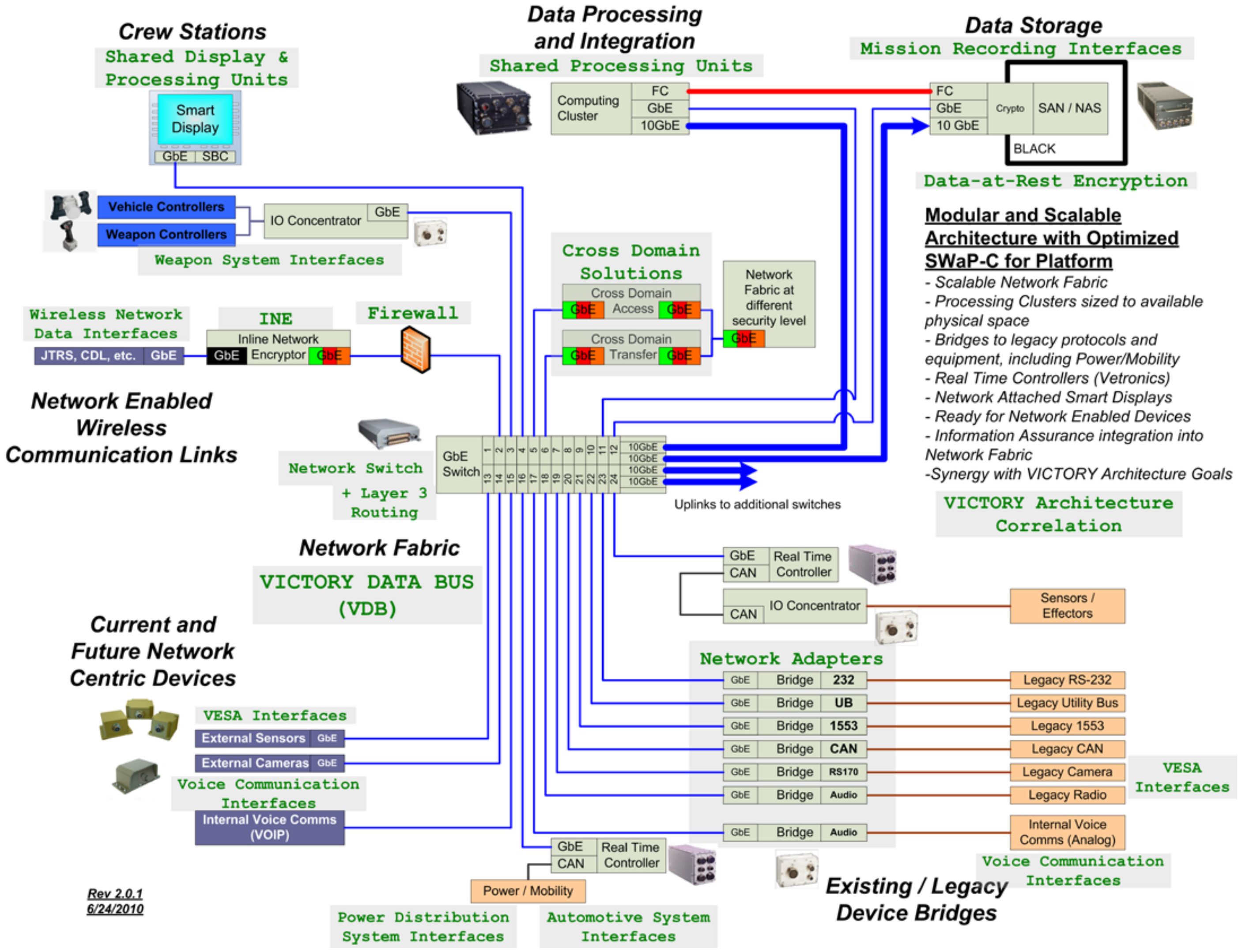

Figure 2: Network Centric Reference Architecture

Concept of Operation

The Network Centric Reference Architecture for Vehicle Electronics distributes interfaces and processing throughout the entire platform. The various elements are selected and optimized (SWaP-C, NRE, Risk, Schedule, etc.) as required for a particular design or family of designs.

The network fabric is provided by Gigabit Ethernet (GbE) Switches, ranging from low cost basic unmanaged switches to comprehensive Layer 2/3 Managed switches with advanced capabilities, such as 10 Gigabit uplinks to additional switches and other high-bandwidth nodes. Multiple switches can be connected in a ring or overlapping star topologies to provide redundant paths in case of a trunk failure. Distributed nodes on the network fabric can use multiple GbE connections for redundancy. Additional redundancy can be achieved by connecting redundant links to two separate switches. Automatic configuration and discovery of nodes on the network is provided through DHCP and associated automatic discovery methods, such as Universal Plug and Play (UPnP).

Distributed processing is provided in computing clusters, which can be trunked to the Network Fabric through 10 GbE links as well as standard GbE links, based on specific platform requirements. Internally, high speed interconnects such as a Serial RapidIO mesh provides high-speed data exchange within the cluster. The mix of processors in the computing cluster run common operating systems and provide middleware layers for distributed processing and interactions. Middleware connectivity is provided using the appropriate middleware as shown in Figure 3. Various non-real-time activities run on the Computing clusters, such as Mission Management, Analysis, Data Fusion, Training and Simulation servers, as well real-time activities as required for particular platforms.

Optimized for particular platform needs, connection to sensors / effectors and other I/O devices is through native GbE connections, CAN, or legacy interface bridges (e.g. MIL-STD-1553B to GbE). Localized I/O Concentrators provide optimized SWAP-C area-of-use interfaces for various types of digital and analog I/O to either GbE (including Real-Time Fast Ethernet) or CAN. The I/O Concentrators can either be connected directly to the Network Fabric, or to a Local Real-Time Controller. A significant benefit of these devices is reducing lengths of complex mixed-signal cabling and removing the tight coupling of platform specific I/O and high value computing clusters, allowing for a platform to change I/O without requiring changes to physical vehicle computers, or costly reservation of numerous spare I/O ports on a computing cluster.

The Local Real-Time Controllers, included as needed for specific platform requirements (such as turret drive), provide

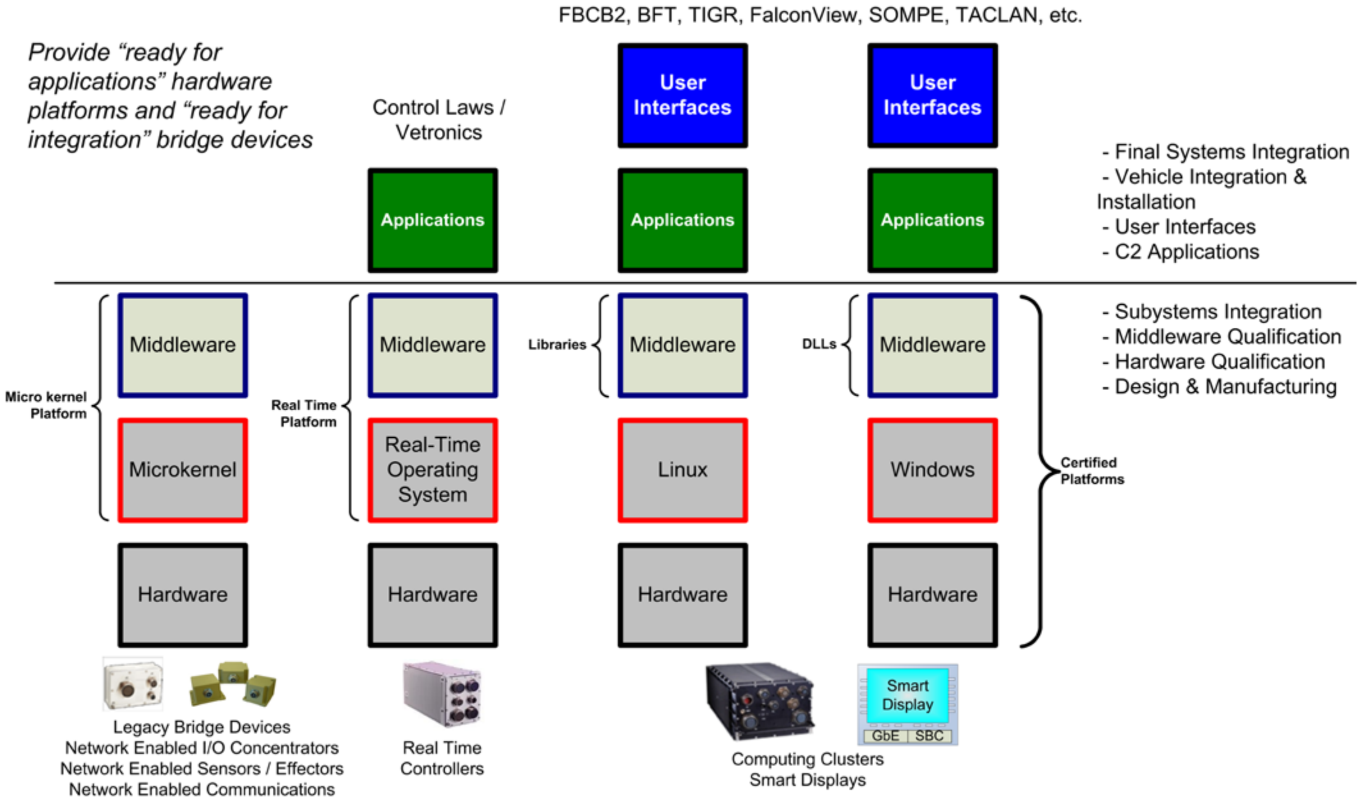

Figure 3: Network Centric Software Platform and Application Reference

segmented and dedicated real-time control-laws integrating sensors, effectors, and controls. These SWAP-C optimized nodes on the Network Fabric provide both flexibility and opportunity for localized customization depending on platform needs. In many cases, especially for smaller, cost driven applications, real-time control may be integrated within a single computing cluster.

High capacity storage is provided by Network Attached Storage (NAS), or on a speed optimized Storage Area Network (SAN) over Fiber Channel. The storage device can contain removable storage module, allowing fast offload and upload of Mission Data. As an alternative to replacing an entire storage device, storage modules provide a clear upgrade path to the infrastructure as higher density modules become available. Storage capacity, NAS or SAN, removability, and performance (throughput) can all be optimized for the particular platform requirements (Cost, data rates, operational concepts, etc.).

Crew Station displays are provided by Smart Displays on the Network Fabric, integrating touch screen, bezel soft keys, with processing provided by tight integration of low cost small form factor computing boards, or scalable and modular integration of computing elements such as 3U VPX Single Board Computers and XMC mounted Graphics Processing Unit (GPU). The Smart Displays will receive video and sensor data over the network from the various other nodes. The capabilities of the Smart Display allow a highly optimized HMI including GUI, physical controls, and data fusion. Additionally, in conjunction with a training and simulation server running in the computing clusters, the Smart Displays will provide locally rendered synthetic video and simulated data inputs for a comprehensive and high performance training environment. The specific Smart Display resolutions, sizing, temperature range, and visibility (night, sunlight readable, etc.) requirements will drive the creation of a specific optimized crew station, ranging from readily available very low cost displays to highly engineered specialized units.

ARCHITECTURAL BUILDING BLOCKS

Network Fabrics

The Network Fabric is provided by Ethernet Switches, packaged for stand-alone use for the specific program, or integrated into Computing Clusters to provide some distributed switching. Switches range from basic unmanaged switches (generally <10 Gigabit Ethernet ports) to sophisticated Layer 2/3 managed GbE switches with 24 port or more. A mix of both types may be used depending on vehicle needs, such as using low-cost switches to concentrate the network within a particular physical area instead of running network lines back to the main switch. Network switches may be enabled with Power over Ethernet (PoE) to provide centrally regulated power for small load (<15W) devices, such as Legacy Bridge devices and I/O Concentrators. The Network Fabric also integrates Information Assurance building blocks, such as Inline Network Encryption, Firewalls, and Cross Domain Solutions. These can be integrated into switches and switch enclosures as required. Built using COTS switch hardware built to open standards, the network fabric is open, scalable, upgradable, and low risk.

Computing Clusters

Computing Clusters are provided in ruggedized enclosures with internal high-speed fabrics and high-speed external interfaces. Single Board Computers, specialized Digital Signal Processing, Internal Storage, and network switching can all be provided within the computing clusters. By embracing a fully decentralized I/O approach, computing clusters can be free of any functional signals other than power and network, allowing an extremely high level of interoperability and scalability as computing clusters will not require any vehicle specific signaling and interfacing other than any specialized mounting provisions.

Network Attached Storage

Network Attached Storage, using standard mass media (flash or rotating) provides a flexible, open, scalable, and upgradeable solution for data storage. Network Attached Storage provides a complete file server in a packaged unit usually optimized for multiple Gigabit Ethernet connections to multiple clients, often with hardware assist for Ethernet protocols. Encryption and key management can be provided allowing for paths to custom solutions and handling of data. Use of removable storage modules in the Network Attached Storage system allows for simple upgrade paths as higher density modules become available, as well as providing straightforward transfer for mission data to and from the vehicle.

The move to flash based storage from rotating will result in lower weight since flash memory has a significantly lower mass than rotating media, and shock isolation specifically required for rotating media can be eliminated.

User Interfaces

User Interfaces are provided by a suite of displays, controls, buttons, indicators, and software graphical user interfaces (GUIs). Depending on specific program requirements, the appropriate sized display (physical, resolution, and aspect ratio) will be chosen. Smart Displays integrating onboard computing can be built up with the addition of a local processing element, such as a 3U Single Board Computer, or smaller form-factor (PC-104, etc.). Graphical User Interfaces are built leveraging common GUI building tools and APIs available for different operating systems, such as SDL, QT, DirectX/FB, GTK, as well as the standard windowing environments of Microsoft Windows and Linux based X-Windows. Bezel soft-keys provide important constancy and tactile feedback of physical buttons for critical controls in addition to touch screen displays.

Data fusion of sensor inputs can be performed by special software and FPGA / DSP based hardware acceleration, such as seamless stitching of 360° Situation Awareness. Common Graphics Processing Units can provide synthetic video for training as well as some acceleration for sensor fusion and unique visualization of data.

Given the high-speed network linking all the user interfaces and processing clusters, remote / virtual desktop techniques, such as the cross platform Virtual Network Computing (VNC) and Microsoft Windows specific Terminal Services / Remote Desktop, can allow a modest capability processor in a Smart Display access to the user interface running on a high capability processing cluster. The use of xHTML and a browser also provides a path to a rich and extremely portable and adaptable user interface.

Handles and controls enable specific station capabilities. These can be connected to the network directly using I/O Concentrators and Protocol Bridges, allowing maximum flexibility in control usage. Attachment of critical controls, indicators, and switches / buttons to Real-Time Control modules provides degraded mode backups in case portions of the Vehicle Electronics architecture are disabled. Although normally providing and receiving control and status via network services, these critical UI elements will default to local direct control of critical real-time systems, such as mobility and weapon system control.

Real-Time Controllers

Real-time controllers provide the necessary processing and connectivity functions to control the tightly coupled, closed loop behaviors required for some vehicle functions. Dedicated communication channels provide the deterministic behavior required by these applications. While any deterministic communication interface may be used, typical interfaces are CAN, RS485/RS422, and MIL-STD 1553 (for legacy devices). A real-time controller may be implemented as a standard chassis consisting of COTS components or, in cases where subsystem requirements dictate, a custom chassis with custom components. In some cases the real-time controller may be provided by a subsystem developer and then linked to the network fabric.

Each real-time controller interfaces with the network fabric directly or through an interface gateway to maintain the interoperability, obsolescence/risk management and upgradability goals of the common architecture. All subsystem data is made available over the network fabric for query, archival, and diagnostic purposes. Operator control of the real-time subsystem may also occur through the network fabric. This facilitates control hand-off when the primary control, such as a commander’s or gunner’s handle, is not available.

I/O Concentration

In order to reduce the amount of special cabling and connections to computing clusters, various inputs and outputs (discrete digital and analog) are abstracted and concentrated at the point of need with only Ethernet or CAN interfaces back to the processing elements. For example, instead of running numerous high voltage isolated digital I/O and shielded analog sensor lines from the engine compartment to one of the Vehicle Electronics computing clusters, a small I/O concentrator is placed near or in the engine compartment to aggregate all the I/O, then transmit it through the network for use by multiple systems as required. In addition to mitigating the risk associated with the complexity of processing and custom I/O in one chassis, the development, cost, obsolescence, and other significant factors requiring changes to one portion will no longer affect the hardware of the other.

I/O Concentrators can be optimized for SWaP-C by rapidly building up a modified design which alters the number and type of channels. Further optimizations are possible by using centralized power distribution by way of Power-Over-Ethernet to eliminate bulky 28V DC power regulation in the I/O Concentrator itself.

Subsystem Interfaces – Native

Various subsystems will connect to the Vehicle Electronics architecture. Native CAN and Ethernet enabled devices will not require any adapters or bridges. Some of the systems involve low data rates (<1 Mb per second, such as audio and most serial buses) and can use 10/100 Mbps Ethernet, and others will be higher data rates, such as video and specialty high-speed synchronous serial interfaces, requiring Gigabit Ethernet.

Subsystem Interfaces – Legacy / Bridging

For the systems which are not native CAN or Ethernet, or may be CAN without a specific real-time need, bridging the protocols and data across to the appropriate networks allows for encapsulation and incremental upgrades of legacy and non-network enabled subsystems. Protocol bridging effectively turns the legacy equipment into a network native, allowing system level software to view the subsystem the same as if it were on the network directly. This allows for clear upgrade paths; once the legacy equipment is refreshed (due to obsolescence, technical updates, consolidation, etc.) the overall system will see small, if any, changes to the network enabled service. Whereas it was previously presented by the bridge device, it is now presented by the network enabled subsystem itself. Such bridges include:

- Serial protocols (RS-232 / 422 / 485)
- Utility Bus
- MIL-STD-1553
- CAN
- Analog Audio
- Analog Video and DVI Video

The two critical portions of these bridges are the physical layer interfaces to both the Ethernet and legacy sides, and the appropriate software to seamlessly carry and route data from one side to the other. Many protocols which ride above standard physical layers can be served by the same hardware, as the bridging function is software driven.

Protocol Bridges, like I/O Concentrators, can be optimized for SWaP by rapidly building up a modified design which alters the number and type of channels. Further optimizations are possible by using centralized power distribution by way of Power-Over-Ethernet to eliminate bulky 28V DC power regulation in the Protocol Bridge itself.

APPLICATIONS

Three hypothetical applications of the Network Centric Reference Architecture are discussed below, demonstrating the flexibility and commonality of the approach.

Cost Effective Light Vehicle, Single Enclave

This cost effective light vehicle has only one security level to demonstrate an entry-level system. Specific example products which fulfill architectural building block roles include:

- Unmanaged 8-port GbE Switch with Power-over-Ethernet
- Smart Display with integrated Single Board Computer for all computing needs
- Small Network Attached Storage
- CAN to Ethernet Bridge (PoE) for engine monitoring
- JTRS unit with Ethernet
- Voice-over-IP Intercom / Headsets

Midrange Flexibility Focused Tactical Wheeled Vehicle, Dual Enclave

This midrange flexibility focused tactical wheeled vehicle has dual security enclaves and must be prepared for any evolving mission. Specific example products which fulfill architectural building block roles include:

- Unmanaged 8-port GbE Switch with Power-over-Ethernet (Red)
- Managed 24-port GbE Switch with Power-over-Ethernet (Green)
- Expansion ports for always changing mix of sensors, radios, equipment provided by externally mounted unmanaged 8-port GbE Switch with Power-over-Ethernet (Green)
- Cross-Domain Access Device (Green/Red)
- Multiple Inline Network Encryption devices (Red/Black, Green/Black)
- Multiple Smart Displays with thin client capabilities
- Large Network Attached Storage (Black)
- Multiple Bridges to Ethernet for legacy vehicle systems (PoE)
- JTRS unit with Ethernet
- Various legacy radios bridged to Ethernet
- Mix of Voice-over-IP Intercom / Headsets and Legacy Analog Intercom / Headsets
- Turret Drive Real-Time Controller
- Single 3U-VPX Computing Cluster for Network Centric Operations Applications (FBCB2, TIGR, ABCS, etc.) and Situational Awareness
- Network-native Cameras

Premium Lethality and Survivability Focused Heavy Vehicle, Multiple Independent Levels of Security

This premium heavy vehicle is focused on Lethality and Survivability, with multiple enclaves. This vehicle incorporates many of the same specific products as in the Flexibility-Focused Tactical Wheeled Vehicle, but also includes:

- Redundant Computing Clusters with fail-over software infrastructure for Network Centric Operations Applications
- Overlapping Star Network Fabrics for redundancy
- Multiple Network Attached Storage devices with integrated Data-At-Rest Encryption for each enclave
- Duplicate legacy bridges and I/O Concentrators for critical systems
- Dedicated Digital Signal Processing Computing Clusters for Sensor Fusion, Analysis, and Processing, including 360° SA, Target Processing, Augmented Reality, Synthetic Video for Training
- High Performance Smart Displays providing additional distributed processing capabilities and redundancy

Application Commonality

Although the some of the physical packaging may change from one vehicle type to another (size of clusters, display resolution and size, etc.) the building blocks have significant commonality. In all cases, distributed I/O and bridge devices can be identical. The fundamental components of the network fabric, such as stand-alone small unmanaged switches can also be identical. In the midrange and premium cases, the high-end managed switches will be typically installed in slots within computing clusters, but may also be in separate single slot enclosures. Depending on physical constraints, the displays can be identical. In addition, the Network Attached Storage devices can also be identical especially if using modular storage allowing for cost and capacity trade-offs.

In all cases, the concept of the architecture stays the same, allowing common understanding, training, user interfaces, and well understood cost / schedule estimating. Of significant note, the core operational software for the system may be largely unchanged across the different vehicles, as the core Vehicle Electronics Architecture will be equivalent.

CONCLUSION

Curtiss-Wright’s Network Centric Reference Architecture provides an open, flexible, capable, scalable, and robust Common Vehicle Electronics Architecture for Ground Combat Systems. It focuses on key architectural goals while leveraging enabling technologies from multiple industries. It provides a clear path forward to high value interconnections on vehicles, whether through incremental modernization efforts or new fully native network designs.

Synergy with the emerging VICTORY Architecture standards is an important aspect of the architecture. Proper application of the Network Centric Reference Architecture to create Common Vehicle Electronics Architectures will provides a low risk modernization path for vehicle integrators to become “Poised for VICTORY”

The architecture allows for rapid development of applications for multiple vehicle types, which in turn allows for the rapid discovery and leveraging of commonality, both at the sub-component and architectural building-block level, ultimately allowing for faster and low-risk systems integration with SWaP-C and performance optimization appropriate to the class of vehicle.