Improved Crew Efficiency and Situational Awareness Through Multi-Function Video Display

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Summary Statement

We are presenting a unified architecture for controlling and displaying all of the disparate sensor systems installed in a Medium Mine Protected Vehicle (MMPV) Type II.

Abstract

The evolving nature of the threat from hazardous buried targets has led to increasing numbers of independent control systems (including imaging sensors, weapons systems, communications equipment, etc.) in the route clearance MMPV Type II crew compartments. This increase in electronic subsystems poses integration challenges to the host vehicle platform, as well as a logistical challenge to the crew required to operate all of the equipment. The U.S. Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) partnering with Project Lead Assured Mobility Systems (PL-AMS) has developed a consolidated control platform called the Multi-Function Video Display (MVD) which provides each crew member a touch screen interface for viewing and controlling all attached subsystems. By combining all of the disparate control and display hardware into one common interface the Size, Weight, and Power (SWAP) constraint on the host vehicle is greatly reduced, as well as the overall system and maintenance costs. In addition, having all sensor outputs controlled by one integrated system allows for improved detection performance through the statistical combination of algorithmic processing results. New systems can be quickly integrated into MVD through the use of the VICTORY (Vehicle Integration for C4ISR/EW Interoperability) communications protocol for Plug-n-Play communications within the vehicle as well as the Integrated Sensor Architecture (ISA) for communicating with systems off vehicle. Night Vision has designed and built a system from the ground up which includes government owned and developed software as well as Mil-spec conduction cooled hardware that meets the needs of the current MMPV platform, while allowing for future growth (addition of new sensors, control of current sensors, algorithm processing, etc.). The MVD is to be part of the MMPV Type II Program of Record (POR) and is currently undergoing Logistics Demonstrations in preparation for Operational Testing. We present a description of the MVD hardware and software architecture along with initial soldier feedback and efficiency gains. We also include an analysis of individual algorithmic performance results compared with the gains that can be expected from intelligently combining algorithm outputs.

1. Introduction

The evolving nature of the threat from hazardous buried targets has led to increased numbers of independent control systems, referred to as vehicle enablers (including imaging sensors, weapons systems, communications equipment, etc.), in the clearance Medium Mine Protected Vehicle (MMPV) Type II crew compartments. Each vehicle enabler comes with its own proprietary operator's station for control and display. Since there is a unique operator's station for each enabler, only the one Soldier assigned to an enabler can actually view and control it. In addition, all of the different operators' stations create an integration challenge with limited room for future capability growth. Even if the operators' stations could all fit in a vehicle, there are too many displays for a single operator to view and control effectively.

To address these challenges in the forthcoming MMPV Type II Program of Record (POR), the U.S. Army RDECOM CERDEC Night Vision and Electronic Sensors Directorate (NVESD) partnered with Project Lead Assured Mobility Systems (PL-AMS) to rapidly develop a software middleware and hardware architecture, called the Multi-Function Video Display (MVD) [1], that efficiently distributes imagery and sensor control to all crew stations within a vehicle, eliminating the current dedicated display per sensor "stovepipes." Each crew station is outfitted with a single touch screen display for viewing and controlling all vehicle enablers, creating a seamless common interface across all enablers. This allows capability growth without increasing display Size, Weight, and Power (SWAP) requirements. Adding a new enabler no longer requires the addition of an enabler operator's station. MVD is a Plug-n-Play VICTORY (Vehicle Integration for C4ISR/EW Interoperability) based architecture that is completely government owned and developed. The software is hardware independent and can run on touch screens, laptops, tablets, smart phones, etc.

The MVD system improves mission capability in three main ways: improved operator efficiency, increased situational awareness, and reduced SWAP requirements for the vehicle. Operator efficiency is improved in several important ways. First, the operator remains focused on one display as opposed to having to move between multiple displays situated within his crew space. Second, the single display presents the operator an identical view of each vehicle enabler from the common user interface that all the enablers share. Similarly, operator controls (both touch screen and gamepad) are shared between all enablers. This requires the operator to learn only one Graphical User Interface (GUI) and one common set of controls to interface with all of the different vehicle enablers, both current and future, and reduces training burden. These benefits combine to greatly improve operator efficiency. Situational awareness is improved in a similar manner. Whereas previously the full motion video from an enabler could only be viewed by a single crew member with the enabler's dedicated display, with MVD any crew member within the vehicle can view full motion video from any or all enablers simultaneously and in real time. With additional eyes on each video feed, situational awareness increases proportionally to the number of crew members with MVD systems. Last, as stated previously, MVD translates into SWAP reductions since as new enablers are added dedicated processing and display hardware does not have to be added as well.

In this paper we describe the MMPV Type II; its mission, sensors, and place in the route clearance company. Next, we discuss the MVD, both hardware and software, and how it meets the needs of the

MMPV Type II and its crew. We describe how the MVD improves operator efficiency and situational awareness within the MMPV Type II and reduces SWAP burden. Lastly, we look at how combining sensor outputs at a central location within the MVD can improve the performance of ATR algorithms.

2. MMPV Type II and the Route Clearance Platoon

The task of clearing routes of explosive hazards belongs to the Route Clearance Platoon. A typical mission for the platoon would consist of clearing hundreds of kilometers of one-way vehicle traffic of explosive hazards at an average detection rate of less than 10kph over the course of a continuous multi-day period. The platoon must operate both day and night, during all weather conditions, and across varied and complex terrain, ranging from primary highways to confined urban roads to dirt trails. The tasks required of the platoon include everything associated with explosive hazards from detection and classification to neutralization, as well as force protection activities and casualty evacuation.

The Route Clearance Platoon consists of a number of different vehicle platforms, each with its own set of enablers and assigned duties. The MMPV Type II is the most common vehicle as it can be easily outfitted with varying enablers to serve a myriad of different tasks. It is a mobile and highly survivable vehicle with a V-shaped hull that is designed to withstand explosive blasts while transporting and protecting Soldiers and equipment. The MMPV Type II serves as the command and control vehicle of the platoon. It is outfitted with various high magnification sensors such as the Vehicle Optics Sensor System (VOSS). The VOSS is a multiple modality gimballed sensor that sits on a retractable mast and gives the Type II crew a clear view of the other vehicles within the platoon as well as the surrounding area making it perfect for performing overwatch and assisting during complex platoon maneuvers. In addition to command and control, all MMPV Type II’s are equipped with either a Common Remote Operated Weapons System (CROWS) or an Objective Gunner Protection Kit (OGPK), allowing them to perform force protection tasks for the platoon.

As stated previously, the MMPV Type II can be outfitted with numerous different sensors and weapons systems. Figure 1 shows a subset of the systems that might be integrated on to the platform. The requirements for the MMPV Type II includes a baseline list of systems that are included on the POR vehicle. In addition to the VOSS and CROWS systems discussed previously, the MMPV Type II may include a Driver’s Vision Enhancement (a thermal sensor used by the driver for driving at night under blackout conditions), an Interrogation Arm (a sensor and crane used for digging and interrogating possible explosive hazards), and a Man Transportable Robotic System (MTRS) (used for remotely interrogating hazards). There are many other systems that will be added to the vehicle in the future or currently reside on the platform but only in small numbers.

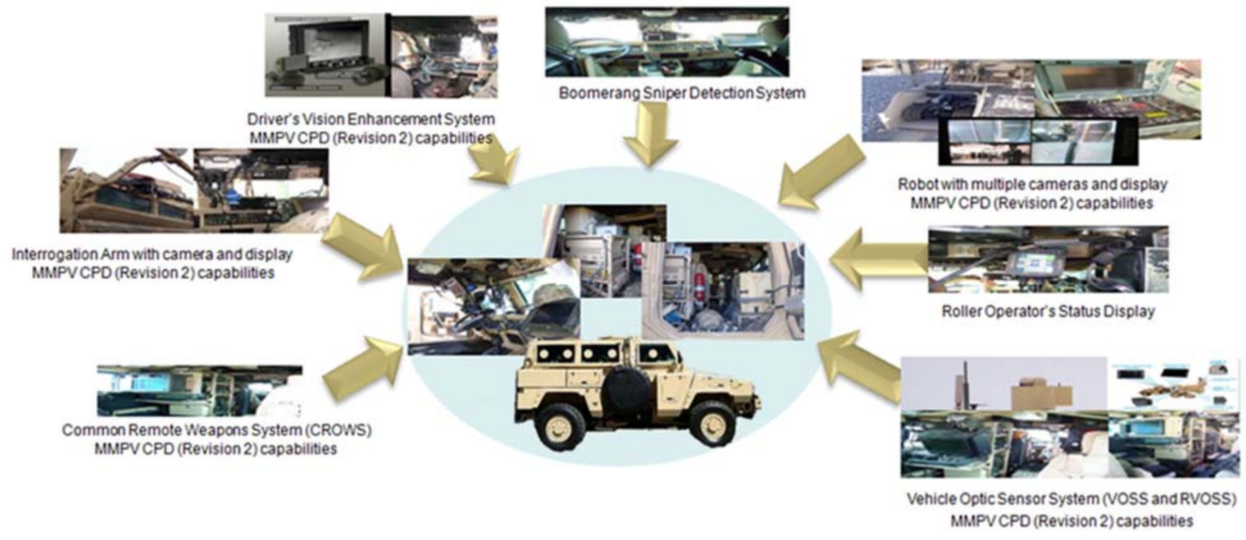


Figure 1: MMPV Type II showing subset of sensors commonly integrated on to the platform.

With the ever expanding list of enablers that the MMPV Type II must support it gets more and more difficult for the vehicle's four man crew. Figure 2 shows the duties of the four-man crew with the base set of sensors and equipment. This figure depicts the way the MMPV Type II was used over the past decade in which each enabler had its own dedicated display that only the crewman tasked with operating the enabler could view. As can be seen, every crew station has at least one enabler requiring a display and controls. The addition of new enablers will add more displays and dedicated controllers to a station, overloading a member of the crew.

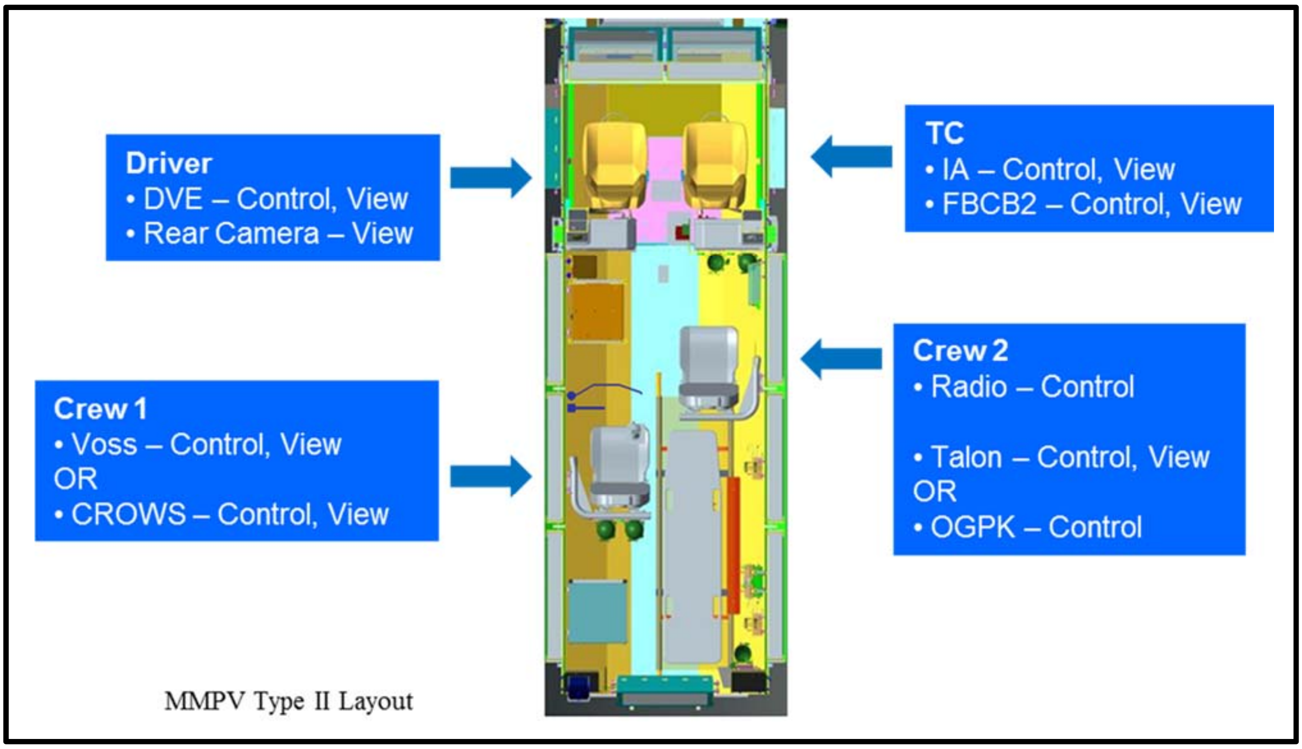


Figure 2: Internal layout of MMPV Type II with crew assignments.

3. MVD Hardware and Software Description

The Multi-Function Video Display project originated from a conversation between NVESD and PL-AMS at the Engineering School related to vehicle requirements for the Medium Mine Protected Vehicle (MMPV). One of the requirements was for a single display system capable of viewing and controlling all attached sensor systems, referred to as vehicle enablers. NVESD had accomplished and demonstrated a related slew-to-cue display effort called Multi-Function Graphical User Interface (MS-GUI) and thought this could be augmented to meet the MMPV single display requirement. This overall requirement called for a common intuitive display to view and control all vehicle enablers at all crew stations simultaneously in real-time that had capability for future growth. The timeline for development was aggressive due to the MMPV fielding schedule. A working prototype system needed to be demonstrated within six months followed quickly by a more ruggedized system version in order to be considered for insertion into the truck during its Army Test and Evaluation Center testing.

As a first step in this very aggressive effort NVESD conducted an architecture study to determine how best to meet the overall project goal. Three target system architectures were identified and hardware and software prototypes were designed for each. Common to each approach was the need to convert analog camera data to digital and the need to fit a large amount of camera data into a limited bandwidth budget for delivery to each display. The first issue arises because the enablers currently on the MMPV have legacy analog cameras. The second issue is that the aggregate bandwidth of all the different vehicle enablers is more than most common COTS interface capabilities. In initial configurations of the system the cameras accounted for close to 3 Gigabits per second (Gbps) of aggregate bandwidth.

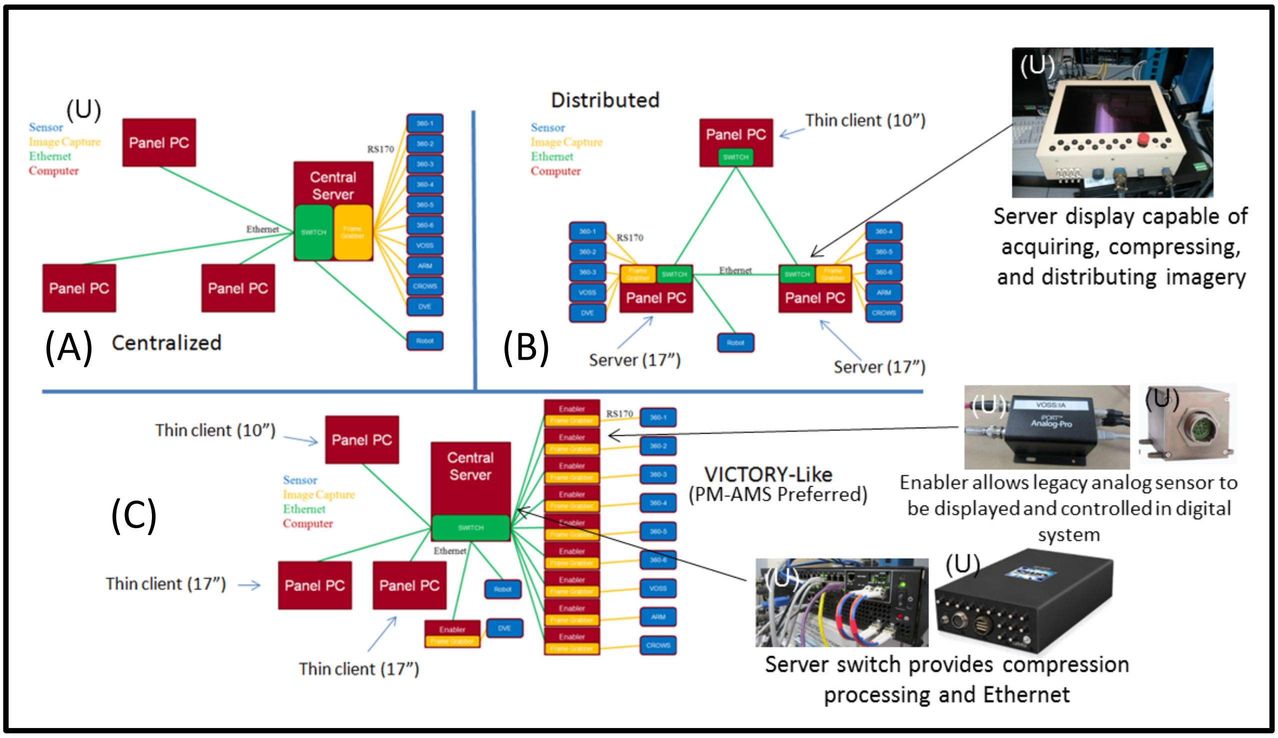


Figure 3: MVD Architecture Study.

The first architecture investigated utilized a centralized approach (Figure 3 (A)). A central server containing multiple video frame grabbers was connected to the analog outputs of the different vehicle enablers. The frame grabbers digitize the analog feeds and store them in system memory. Once in memory, the server compressed the raw sensor data using an H.264 video encoder and sent the compressed feeds by Gigabit Ethernet to each of the client touch screen displays which decompress the imagery and present it to the operator. This architecture suffered several drawbacks. If the server died then all sensors would become unusable. Secondly, if frame grabber ports died it would be difficult to repair in the field except by replacing the whole server. Lastly, as future sensor systems move away from analog and become digital, the server will be left with a large amount of unusable hardware.

The second architecture utilized a more distributed approach (Figure 3 (B)). In this case, each display was outfitted with its own set of frame grabbers. Each display would be the primary server of a subset of enablers, compressing the imagery from these sensors, and distributing it to the other displays. It would receive data from the other displays and present this data to the operator along with the data it collected itself. This approach improved on the central approach by eliminating a single point of failure; now one monitor failing would only result in the loss of a subset of sensors. It still had the problem that future sensor improvements would leave all of the analog frame grabber hardware obsolete. It also introduced a new problem: adding frame grabber functionality to the displays greatly increased their thickness. This increased display thickness was deemed unacceptable for rapid vehicle ingress and egress.

The final approach was a network-centric approach (Figure 3 (C)). As opposed to having frame grabbers in a server or in the monitors NVESD chose to use stand-alone media converters that would take individual analog inputs, digitize them, packetize them for use on Ethernet, and distribute them as required. Along with these media converters the final approach made use of a server switch that takes in numerous Ethernet inputs, aggregates them on the server's internal 10 Gigabit Ethernet link, compresses the video, and distributes it to the displays. This approach improves on the limitations of the other architectures. If the server dies, as long as the switch is still working, the client displays can still access the media converters and act as servers themselves. Also, since the displays don't have frame grabbers inside of them they can remain thin and lightweight. Finally, as sensors shift away from analog the media converters can be removed and the new digital sensors can tap directly into the server switch. This final system architecture was chosen as the approach for the rapid system development and is depicted in Figure 4. Over the course of the MVD system development NVESD worked closely with multiple hardware vendors to transition each of the three main system architectural components (server switch, touch screen smart display, media converter) from lab grade prototypes to full Mil-spec, conduction cooled, production products capable of operating in the extreme environments of the MMPV. This transition involved numerous hours of discussions between the NVESD development team and vendors on prototype designs and testing of these prototypes by NVESD to ensure that the hardware operated as desired. This approach ensured that at the end of the software development phase a reasonable set of hardware components was available ensuring successful demonstration of the system in a surrogate MMPV. Upon successful demonstrations highlighting the robustness of the software the NVESD development team held multiple rounds of deliberations with vendors to evolve the hardware further to meet the needs of the MMPV at minimal cost.

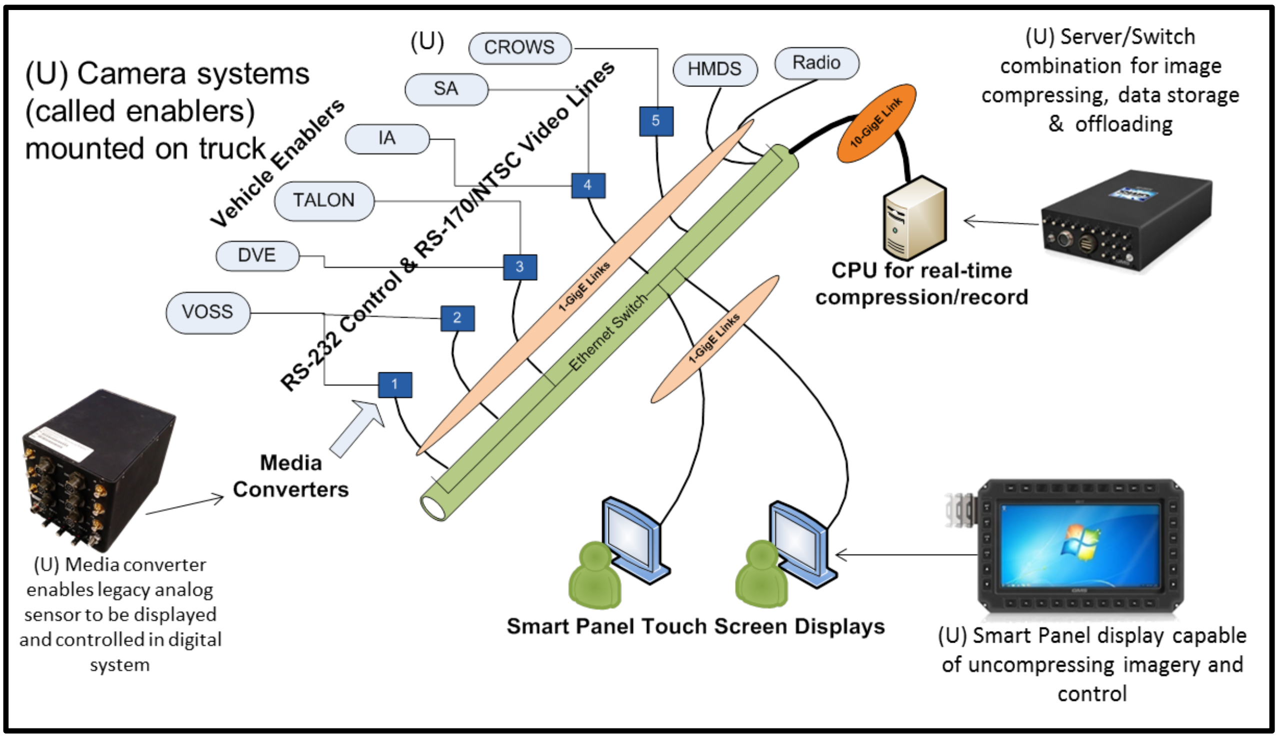


Figure 4: Architecture chosen for use in the MVD system.

Each of the MVD system components had a unique journey from prototype to production. The media convertor began as a GigE Vision (a standard for distributing video over Ethernet) lab device that met the project needs of converting analog video and control to Ethernet packets (Figure 5 (A)). This device accepted two analog RS-170 feeds and digitized and packetized them for distribution over Ethernet. It also had two RS-232 inputs for sensor control which also were accessible via Ethernet. This device had a simple transition path as there was already a company licensing the IP and using it to make a Mil-spec device (Figure 5 (B)). The baseline configuration of the MVD requires six analog feeds necessitating the need for three of these Mil-spec devices. This turned out to be prohibitively expensive. To keep costs low and SWAP down, NVESD worked with a second vendor to make a stripped down Mil-spec media convertor that had the bare minimum required feature set (only supporting a subset of the GigE Vision standard) and fit all of the hardware into a single box (Figure 5 (C)).

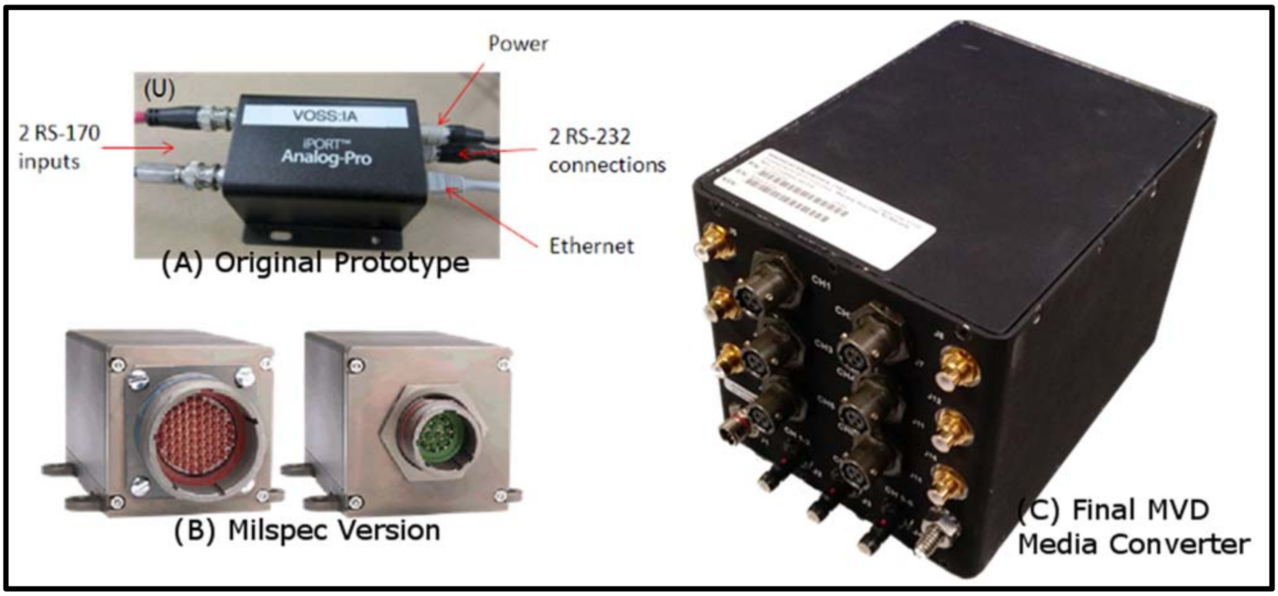
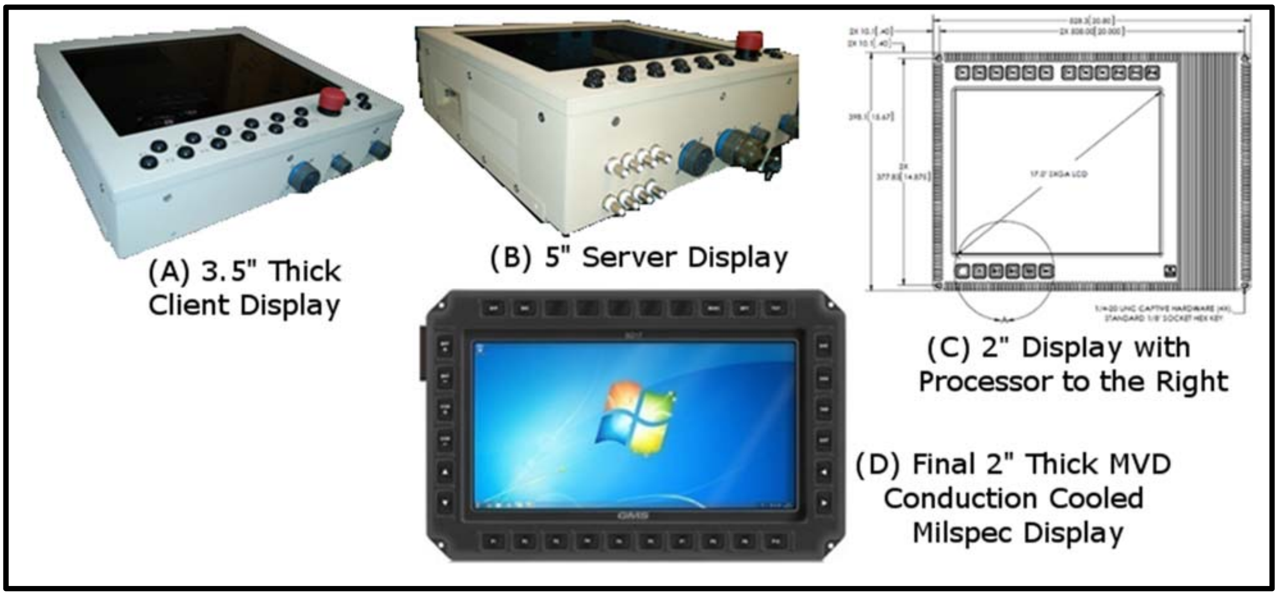


Figure 5: MVD media converter progression.

The smart displays followed a different path. There was not an obvious product that could fit the desired processing power (quad core i7 used for video decompression and future algorithm growth) into a sealed display thin and light enough to meet the requirements of the vehicle (minimized SWAP for quick egress). NVESD worked closely with multiple vendors to come up with various smart panel designs all the while continuing the search for an existing solution. The initial display thickness requirement was that the display had to be less than five inches thick. A vendor was found who designed and built prototype displays for the project that could demonstrate each of the different system architectures; this included a 3.5 inch thick client display (Figure 6 (A)) as well as a five inch thick server display with built-in frame grabbers and a switch (Figure 6 (B)). Although these displays worked well for early demonstrations, it was quickly determined that even 3.5 inches was much too thick. At this point the requirement changed to a two inch display. This vendor could not get the display thickness down to two inches thick with vents and fans and definitely could not provide a sealed conduction cooled Mil-spec solution at that thickness. NVESD worked with a second vendor to produce several designs that attempted to reduce thickness by increasing other dimensions. One design moved the processor from behind the LCD to the side of it, decreasing thickness but increasing width (Figure 6 (C)). A second design kept the processor behind the LCD but had a bump out in the center of the display for the processor while keeping the display two inches thick everywhere else, the idea being to hide the bump out in the final display mount. In the end, all of the designs succumbed to the same problem, that they could not cool the processor of the display in such a tight, air-sealed enclosure. At this point, a vendor was discovered with a new patent for cooling the display processor by putting it in a sealed chamber filled with a liquid silver compound (RuggedCool^{TM} Technology) [2]. The heat is then dissipated to the system enclosure and then into the monitor mount. This new technology is able to keep the processor cool enough to fit into the thin profile required of the MVD monitor (Figure 6 (D)).



(A) 3.5" Thick Client Display

(B) 5" Server Display

(C) 2" Display with Processor to the Right

(D) Final 2" Thick MVD Conduction Cooled Milspec Display

Figure 6: MVD Display Progression.

The evolution of the system server-switch followed yet another path. The network-centric architecture required a server with a large number of Ethernet connections for handling all of the media converters and smart displays. To this end NVESD worked with a vendor to combine a dual processor Xeon server with 24 port gigabit switch (Figure 7 (A)). The server and switch were connected via two 10 gigabit ports so that the server would have the bandwidth to obtain all of the raw uncompressed imagery. After completing the initial system demonstrations the search for Mil-spec server and switch solutions began. There are many ruggedized servers and switches packaged separately and initially NVESD investigated down this route (Figure 7 (B) and (C)). The main issues of this path were the increased size and cost of having two separate Mil-spec components. Software switches were investigated to remove the need of a separate switch but they proved unable to handle the high bandwidth, low latency traffic of the MVD as well as having a steep price tag. Finally, after researching hardware acquisitions on other government projects NVESD found that the ruggedized servers used by PM Warfighter Information Network-Tactical (WIN-T) almost perfectly met the needs of MVD. In addition, the vendor of the servers was open to the idea of embedding a switch inside of the server. The final MVD server is fully sealed and conduction cooled with an eight core Xeon processor and a 12 port gigabit switch (Figure 7 (D)). The server and switch are internally connected with a 10 gigabit port and there is a second 10 gigabit switch port routed externally so that two servers can be chained together if more processing is necessary.

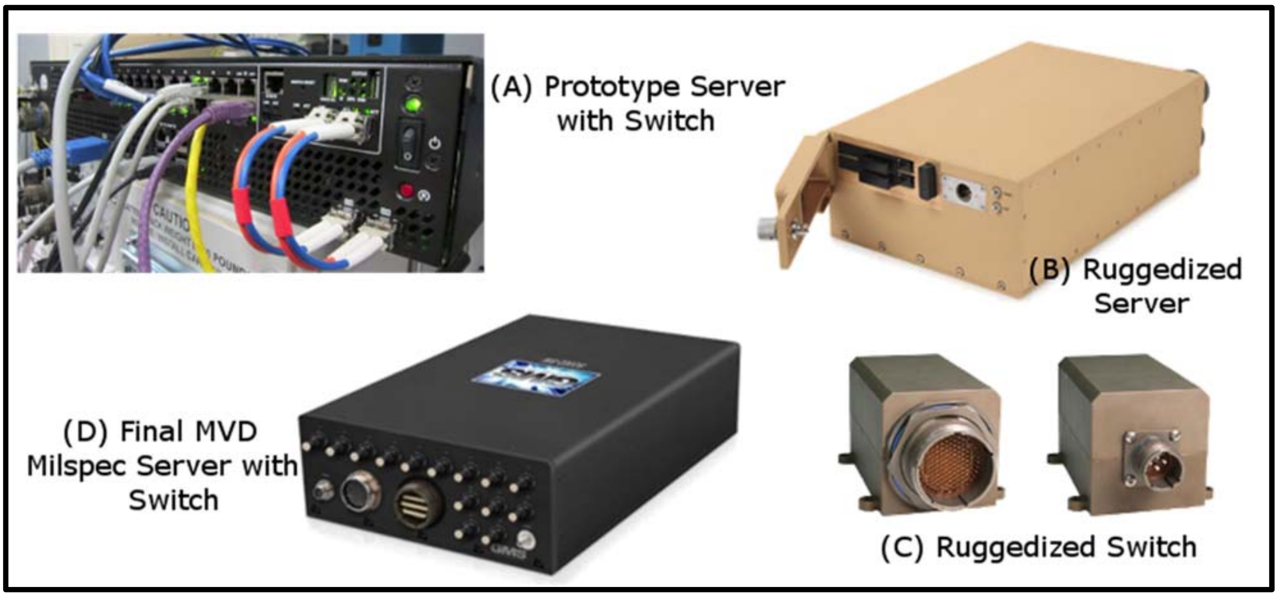


Figure 7: MVD Server/Switch Progression.

The MVD software itself is hardware independent such that it operated on all three architectures and hardware variations with just minor modifications to where certain software modules resided. MVD design is novel in that it uses a modular plugin based architecture enabling new sensor systems to be added without modifying or recompiling any of the pre-existing code. This is a tremendous cost saving as the explosive hazard threat is continuously evolving requiring new vehicle enablers. The MVD software is comprised of many thousands of lines of C/C++ code spread between core libraries, the graphical user interface frontend, and the server backend. This code was authored by Government personnel at NVESD quickly to meet the aggressive six month development schedule. The code has been through multiple rounds of static analysis to ensure reliability and best programming practices, and has undergone code coverage testing to ensure that every line operates as intended without any errors. In addition, there are three thousand lines of Java code for running a version of the system on Android devices. This mobile platform version of the code allows an operator to continue viewing and operating enablers while dismounted from the vehicle. The system uses industry standards for interfaces and data formats, including those from the Motion Imagery Standards Board (MISB) for imagery and metadata, and VICTORY for control. Along with image display, the MVD system can also act as a Digital Video Recorder (DVR) allowing for the capture and playback of video sequences as well as snapshots. The system currently allows for the full control of the Vehicle Optics Sensor System (VOSS), the interrogation arm camera, and the TALON Robot, as well as the display of nine separate camera feeds. The system has demonstrated robustness by being tested with 14 full motion video feeds simultaneously being captured and displayed in real-time. This is almost 3 times more enabler feeds than any single configuration of a typical MMPV platform. This was the key demonstration that provided the assurance PL-AMS needed to select the MVD system as the scalable display solution for its MMPV Type II Program of Record.

A key constraint that the MVD system must meet is that imagery must have less than a 100ms glass-to-glass latency. In ground based on-the-move scenarios studies have shown that a latency of more than 100ms between when an operator feels a bump to when he views it in imagery can lead to motion sickness. NVESD performed multiple latency tests to ensure that end-to-end system latency did not exceed this threshold and in fact found that measured system latencies were considerably lower. For the latency testing two photo detectors were connected to an oscilloscope. The first photo detector was connected to a camera pointing at a flashing light. This detector measures the time that the flash occurs. The image of the flash gets captured by the camera, then digitized by the media converter and sent to the server. The server compresses the video and multicasts it out to the client displays. Each display receives the compressed video, decompresses it, and displays it. A second photo detector held against the display measures the time at which the flash is displayed. The latency is measured as the time between the photo detector waveforms on the oscilloscope. Figure 8 depicts the test setup for the system latency testing.

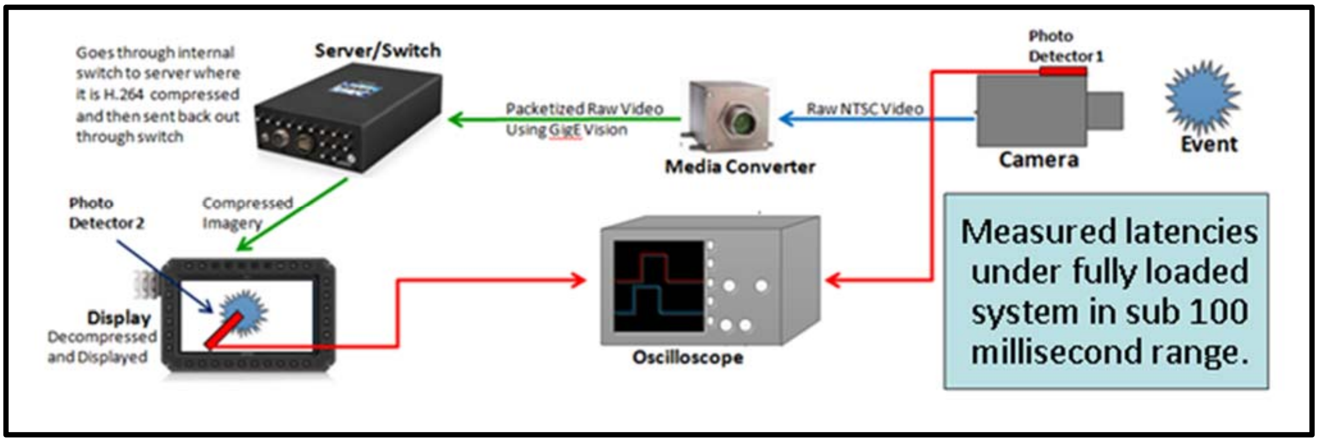


Figure 8: Latency test setup.

4. MVD SWAP Analysis

An important benefit of the MVD is that it puts a stop to the ever expanding SWAP burden that dedicated displays and controllers require. As new systems are added to the MMPV Type II there is no longer a need to add a new display, and as MVD begins to control more and more enablers there will be no need for dedicated controllers either.

The initial baseline version of the MVD does not actually lead to a SWAP reduction - in fact it increases SWAP - but it lays the groundwork for reducing SWAP as new systems are added. From Table 1 [3] [4] [5] [6], all SWAP categories show increases when the initial baseline MVD system is installed. MVD consists of a server, a media converter, and either two or three smart displays depending on the truck configuration, but this equipment set remains constant regardless of the number of additional enablers. The front display and one of the rear displays replace existing dedicated displays. The second rear display is a new display that did not previously exist in the truck (that station was either manned by a gunner who would be in the turret or the MTRS operator who uses a stand-alone laptop). Similarly, the server and media converter are new additions to the platform, although the media converter can be removed as the Army moves away from legacy analog sensors. The average power increase of 145% is due to the addition of CPU/GPU processing on the smart displays and server. Again, the upfront increase with the initial baseline MVD allows for future growth and capability without having to add additional resources.

Display and Control SWAP	Current MMPV Type II	With Baseline MVD	Difference	% Savings
Size (cubic in.)	2703.77	3415.06	-711.29	-26%
Weight (lb.)	49.05	108.25	-59.80	-122%
Average Power (Watts)	193.60	475.00	-281.40	-145%
Max. Power (Watts)	305.40	735.00	-429.60	-141%

Table 1: Display and Control SWAP savings on the MMPV Type II with initial MVD baseline installed.

The size and weight of the new components are largely offset by the thousands of pages of manuals that the MVD makes unnecessary. Currently, the MMPV Type II must carry the operator manuals for every enabler on the truck as well as the truck manual itself. The binders of materials that must be readily available do not currently have a dedicated home on the truck and sit in a box blocking the rear exit. MVD has the ability to digitally store and view its own manual along with all of the other necessary manuals. So with MVD these manuals can either be left behind or, if physical copies are still required, they can be stored in one of the containers on the outside of the vehicle.

As more enablers are added to the MMPV Type II, and MVD takes control of more of the current enablers, SWAP will begin to decrease. In the near term PL-AMS has asked NVESD to more closely tie a number of current enablers into MVD. MVD currently only views and controls the camera of the interrogation arm, but NVESD is working to have MVD fully control the interrogation arm itself which will remove a large and cumbersome dedicated arm controller that sits in the front of the vehicle. Similarly, the dedicated CROWS display and FBCB2 display are being analyzed for possible replacement with MVD. NVESD is also working to control the MTRS fully through MVD, which will remove the need for the MTRS laptop controller, or at the very least allow it to be stored away until the MTRS needs to be controlled while dismounted. In addition, there are many new requirements coming to MVD calling for remote visualization capabilities. These capabilities require that the MVD be able to view and possibly control enablers on other vehicles in and outside the platoon, such as Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs).

Another way to look at the system SWAP is to compare the capability MVD provides to the equivalent capability using dedicated displays, as shown in Table 2. With the baseline enabler set, MVD is viewing nine different video feeds simultaneously at three different crew stations. Even assuming that some of the dedicated displays allow the operator to switch between multiple feeds (the DVE display can switch between two feeds and the VOSS display can switch between three) each station would still need three VOSS displays to view all of the feeds, and that would only allow for viewing three feeds simultaneously. A station would need nine dedicated displays to see everything at the same time. In addition, each station would need to have a VOSS controller and the interrogation arm display, which has the camera controls built into it. Looking at it this way, even the baseline MVD configuration provides significant SWAP savings. For simplicity we calculated the matching dedicated display numbers by assuming each station would have to have a complete set of baseline enablers (this will become closer to reality as MVD is able to control the CROWS and MTRS). Table 2 shows SWAP savings across all categories on the MMPV Type II, with the largest SWAP gain in size, with a projected 58% savings.

Display and Control SWAP	MMPV Type II 9-Feed Dedicated Displays	MMPV Type II With MVD	Difference	% Savings
Size (cubic in.)	8111.31	3415.06	4696.25	58%
Weight (lb.)	147.15	108.25	38.90	26%
Average Power (Watts)	580.80	475.00	105.80	18%
Max. Power (Watts)	916.20	735.00	181.20	20%

Table 2: Display and Control SWAP savings taking MVD capabilities into account. The initial MVD baseline provides control and display to 3 separate crew workstations without the need for additional hardware.

5. MVD Efficiency Gains

When developing the requirements for the MMPV Type II the efficiency gains that could be obtained by having a single universal display at each crew station was a motivating factor behind the requirement for the MVD. As stated previously, to accommodate all of the varying enablers required to successfully detect and neutralize explosive hazards, route clearance vehicle crew stations have become overburdened with displays. Figure 9 shows an example of an actual crew station with three displays for viewing and controlling three different enablers. Trying to keep track of what is happening on multiple different displays each with a different user interface and control scheme over the course of an eight-hour mission is exhausting. MVD eliminates this difficulty by bringing all sensor feeds and controls into a single display. The display is customizable to allow the operator to view all feeds simultaneously, a single enabler of interest, or any subset of enablers; allowing the operator to focus in on only the information that is relevant at the moment.

Figure 9: Current crew station includes separate displays for each of the enablers in use, limiting room for future capability growth and creating integration challenges.

MVD also tries to make the user interface and control scheme for each enabler as similar as possible to limit the amount of confusion an operator experiences when switching between enablers. A perfect example of this is to compare the MVD user interfaces for the three cameras of the VOSS and the single Interrogation Arm camera versus their original dedicated proprietary controllers. The VOSS uses a large hand controller with a series of knobs and buttons for the various camera features and control of its gimbal. The majority of buttons are overloaded and do different things depending on which camera is currently selected or how long the button is held. Most common functions are listed next to the button that performs the function but a sizeable number of functions are only described in the VOSS operator’s manual. The Interrogation Arm takes a different approach and builds the joystick and buttons used for controls right into the dedicated display. Both proprietary controllers can be seen in Figure 10.

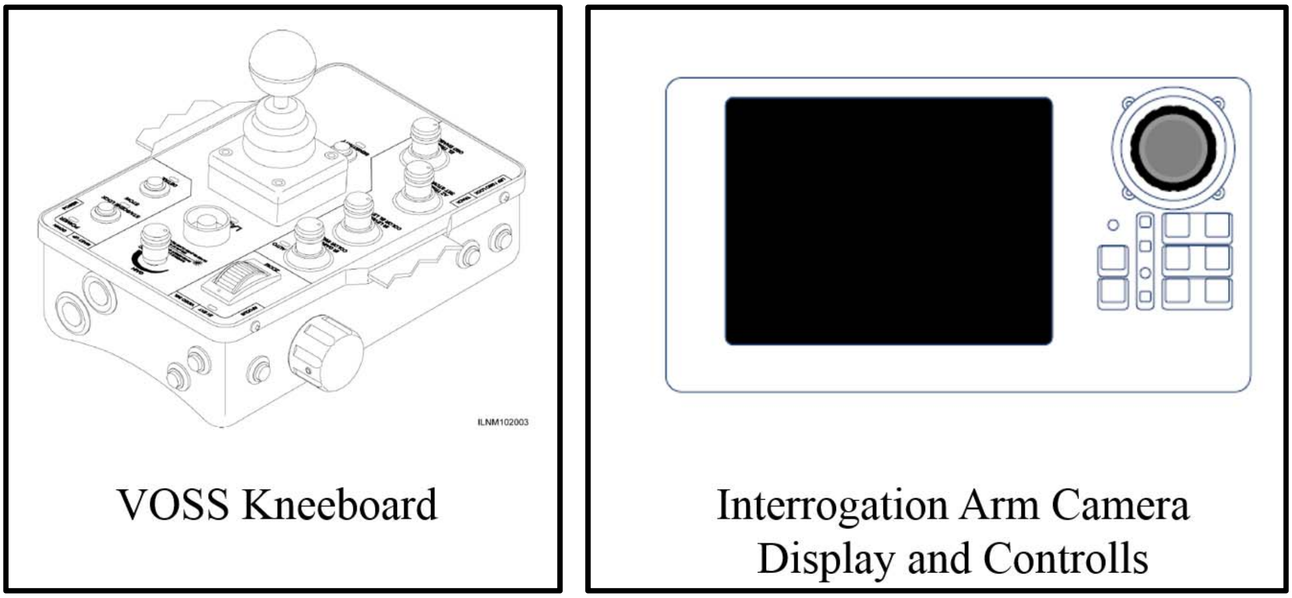


Figure 10: Proprietary Enabler Controllers.

The MVD does away with these proprietary controllers and allows the operator to control the enablers through a combination of a touchscreen and a game controller (Figure 11). The MVD game controller is a Logitech Gamepad F310 which is functionally equivalent to the Xbox and Playstation controllers Soldiers have grown up using. The controls are completely duplicated between the touch screen and game controller so an operator can use whichever interface is more comfortable and familiar to them. Since a large number of functions such as focus, zoom, and iris are used across all of the cameras these elements of the user interface are identical. Camera specific controls are grouped together in a dedicated location. Once an operator understands how the controls work for one enabler the controls for another enabler can be learned almost immediately.

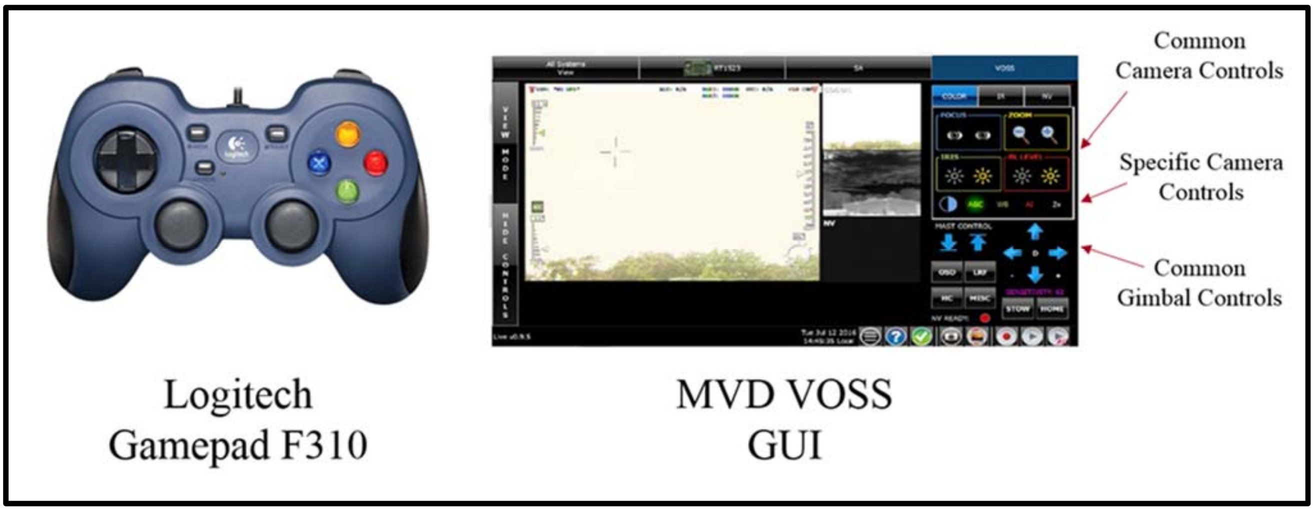


Figure 11: MVD VOSS User Interface.

To get a better feel for how MVD could improve actual route clearance related activities NVESD and PL-AMS worked with Soldiers who had just finished the operational testing of the MMPV Type II truck itself, so they had been trained to use all of the truck enablers for carrying out real world route clearance operations. After installing MVD on a pair of MMPV Type II's the Soldiers received approximately four hours of training on MVD and then were asked to complete both day and night scenarios identical to what they had done during operational testing. The feedback from the soldiers was very positive. They found MVD intuitive and easy to learn. One soldier said "I wish we had it all test" and another said "MVD would have made my life easier." The head OT trainer described MVD as fantastic and will change the way we fight. Along with this feedback came a wish list of additional features as well as a discussion on ways certain tasks are improved with MVD. The biggest take away from the discussions was that the person tasked with controlling a specific enabler may not have the tactical experience necessary to make decisions or may not be the one that requires the information coming out of the enabler. In these cases the enabler operator must verbally convey what he or she is seeing to another member of the crew. This can often be frustrating and confusing and increases the time the platoon spends in harms way interrogating a target or performing a complex maneuver. These problems are all solved with the MVD. Since there is a display in each crew station and each station is receiving all of the feeds and controls of the vehicle enablers the person who needs the enabler information has it. Once the future remote visualization requirements are implemented into MVD, this capability will only increase as decision makers will not only have the enabler feeds on their own trucks but will also be able to see feeds from other vehicles in the platoon.

6. MVD Situational Awareness Improvements

Another benefit of the MVD is that situational awareness for all MMPV crew members is greatly improved because the MVD can show all enabler feeds at all crew stations simultaneously. Without MVD if a crew member operates an enabler that has no value in the current situation (such as the MTRS while the truck is moving) then that crew member can only contribute to situational awareness by looking out the window. If, on the other hand, they have access to all of the vehicle enablers they can be yet another set of eyes looking for explosive hazards. This is particularly true if the truck is outfitted with sensors like VOSS that provide information that is not in the human visible spectrum and at high magnifications.

In addition to improving the situational awareness of the truck as a whole, MVD can also improve the situational awareness of an operator. Many of the best sensors used for roadway threat detection are high magnification sensors with a very narrow field of view. These sensors have a large number of pixels on target and provide the detail necessary to perform target confirmation at greatly enhanced stand-off ranges. The downside of these sensors is that since the field of view is so narrow the operator has limited knowledge of activities occurring in the immediate vicinity. On the flip side, wide field of view sensors can give an operator excellent situational awareness across a field of regard but they lack the resolution necessary to confirm threats. With MVD an operator can quickly switch between narrow field of view sensors and wide field of view sensors so that they can perform threat detection tasks while maintaining situational awareness.

With all sensors viewed and controlled through MVD there is even the ability to use one set of sensors to cue another set, similar to the capability designed into the MS-GUI (Figure 12) [7]. MVD contains a plugin that enables a wide field of view sensor to slew a high magnification narrow field of view gimbal mounted sensor while on the move. This allows operators to perform roadway and roadside threat detection at extended ranges while on the move. Testing using a wide field of view DVE and visible camera along with a narrow field of view VOSS has shown that this efficient slew-to-cue operation can increase detection standoff by 2 to 10 times that of eyes only.

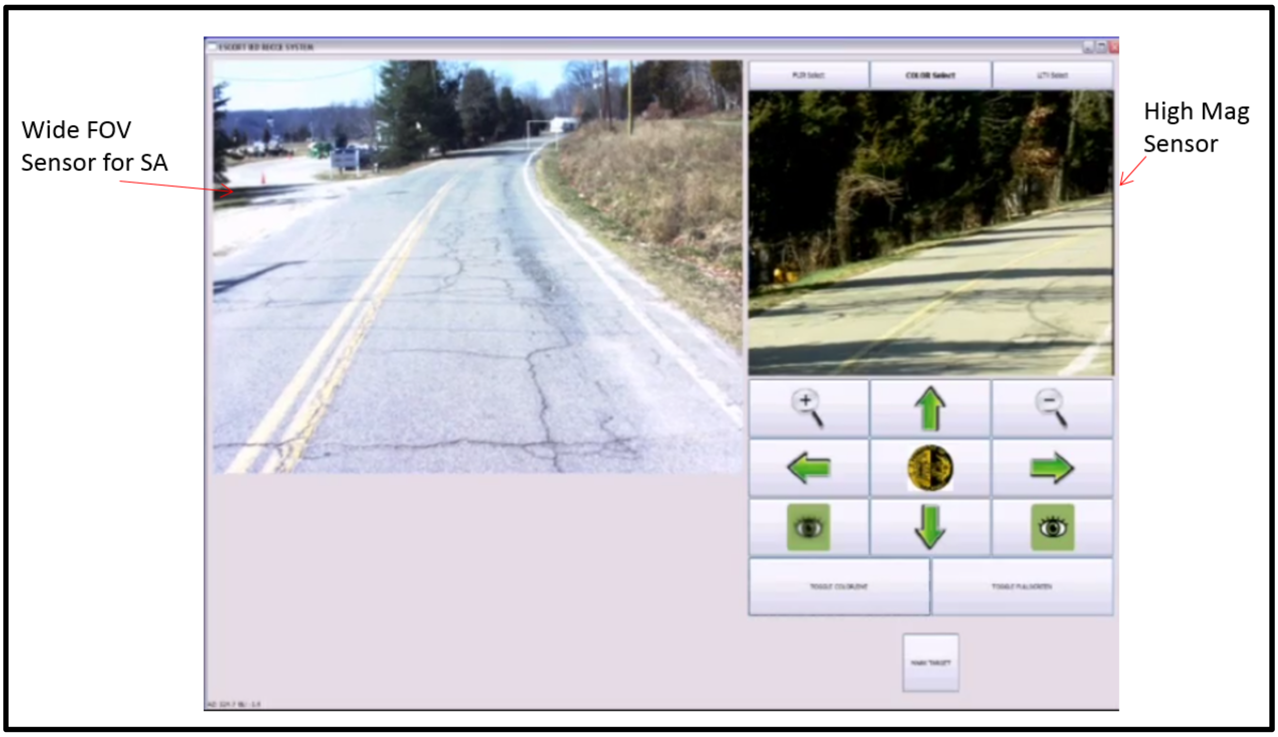


Figure 12: Slew-to-Cue Using MS-GUI.

7. MVD Threat Detection Algorithm Analysis

With all of the vehicle enablers networked together, MVD can also have an impact on algorithm performance. The MVD server has a ten core Intel Xeon processor and each display has a quad core Intel i7 processor, so there is more than enough processing power to run sophisticated detection and tracking algorithms within MVD. This means that MVD can be used algorithmically to aid operators in detecting threats. In addition, with all of the algorithms running on the same platform there is no reason that their outputs cannot be combined together to improve Probability of Detection (PD) above that of a single sensor and reduce False Alarm Rates (FAR).

To test out the idea of combining algorithm outputs to improve performance, NVESD used the roadway threat detection results of multiple sensors that were run across the same test lane. The sensors included a Ground Penetrating Radar (GPR), a metal detector, the VOSS (visible and MWIR), and the Multi-Sensor Suite (MSS) Gimbal (visible, MWIR, SWIR). It does not matter that the sensors are from different modalities since only the final detection outputs are being compared. Table 3 shows the performance of the individual algorithms. The GPR far outperforms the other sensors detecting nearly all of the targets (buried metallic inert explosive devices) with considerably fewer false alarms but even 14 false alarms per kilometer is too many when each alarm must be interrogated.

System	PD	FAR (/km)
VOSS	<<1	27
MSS	<<1	50
GPR	~1	14
Metal Detector	<<<1	18

Table 3: Overall Performance of Detection Algorithms.

Because the sensors in this test (as well as the enablers on an MMPV Type II) were not collocated with the same fields of view, orientations, and focal plane sizes (they were on different vehicles taken at different times), the algorithm results from each sensor must be transformed into a common system of reference so that they can be used together. Figure 13 shows an example of how complicated this can be. MVD can perform this task for both sensors on the platform as well as remote sensors. This will become important once remote visualization related capabilities are integrated into MVD.

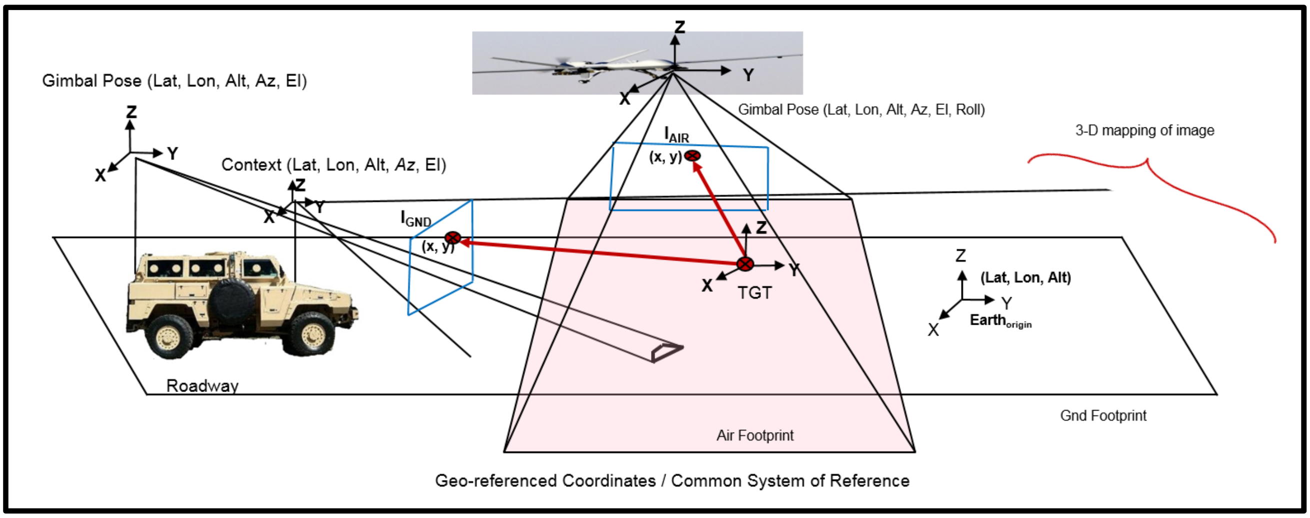


Figure 13: Geo-referencing Sensors into a Common System of Reference.

Sensor outputs are combined using a simple correlation function (Equation 1) that includes values determined from past performance and performance on a training lane. C_i is the confidence value of sensor i, that is how confident the algorithm is that this detection is a real target. N is the number of participating sensors. *TOD* is an individual sensor's time-of-day performance (PD/PFA). This is particularly important for IR sensors whose performance can vary drastically with insolation. Lastly, $P(Target|S_1 \ldots S_N)$ is the probability that a target exists given the declaration (threat or no threat) of each participating sensor. This last term is determined from the training data.

$$Correlated\ Confidence = f(C_i \ldots C_N,\ TOD,\ P(Target|S_1 \ldots S_N))$$

Equation 1: Correlation Function Based on Analysis of Sensor Performance on Training Lane.

Four different confidence functions were used ranging from a simple mean of each sensor's confidence to a rule-based function that included time of day and training performance values but would always declare a detection if the normalized GPR confidence was high. Figure 14 shows the output of the different methods compared to the output of the GPR alone. The rule-based confidence performs the best, consistently outperforming the GPR by about 5% over the key region below three false alarms per kilometer. The gains are small but this study was performed without any knowledge of what complementary information each sensor provides. These results are over a limited data set and are used primarily to illustrate the potential benefits of real-time sensor/information fusion that MVD is capable of. More sophisticated algorithms can be developed that better combine sensor information, such as the wire detection algorithm of the MSS gimbal system which uses an illuminated SWIR to detect wires while using a MWIR sensor to help reduce false alarms [8].

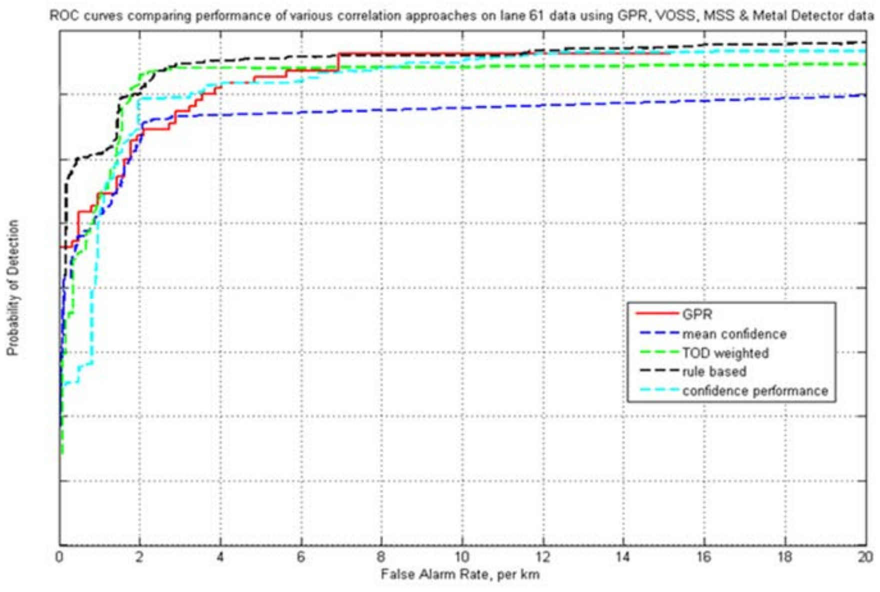


Figure 14: Correlation Algorithm Performance.

8. Conclusions

With the multiple improvements it represents in capability, as well as the built-in processing headroom it provides for future capability growth, MVD was PL-AMS' natural choice to be the display system in the MMPV Type II POR. It will improve communication within the MMPV Type II vehicle crew and decrease the time spent searching for suspected explosive hazards, allowing route clearance teams to become more efficient while keeping them safer when performing their mission.

This system has the potential to tap into many of the combat developers' future capability production document programs and tie them together while improving the way that route clearance will be done in the future. The stove-piped method of adding new capabilities and sensors is gone, replaced by the "tablet-like" capability of the MVD. The benefits of the MVD system don't stop there; MVD has the potential to affect all DOD ground vehicles with sensors by acting as a common operator's display, thereby achieving substantial SWAP reductions and saving money.

9. Work Cited

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