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TOWARD A SOFTWARE BASED INTERCOMMUNICATIONS CAPABILITY FOR ARMY GROUND VEHICLES

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ABSTRACT

The confluence of intra-vehicle networks, Vehicular Integration for (C4ISR) Command, Control Communication, Computers, Intelligence, Surveillance, Reconnaissance/(EW) Electronic Warfare Interoperability (VICTORY) standards and onboard general-purpose processors creates an opportunity to implement Army combat ground vehicle intercommunications (intercom) capability in software. The benefits of such an implementation include 1) SWAP savings, 2) cost savings, 3) simplified path to future upgrades and 4) enabling of potential new capabilities such as voice activated mission command. The VICTORY Standards Support Office (VSSO), working at the direction of its Executive Steering Group (ESG) members (Program Executive Office (PEO) Ground Combat Systems (GCS), PEO Combat Support and Combat Service Support (CS&CSS), PEO Command Control Communications-Tactical (C3T) and PEO Intelligence, Electronic Warfare and Sensors (IEW&S)), has developed and demonstrated a software intercom prototype that proves out the concept and sets the stage for development of a deployable software intercom capability. This paper describes that effort to date including benefits to the Army, technical trades explored and potential for extended capabilities.

1. INTRODUCTION

Most U.S. Army ground vehicles have a requirement for an onboard intercom system that provides voice communications capability between all soldiers onboard the vehicle as well as a push-to-talk (PTT) mechanism to communicate via radio(s) with personnel in other vehicles. Today's intercom systems, primarily the Vehicle Intercom Systems (VIS) models VIC-3 and VIC-5, are physical, single purpose hardware systems that utilize a master station (control box) and crew stations along with dedicated cabling and analog headsets. Though these current systems perform their function, they have the following limitations: 1) they use up precious size, weight and power (SWAP), 2) because they are dedicated hardware (HW) solutions, they are expensive to install and/or replace and 3) there is currently no acquisition strategy or procurement approach to upgrade them.

Given advances in technology and a programmatic void to fill, there is an opportunity to rethink the implementation of vehicle intercom systems. The VICTORY ESG, realizing this

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opportunity, directed the VSSO to investigate and, if possible, complete a prototype of a software (SW) based intercom system on representative HW already installed on many U.S. Army vehicles.

Taking this direction, Agile Communications, under direction of the VSSO, completed the following: 1) conducted trades and completed design of a SW intercom system, 2) developed SW and HW adapter components necessary to implement the design, 3) acquired representative vehicle HW to integrate the prototype with, 4) conducted experiments to prove out the capability and collect data, 5) demonstrated the capability on two different representative implementations and 6) documented design, results and costs. The prototype implementations were completed and demonstrated at Aberdeen Proving Ground (APG), MD in February 2019. All documentation was completed and provided to government stakeholders for review and comment.

2. BACKGROUND

In order to understand the context for, benefits of and implementation concepts of a SW intercom system, it is necessary to have a high-level understanding of the functional requirements and implementation of current HW intercom systems and the basics of VICTORY, which provides the underlying infrastructure, management and control needed to implement a SW based intercom.

2.1. Current Intercom Systems

Currently, most U.S. Army vehicles requiring an intercom capability utilize a VIC-3 system. There are currently over 120,000 systems purchased [1] and have been in use/sustainment for over 17 years. Over 100,000 of these were at one time deployed to Afghanistan and Iraq [2]. There is also a VIC-5 system that has been purchased in small quantities (<2,000) over 8+ years.

Figure 1: VIC-3 Hardware Configuration in a Lab Environment

The VIC-3 system provides internal communications capability between those onboard a vehicle and PTT capability via a tactical radio, such as Single Channel Ground and Airborne Radio System (SINCGARS) or a Soldier Radio Waveform (SRW) capable radio, to provide voice communications with other vehicles. The VIC-3 system consists of the following components: 1) Master Control Station (MCS) which provides configuration and control of the VIC-3 system and radio interfaces, 2) Full Function Crew Stations (FFCS) which provides each user with controls including channel selection and volume control, 3) analog headsets for each user and 4) dedicated cabling to connect the master station, user stations and headsets [3]. A depiction of the master station, three crew stations and associated cabling is provided in Figure 1 (headsets not included).

2.2. VICTORY

The VICTORY initiative produces and manages a set of open standard specifications that govern the sharing of information between systems onboard Army ground vehicles. The information is shared via a set of common message standards including VICTORY Data Messages (VDMs) via an Ethernet network known as the VICTORY Data Bus (VDB). The objectives of the VICTORY initiative are: 1) to provide better interoperability between systems on Army ground vehicles, 2) enable the adoption of shared processing and display systems reducing the reliance on stovepipe systems, 3) enable the reclaiming of SWAP on Army ground vehicles, 4) increase open competition, and 5) save cost and ease integration of future Army ground vehicle systems and capabilities. The VICTORY initiative is sponsored by four PEOs: PEO GCS, PEO CS&CSS, PEO C3T and PEO IEW&S and is managed by the VSSO. More detailed information on the VICTORY initiative can be found at http://www.victory-standards.org/.

3. SW INTERCOM DESCRIPTION

3.1. SW Intercom Design Objectives

The primary objectives of the SW intercom design were to:

- Replicate the primary functionality of a current intercom (VIC-3) system including, but not limited to, voice between all stations on a vehicle, PTT, channel group selection control, volume control and master station status and group definition and controls.
- Implement SW master and user stations on currently available Shared Processor Unit (SPU) HW and surrogate HW of potential future systems.
- Utilize tactical radios in the current inventory to demonstrate PTT capability.
- Integrate and demonstrate ability to work with both legacy analog headsets and USB digital headsets.
- Utilize available SW packages based on commercial standards for voice streaming and session control (low cost solutions).
- Create the ability to control the SW intercom from commonly available displays, meaning a dedicated control box HW would no longer be necessary.
- Utilize the VICTORY Intercom Component Type to provide intercom control and monitoring functions.
- Minimize time to boot.

A table of key operational design requirements and considerations are included in the prototype's design documentation.

3.2. SW Intercom Design

With the design objectives in mind, key technical trades were conducted to ensure all design objectives were met and optimized as much as possible. The following diagram is a block diagram of the overall design.

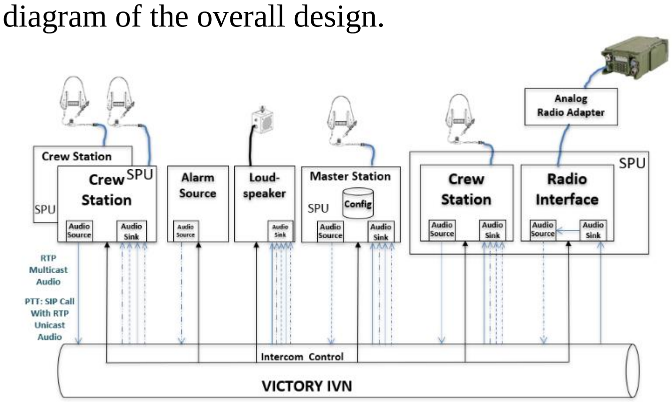

Figure 2: SW Intercom System Design Diagram

Note that the system includes a master station, multiple crew station, headsets, connections to a tactical voice radio and other auxiliary equipment. All of the voice is converted into multicast Voice over Internet Protocol (VoIP) and transported over the VDB, which is simply an Ethernet capability on the vehicle. The master crew station functions run on shared processor units (SPUs) that are already in the Army inventory of systems such as Mounted Family of Computer Systems (MFoCS), smart display units (SDUs) or processing power available on future systems such as Mounted Position, Navigation and Timing (PNT) systems. Below is a block diagram of the crew station functionality.

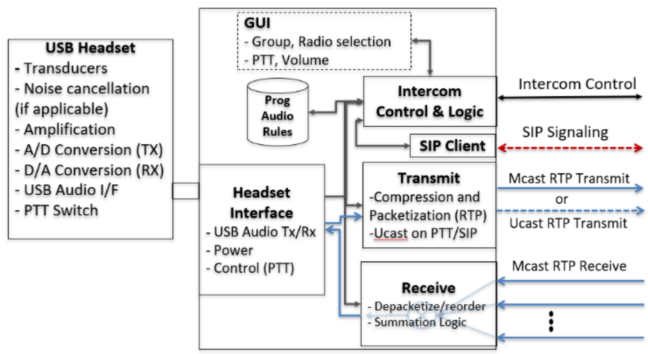

Figure 3: SW Intercom Crew Station Design

This design was chosen to perform all the necessary functions of an intercom system while utilizing open source SW, industry standards and protocols, and limiting the amount of computing resources required to execute. This architecture also enables one very key feature and advantage of a SW intercom; more than one instantiation of intercom on an SPU. For example, two intercom crew stations can reside on the same SPU or one master and one other crew station can reside on the same SPU. There is no need for a mapping of one processor unit per intercom instantiation. Instead, one SPU can serve up to N intercom instantiations, limited by processing power and number of headset interfaces that can be made available.

To realize this design two key design implementation choices are summarized:

- Session Initiation Protocol (SIP) used for voice session control – this is an industry standard protocol with many available implementations.
    - The specific package we choose to use is BareSIP (available for free without restriction on usage, provided all functionality needed).
    - A loosely coupled conference approach (multicast, no signaling relationship) was chosen.
- Gstreamer (an open source multimedia package) was chosen for audio (packetization functions of VoIP).

A more complete set of design trades and rationale can be found in the SW intercom final design document. Requests for this document can be directed to the VSSO.

3.3. SW Intercom vs Legacy HW Intercom

In addition to eliminating the need for dedicated HW, there are also several other differences if a SW intercom approach is adopted. The following is a summary of some of the key differences:

- SW intercom eliminates certain constraints imposed on HW implementations (for example the number of radios is limited to 6 by a physical selector on VIC-3; no such constraint is present on a SW implementation).
- Can instantiate different implementations to meet needs (for example, a simple pre-configured setup could be implemented on two person trucks with only PTT and volume controls).
- SW intercom creates the opportunity to adopt digital headsets
- SW intercom is dependent on boot time of the processor it is running on where as the HW intercom is available almost immediately upon vehicle power up. However, the limiting factor in having full capability up is the boot time of tactical voice radios.
- SW intercom opens up future capability possibilities such as voice commanded apps; HW intercom has no open interfaces so is limited to functionality as built.

4. PROTOTYPE EXPERIMENTATION AND RESULTS

The SW intercom prototype design was implemented on HW primarily contained in the Army inventory or on surrogates for future systems such as Mounted PNT. The implementation was then tested to ensure correct behavior and to capture performance data where appropriate. The following summarizes testing and results:

- Intra-vehicle communications – can I voice communicate clearly with everyone onboard? RESULT: Passed.
- Inter-vehicle communications - positive (PTT) – can I use PTT to communicate via a tactical voice radio to another vehicle? RESULTS: Passed.
- Inter-vehicle communications – negative - if not configured to use radios make sure that users can't perform that function. RESULTS: Passed.
- Radio access – ability to change transmit and receive settings. RESULTS: Passed.
- Intercom management – can I use VICTORY to control, manage and monitor intercom? RESULTS: Passed.
- Robustness testing – will intercom operate on other stations if one of the SW instantiations fails? RESULTS: Passed.
- Boot time to intercom availability – how long does it take to get intercom online from a cold start? RESULTS: Depends on boot up time of SPU; for SDUs used, it was approximately 35 seconds.
    - Additional time to start intercom services was negligible.
    - To achieve full capability, the tactical voice radio needs to be booted and online. This was the limiting factor to full capability, not the SPU or the intercom SW.

The testing conducted demonstrated that the implementation operated correctly and satisfied all functional requirements. Detailed test plans and results documents were created and can be requested from the VSSO.

5. DEMONSTRATION CONFIGURATION

As part of the prototype effort, a demonstration was comprised and conducted for government personnel at APG, MD. The demo configuration consisted of two different types of implementations meant to be representative of two different classes of vehicles:

- One implementation is a vehicle with an inventory of already existing C4ISR systems including MFoCS with Joint Battle Command-Platform (JBC-P) running on it, two SDUs and tactical radios (think Stryker)
- The second implementation is a thin implementation of the future containing only a Mounted PNT device and a tactical radio with no displays onboard (think Family of Medium Tactical Vehicles (FMTV)).

The two different implementations were able to communicate with each other via tactical radios running on a common SRW network. This enabled the PTT capabilities to be demonstrated. The following are block diagrams of both the heavily loaded C4ISR vehicle (Stryker) and the thinly populated vehicle (FMTV).

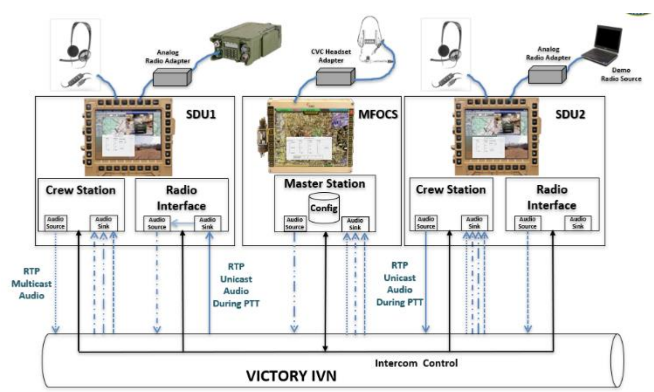

Figure 4: SW Intercom C4ISR Vehicle Demo Configuration

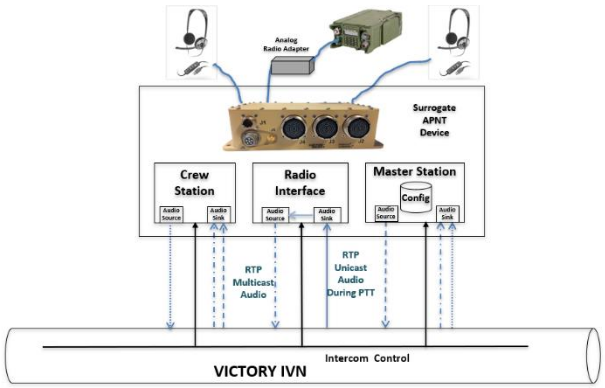

Figure 5: SW Intercom Truck Demo Configuration

The flexibility of a SW intercom approached is highlighted by the ability to implement very different configurations with the same simple pieces of SW. The C4ISR vehicle has multiple processing units and these are utilized to provide services to the multiple crew stations. The display units get used to provide both master control station and user station Graphical User Interfaces (GUI). The truck vehicle has no display, and the intercom is pre-configured with the users able to control volume and PTT from their headsets.

In order to provide control of the master and crew stations in the C4ISR vehicle, a simple GUI that mimics the same controls and terminology of the VIC-3 control boxes was created. Below are diagrams of the master and crew GUIs used in the demonstration.

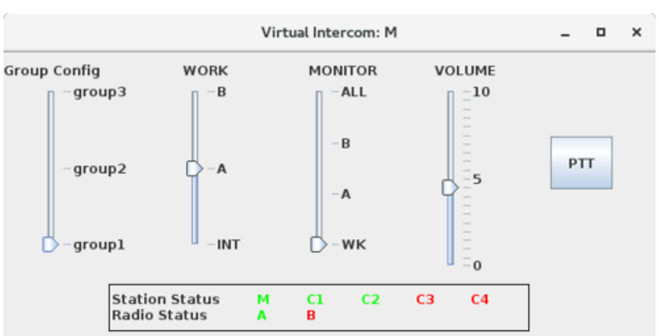

Figure 6: Master Control Station GUI

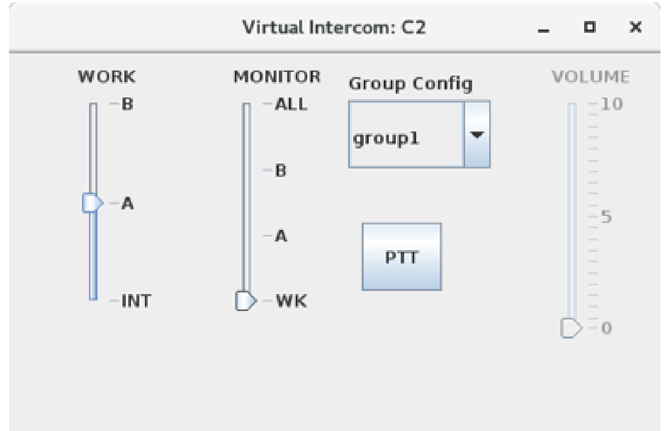

Figure 7: Crew Station GUI

It is also important to demonstrate that the implementation of a SW intercom does not interfere with the operation of other SW applications that typically run on an MFoCS. To validate this aspect, we demonstrated the MFoCS running JBC-P SW concurrently with SW intercom. In this case, both the master station (along with GUI) and JBC-P are executing simultaneously. The figure below shows both the GUI and JBC-P map on the same MFoCS display.

Figure 8: Master Station and JBC-P operating simultaneously on an MFoCS

During the demonstration four major demo threads were executed:

- Thread 1: intra-vehicle intercom
  - Voice shared among the crew
  - Both analog and digital headsets
- Thread 2: radio interfaces
  - Monitor selection of radios
  - Work control selection and PTT

- Thread 3: Program based access (who can access a tactical voice radio and who can't)
- Thread 4: Distributed intercom control using VICTORY

As part of the demonstration effort, a video version was created for future viewing. Information on this video can be obtained from the VSSO.

6. APPLICABILITY, RISKS AND POTENTIAL RETURN ON INVESTMENT

In order to apply a SW based intercom to a vehicle, there is no need to change intercoms on other vehicles. In other words, an Army unit can consist of a mix of SW based and legacy HW intercoms. This implies a significant flexibility in deploying SW intercoms, since there is no need to remove HW intercoms where already installed to realize the benefits of them on new installations. SW intercom can therefore apply to any legacy Army vehicles with an intercom requirement that is being upgraded as well as new vehicles.

There are very large potential returns on investment (ROI) for adoption of a SW intercom. Just to bound the problem, there are over 120,000 vehicles with legacy intercom systems. The cost of these for purchase and install was approximately $12K per unit based on available data [4]. Multiplying the number of units by the cost per unit ($12K x 120,000 vehicles) this is a total of about $1.4B. This does not include the sustainment chain of parts and the cost to do any upgrades or fixes, which all involve accessing HW. The cost to develop a SW intercom prototype was on the order of $275K. This is not a deployable system, so even if the cost to develop a deliverable system is an order of magnitude or more, it is in the $5M range. The install cost is very low since it is a SW app installed on existing processing HW. There also are no licensing costs if developed from open source SW, or even if the government commissions development of its own version of these industry standards. Given all this, in large quantities we will assume a per install cost that is less than $1K or the potential over the entire fleet to save over $1B as the fleet is replenished over time.

There is one technical requirement risk to realizing a SW intercom on Army vehicles and that is mitigating the startup time of the SW intercom, which is limited by the boot time of the processor (SPU) on which it is installed. In reality, there are many vehicles on which it may be possible to relax this requirement since it is a relatively short time and, in any case, the longest delay in realizing the full intercom capability is the boot time of the tactical voice radios. In this case, it becomes a trade of saving SWAP and cost. Possible risk mitigations include:

- Commissioning a technical study to optimize SW intercom start up time – in this prototype effort, we did not look for ways to optimize and there are likely ways to improve on results from our experimentation.
- Relaxing requirements on availability of intercom system from immediately upon power up to a non-zero delay after power up.
- Utilizing a small battery or dedicated power source to keep an SPU running with the intercom even when the vehicle is powered down.
- Employing a mix of HW and SW intercom in the fleet to outfit key vehicles with immediate intercom capability on startup. In vehicles where this requirement can legitimately not be relaxed, a legacy HW intercom system can remain in place.

The only other risks are programmatic in nature, such as gaining commitment to developing the capability, mitigating the mindset of requiring dedicated HW solutions, and embracing open standards and shared systems. This class of risk is not addressed in this paper.

7. CONCLUSION

The SW intercom prototype effort described in this paper was meant to demonstrate 1) the concept was technically viable using industry standards, 2) can be implemented at low cost and reuse open source SW, 3) can utilize the VICTORY intercom component type for management and control and 4) can operate on existing HW systems already in the Army inventory. The effort demonstrated all of the above.

In addition to successfully proving out the concept, the adoption of a SW based intercom system opens the door to a new world of future capabilities. With digitized voice available on a common VDB (Ethernet) on a ground vehicle, it is possible to start developing concepts for voice activated and controlled systems. Voice activated C4ISR and weapon systems could relieve the warfighter of the burden of trying to type or push buttons in a vehicle that is moving and vibrating. The ability to push the buttons and enter data via a keyboard in a moving, vibrating vehicle is often cited as one of the biggest impediments to fully realizing the capabilities of digitized systems such as JBC-P.

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