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INTEGRATED COMBAT RADIO REMOTE CONTROL VIA VICTORY

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ABSTRACT

*Improved combat and tactical radios along with battle command systems that provide real-time communication and situation awareness information are frequently appliqued into the Army's ground combat vehicles to support its modernization initiatives. During the integration of these devices within the vehicle it is often the case that the additional components cannot be placed in a readily accessible proximity to the crew, due to the space-constrained interiors as well as the equipment's expanded SWaP (*Space Weight and Power*). This paper describes an ongoing effort/project to design and implement a VICTORY RADIO ADAPTER (VRA) which supports the integration and single point control of multiple radios having different physical and logical interfaces. The VRA will minimize SWaP, cable count and provide a scalable/agnostic combat radio integration environment that allows control using VICTORY compliant messages. This paper further details the VICTORY RADIO ADAPTER concept along with its architecture, design implementation considerations and project progress.*

INTRODUCTION

To improve and modernize the warfighter's capability and use of real-time voice and data communication for enhanced situation awareness information within ground vehicles, the Army has integrated a number of combat/tactical radios and battle command systems into its vehicles. Due to the limited SWaP (*Space Weight and Power*) available to host C4/ISR systems as well as MEPs (*mission equipment packages*), crew members and stowage items (*e.g.* water, meals, ammo), often the new radio components are not placed where they are readily accessible to the crew because of the vehicle's space-constrained interiors. In particular the combat radios pose the most challenge for the crew because they are typically not placed in premium locations having arms reach access like the main operator terminal interfaces of the battle command system (*e.g.* JBC-P). A premium location placement of the combat/tactical radios would be advantageous due to their frequent use during missions. The warfighter interacts with the on-vehicle radios on multiple occasions during a mission to update settings, such as volume and preset/channel selection.

These issues become apparent in the MRAP (*Mine-Resistant Ambush Protected*) Family of Vehicles (FoV). In particular, the MRAP All-Terrain Vehicle (M-ATV) was designed to have improved mobility resulting in a smaller vehicle with less space in the cab interior. This caused placement and SWaP constraints that resulted in the mounting of some combat/tactical radio systems outside the vehicle cab in armored enclosures located in the rear bed of the vehicle. Access to the radios controls was then impossible without the installation of remote KDUs (*keypad display unit*) mounted within the vehicle interior so that the crew could control the exterior mounted radios. However, this approach can leave a vehicle commander with multiple KDUs at his position occupying valuable vehicle space.

The VICTORY (*Vehicular Integration for C4/ISR/EW interoperability*) initiative suggests an approach to alleviate the SWaP problem in ground vehicles. The "C" in VICTORY, standing for "C4ISR/EW", means that VICTORY covers a majority, if not all, of C4ISR/EW systems to be integrated into a vehicle platform [1]. SWaP reductions are made possible because VICTORY provides a standardized messaging architecture that enables compliant equipment to share information and perform management (control) functions over standard interfaces. This can result in the elimination of redundant equipment. Incorporating VICTORY compliant components could simplify vehicle architecture as well as facilitate reductions in SWaP. However, until VICTORY compliant equipment is available, adapter software can be employed to bridge the gap between VICTORY protocols and native equipment protocols.

The VRA (*VICTORY RADIO ADAPTER*) project is such an effort to demonstrate a solution for the use and control of legacy and modern combat/tactical radios to facilitate crew interaction, to demonstrate the utility of the VICTORY standard, and provide a template for future integration efforts. This paper will describe the rationale, architecture, development and progress of the project.

VICTORY RADIO ADAPTER Rationale

There are a number of reasons to develop and incorporate a device such as the VRA within today's ground vehicles, specifically the MRAP vehicle. The main purpose of the VRA is to reduce interface complexity as well as SWaP consumed within the interior of vehicle, while improving the operator's interaction with and simplifying the ease of use of the combat radios with a standardized GUI interface. The VRA's design aims to facilitate consolidation of all of the combat or tactical radio KDUs to a central control station or Operator Terminal. This frees the space occupied by multiple KDUs and reduces the associated cabling. Figure 1 illustrates the common radio installation and configuration approach in a notional ground vehicle.

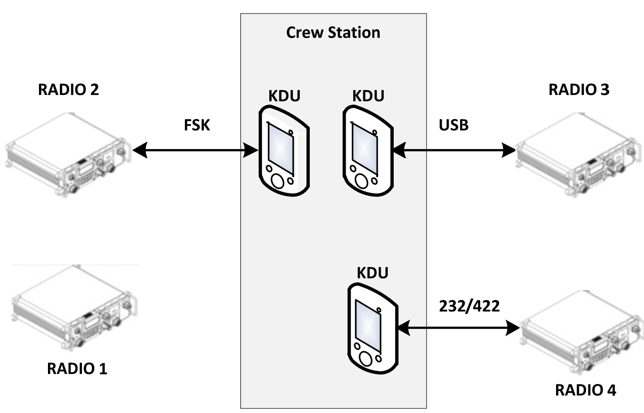

Figure 1: Common radio configuration.

As depicted in Figure 1, each radio is associated with one KDU. KDUs are typically mounted directly to the radio itself (*i.e.* Radio1 of Figure 1) or they can be mounted remotely in a location convenient to the crew, usually at some distance from the physical radio. Either configuration will allow the operator to manipulate and control the radio settings/presets via the KDU. Given that premium locations (*e.g.* operator terminal) within the vehicle (*e.g.* MRAP) are limited, only a subset of KDUs can be placed in the premium location. Additional movement or extended reaching may be necessary for the operator to physically interact with some KDUs. The VRA provides an extensible solution for interfacing multiple legacy and modern networked radios without loss of radio performance and/or functionality. Regarding integration, the VRA concept improves design flexibility and physical placement flexibility of component hardware. And finally, the VRA supports VICTORY compliance, allowing radio control by the use of VICTORY messages. A summary of the VRA technical concept as well as a discussion of the various design architectures are provided in the following sections.

VICTORY RADIO ADAPTER Technical Concept

The VRA's main purpose is to serve as a centralized space-saving mechanism capable of replacing the KDUs of multiple combat/tactical radios, which may vary in their physical and logical interfaces. Along with coordinating multiple physical/logical radio interfaces, the VRA enables radio control and configuration using VICTORY messages.

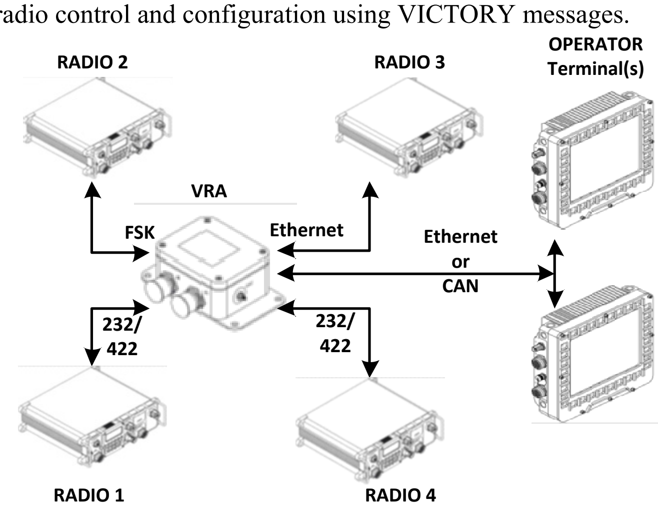

Figure 2: VRA high-level concept.

Figure 2 depicts the general VRA concept, which results in the replacement of multiple KDUs by a single adapter unit, whose main function is to interpret/process radio control messages for a variety of radio types via the command/control of one or more operator terminals. The VRA must be able to efficiently communicate over each of the unique radio-remote control interfaces, while supporting the command set and functionality of all radios that are to be controlled by a centralized operator terminal. As an example, the common legacy (SINCGARS) radios support an **FSK** (*frequency shift keyed*) connection while, the more modern combat/tactical radios utilize remote control protocols based on *point-to-point* serial (**RS232/422**), and **Ethernet** connections.

Criteria #	Description
[1]	Maintain radio functionality and performance.
[2]	Leverage existing HW/SW.
[3]	Utilize COTS equipment if possible.
[4]	Incorporate system expandability in the design.
[5]	Provide enhancement/upgradeability path.
[6]	Utilize proprietary or open standard interfaces.
[7]	Reduce SWaP when possible.

Table 1: VRA design criteria.

Both legacy and modern combat radios will interface to the VRA unit, as shown in Figure 2. The main advantage of this configuration is that the combat/tactical radios as well as the VRA unit(s) are no longer limited to the vehicle interior or the immediate proximity of the operator. One or more operator terminals which function as the control display for all combat radios will interface to the VRA units over the TCP/IP Ethernet open standard. The VRA will be equipped with a CAN (*controller area network*) interface to provide a backup control mechanism in case of Ethernet failure. This architectural decision promotes flexibility in design, physical component placement and user operation. Expecting the technology for modern combat radios to progress because of improvements made in physical interfaces or communication protocols, the VRA hardware and software will be designed to accommodate the growth and complexity required to meet future enhancements as well as upgradeability and expansion capability. The ultimate goal is to have the VICTORY service embedded in the radios to further reduce SWaP.

Interface / (# Ports)	Design Specs
Ethernet / (1)	MIL-STD-810
RS232/422 / (4)	MIL-STD-461
CAN / (1)	MIL-STD-1275E
USB / (1)	Temp Range -40°C to +85°C
FSK / (2)	Convection Cooled
Video / (1)	VICTORY *VT60202-V1.6*

Table 2: VRA base hardware requirements.

One of the main objectives of the VRA unit is to serve as a combat radio remote control device able to support both legacy and modern combat/tactical radios. The new development of both hardware and software implementations are required to accomplish this objective and meet the design criteria shown in Table 1.

Hardware development will proceed in *two* stages.

Stage 1 implements a prototype design that utilizes existing FSK hardware for legacy radio support. Processing local to the VRA is provided by an industrial grade SBC (*single board computer*). Additional radio control interfaces, serial and Ethernet are provided by the SBC. This prototype version is not ruggedized and may not provide full functionality.

Stage 2 will complete the implementation of the VRA. This will include ruggedization so that all design specifications are met and the VRA is suitable for fielding in a vehicle. Table 2 shows the minimum requirements that the VRA is planned to meet. Additionally, a new FSK modem will be developed that is more compact and provides more complete functionality.

Software development will parallel the stages of hardware development. Since the VRA is intended to be used in conjunction with an operator terminal, Stage 1 software will take advantage of the existing operator terminal and FSK module to a great extent. As the Stage 2 hardware becomes available, the software will be ported to the VRA and VICTORY services more completely integrated.

The following sections provide a more detailed discussion of the software-related issues, especially VICTORY service integration/ compliance and descriptions of the hardware products of stage 1 and stage 2.

VICTORY Integration

The IB (*Integrated Bridge*) software used in the M-ATV supports display centralization and provides the *Time* and *Position* VICTORY services, along with the requisite core utilities. These VICTORY services can be provided on any sufficiently powerful processing unit that has access to the native interface of the device associated with the VICTORY service. Since the VRA will support all remote control interfaces to the combat radios of the vehicle, it is logical to host the associated VICTORY services on the VRA. To accomplish this in the desired time frame, the services of the VSSO, the TARDEC VSIL (*VICTORY System Integration Lab*), and the VECTOR (*VICTORY Enabled Company Transformation*) effort will be utilized as appropriate to provide software elements.

While overall familiarity with the concepts associated with VICTORY are assumed to be known by the reader, the following provides a brief summary. The VICTORY architecture, described in [3], specifies a large number of messaging protocols. These serve many purposes including defining message sets for a large suite of C4/ISR equipment. These message sets are supported by VICTORY services. A VICTORY service can be hosted natively on any piece of equipment. But, since no such equipment currently exists, the VICTORY service can be hosted on a processor with access to the information and control interface required to provide the specified data and control. Clients can connect to the service and use the VICTORY-specified messages to interact with the equipment.

Voice Radio Device Management Parameter	Operations
Unit ID	*Get()*
Workgroup	*Get()*
Radio Type	*Get()*
Available	*Get()*
Input Gain	*Get(), Set()*
Output Gain	*Get(), Set()*
Minimum Frequency	*Get(), Set()*
Maximum Frequency	*Get(), Set()*
SINCGARS Device Management Parameter	**Operations**
Communication	*Get(), Set()*
Power	*Get(), Set()*
Mode	*Get(), Set()*
COMSEC	*Get(), Set()*
Active Channel	*Get(), Set()*
Channels	*Get(), Set()*

Table 3: Voice/SINCGARS radio services.

To support the provision of remote control of voice radios, the VICTORY specification (*VT60202-V1.6*) provides two services: **Voice Radio** (15005–20131031, Pro) and **SINCGARS Radio** (15006–20131031, Pro), which are both defined in the Voice Radio Management Interface section of the specification [2]. These services are at the proposed level of maturity, similar to most services found in VICTORY specifications. The operations supported by each of these services are shown in Table 3. The ***Get()*** operation provides a means for reading the parameter values of the specified radio using the VICTORY management interface. Likewise, the ***Set()*** operation provides a write mechanism to update the parameter values of the specified radio, using the VICTORY management interface. These parameters do not constitute a complete set of radio read/control characteristics. Nor are they the same as the characteristics displayed/controlled on the MRAP Operator Terminal WMI (*Warfighter/Machine Interface*) provided by the IB (Table 4).

Radio Parameters	Operations
Active Channel	*Get(), Set()*
Volume	*Get(), Set()*
Available	*Get()*
Mode	*Get()*
Function Switch	*Get()*
Battery Usage	*Get()*
COMSEC	*Get()*
TEK Number	*Get()*
Power	*Get()*
Packet Mode	*Get()*

Table 4: MRAP Radio Management S/W Characteristics.

The relationship between the data elements provided by the two VICTORY services and those provided by the MRAP WMI is shown in Figure 3. Note that the VICTORY support for non-SINCGARS voice radios is minimal. The shaded circle shows the characteristics that are included in the VICTORY Voice Radio and SINCGARS Radio services. The white circle contains the characteristics that are displayed and/or controlled by the IB WMI in the MRAP. The intersection contains these elements common to both. From this Venn diagram it is evident that VICTORY messages, by themselves, cannot provide functionality equivalent to that provided by the MRAP Radio Management Software of the IB. On the other hand, there are functions available through VICTORY messages, such as *Power.Set()*, *Mode.Set()* and *COMSEC.Set()*, that are not available in the IB's Radio Management Software.

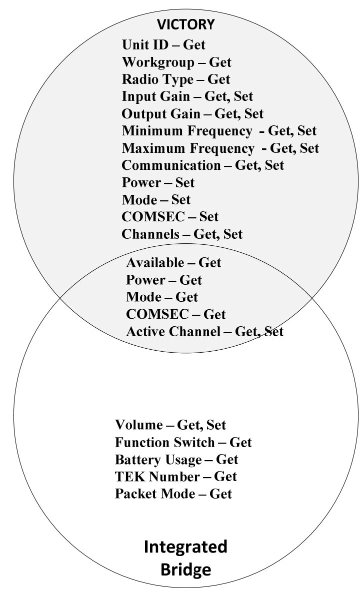

Figure 3: VICTORY/MRAP radio relationships.

The challenge is how to merge the use of VICTORY into the existing system. Generally, the existing system will consist of one or more data consuming clients (*e.g.* displays), a data producing device (*e.g.* SINCGARS radio) with a data transport mechanism between them (*e.g.* Integrated Bridge). These components will typically be designed to work together using some appropriate set of protocols. VICTORY, which conceptually is a new data transport mechanism, provides its own set (new/different) of protocols. Since existing radio equipment does not include VICTORY services, the services must be provided by alternate equipment software. Assuming that it is desirable to preserve the existing capability base of the MRAP radio management software, *four* basic options for including a new data transport mechanism, such as VICTORY, are available (see Figure 4). In Figure 4, the existing or modified functions are shown on the right and the new on the left. There is no implied hardware allocation in Figure 4. The entities depicted as circles represent functional elements.

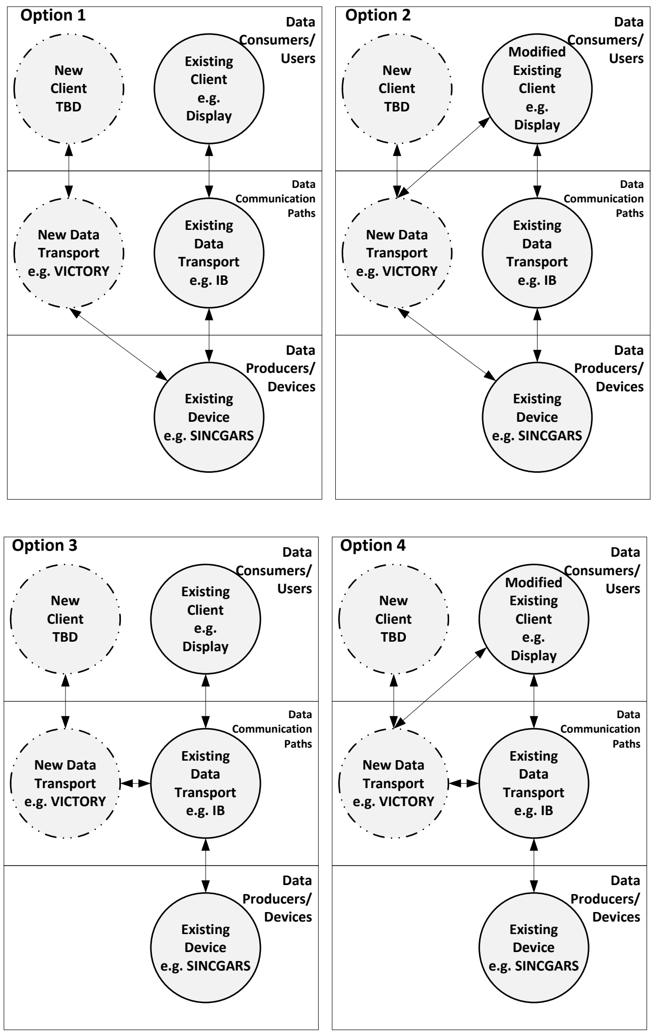

Figure 4: New data transport options.

Option 1: Connect the new transport (VICTORY) directly to the device (*e.g.* Radio) and make the VICTORY service for the component available to any newly developed applications. Do not modify any existing functionality.

Option 2: Connect the new transport (VICTORY) directly to the device (*e.g.* Radio) and modify the existing client to communicate with the VICTORY service in addition to the existing data transport mechanism. The VICTORY service is also available to newly developed applications.

Option 3: If the existing data transport mechanism supports multiple connections, then connect the VICTORY service to it, making it available to any newly developed applications. Do not modify any existing functionality.

Option 4: If the existing data transport mechanism supports multiple connections, then connect the VICTORY service to it and modify the existing client to communicate with the VICTORY service in addition to the existing data transport mechanism. The VICTORY service is also available to newly developed applications.

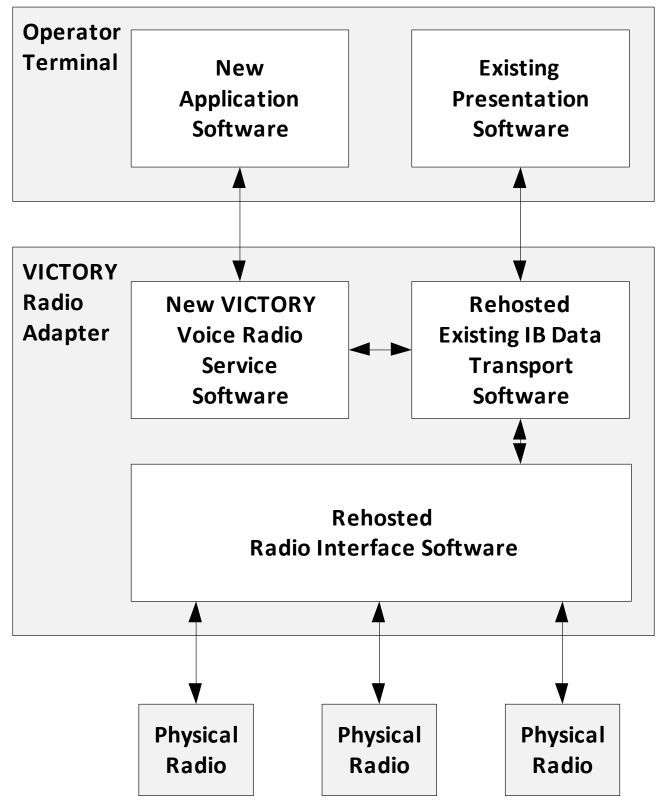

Figure 5: System software allocation.

Since the IB provides a client-server interface for its transport, *Option 4* would seem to be the logical choice for the best integration of VICTORY into the existing implementation. The VICTORY service would provide a portion of the functionality required by the client and the rest would be provided using the existing IB. However, the dual data paths require significant coordination on the client side, making the existing software unnecessarily complex. So, at this point, *Option 3* is a more desirable implementation choice.

Figure 5 shows the allocation of the software elements to hardware in a representative notional system implementing *Option 3*. By hosting all of the radio interface software, including the existing IB data transport software and the VICTORY Voice Radio Service software into the VRA, a

VICTORY compliant radio adapter will be ready for the field, easy to integrate and feasible to implement.

VICTORY RADIO ADAPTER Design Solutions

To meet the VRA requirements for various schedule milestones, two hardware configurations which support different capabilities have been proposed. This section offers a summary detailing the high-level architecture, capabilities and limitations of each VRA hardware configuration.

Prototype Design Solution

The **PROTOTYPE** VRA design solution (Figure 6) represents the VRA effort's initial delivery of hardware and demonstration of capability. The implementation of this hardware configuration is currently underway and has an anticipated completion of August-2014. The prototype VRA implementation will operate in a SIL environment and be capable of demonstrating the radio control goals of the VRA concept. This implementation may not fully support VICTORY message control. The generation and reception of the FSK data stream to support the legacy SINCGARS radio is provided by an existing (custom) implementation.

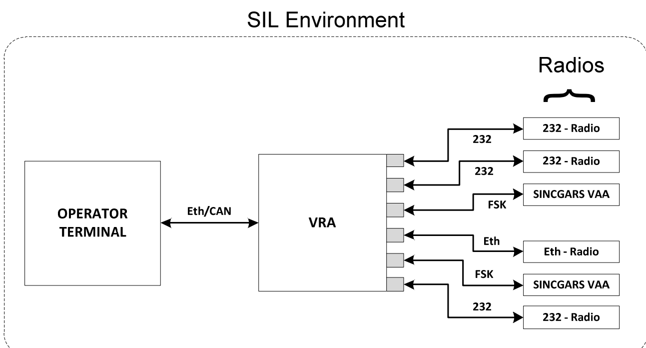

Figure 6: Prototype design solution.

Vehicle Design Solution

The **VEHICLE** VRA design solution (Figure 7) will represent the project's second delivery of hardware and demonstration of VRA capability. The design of this hardware configuration is currently in progress and has an estimated completion of December-2014. This VRA design deliverable will operate in the vehicle environment and will support VICTORY read and control messages. This implementation will include a newly developed and fully ported FSK interface along with modified software.

If schedule permits the legacy radio translator front-end will be replaced with a more efficient FSK modem design. The software architecture on the Vehicle VRA unit may evolve to have multiple configurations depending on available software reuse, feasibility and schedule. Similar to the Prototype design, the central operator terminal functionality will be carried out by an SDU (*smart display unit*). Additionally, for demonstration purposes, a laptop computer containing a VICTORY client will serve to demonstrate VICTORY message functionality.

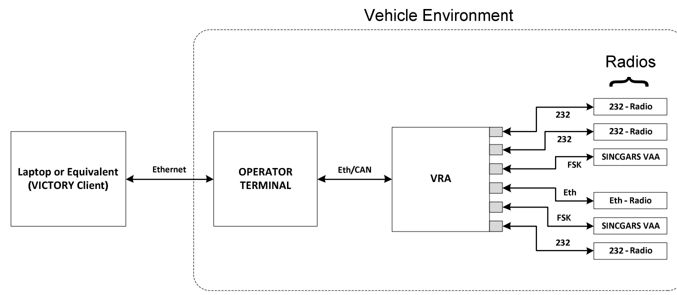

Figure 7: Vehicle design solution.

Future Work

The immediate tasks will include the completion of the VRA Prototype and Vehicle design solutions. This entails completing the interface and I/O requirements for the Prototype/Vehicle design solutions along with modifying the FSK translator on the Vehicle design solution to incorporate a dedicated FSK modem for legacy radio interface support. Upon completion of the VRA vehicle design solution, assuming the availability of the VICTORY test suite, VICTORY compliance testing will be performed to ensure that the resulting service is compliant. Additionally, software work will be undertaken to enhance the VRA's ability to provide a more complete set of radio control, in particular keypad emulation of the most common KDU elements. There will be continued work with the VSSO (VICTORY STANDARDS SUPPORT OFFICE) to enhance the Voice Radio Component Type specification so that it can provide a better service. In addition, we will work with the VSSO to provide a Data Radio component type specification. Once complete, we will incorporate the Data Radio Service capability into the VRA. Lastly, the VRA provides a solid basis for hosting other applications and performing expanded roles in a ground vehicle. It can be easily adapted to become a stand-alone power controller, attach a dumb terminal or a simplified central operator terminal.

Conclusion

As the warfighter's demand for real-time voice/data communications within ground vehicles has increased, the approach has been to integrate a number of combat/tactical radios and battle command systems, resulting in some of these radios being mounted outside of the vehicle's cab due to limited SWAP within the vehicle interior. As a result, manipulation and control of these radios is made possible by the use of remote KDUs located within the vehicle's interior.

However, sometimes the KDUs are not located in the premium space near the vehicle's main operator terminal. Instead, these KDUs have been placed greater than an arm's reach away from the main operator terminal. This is cumbersome for the crew member that must frequently operate and interact with the radios. To minimize SWaP due to multiple KDUs and simplify the operator's access to the KDUs, this paper has introduced a novel concept, the VICTORY RADIO ADAPTER (VRA), which serves as a common remote control interface that consolidates the KDUs of both legacy and modern combat/tactical radios having different logical/physical interfaces along with operating as a VICTORY compliant component. VRA's incorporation of the VICTORY infrastructure makes it possible for the radio's control/settings to be accessible over the VDB (*VICTORY Data Bus*). Various stages of the VRA development (*Prototype* & *Vehicle*) phases were discussed. This work has demonstrated the feasibility of integrating component types that are compliant with a portion of the VICTORY specification. Additionally, this paper has demonstrated some limitations of the VICTORY specification but has also described the development of a broadly applicable hardware and software component that reduces SWaP.

ACKNOWLEDGEMENTS

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