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General Overview of the Use of SUGV and Centralized Controllers Type I and II During Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance On The Move, Event 08 (C4ISR OTM E08)

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Aberdeen Proving Ground, MD 21005-5425

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14. ABSTRACT

This report summarizes the usability of two different types of controllers that were used during the Command, Control, Computers, Communications, Intelligence, Surveillance, and Reconnaissance On The Move, Event 08 (C4ISR OTM E08). Data collection was conducted by observation methods of the operator control unit (OCU) operators during the missions. The two controllers used in this experiment were designated as Type I and Type II. The Soldiers using the Centralized Controller Type I (CC-Type I) were the primary Small Unmanned Ground Vehicle PACKBOT operators. The Soldiers using the Centralized Controller Type II (CC-Type II) utilized the PACKBOT and various camera sensors to obtain eyes on the objective during each mission of the C4ISR OTM E08. Four Soldiers participated in the operation or observation of the PACKBOT and its associated centralized controller. MANPRINT, human factors, and Soldier survivability issues were identified during the experiment. Overall, both the PACKBOT operators with their CC-Type I controllers (Future Combat Systems [FCS] and spin out) and both the CC-Type II operators (FCS) used their respective technologies as designed.

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SUGV, centralized controller, usability, C4ISR

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1.   Introduction

This report summarizes the usability of two different types of controllers that were used during the Command, Control, Computers, Communications, Intelligence, Surveillance, and Reconnaissance On The Move, Event 08 (C4ISR OTM E08). This event was conducted at Fort Dix, NJ, during the summer of 2008 and sponsored by the Communications-Electronics Research, Development, and Engineering Center (CERDEC). Each controller was used to drive a robot, control the cameras on a robot, and control fixed cameras that were mounted on pan/tilt mechanisms. Two U.S. Army platoons participated in a series of scenarios designed to evaluate equipment and networks as candidates for Future Combat Systems (FCS) risk mitigation programs. Each of these platoons used one or both of the controllers and played the role of a spin out (SO) platoon or a FCS platoon.

The SO platoon was equipped and configured as though it were a current force or near term spin out platoon. As such, its capabilities both in terms of modern or futuristic equipment and communications capabilities were quite modest.

The FCS platoon was equipped and configured like a platoon that would deploy under the FCS concept. While much of the equipment that the FCS platoon used was surrogate equipment, the type of and capability of that equipment was similar to what will be present in a FCS platoon. The FCS platoon had more capability due to that fact that it had more equipment with enhanced capability. It also had better communications capability as it had a more substantial local communications network that included a better link to higher levels of command. The equipment used in this experiment was not part of the FCS program.

2.   Method

2.1   Procedure

Data collection was conducted by observation methods of the operator control unit (OCU) operators during the missions. Observations and comments were annotated. Additionally, a usability questionnaire (in the appendix) was administered to the operators to obtain information about the usefulness of the system. Interviews were conducted with each operator to clarify any issues they encountered during each mission. A sample size of two was not enough to conduct inferential statistical analysis. Therefore, the results are descriptive in nature.

The two controllers used in this experiment were designated as Type I and Type II. The Soldiers using the Centralized Controller Type I (CC-Type I) were the primary Small Unmanned Ground Vehicle (SUGV) PACKBOT operators. Communications between the PACKBOT, a Common

Controller, or a subsystem on a Program Manager (PM) C4ISR Highly Mobile Multi-Wheeled Vehicle (HMMWV) was done via ad-hoc networking implemented over Institute of Electrical and Electronic Engineers (IEEE) 802.11g. For this experiment, HMMWVs designated as PM-2, PM-7, PM-8, PM-14, and PM-17 had ad-hoc network nodes mounted on them. While a maximum effective range of ~400 m between ad-hoc nodes has been observed,[1] experience indicates that a better working number for mixed terrain is ~185 m. In addition to serving as normal network nodes, the ad-hoc nodes can also serve as repeater nodes. That is, the maximum effective distance between two end nodes can be increased by inserting a repeater node in between them.

The Soldiers using the Centralized Controller Type II (CC-Type II) utilized the PACKBOT and various camera sensors to obtain eyes on the objective during each mission of the C4ISR OTM E08. The FCS platoon was assigned one PACKBOT, one CC-Type I, and two CC-Type IIs. The Soldier with the CC-Type I was designated to be the primary PACKBOT operator. One of the CC-Type II operators was co-located with the PACKBOT operator while the second CC-Type II operator was always in a different location. The SO platoon was assigned one PACKBOT and one CC-Type I only. During missions, the PACKBOT operator would drive the PACKBOT and control its camera head while, in the FCS platoon only, the two CC-Type II operators viewed the streaming video on the centralized controller. Using the U.S. Army Research Laboratory (ARL) software package, Collect-Control, each operator was able to view video, chip images, annotate images, record video, and forward each piece of data to the ARL data stores. From those stores, MIL-STD-2525B[2] symbology and imagery was viewable on the ARL visualization tool Shared-Ink and was made available to the CERDEC application Component Information Management System (CIMS). CIMS was responsible for passing the information on to Force XXI Battle Command Brigade and Below (FBCB2) at all command levels in the C4ISR OTM network. The information was passed to FBCB2 in the form of position reports (symbology) and size, position, observation and time (SPOT) reports (imagery).

Vehicles PM-2, PM-7, PM-8, and PM-14 were assigned to the FCS platoon. PM-7 hosted the data stores for the FCS platoon and was the ad-hoc gateway, or entry point, into the PM C4ISR Soldier Radio Waveform (SRW) radio network for all ARL systems serviced by the IEEE 802.11g ad-hoc network. In order for a centralized controller to establish connectivity with the data stores on PM-7, the controller either needed to be within 185-m of PM-7 or be able to make a series of "hops" that were each less than the 185 m maximum hop distance. The type of terrain and the amount and type of foliage had a significant effect on connectivity.

The SO platoon only had a single vehicle with an ad-hoc node mounted on it. That vehicle (PM-17) served as the host for the data stores for that platoon and the ad-hoc gateway for that

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[1]O'Brien, B.; Baran, D.; Luu, B. *Ad Hoc Networking for Unmanned Ground Vehicles: Design and Evaluation at Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance On-The-Move*; ARL-TR-3991; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, 2006.

[2]MIL-STD-2525B. *Common Warfighting Symbology* **2005**.

platoon. As there was just the single vehicle, the SO platoon did not have the option to spread out its vehicles in order to achieve a greater distance between its centralized controller and its gateway into the SRW network.

2.2 Participants

Four Soldiers participated in the operation or observation of the PACKBOT and its associated centralized controller. One Soldier from each platoon physically controlled the movement of the PACKBOT platform and payload using the CC-Type I. The FCS Platoon had an additional two soldiers utilizing the CC-Type II, but was unable to control the platform or payload. They only had the capability to view the live feed and chip and annotate images.

2.3 Training

Training was provided to the operators of the PACKBOT and the Common Controllers. This training covered operation of the PACKBOT as well as the software that controlled the PACKBOT, its payload, and other sensors. Extensive training time was spent on the capabilities of the ARL software Collect-Control, SharedInk, and ARL digital video recorder (ARL-DVR). Training consisted of a presentation that reviewed driving the PACKBOT, capabilities of the various software, control of other sensors using Collect-Control, switch and button activation of the common controllers, as well as various tactics, techniques, and procedures (TTPs). A hands-on portion allowed the operators to become familiar with driving the PACKBOT. This familiarization continued until all operators were comfortable with driving the PACKBOT. Completion of an obstacle course and identification of possible improvised explosive devices (IEDs) within the obstacle course was used to determine the operator's proficiency as well as subject matter experts (technicians, expert operators, maintainers) approval.

2.4 Equipment

2.4.1 Centralized Controller Type I (CC-Type I)

The CC-Type I OCU (figure 1) was used to control robots and display map information. The OCU communicates with a robot via a wireless network operating using the IEEE 802.11g protocol. Joysticks mounted on the side of the unit are read by software running on the OCU and used to generate control commands that are sent to the robot over the 802.11g network. A spare wired ethernet port on the router can be used to provide either a wired or wireless connection to high levels of command. Wireless connection was used during this experimentation. The OCU is made up using the following commercial products: Itronix model IX325 tablet PC, LinkSys model WRTSL54GS wireless router, two BB-2590 batteries, joystick assembly, and shoulder strap. The tablet and router are powered by the BB-2590 batteries. The internal battery in the tablet was removed. The joysticks are attached to a mounting plate that doubles as a mounting plate for the tablet and the LinkSys router. The tablet is attached to the plate with screws and the router is attached to the plate with heavy-duty Velcro. The antenna for the wireless router is visible near the right side of the top of the tablet. The unit can be slung over the operator's

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Figure 1. The CC-Type I.

shoulder while in transport. The unit can be operated by grasping the joysticks and moving them with the thumb movements. The unit can also be supported by the strap and one hand while the other hand is used to operate the OCU's touch screen. The CC-Type I has an 8.4-in super video graphics array thin-film transistor (SVGA TFT) outdoor transmissive display with digitizer control panel touch screen and passive touch screen. The resolution is 800×600. The display has a contrast ratio of 350:1, a refresh rate of 40 Hz, and a maximum brightness of 300 nit. It was nearly useless in the bright sunlight. Each system had a few hard buttons. These buttons consisted largely of those required to power on and login to the system. They ranged in size from ~0.25 to 0.5 inches in diameter. Detailed hardware characteristics such as button size were not considerations in selecting the hardware for these systems. Rather, the hardware was selected because it was available and was assessed as being capable of hosting the software in the field for ~30 days. The buttons could not be operated by an operator wearing mission-oriented protective posture (MOPP) gear or heavy winter gloves. The Joysticks were used to send driving and sensor control command to the PACKBOT. The CC-Type I weighed less than 4 lb. The connection point for the auxiliary network connection is on the left hand edge of the router. The BB-2590 batteries that power the router are carried in cloth cases that can be worn on the Soldier's belt or attached to the Soldier's interceptor body armor (IBA). The connecting cable runs from one of the battery pouches to the left hand edge of the router. The CC-Type I was used in this experiment as the primary OCU for the PACKBOT and its sensor. Operators viewed streaming video that allowed them to navigate to and around the objective.

2.4.2 Centralized Controller Type II (CC-Type II)

The CC-Type II was a Fujitsu tablet PC with a daylight readable screen, an ARL ad-hoc network node, and an ordinary game controller that was used for controlling the cameras and robots. Figure 2 shows a photo of the complete assembly. For field use, the units run on a pair of

Figure 2. The CC-Type II.

BB-2590 military batteries. Power to the tablet is provided by a commercially available AC-DC power adapter that has been designed specifically for the BB-2590 battery. The power adapter is a Lind Electronics model MBC1540-1928 battery caddy that has been specifically designed to hold a BB-2590 battery. This unit was used with a custom cable manufactured by Lind Electronics that allowed the caddy to be operated on a pair of BB-2590 batteries rather than a single battery. This feature allowed batteries to be changed without shutting the centralized controller down. The batteries were carried in a pair of pouches. When the battery pouches are belt mounted, one pouch rides on each hip. A battery interconnecting cable rides along the belt on the operator's rear. The battery pouches may also be mounted on a Soldier's IBA. In this configuration, the pouches may be mounted on the IBA in whatever location is most convenient. For laboratory use, the units run on AC power adapters that are supplied with the unit. The CC-Type II is a 10.4-in indoor/outdoor viewable (reflective front light) TFT display with resolution of 1024×768. The manufacturer claims that the screen has been optimized for outdoor use. This controller was more useful in the bright sunlight than the CC-Type I.

The buttons could be operated by depressing them with the pen provided as part of the touch screen system. The pen could be held by someone wearing light winter gloves. The controller software used one drop down menu. The drop-down menu was to select the sensor feed that the operator wanted to view or control. Drop-down menus are extremely difficult to operate with a touch-screen/pen system unless the screen is extremely well calibrated. Other screen-based controls were radio buttons, check boxes, and push buttons. The push buttons were ~0.25 × 0.25 in. These buttons were reasonably easy to use even if screen calibration quality was marginal. The CC-Type II weighed 4.18 lb.

The tablet/network node consists of a Fujitsu ST5011D tablet and a LinkSys WRTSL54GS 802.11g wireless router that has been re-flashed with ARL ad-hoc network software. The tablet was carried in a tight fitting cloth pouch that provided a level of protection for the tablet and served as an attachment point for a shoulder strap that may be used to carry the unit when it is not in use. The ad-hoc network node is attached to the underside of the tablet. The router was a wireless router that operates in the 802.11g (2.4 GHz) frequency range. As the hardware was unmodified, the unit met FCC requirements for home use on desks and various other "office like" environments in the close proximity to humans. The single power cable that runs from one of the battery pouches to the tablet/network node assembly may be easily disconnected from the tablet/network node assembly. Since the tablet carries its own battery, this allows the user to disconnect the user from the battery pack without shutting the tablet down. Disconnecting the power cable will shut off the ad-hoc node and temporarily disable network communications. By keeping the tablet operating when it is disconnected from the BB-2590 batteries, the time required to resume operations is significantly reduced. The power cable may be routed from either the right hand battery pouch or the left hand battery pouch depending on the user's preference. The CC-Type II was used in this experiment as only a remote video terminal and provided the same streaming video from the PACKBOT's sensor. The CC-Type I is capable to controlling the PACKBOT, but was not utilized during this experiment.

2.4.3 Centralized Controller Type II (CC-Type II) Game Controller

The game controller was a standard commercial-off-the-shelf (COTS) Saitek model PP17 universal serial bus (USB) game controller (figure 3). The USB cable plugged into a connector on the upper right hand edge of the tablet. This controller allowed the operator to drive robots and to control cameras mounted in the area of operations (AO).

Figure 3. Saitek model PP17 USB game controller.

2.4.4 Collect-Control

Collect-Control is the ARL software package (figure 4) used to view video from video sources, control pan/tilt cameras, and control robots and the assets mounted on those robots. This application runs on platforms of varying size and scale. The same application that runs on a small system such as a controller also runs on a larger system such as a HMMWV. The primary uses may be different. In a small-scale installation, the primary use may be that of robot and camera control. In the case of a large scale installation, the primary use may be that of viewing and/or annotating primary source imagery from remote sensors. Operators used Collect-Control as the software that provided the streaming video and allowed the operator to navigate the platform and its sensor.

Figure 4. Collect-Control user interface.

2.4.5 Shared-Ink

Shared-Ink is the ARL mapping software package (figure 5). Shared-Ink is a Commercial Joint Mapping Toolkit (C/JMTK)-based visualization application that displays MIL-STD-2525B symbology on a standard map background. It also allows users to draw on the map and share those sketches with each other.

Figure 5. Shared-Ink user interface.

2.4.6 ARL-DVR

ARL-DVR is the ARL digital video recording software package (figure 6). ARL-DVR is a recording application that automatically and continuously records the video from all available sensors on the battlefield. This video is time stamped and can be reviewed at any time.

Figure 6. ARL-DVR user interface.

2.4.7 iRobot PACKBOT Explorer

The PACKBOT Explorer, a variant of the PACKBOT that has been fielded since 2003, was used as the SUGV platform during C4ISR E08 (figure 7).

Figure 7. The iRobot PACKBOT Explorer.

2.4.7.1 Platform. The ARL PACKBOT consisted of an iRobot PACKBOT Explorer with an ARL-designed payload carried in the payload bay of the robot chassis. The payload carries a LinkSys model WRTSL54GS wireless router that is used as a network node for communicating with the robot's OCU. The router is a standard router that was modifie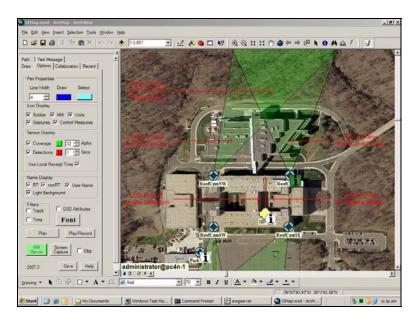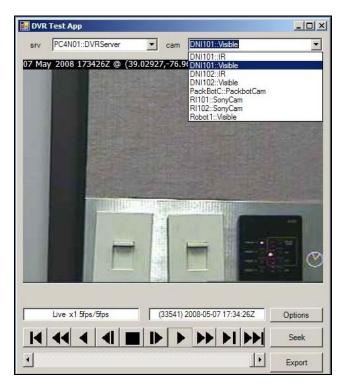d to use an external antenna. The robot was a standard, unmodified PACKBOT Explorer. The PACKBOT was 7 in high, 16 in wide, and 27 in long, track driven, and teleoperated. When the flippers were deployed to overcome obstacles, or right an overturned system, the total width is 20 in and length increases to 34.6 in. It weighed 40 lb, and fits into a modular lightweight load-carrying equipment (MOLLE) pack. NiCad battery packs provided power. The PACKBOT has a payload capacity of 35 lb. The PACKBOT Explorer used standard iRobot rechargeable batteries which are currently used in theater and carries a global positioning system (GPS), compass, and temperature sensors used to report robot position, attitude, and operating temperature. The PACKBOT supports wireless network communications in the IEEE 802.11b frequency band. This capability has been disabled and replaced with IEEE 802.11g communication via the ARL payload. The ARL 802.11g payload provides extended range and additional bandwidth compared to the stock radio and also provides mobile ad-hoc networking capability.

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2.4.7.2 Payload. The ARL ad-hoc network node payload consists of a commercially available LinkSys model WRTSL54GS wireless router that has been loaded with network software and a 24-to-12 Voltage Direct Connect (Vdc) converter. The payload chassis is manufactured out of non-conductive plastic and is firmly mounted to the PACKBOT chassis with screws. The wireless router transmits and receives in the standard commercial IEEE 802.11g frequency band. The PACKBOT also carries an electronics payload mounted on an extendable arm. This payload includes cameras used for both driving and intelligence gathering. The arm will raise the payload ~18 in off the top of the robot and will rotate to any angle and attitude. There is a pointer laser as part of the system but it was disabled during the exercise.

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3. Results

3.1   Manpower and Personnel Integration (MANPRINT) Issues

MANPRINT, human factors, and Soldier survivability issues were identified during the experiment. When operating the SUGV PACKBOT, the operator was so focused on driving the platform that he was unable to provide his own security and an additional Soldier was tasked with providing security for the PACKBOT operator. Several human factors issues were identified to include weight, packability, awkwardness regarding simultaneously physically holding and operating the platform, readability of both CC-Type I and II screens, and situational awareness of the platform. Operators had a difficult time determining where the platform was in relationship to themselves. A Soldier survivability issue was identified during night operations. At night, the illumination of the centralized controller screen was too bright increasing the probability that the Soldiers position would be compromised.

3.2   Observations for the CC-Type I

Overall, both the PACKBOT operators (FCS and SO) found the CC-Type I easy to use and used the unit as designed. Operators were able to easily drive the PACKBOT using the joysticks, control the PACKBOT camera using the joysticks, zoom in and out with the camera, chip and annotate images, record video, and find and understand information on the OCU. The major benefit of this system is the ability to view an area without compromising their position, especially when utilizing the zoom in/out function on the high-resolution camera.

The major issue was with connectivity and occurred in the FCS platoon with PM-7, which was a gateway for other technologies as well. PM-7 Commander's (CDR's) vehicle needed to be in an open area for connectivity to unmanned aerial systems (UAS) (Buster and Micro Aerial Vehicle [MAV]), but also needed to stay within range for PACKBOT connectivity. It seemed as though the UAS's took priority and as a result, the SUGV failed to have consistent connectivity.

Recommend for C4ISR OTM E09 that the UAS and SUGV technologies have separate vehicles for their gateways.

One of the biggest shortcomings of any tele-operated robotic system is that it takes the operator out of the fight. This system is no exception. In fact, the biggest complaint of the operators was that they were unable to carry their weapon, except for in the slung position while on the move and were not able to provide their own security while operating the PACKBOT. As a result they often complained about losing complete situational awareness of their immediate area because they were so immersed in controlling the PACKBOT (workload data was not collected).

Soldier comment:

- "I need another man to carry my weapon and provide security for me."

Individual operator issues were readability, awkwardness in holding the controller while controlling the platform and chip images (all at the same time), and situational awareness.

During missions, the biggest complaint was readability of the screen. The glare from the sun made it nearly impossible to see the CC-Type I screen almost to the point that they were unable to continue driving the PACKBOT or view the streaming video until they found some shade.

Soldier comments:

- "The screen is nearly impossible to see in the sunlight."

- "I'm not exactly sure where I am with this thing. The glare is too bad."

- "Glare is still bad. If I didn't have these sunglasses on, I wouldn't be able to see anything."

Additionally, night operations presented a Soldier survivability issue as stated previously in this report. The operators dimmed the screen brightness as much as they could, but through night vision goggles, the illumination easily gave away their position. In addition, the screen was too bright to view under night optical devices (NODs)

Soldier comment:

- "The screen whited out my NODs."

Operators experienced problems while attempting to use the stylus. They had a difficult time pinpointing a button selection with the stylus. These issues may be easily resolved by ensuring the touch screen is calibrated more frequently.

The operators often had issues with physically handling the OCU. It was very difficult to attempt to operate the joysticks, chip images, and hold the controller simultaneously.

Soldier comment:

- "Controlling the PACKBOT while on the move and carrying your weapon is like juggling."

The CC-Type I was designed to be carried during operational use with a strap that goes around the neck. This was very uncomfortable and caused neck strain. A field modification was made using D-rings to attach the strap to the front of the Soldier's IBA. This alleviated the neck strain. However, there was no method to secure the bottom of the unit to the Soldier. The only solution was to have the unit sit on top of the Soldier's IBA pouches to keep the unit in a horizontal position. This caused instability of the OCU as they negotiated the battlefield. The unit would often fall from the make-shift shelf into a vertical position. One of the OCU's would power down as a result. An unsuccessful attempt was made to fix what was thought to be a loose wire, but the problem still persisted. As a result, another field modification was made using zip ties and D-rings to secure the bottom of the OCU to the IBA. This fixed the instability problem.

Soldier comment:

- "The strap around the neck hurts. It's very strenuous. A better solution would be for it to hook onto the IBA."

Maintaining situational awareness of the location of the PACKBOT platform was a key issue for the operators. There were several instances where the operator didn't know where the PACKBOT was in relation to where he was.

3.3   Observations for the CC-Type II

Overall, both CC-Type II operators found the technology easy to use and used the unit as designed. Operators were able to view the streaming video from the PACKBOT as well as easily switch between stationary cameras located in and around the objective. They were easily able to chip and annotate images as well as record video.

Connectivity was a problem with the CC-Type II. The units needed to remain within 185 m of the ad-hoc node to receive video from the PACKBOT camera and the gateway needed to be within range for any chipped images or video to get into the network. As previously mentioned, the major issue with connectivity occurred in the FCS platoon with PM 7, which was a gateway for other technologies as well. PM7 (CDR's vehicle) needed to be in an open area for connectivity to UAS (Buster and MAV), but also needed to stay within range for PACKBOT connectivity. It seemed as though the UAS's took priority and as a result, the SUGV failed to have consistent connectivity. Recommend for C4ISR OTM E09 that the UAS and SUGV technologies have separate vehicles for their gateways.

Although the operator of the CC-Type II was not permitted to physically control the PACKBOT, he was still fully engaged while viewing the incoming video and chipping and annotating images. As a result, these operators were also taken out of the fight. The operators could carry their weapon while on the move, but neglected the incoming video because the CC-Type II was slung in a vertical position while on the move. Similar issues for these operators were present with respect to personal security. The operators not only were unable to provide their own security while operating the unit, but lost complete situational awareness of their immediate area because they were so immersed in viewing the various video feeds of the battlefield.

Individual operator issues for the CC-Type II were similar to those of the CC-Type I. Readability was an issue because the sun caused glare issues. Soldier survivability could be an issue because the screen was too bright during night ops. Physical handling of the OCU during operation was cumbersome. Maintaining situational awareness of the PACKBOT's location relative to the operator proved challenging. Ruggedness of the hardware needs to be improved in future versions.

During missions, the biggest complaint was readability of the screen. The glare from the sun made in nearly impossible to see the CC-Type II screen almost to the point that they were unable to view the streaming video until they found some shade. Additionally, night operations presented a Soldier survivability issue. The operators dimmed the screen brightness as much as they could, but, through night-vision goggles, the illumination easily gave away their position. There were also issues while attempting to use the stylus. Soldiers had a difficult time pinpointing a button selection with the stylus. These issues may be easily resolved by ensuring the touch screen is calibrated at least weekly.

The operators often had problems physically handling the unit. It was very cumbersome to attempt to view the streaming video, chip images, and essentially hold the unit horizontally simultaneously. The CC-Type II was designed to be carried during operational use with a strap that goes around the neck. This was extremely uncomfortable and caused neck strain. There was no method to secure the bottom of the unit to the Soldier. The only solution was to have the unit sit on top of the Soldier's existing pouches on the IBA or the operator would hold the OCU horizontally while operating it. This caused instability of the OCU as they negotiated the battlefield. The unit would often fall from the make-shift shelf.

Maintaining situational awareness of the PACKBOT platform was a key issue for the operators. There were several instances where the operator didn't know where the PACKBOT was in relation to where he was. Although the CC-Type II operator didn't control the PACKBOT, knowing the location of the PACKBOT in relation to where this operator was would have been helpful in improving overall situational awareness. In addition, there were often times where the CC-Type II operator was co-located with the CC-Type I operator. During these times, the CC-Type II operator would assist the CC-Type I operator with navigation tasks, acting as a

"co-pilot." When the operators lost situational awareness of the PACKBOT in relation to where they were, this teaming effort suffered.

Although it should be noted that the CC-Type II was not a fielding piece of hardware, future versions must be ruggedized. For example, there were several instances when wires were pulled out of the unit by branches as the Soldier negotiated through the woods.

3.4   Observations for the Collect-Control Interface

Operators found the Collect-Control interface easy to understand and use. They found it easy to boot up, select video source, view video, chip and annotate images, record video, and switch between cameras. The most effective feature was the ability to draw on a chipped image and send it into the network. This gave the operators the ability to pinpoint, by way of annotation, a target on a chipped image and even relay details regarding that target directly on the chipped image.

Major issues with Collect-Control centered on the video, specifically resolution and frame rate. Resolution is only as good as the cameras on the platform. The driving (low-resolution) camera on the PACKBOT did not give the Soldier the clarity they needed to effectively identify possible targets. The high-resolution camera provided the operators better clarity as they zoomed in and out and provided a more effective means of target identification. The desire to use both cameras, each for a different function, caused a conflict as the PACKBOT/Common Controller system only supports the use of one camera. This limitation is driven by available communications bandwidth. Even the choice of using the high-resolution camera as opposed to the low-resolution camera can adversely affect the performance of the communications link between the PACKBOT and its controller. The frame rate would often drop so low that it was impossible for the operator to continue driving the PACKBOT because the response time through the video rendered the PACKBOT virtually inoperable. While many of the cameras used in the E08 would support resolutions greater than 640×480, resolutions of 320×240 were used most of the time. More-over, frame rates were usually held to 7 frames per second (FPS) (or less). Experience has shown that resolutions higher than 320×240 or frame rates higher than 7 FPS has a negative impact of available network bandwidth of such magnitude as to render a system useless.

Soldier comment:

- "Hard to see where you are going when you only get 1 frame per second."

For operators to effectively negotiate the PACKBOT on the battlefield, they would have to wait for the frame rate to increase. The low frame rates were most likely due to the operators pushing the limits of the PACKBOT's range from the ad-hoc node. When the PACKBOT operator and his CC-Type I were within acceptable range of the ad-hoc node and the PACKBOT platform, frame-rate issues were virtually non-existent.

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3.5 Observations for Shared-Ink

Operators found the Shared-Ink interface easy to understand and use. They found it easy to boot up, find assets on the map, view images chipped from various sensors, and re-annotate chipped images. The CC-Type II operators were the primary users of this software. The CC-Type I operators were the PACKBOT drivers. Their workload was such that they did not have time to utilize this software. The majority of their workload was centered on driving the PACKBOT using the Collect-Control software. This software allowed the CC-Type II operators the ability to view the images that were chipped by the PACKBOT operator during a mission through a thumbnail view where all chipped images and videos were stored. Operators were notified that an image or video was available for viewing by the appearance of a yellow icon containing the letter "i" on the map. This icon was rendered at the image's source location. The operator would click on the icon and the thumbnail viewer would open, displaying all images or video taken from any available sensor. For example, they were able to see any images that had been chipped from various sensors on the battlefield such as the Sony ball camera or an unmanned ground sensor (UGS). These operators were also able to re-annotate any image by clicking on the thumbnail of the image, writing or drawing on the image and sending it back into the network as an analyst. Any image or video sent to Shared-Ink would also propagate to FBCB2, giving Platoon Sergeants (PSGs), Platoon Leaders (PLs) and CDRs eyes-on situational awareness of the enemy and enemy activities. It is important to note that images were always "tagged" by the last person or system to annotate them. This feature gives any consumer of an image the ability to discern whether an image is from a primary source or from a secondary source.

During this experiment, the operators did not place military symbology on the map. They were only given the ability to view the map of the area of operations (AO) and view the images and video taken from the available sensors. In addition, because the images and videos populated through FBCB2, the Soldiers in vehicles (i.e., PSGs, PLs, and the CDR) rarely utilized Shared-Ink in their vehicles even though it was available to them for viewing.

3.6 Observations for ARL-DVR

The ARL-DVR application's ability to continuously record all video from any available source for later review was very beneficial, especially as an after-action review (AAR) tool. Unfortunately, the ARL-DVR was rarely used during the exercise. It was nearly impossible for the operators to utilize this software during a mission. The CC-Type I operator was too busy driving the PACKBOT, chipping and annotating images, and recording mini-videos with Collect-Control to switch to the ARL-DVR and review recorded video. Similarly, the CC-Type II operator was equally as busy viewing the live streaming video, helping navigate, chipping and annotating images, and recording mini-videos with Collect-Control. There were however, a few instances when the PACKBOT was having connectivity issues rendering it inoperable, that the CC-Type II operator was free to switch to the ARL-DVR and review recorded video.

Soldier comment:

- "The ARL-DVR would definitely make a great AAR video so that the CDR can see what we did right and what we did wrong."

There were several instances when the CC-Type II operator needed to close the ARL-DVR in order for the Collect-Control to acquire a sensor. In one instance the ARL-DVR crashed the Collect-Control software. Operators tended to immediately close the ARL-DVR to avoid those problems.

3.7 Observations for the PACKBOT

Connectivity was a consistent issue with the operation of the PACKBOT. As previously mentioned, in the FCS platoon, an ad-hoc node located in vehicles, PM 2, 8, or 14 needed to be close enough (no more than 185 m) to ensure that the PACKBOT operator's CC-Type I had connectivity with the PACKBOT robot. In addition, the gateway located in PM 7 needed to be no more than 185 m from the CC-Type I to ensure images and video could be populated in FBCB2. In the SO platoon, PM 17 was an ad-hoc node and the gateway. Therefore, PM17 needed to stay within range (no more than 185 m) of the PACKBOT operator's CC-Type I to ensure connectivity with the PACKBOT robot as well as ensuring images and video could be sent through the net.

Soldier comment:

- "In a real combat situation, I would never have them this close."

PACKBOT operators generally carried the PACKBOT in a backpack from the vehicle rally point (VRP) to their respective observation point (OP) while carrying their normal combat load and their weapon. Attempts were made initially, to drive the PACKBOT to the OP, but it slowed the squad down so they decided the best course of action (COA) was to carry it to the OP. This added no <40 additional pounds to the Soldier. It was very cumbersome to carry the PACKBOT either by the handle or in the backpack. Packing it into the backpack proved to be a challenge as well.

One of the major complaints of the PACKBOT platform was how noisy it was. It gave away the Soldier's position as well as alerting the enemy of the PACKBOT's presence. In fact, the PACKBOT in the FCS platoon had a squeaky head and even though it was stationary in a close position near the enemy, any movement of the head alerted the enemy of the PACKBOT's position. In one instance, however, the operator used the cover of the noise from the MAV to move in closer to the enemy, find a good hiding position and capture detailed images and video of their activities. The noise level of the MAV should be well documented in MAV test reports and is beyond the scope of this document. What is suggested is that the robot's operating environment might be used to make up for a deficiency in the robot. Often times, noise on the battlefield such as other unmanned systems or even helicopters can mask the noise that PACKBOT platform emits. That deficiency is also beyond the scope of this report as it is a

centralized controller report and not a PACKBOT report. Camera resolution on the driving camera was less than adequate for target identification.

Soldier comments:

- "Not enough depth of the camera to see where you are."

- "Needs brighter contrast. Impossible to see where I am going."

Operators tended to use the high resolution camera even for driving tasks. The high resolution camera provided better details and gave the operator the ability to zoom in and out. During one mission, the PACKBOT operator parked the PACKBOT behind a container roughly 50 m from the enemy and used the high-resolution camera to zoom in and capture extremely detailed images and video of the enemy activity. During night operations the operators used the near infra-red capability to drive the PACKBOT and view the incoming video. The operators encountered a viewing distance of three to five feet visibility, essentially, rendering it ineffective. As a result, the operator, if they could find them, would need to be 3–5 ft away from the enemy to chip any images, which would compromise the PACKBOT.

Soldier comment:

- "It literally is like driving it in the dark."

4. Conclusions/Recommendations

Overall, both the PACKBOT operators with their CC-Type I controllers (FCS and SO) and both the CC-Type II operators (FCS) used their respective technologies as designed. In several missions, the SUGV (PACKBOT) was able to give the platoon eyes on the objective but still remain hidden. During full connectivity, annotated images and video of the opposing force (OPFOR) populated throughout the platoon providing increased situational awareness. The following suggestions for improvement came from observations from both the experimenters and the Soldiers.

4.1 Suggestions for Improvement for the CC-Type I

- Design the OCU in such a way that it can fold up against the chest of the operator while he is on the move and fold back down when he is ready to operate the PACKBOT.

- A troubleshooting function needs to be added so that an operator can troubleshoot an issue without closing the operational program. When something malfunctions, the operator needs to be able to fix it on the fly without immobilizing the robot for five minutes or more.

- Incorporate a dim button directly on the OCU for night operations.

- A suggestion was made to incorporate a thermal camera to better identify the enemy through heat signatures since identification of the enemy with the current camera is nearly impossible.

- Recommend for C4ISR OTM E09 that the UAS and SUGV technologies have separate vehicles for their gateways.

- Incorporate Military Grid Reference System (MGRS) for all sensors on the battlefield and display them on the Centralized Controller for immediate reference to allow Soldiers to better identify the location of a target based on the MGRS grid of a specific camera capturing images of that target.

4.2 Suggestions for Improvement for the CC-Type II

- Design the CC-Type II in such a way that it can fold up against the chest of the operator while he is on the move and fold back down when he is ready to view streaming video.

- Make future versions more ruggedized by eliminating exposed wires.

- Recommend for C4ISR OTM E09 that the UAS and SUGV technologies have separate vehicles for their gateways.

4.3 Suggestions for Improvement for the Collect-Control interface

- One suggestion was for a head centering button on the Collect-Control interface that would automatically center the head of the PACKBOT at 0°. Additional options of 90°, 180°, and 270° might also be helpful.

- The methodology for annotating images should be expanded. While smaller systems usually only have "mouse like" input devices attached to them, larger systems typically include keyboards. For example, the CC-Type I includes a pen as an input device. The HMMWV based systems used by PM C4ISR OTM include keyboards that are used as input devices. In cases where a keyboard is available, Collect-Control should support image annotation via typed text entry. Whether that text should be embedded in the image or included as a separate metadata file attached to the image is an open debate. An argument exists to keep the metadata separate in a separate file as it opens up the possibility of performing a number of search and/or fusion operations without having to be encumbered with the large amount of data associated with the imagery. The opposing argument to this supports the idea of embedding the metadata in the image as it allows the transmission of imagery, annotation, and date/time information to a legacy system that is only capable of displaying images on a screen. Additional research and testing needs to be conducted to improve the capability to annotate images.

4.4 Suggestions for Improvement for Shared-Ink

- Incorporate a filmstrip view for the chipped images so that you can view a larger image of the picture without having to open it. In addition, a next and previous button should be included.

- The use of the yellow "information" icon should be modified so that it can clearly indicate whether it is being used to flag unviewed imagery or imagery that has been previously viewed.

- All references to geo-location should be changed from latitude and longitude to the MGRS.

4.5 Suggestions for Improvement for ARL-DVR

During a mission, ARL-DVR should be utilized in a tactical operations center (TOC) where workload isn't as high as with the operators on the ground. It was also suggested that the ARL-DVR be used as an AAR tool to review any major activities that occurred during the mission.

4.6 Suggestions for Improvement for the PACKBOT

- Improve connectivity issues.

- Add handles on both sides of the PACKBOT for a two-man lift.

- Add a center head button on the Collect-Control interface that would automatically center the head of the PACKBOT at 0 degrees. Additional options of 90°, 180°, and 270° might also be helpful.

- Future versions of the SUGV should be lighter and quieter.

- TTPs need to be developed to ensure that operators are familiar with terrain features or man-made objects that can interfere with the connectivity of the PACKBOT.

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Appendix. Operator Usability Questionnaire

This appendix appears in its original form, without editorial change.

Please answer the following questions using the scale from Strongly Disagree to Strongly Agree

		Strongly Disagree						**Strongly Agree**
		1	**2**	**3**	**4**	**5**	**6**	**7**

DURING OPERATION OF THE PACKBOT USING THE OPERATOR CONTROL UNIT (OCU) COMMON CONTROLLER (CC) TYPE 1 IT WAS EASY TO…….

1   Drive the Packbot using the joysticks
2   Control the Packbot camera using the joysticks

3   Zoom in/out with the camera
4   Maintain situational awareness
5   Chip images
6   Annotate chip images
7   Read the display outdoors
8   Find Information I needed on the OCU
9   Understand what the icons meant
10   Use the touch screen buttons
11   Read the text on the touch screen buttons
12   Select a specific button on the OCU
13   Unintentionally activate function on the OCU
14   Know the location of the Packbot

15   Know the orientation (e.g., front, back, location of flippers) of the Packbot

16   Know the operational status (e.g. stopped, moving, stuck in location) of the Packbot
17   Use the stylus

Please answer the following questions using the scale from Strongly Disagree to Strongly Agree

		Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	n/a
	DURING OPERATION OF THE PACKBOT USING THE OPERATOR CONTROL UNIT (OCU) COMMON CONTROLLER (CC) TYPE 2 IT WAS EASY TO…….								
1	Drive the Packbot using the game controller								
2	Drive the Packbot using the on-tablet controls								
3	Control the Packbot camera using the game controller								
4	Control the Packbot camera using the on-tablet controls								
5	Zoom in/out with the camera using the game controller								
6	Zoom in/out with the camera using the on-tablet controls								
7	Maintain situational awareness								
8	Chip images								
9	Annotate chip images								
10	Read the display outdoors								
11	Find Information I needed on the OCU								
12	Understand what the icons meant								
13	Use the touch screen buttons								
14	Read the text on the touch screen buttons								
15	Select a specific button on the OCU								
16	Unintentionally activate function on the OCU								
17	Know the location of the Packbot								
18	Know the orientation (e.g., front, back, location of flippers) of the Packbot								
19	Know the operational status (e.g. stopped, moving, stuck in location) of the Packbot								
20	Use the stylus								
21	Use the Collect Control								
22	To view the video from the Collect Control								
23	Use the Shared Ink								
24	Understand the field of views from the sensors								
25	Know the location of the BLUFOR								
26	Know if an information icon was available for viewing								
27	View the chipped images associated with the information icons								
28	Get symbol information associated with an symbol/icon								
29	Draw gestures on the map								
30	Annotate images with audio								
31	Review the thumbnails of chipped images								
32	Use the ARL DVR								

33   Find a specific event through the ARL DVR
34   Carry the OCU
35   Hold the OCU while operating it

List of Symbols, Abbreviations, and Acronyms

AAR	After Action Review
AO	Area of Operations
ARL	U.S. Army Research Laboratory
C/JMTK	Commercial Joint Mapping Toolkit
C4ISR OTM	Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance On The Move
CC-Type I	Centralized Controller Type I
CC-Type II	Centralized Controller Type II
CDR	Commander
CERDEC	Communications-Electronics Research, Development and Engineering Center
CIMS	Component Information Management System
COA	Course of Action
COTS	Commercial Off The Shelf
DVR	Digital Video Recorder
FBCB2	Force XXI Battle Command Brigade and Below
FCS	Future Combat Systems
FPS	Frames Per Second
GPS	Global Positioning System
HMMWV	Highly Mobile Multi-Wheeled Vehicle
IBA	Interceptor Body Armor
IED	Improvised Explosive Device
IEEE	Institute of Electrical and Electronic Engineers
MAV	Micro-Aerial Vehicle

MGRS	Military Grid Reference System
MOLLE	Modular Lightweight Load-Carrying Equipment
MOPP	Mission-Oriented Protective Posture
NOD	Night Optical Devices
OCU	Operator Control Unit
OP	Observation Point
OPFOR	Opposing Force
PL	Platoon Leader
PM	Program Manager
PSG	Platoon Sergeant
SO	Spin-out
SPOT	Size, Position, Observation, Time
SRW	Soldier Radio Waveform
SUGV	Small Unmanned Ground Vehicle
SVGA TFT	Super Video Graphics Array Thin-film Transistor
TOC	Tactical Operations Center
TTP	Tactics, Techniques and Procedures
UAS	Unmanned Aerial System
UGS	Unattended Ground Sensors
USB	Universal Serial Bus
Vdc	Voltage Direct Connect
VRP	Vehicle Rally Point

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