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SMART DISPLAY BASED VEHICLE C4ISR ARCHITECTURE

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ABSTRACT

This paper illustrates the effectiveness of using smart displays to further reduce size, weight, and power (SWaP) in ground vehicles while also providing a path to implementing a network for vehicle C4ISR architectures such as VICTORY. This is done by introducing smart displays and how they can be configured and implemented to take on various functions to provide capabilities such as sensor viewing, vehicle health monitoring, and blue force tracking. The smart display's interfaces and application software allow it to act as network adapter for legacy end nodes in digital backbone architectures.

INTRODUCTION

Military ground vehicles have become extremely crowded and burdened with the addition of many stand-alone, bolt-on systems [1,2]. Digital backbone C4ISR/EW (Command, Control, Communications, Computers, Intelligent, Surveillance, and Reconnaissance / Electronic Warfare) architectures, such as VICTORY (Vehicular Integration for C4ISR/EW Interoperability) architectures, provide a method to remove the clutter in the vehicle and reduce the size, weight, and power (SWaP) of these separate systems. Full implementation of digital backbone architectures may be a few years out requiring legacy systems and end nodes to use adapters for compatibility of data and management interfaces and messages.

A single user interface such as a multi-function display used to integrate stand-alone systems reduces the clutter of multiple displays in the vehicles. Placing the processing in the display could reduce SWaP requirements on the vehicle by removing the need for a separate processing unit for each dedicated bolt-on system. Vehicle applications that require multiple user workstations can implement smart displays and a digital backbone to interface and share access to the various on board sensors and systems.

Smart Display Centric Architecture

A simple method to reduce user display count is using multiple video inputs on displays to give the user a view of the different systems/applications. This still leaves processing with the federated systems. Additional SWaP savings is realized when using the smart display as a central point of sensor integration and application hosting. This capability can be provided by smart displays that possess the interfaces of the separate systems and the processing power and hard drive capacity to support applications to drive and/or interpret the data on those interfaces. Virtualization in the CVSD may be required to assign specific resources (processing, memory, I/O) to specific virtual machines hosting the various applications. **Figure 1** illustrates an example of such an architecture.

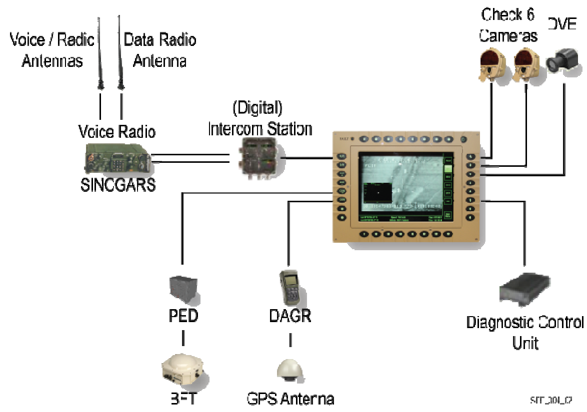

Figure 1. Example Smart Display Centric Architecture

There are certain features of smart displays that have allowed for this type of sensor integration and reduction of user displays. These features of smart displays are discussed in the sections below.

Embedded Processing and Data Storage:

Breakthrough technologies, such as system-on-a-chip (SoC) processers, have driven up performance while lowering and/or maintaining thermal and power requirements of embedded processors. These characteristics of embedded processors are key enablers of smart displays. The lower thermal dissipated power (TDP) and power demand of industrial temperature rated embedded processors allow the smart display to be environmentally sealed for military applications without giving up the needed CPU performance needed to host multiple applications or requiring complex thermal solutions [3]. Intel's Hardware-Assisted Virtualization Technology enable smart displays that employ the Intel VT to host hypervisors with virtual machines and support multiple security enclaves on a single platform.

In order for the smart display to host multiple applications, enough data storage capacity must be available. Solid State Drives (SSD) have continuously increased in capacity and performance. This technology tends to be the top choice for rugged data storage for its performance capabilities and robustness for extreme temperature and vibration environments. The common 2.5" form factor for SSD is also well suited for embedded applications such as smart displays as it provides a compact size with high capacity capability.

User Interface

The smart display can also provide the user interface for the software applications it hosts. It is common to find smart displays with resistive touch sensor for stylus, bare hand, and gloved hand operations in military or other rugged applications providing direct user input to applications' soft buttons on screen. Software programmable and hardware controlled bezel buttons are also commonly found distributed around the display bezel. The software programmable buttons can be configured to work with any hosted application and are distributed evenly around the display to allow for alignment with on-screen buttons or other images, while the hardware controlled buttons are generally used for functions such as power and bezel backlight control. Universal Serial Bus (USB) interfaces allow other interface devices, such as keyboards and mice to be used in addition to the bezel buttons and touch screen.

Common Smart Display Interfaces

Without an established digital backbone to communicate with the various C4ISR devices on a platform, legacy interfaces for these devices must be used. Common smart display interfaces include:

- Ethernet
- Analog and Digital Video Inputs/Outputs
- USB 2.0
- RS232/RS422/RS423
- CAN 2.0
- MIL-STD-1553B
- Audio Inputs/Outputs

A single smart display that features these interfaces may be suitable for vehicle applications that have a small crew or a small number of devices that are being integrated. Networked smart displays may be required for applications where multiple users require a display and/or where there are many devices required that would exceed the interface limitations of a single smart display.

Data Access Cross-Domain Solution

Cross Domain solutions may be required in vehicle applications that involve multiple security levels and networks, and a smart displays offer a reasonable point in the vehicle architecture to place a cross domain guard when used as a central point of sensor/interface integration.

Different Capability Levels

When operating in a single security domain, the smart display's operating system and applications can be hardened according to DISA STIG's / NSA SNAC guides, and industry best practices for security, and be compliant with applicable DoD8500.2 IA controls for the Mission Assurance Category (MAC) and Confidentiality Level assigned to the display or system into which the display is integrated. This includes Information Assurance Vulnerability Management (IAVM) process implementation to provide patches and configurations are periodically updated to address emerging vulnerabilities.

Smart displays can be configurable for Multiple Independent Levels of Security (MILS), using certified, secure hypervisor / separation kernel technology that hosts and controls separate "guest" virtual machine (VM) access to the underlying physical hardware according to the requirements and classification level of each virtual machine. All instances of individual VM's should be hardened according to DISA STIG's / NSA SNAC guides, and industry best practices for security, and be compliant with applicable DoD8500.2 IA controls for the MAC and Confidentiality Level assigned to the individual VM. This includes IAVM process implementation to make certain patches and configurations are periodically updated to address emerging vulnerabilities. The IAVM process will address the hosting hypervisor/separation kernel operating system as well.

To provide platform integrity and authenticate to / from externally connected hardware devices, Trusted Platform Module (TPM) technology should be implemented on the main board of the smart display. TPM can be used at the hardware Basic Input/Output System (BIOS) and host Operating System (OS)/hypervisor level, and may possibly be extended to "guest" virtual machines via "virtual TPM".

Transfer of Data

The transfer of data between different security domains is based on the use of a Cross Domain Solution (CDS) guard software component that interfaces with the hypervisor/separation kernel that can be integrated into the smart display architecture as depicted in **Figure 2**. The CDS guard software distributes information between varied security classification environments, providing effective interoperability and serving as a link to ensure that data maintains sensitivity levels throughout the information-sharing and transmission processes. The CDS guard software can be configured to distribute information between security domains in either one-way or bidirectional fashion according to strict and robust policies implemented.

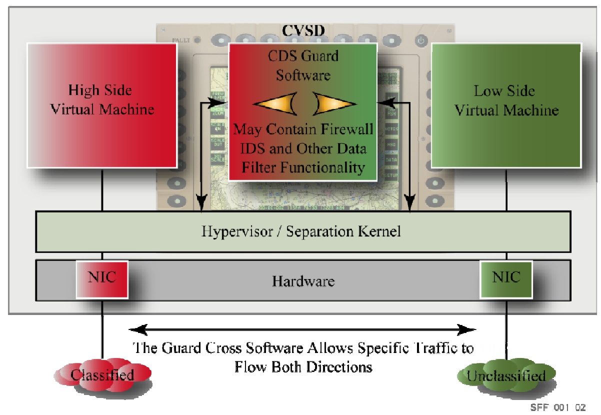

Figure 2. Cross Domain Solution

Virtualization

Integrating multiple software applications with more than one operating system onto a single computing platform is accomplished through the use of virtualization technology which allows guest operating systems to run as virtual machines on the host operating system. An example of this virtualization approach is to run Windows based Non-Development Software (NDS) on a common computing platform utilizing Linux Red Hat as the host operating system. This can eliminate the need to re-host the code to be compatible with Linux. Virtualization technology can be used to allow smart displays to host multiple software applications and as a shared computing resource, or shared processing unit, for the entire vehicle.

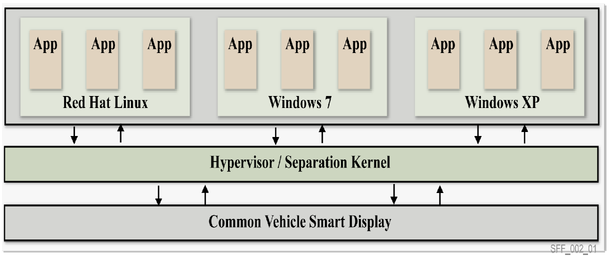

Figure 3. Common Vehicle Smart Display Virtual Application Architecture

A virtualization approach applied to the smart displays features the use of a COTS hypervisor component which serves as an interface between the host operating system and the guest operating systems as illustrated in **Figure 3**. The hypervisor is responsible for handling tasks such as scheduling and memory management for the guest operating systems. In order to support high assurance computing (necessary to transfer data across security domains) the hypervisor can be configured with a separation kernel which provides a mechanism for the strict enforcement of partitioning and isolation of the virtual machines.

Size, Weight, and Power (SWaP) Reductions through Smart Display Implementation

Packaging the processing and display/user interface in a package that is comparable to split system display units alone allows for great SWaP savings in vehicles. Table 1 compares the SWaP of an Appliqué+ JV5 and Raytheon's Common Vehicle Smart Display (CVSD) to illustrate the SWaP savings when using a smart display with analogous processing and interfaces for blue force tracking applications [4]. When provided a smart display that possesses adequate processing performance and interfaces, greater SWaP savings can be realized when the functions of processor units and displays for other applications are also hosted on a smart display.

Table 1: Comparison of FBCB2 JV and CVSD SWaP

Feature	FBCB2 JV5 [4]	CVSD	Savings Provided	
Size	PU - 12.95" x 11.5" x 5.4" DU – 13.35" x 10.10" x 2.8"	13" x 10" x 3.2"	> 765 in^3	~65%
Weight	PU – 17.4 lbs DU – 7.25 lbs	14.1 lbs	> 10.5 lbs	~43%
Power	≤80 W	<70 W	> 10W	~12.5%

Stepping Stone to VICTORY

The following sections outline possible features of a smart display that enable digital backbone architectures, such as VICTORY, to be implemented in ground vehicles.

Shared Processing Unit Capability

Smart displays can provide hardware resources (memory, processor, etc.) to act as the Shared Processing Unit (SPU) for a VICTORY network. The processor of a smart display can provide virtualization technology to allow for separation kernels to host various software applications, operating systems, and multiple security domains. The smart display must also support a VICTORY data bus interface for each security domain with which it interfaces [5]. The interfaces to the computing resources within smart display should be open industry standards to allow for scalability of the computing resources (processor performance, throughput, memory, etc.) by implementing any one of a number of available commercial-off-the-shelf (COTS) boards that adhere to these standards to meet the desired shared processing abilities. Vehicle architectures that feature many on-board sensors, digital moving map, and other C4ISR applications may require additional computing performance compared to architectures that may feature a single sensor and digital moving map.

Network Adapter Capability

Until end nodes are developed to communicate on the VICTORY Data Bus (VDB), network adapters will be required. Smart displays can provide a stepping stone to a completely VICTORY implemented vehicle architecture by acting as a network adapter for legacy systems through the common legacy interfaces. With adequate application software, smart displays can provide the necessary data conversion to make these legacy systems available to the VICTORY data bus. When the devices that utilize these legacy interfaces start to incorporate VICTORY interfaces in the future, the smart displays can communicate with these devices through its Ethernet interfaces on the VICTORY data bus. This capability of the smart displays provides the platform integrator with numerous options for vehicle C4ISR/EW architectures on a single platform and allows for scalability to fit the capabilities required for the end user and the budget of acquisition office. These open interfaces in the smart displays can then be used for integrating future technologies and capabilities into the vehicle C4ISR/EW architecture and/or eventually, be phased out of the smart display.

Complex vehicle C4ISR/EW architectures can utilize the smart displays with different specialized functions to act as VICTORY network adapters at the various user locations. Examples include using a smart display configured with CAN, MIL-STD-1553, and vehicle back-up camera interfaces at the driver location; a smart display with radio, camera, and multiple serial interfaces at the vehicle commander's location; and advanced video and specific discrete interfaces at the sensor or remote weapon station (RWS) operators. The common threads between these configurations are Ethernet interfaces and the capability to act as a network interface for the connected devices and interface with the VICTORY Data Bus. **Figure 4** illustrates an example of a VICTORY architecture using the smart displays in the previous example.

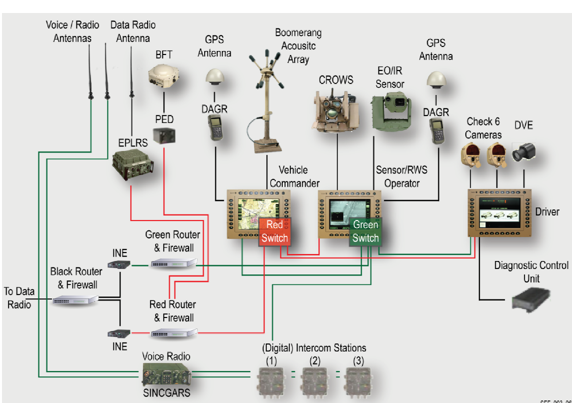

Figure 4. Example VICTORY Architecture with Multiple Common Vehicle Smart Displays acting as Shared Processing Units and Network Adapters.

Full VICTORY Implementation

With full VICTORY implementation in a vehicle C4ISR architecture, the need for specific interfaces based upon the users mission role are greatly reduced and ultimately increases hardware commonality among smart displays implemented in the architecture. Even though the external interfaces to the smart display are common with full VICTORY implementation, there may still be a need for specialized capabilities or functions of certain user's smart display based upon their mission role. Examples of these specialized functions include: high performance graphics processing for 3D map rendering; advanced video processing capabilities to provide video server services; or VICTORY network routing capability by dedicating all interfaces strictly to power, a few USB interfaces for human-machine interface devices, and Ethernet. Some applications may even require a headless configuration where the display and bezel assembly is replaced with a cover and the smart display functions strictly as a rugged computer, or shared processing unit. Until full VICTORY implementation can truly be realized, when the VDB extends all the way from end node to end node with no need for network adapters in between, the smart display offers a solution for SWaP reduction in vehicles.

REFERENCES

[1] "VICTORY Standard Specifications – Version 1.1", 31 January, 2012.

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[4] "Performance Specification for FBCB2: Appliqué+ JV5 (Dual Core) Computer System", PM-FBCB2, 12 June 2008.

[5] "VICTORY Architecture - Version A1", 16 January, 2012.