Immersive Visualization, Advanced Sensor Technologies, and Computer Automation in a Multi-Mission Armoured Vehicle

Major Mark Espenant
National Defence Headquarters
DAVPM 2-6
MGen George Pearkes Building
101 Colonel By Drive
Ottawa, Ontario K1C 2J5
CANADA

Mike Greenley
Greenley & Associates
216-1725 St. Laurent Boulevard
Ottawa, Ontario K1G 3V4
CANADA

Kris Boyle
General Dynamics Canada
3785 Richmond Road
Nepean, Ontario K2H 5B7
CANADA

ABSTRACT

Future Armoured Fighting Vehicles (AFVs) will use advanced technologies to greatly increase the information from on-board sensors. In addition, they will receive information from integral autonomous unmanned sensors, and from other friendly vehicle and sensor assets via the Battlefield Management System. This information should vastly increase the crew's Situation Awareness and, as a result, their effectiveness on the battlefield. However, if not properly managed, the sheer complexity and volume of this data may actually reduce their effectiveness by overloading and confusing them.

It is also technologically feasible for future AFVs to fire in rapid sequence directly at threats, indirectly at threats they are unable to see, and at air targets. They could use remote sensors and unmanned vehicles to increase the range of their sensing and shooting. This multi-mission capability has the potential to greatly increase the combat effectiveness of individual vehicles, to increase the flexibility and range of options for their employment, and reduce logistic and manpower requirements. However, the demands on the vehicle crew would be high, and the multi-mission paradigm may not represent the best allocation of scarce military resources.

To answer questions about the combat effectiveness of a multi-mission vehicle using advanced technologies in a future force framework, Defence R&D Canada, General Dynamics Canada, and Greenley & Associates are conducting a joint technology demonstration, the Multi-Mission Effects Vehicle project. MMEV is developing real vehicle technologies and integrating them in a light armoured vehicle; modelling the technologies with a revolutionary soldier-machine interface in a motion-based virtual environment; and creating a constructive simulation. A multi-build approach, with extensive user and Human Factors involvement, is being employed.

The soldier-machine interface will include a 360-degree representation of the outside world in a head-mounted display. The display will include overlaid symbology for tactical, navigational, and administrative information, including automated decision aides and system management. The vehicle will have 360-degree

Paper presented at the RTO SCI Symposium on "Critical Design Issues for the Human-Machine Interface", held in Prague, Czech Republic, 19-21 May 2003, and published in RTO-MP-112.

target detection and recognition, and automated computer target engagement. Direct voice input and multi-function controls will be the primary control mechanisms. The real vehicle will include key enabling components of this interface, and will validate the performance of vehicle sub-system technologies. Constructive models will be used for parametric assessments of technology performance, and for validation of the overall virtual system and crew performance.

INTRODUCTION

Future Battlefield

The future Armoured Fighting Vehicle will operate in an environment very different from its predecessors. Information about the location and disposition of enemy and friendly forces will be provided by on-board and autonomous sensors, by other manned and unmanned air and ground vehicles, and by other assets. This and other tactical and navigational information will be available in an integrated network, with voiceless communication, and will be presented to the vehicle commander as part of an integrated operator interface to give him unparalleled situation awareness.

Advanced technologies will enable the future armoured vehicle to detect and identify targets at long range, engage seen and unseen threats, collaborate with remote sensor or shooter platforms, change vehicle characteristics to blend into the background, move about the battlefield with ease, and engage different targets with a single munition. Coupled with the increased tactical and situation awareness, these abilities will create a battlefield no longer rigidly defined by organizational boundaries and distinct lines between own forces and the enemy, and with greatly increased operational tempo and fluidity.

In the absence of the traditional linear battlefield, the fight will move to much more complex terrain, including the urban environment. Therefore, in spite of their increased capability to fight at long distances, future armoured vehicles will frequently be required to operate in extremely close quarters, and to collaborate intimately with dismounted forces and autonomous unmanned vehicles.

The likely asymmetric nature of future conflict also means that the future armoured vehicle must be capable of deploying to strategically significant distances at short notice.

Armoured Vehicle Design Challenges

The nature of the future battlefield, the rapid advance of technology, and budget and manpower pressures will lead to significant challenges in designing future armoured vehicles:

- Advanced technologies can have significant benefits, but they come at high cost, and technologies do not always work together to produce synergistic effects on vehicle performance.
- Too much information can overload the crew, or they can be confused by the wrong info at the wrong time. A vastly increased task load will require task management support for the crew, likely using automation or computer decision aides.
- The changing nature of conflict will place increased emphasis on Situation Awareness, that is, knowledge of the location, composition, and intentions of enemy and friendly forces, commander’s intent, and navigational and task information. This will require crew interfaces (Soldier-Machine Interface or SMI) that intuitively present required information while allowing effective viewing of the external battlefield.

- The requirement for high strategic mobility will limit vehicle size and weight, impacting the sensor or weapon carriage and the crew size. These lighter vehicles will be difficult to protect to the same degree as current heavy main battle tanks.
- Manpower shortages and limitations on vehicle size dictate reducing crew size; coupled with increased task demands, this will require innovative SMI solutions and integration of computer aides. At the same time, the increased capability required of the crew will require more highly-qualified individuals and revised training.
- Logistics requirements can be reduced significantly by having a common vehicle, but this further increases the task loading of the crew.

Multi-Mission Concept

To meet these challenges of armoured vehicle design, and to give optimum battlefield effectiveness, a novel design concept has been proposed: multi-mission capability. The crew of a multi-mission vehicle would have the ability to fire sequentially at targets that it can see, at targets beyond its line-of-sight, and at air targets. In addition, using computer-engagement of remotely designated targets, parallel engagement would also be possible. This battlefield concept would include organic and other unmanned air and land vehicles for target acquisition and engagement, and integration in a network-centric battlefield. A multi-mission vehicle would have the following specific capabilities:

- Be aware of all targets within it's region of interest;
- Fire at targets within- and beyond-line-of-sight;
- Fire at low-level air targets;
- Conduct reconnaissance and targeting with organic air vehicles;
- Use other unmanned vehicles for sensing and shooting;
- Respond to fire requests from other vehicles or headquarters, and transmit fire requests to other vehicles.

A multi-mission vehicle concept integrated cooperatively with other platforms and infantry could offer a revolutionary increase in military capability – it could: see farther and shoot from out of harm's way; have greater lethality and survivability; have much improved tactical and strategic mobility; make optimum use of, and contribute to, information dominance and the synchronization of sensors and shooters; operate in a wider range of tactical scenarios; and offer a commander much-improved flexibility in employing his multi-mission vehicles in rapidly changing tactical situations. In addition, a formation equipped with a multi-mission vehicle could have reduced manpower & logistics requirements due to smaller crew size and a common platform. While the training challenge could be more complex, the multi-mission concept would also streamline training, in that all vehicle crews would take the same set of courses, use the same simulators, and use vehicle-based embedded training.

Multi-Mission Enablers

The capabilities envisioned of a multi-mission vehicle rely heavily on several key enablers. First, the "net-centric" ability to pass information on enemy and friendly forces between all entities on a battlefield is critical. Second, future vehicles must have significantly improved reconnaissance capability, and unmanned air and ground vehicles must be capable of autonomous or, at least, semi-autonomous operation in a combat environment. Third, weapons and munitions suitable for the three missions must be able to be integrated on a single vehicle and operable by a vehicle crew. Lastly, recruitment, training, and maintenance of crew skills must be suitable to meet the demands placed on a multi-mission crew over a wide range of operational situations.

MULTI-MISSION EFFECTS VEHICLE TD PROJECT

Project Overview

There are programs in countries around the world working to prove the technological feasibility of the multi-mission enablers, and on defining the strategic and tactical operation of a force equipped with net-centric vehicles. The multi-mission capabilities described above are extremely promising in creating an armoured vehicle for the future with revolutionary battlefield effectiveness. However, few of the technology development programs are taking a hard look at the multi-mission promise – is multi-mission capability with all its implications the best way of achieving improved battlefield effectiveness?

The Multi-Mission Effects Vehicle (MMEV) Technology Demonstration project is sponsored by Defence R&D Canada, and seeks to answer several key questions about multi-mission capability:

- How would the Future Force be organized, particularly within a Canadian context, and how would a multi-mission capability be used most effectively in a Future Force?
- How would the multi-mission force work collaboratively with coalition forces, particularly the US Objective Force?
- What would be the impact on crews of merging three different sets of doctrine and procedures (armour, artillery, air defence), of the Situation Awareness requirements related to multiple weapon systems, of the workload implications of reducing the crew size to two, and on crew skill and training requirements?
- How would a multi-mission vehicle operate with other combat arms in complex and urban terrain?
- What is the individual impact of key advanced technologies, and the potential synergy from the application of multiple technologies?
- What are the risks of developing a multi-mission capability, in terms of technological feasibility, cost, and schedule?
- Is a force equipped with multi-mission vehicles in a net-centric environment more effective on the battlefield than a similar-sized force with conventional structure and equipment?

MMEV Activities

To answer these questions, the MMEV TD project will conduct five evaluations over a four-year period in a virtual environment and in a real vehicle. In addition, the MMEV system will be modeled in a constructive[1] environment for comparison and performance prediction. MMEV TD virtual development and evaluation will be done in a four-build spiral development process, with a parallel stream of real technology development, vehicle integration, and evaluation. Figure 1 shows the key activities in MMEV, and the following paragraphs briefly outline these activities.

[1] Constructive simulation refers to computer models of both equipment and of the humans, as opposed to virtual simulation, which has real humans in-the-loop and computer modelled equipment.

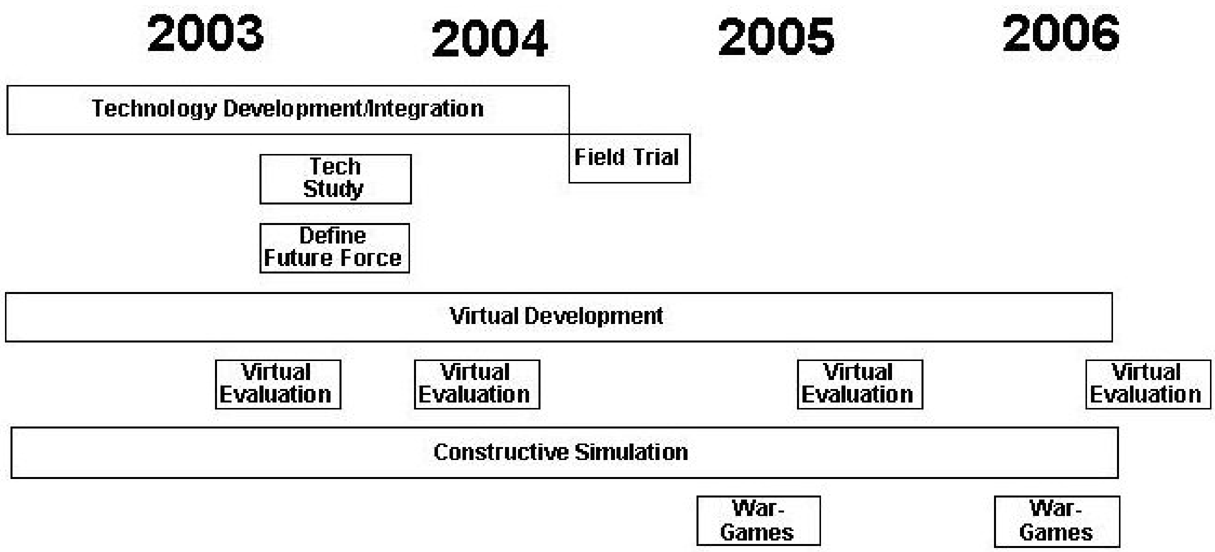

Figure 1: MMEV TD Schedule.

Technology Definition, Development, and Integration. Key advanced vehicle technologies are being developed in Canadian military labs and civilian industry, and will be integrated on a Light Armoured Vehicle III for field trials. A review of the state of technology will be carried out – this review will examine technologies that are not currently employed in AFVs, but have the potential to offer revolutionary capabilities. The results of this review, and of the technology development, will determine the technologies to be modeled in the virtual environment in later builds of MMEV. A later section of this paper briefly reviews the technologies that are planned for implementation or modelling in MMEV.

Field Trials. The LAV III equipped with advanced integrated technologies will take part in field trials to evaluate the performance of the individual technologies, and of the vehicle and crew under realistic tactical scenarios. The vehicle will be capable of automatic detection and recognition of targets, fusion of sensor and battlefield management system information by a commander's decision aide, automated defence, immersive visualization in a head-mounted display-based soldier machine interface, and automatic adaptation to the visual and thermal characteristics of the background.

Define Future Force Structure. A future force structure will be defined in collaboration with the Strategic Concepts section of the Canadian Army, with the participation of the armoured corps, infantry, air defence, other technology demonstration and acquisition projects, scientists and engineers, and civilian industry. The necessary tasks and resulting desired capabilities will be defined for a future Army; technological solutions will be discussed and the optimum integration of these solutions in a future vehicle and force structure will be determined. This force structure definition activity will be repeated for each of the subsequent builds.

Virtual Development and Evaluation. A virtual environment was created as part of a previous project, including computer-generated imagery, motion, vehicle and systems models, computer-generated enemy and friendly forces, performance modelling, and High Level Architecture, as shown in Figure 2. A virtual multi-mission vehicle will be developed in four builds, with increasing complexity of technology modelling, vehicle capabilities, simulation technology, and HLA Federation size and complexity:

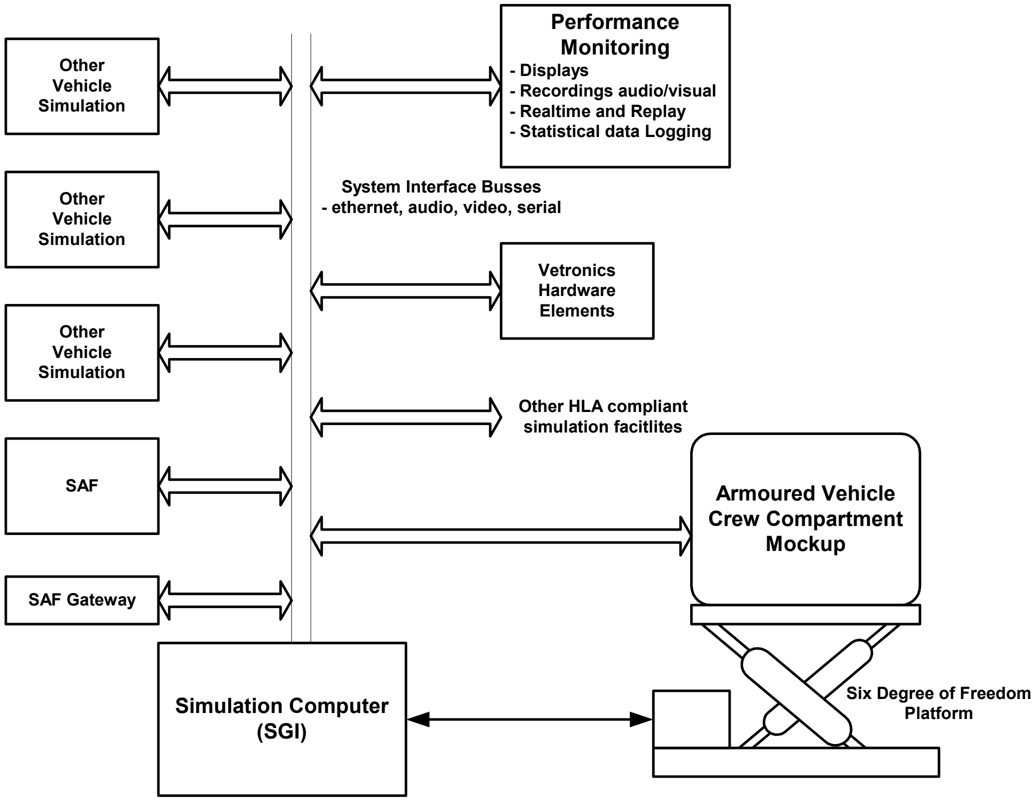

Figure 2: HLA Virtual Environment.

- Build 1 – Basic Soldier-Machine Interface and HLA link. The first build was completed with an evaluation in March 03; the results of the evaluation will be reported later in the paper. This build included a head-mounted display for the commander, with an overlay in the display to show detected targets and friendly entities and other Situation Awareness information. Operator control used joysticks and Direct Voice Input. An HLA link was created with a tactical helicopter simulation.
- Build 2 – Basic Multi-Mission capability, Net-Centric model, and extended HLA. Models of indirect fire and air defence weapons will be added to the simulation, and the SMI will be modified for their control. The vehicle will be part of a net-centric environment and will be able to call for fire and respond to requests for fire. The HLA federation will include two tactical helicopters with ERSTA capability and a three-vehicle Unmanned Combat Demonstration (UCD) from the US Tank and Automotive Research Development and Engineering Center (TARDEC) to act in an armed reconnaissance role. The evaluation will be based on Platoon[2]-sized operations in offensive and defensive scenarios, and will include comparison of the SMI of the MMEV and UCD, assessment of the contribution of individual technologies, comparison of multi-mission vs conventional performance, and assessment of collaborative activities.

[2] Traditional Canadian organization names are used in this paper, although for the purposes of MMEV they are likely to be changed as part of the Force Structure Definition activity. Combat Team is a Company-plus grouping of armour, infantry, engineers, air defence, and other assets, while Battle Group is the same at Battalion level. The US Army Objective Force has defined Unit of Action as their equivalent to Battle Group and Unit Cell as the equivalent to Combat Team.

- Build 3 – Upgraded simulation, unmanned vehicles, extended HLA. The simulation facility will be upgraded to increase the level of fidelity and performance. Models will be created of organic air vehicles and the SMI will be modified for their control, and for direct interaction with other unmanned air and ground vehicles; the MMEV will be capable of directly using these other vehicles as sensor and shooter platforms. The SMI will be refined for operation by a two-man crew. The HLA federation will be significantly expanded to include man-in-the-loop reconnaissance vehicles, unmanned air and ground vehicles, and dismounted soldiers. The evaluation will be based on Combat Team-sized operations in offensive and defensive scenarios, including combined operations in urban terrain. The evaluation will include assessment of remote sensing and shooting, evaluation of the effectiveness of a two-man crew, and assessment of collaboration with multiple other vehicles in the net-centric environment.
- Build 4 – Command elements. The commanders of a Battle Group-sized force will be set up as a Command Post Exercise and linked via HLA to the MMEV federation. Some of the commanders will have command via voice and data-link with human-in-the-loop forces, some will command constructive elements, and others will participate in seminar war-gaming. The SMI and other elements of the simulation and modelling will be modified as required based on the previous evaluations. The evaluation will include assessment of the feasibility and issues with commanding a future force with net-centric multi-mission capability.

Constructive Simulation and War-Gaming. Three constructive simulation activities will be conducted in MMEV. Models of the vehicles will be created in OneSAF and vignettes up to Combat Team level will be conducted, allowing analysis of the effects of individual technologies and overall battlefield effectiveness. A Task Network Model (TNM) of the MMEV will be created in the Integrated Performance Modelling Environment (IPME) software, which will allow technology evaluation, performance prediction, and support to the virtual vehicle design effort. Lastly, war-gaming using the Janus tool will be done in larger-scale scenarios, evaluating the battlefield effectiveness of a Battle Group-sized force in a range of scenarios, based on vehicle and technology performance results from the virtual evaluations.

Soldier-Machine Interface Challenges and Solutions

The MMEV project team has incorporated a series of Soldier-Machine Interface (OMI) design approaches to address the human-system interaction design challenges of the overall system. These SMI design approaches or solutions include:

360-Degree Target and Threat Detection. The MMEV SMI has been designed with continual 360-degree imagery, with an Automatic Target Detection and Recognition (ATDR) system, and an integrated multi-function Defensive Aides Suite. Both of these systems will be fully integrated into the SMI to help address the Situation Awareness challenges of a crew embedded in the hull of an armoured vehicle. Automated assistance will be provided for the crew to process ATDR, DAS, and Battlefield Management System (BMS) data to detect, identify and prioritize (against the active target prioritization matrix) the various potential targets on the battlefield. By re-allocated some of the current visual and cognitive processing to the automation features of the computer, the MMEV SMI should permit an enhanced situational awareness while managing workload as the crews' information density increases.

Shared Picture. Current-day armoured vehicle crews spend significant time sharing positional and target-related information amongst the troop of vehicles. MMEV will include a 'shared picture' whereby targets and threats detected and identified by one vehicle (using ATDR and DAS) are automatically shared across all vehicles in the group, with presentation of this information on both BMS map interfaces and sight display interfaces. This type of interface enhances the situational awareness capability of the crew while decreasing the amount of user effort and voice communication required to generate this awareness.

Virtual Terrain Reconnaissance. The future battlefield requires the MMEV-generation vehicles to have much more mobility. This requires the crews to be continuously aware of their surroundings, allowing them to advance with speed and confidence. The digital terrain data in MMEV will permit the crew to use their primary sight display to 'raise above' their vehicle and view a 3D virtual representation of their immediate surroundings, including the ability to fly through that terrain using their primary sight control interface. This will permit crews to very quickly and continually 'recce' the battlespace around them, allowing them to develop and maintain an accurate awareness of terrain, resulting in navigation and movement with enhanced confidence and tactical efficiency. The resulting SMI should enhance situation awareness while affording 'just-in-time' mission rehearsal capabilities at the vehicle and troop level.

Within-Vehicle Augmented Reality. Whether the final vehicle has a two or three person crew it will be essential that the crew act as an entirely integrated team. The core MMEV Fire Control System (FCS) already has a suite of features to support this based on the past 6 years of R&D; however, future SMI functionality must provide further advances in this area. Augmented reality is one SMI technology that is expected to further facilitate this intra-crew coordination requirement, by permitting one crew member to view their sight picture and note features such as areas of interest, arc markers, or way points that are then visually augmented on the sight pictures of other crew members.

Operator Interface Information Fusion. Current-generation vehicles require the crew to continually translate information between two perspectives: the 'plan' view of the world provided by the BMS map; and the 'elevation' view of the world provided by the sight. The cognitive effort required to continually translate and integrate these two perspectives is demanding and is a source of human error. Increased command and control requirements of a multi-mission vehicle, combined with increased operational tempo, demand an SMI that eliminates this operator information translation requirement. MMEV will fuse the relevant information, whereby the operator can overlay traditional map data such as boundaries, obstacles, phase lines, kill zones, or way points onto their sight view using virtual augmentation. Similarly, the operator will be able to overlay traditional sight data such as ATDR targets onto the BMS map data. This type of SMI will afford enhanced situation awareness, while reducing crew workload by converting a continual cognitive processing task to an 'on demand' direct perception task.

Common Task Flow for Common Tasks. The skill complexity challenge of a multi-mission vehicle stems from the requirement to be able to learn and then manage three different main weapon systems (direct fire, indirect fire, and air defence) in addition to understanding the command and control and tactics associated with the employment of each. One way to reduce this complexity is by having common task flows across weapon systems. The resulting SMI will allow the crew to have one well-rehearsed task flow for the engagement sequence that is used regardless of the weapon to be fired. If the crew detects a land or air direct fire target they will be able to 'lock on' (using ATDR) and 'fire' in exactly the same manner, the only difference being the ammunition selected, which may be selected automatically by the computer (direct fire or air defence ammunition). Similarly, the crew will be able to view a target through the sights on an unmanned air or ground vehicle, and 'lock on' and 'fire' at that target in exactly the same manner, even through the weapon that would be fired would be the indirect fire weapon. With common task flows across common tasks regardless of weapon type, the multi-mission aspects of the vehicle should become more transparent to the MMEV crew, further reducing crew workload and training requirements.

Fully Immersive Visual Environment. MMEV TD assumes that future vehicle crews will be embedded in the hull of the vehicle. This will provide protection, and permit more condensed crew stations in the smaller vehicle profile, but will also result in the crew struggling for the current daytime 'out of hatch' sensory awareness. SMIs based on helmet mounted displays (HMDs) that fully immerse the crew in the fused information environment, are one solution area that will be fully explored in MMEV, as HMDs have the potential to allow the crew to move their head to look around in a very wide field of view visual scene. This type of naturalistic interface would be expected to increase situational awareness while managing the workload associated with line-of-sight management.

Simplified, Naturalistic Interaction. The use of a fully immersive HMD with head tracker is one example of a natural SMI interaction mechanism. Others will include Direct Voice Input (DVI) whereby the crew will speak commands to the onboard computer, with the computer being perceived as an additional crew member. DVI is particularly required in the HMD environment, as the crew will not be able to interact with arrays of switches, and large switch arrays will generate undesirable skill complexity in a multi-mission vehicle. Other interface technologies such as 3D audio or tactile vests offer further opportunities to present information to the crew in a manner that is natural and obvious, to continually increase situation awareness without increasing the load on any one human sensory channel.

Automation of Demanding Psychomotor Tasks. As the crews multi-tasking requirements increase with a multi-mission vehicle, any task that totally dominates crew attention for an extended period of time will decrease crew task performance and increase workload. Future SMI design must examine opportunities for automation support to these types of tasks. An example of this is the engagement sequence, which requires a crew member to detect a target, identify it, track it, range to it, continue to track it, and fire at it all the while consuming the entire focus of the crew member. Advances in ATDR being demonstrated today will be extended in this example, so that the user will be able to select an automatically-detected and -identified target and direct the computer to engage it; the computer will track, maintain track, range the target, and fire the weapon at it. Advanced SMI features such as 'computer engage', if found to be reliable under a range of visual and movement conditions, have the opportunity to further reduce skill (and associated training) requirements as well as reducing multi-tasking workload demands.

Technology Development and Simulation

In the MMEV project, real technologies are being developed and integrated in a LAV III, and more advanced technologies will be modelled and simulated in the virtual environment. Real technologies include the following:

- A mmW radar, capable of high range resolution, with target search and identification modes.
- Multi-focal IR camera with automated scanning and target search modes.
- Automatic target recognition system based on biomimetic neural networks, operating on the radar and IR information.
- Automated Defensive Aides Suite, with sensors including missile approach warning, laser and beam-rider warning, and IR and visual imagers. Countermeasures include laser dazzling, false target generation, obscurants, and counter-fire.
- An immersive camera system, which gathers information all round the vehicle in real time, and can overlay symbology on the video to represent tactical and navigational information.
- Fusion of target information from on-board sensors and from the Battlefield Management System, to create a single Situation Awareness picture and decision aide for the commander.

- A Soldier-Machine Interface that integrates a head-mounted display and joysticks to create a "glass turret" view of the world.
- Adaptive camouflage elements and sensors, with a computer controller that varies the element visual and IR signature to match that of the background.

To effectively demonstrate the potential impact of a future multi-mission vehicle, the MMEV project must simulate technology capabilities that could reasonably be expected to exist in the relevant time frame. This need must be balanced by the requirement for realistic technology performance. The technology study will identify key technologies and their use in a multi-mission vehicle, and suggest how to realistically simulate their performance and integration in the vehicle functionality. The technology study is not done, so the list of technologies is incomplete; however, it is likely that the following will be included:

- Indirect and direct-fire weapons, including guns and missiles. The missiles may include vertical-launch and turreted systems, and may include hyper-velocity kinetic energy warheads and loitering munitions.
- Multi-role munitions, in which the detonation characteristics of the round can be changed depending on the type of target (aircraft, helicopter, armoured vehicle, installation, personnel, etc).
- Unmanned air vehicles organic to the MMEV vehicle and controlled from it. These OAVs will require the capability for at least semi-autonomous operation, and models of suitable sensors.
- Decision aides to fuse information from various sensors and information sources, and present only relevant and timely information to the crew.
- Soldier-machine interface technologies such as: 3D Audio and or tactile cues, to indicate the direction of a threat warning, radio or data link message, or other information; enhanced and synthetic imagery in the head-mounted display to increase the crew's ability to visualize the surrounding terrain.
- Multi- or hyper-spectral imaging, Magnetic Anomaly Detection, and 3D LIDAR scanning for improved target detection and recognition.
- Automatic Target Recognition.
- Active suspension with hybrid electric drive.
- Automated defence system capable of defeating kinetic energy warheads.

Soldier-Machine Interface Design Details

The actual SMI for the MMEV has been developed to implement the SMI solutions discussed earlier. Figure 3 below illustrates the current crew station with the crew in a fully supportive seat, with 4 or 5-point harness, joysticks in each hand, and an HMD-based fully immersive visual environment. The HMD shown is clearly an experimental unit and in no way represents the physical form factor required of a future operational system.

Figure 3: Crew Station Concept.

The immersive visual image is illustrated in Figure 4. This crew view has a number of noticeable features, including:

- Wide-angle immersive sight view in day or thermal modes. This view is presented to the crew in stereo to allow depth cues.
- ATDR targets both in view and out of view.
- Non-visible target indications based on targets viewed by other troop members.
- Contact rings mapping 360-degree targets around the vehicle.
- Virtual augmentation for waypoints and arc limits.
- Digital range feedback, continually indicating range at centre of gaze.
- Overlay of digital map data (boundaries, obstacles) on the visual scene.

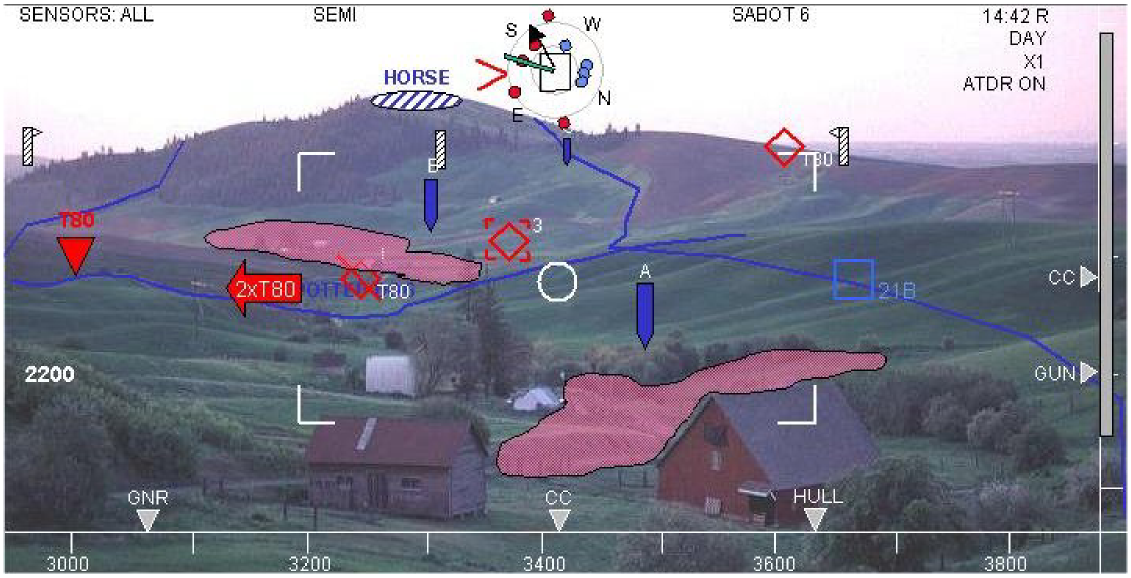

Figure 4: Immersive View.

With the crew fully immersed in the visual environment, a number of features have been designed into the SMI to allow the user to view their map (by looking down into their lap or using a voice command), system status, and BMS displays.

The primary crew interaction with the vehicle is via Direct Voice Input. The primary hard user control is presented through the two multi-function joysticks under each hand, shown in Figure 5. The user can conduct almost all interactions with the system through these joysticks.

Figure 5: Multi-Function Joystick Controls.

The MMEV SMI concept allows the crew to operate all three weapon systems (direct, air defence, and indirect) via a common interface, and to also control an unmanned air or ground vehicle using the same SMI.

RESULTS OF MMEV FIRST EVALUATION

Performance

The first evaluation of the MMEV was completed just prior to the completion of this paper, so at the time of writing the vehicle engagement performance data was not fully analyzed. Rough data obtained during the actual trial indicated that the engagement performance was similar to prior versions of the system for manual engagements (better than Leopard C2 or M1A2 firing table timeline and accuracy targets). Engagement performance using the ATDR system and the "computer engage" feature was generally thought to be slower than manual engagements at longer range with moving vehicles, but equal to or faster than manual engagements at shorter ranges, especially with static targets. This "computer engage" performance was tied to the performance of the ATDR system, which was far less than optimal under moving conditions. The ATDR in the simulation version tested performed worse than early prototype systems testing on real imagery, and will therefore be a focus of improvement for the next series of experiments.

Operator-Machine Interface Usefulness and Usability

The recent MMEV evaluation included a wide range of usability metrics, as well as significant subjective input from crews obtained during post scenario de-briefs and structured focus crew discussions.

In this evaluation the Gunners were using a Flat Panel-based SMI with two-handed traditional "yoke" controllers, while the Crew Commander used the immersive HMD SMI with joysticks as described above. Figures 6 and 7 illustrate the results of usability ratings of the MMEV system from the perspective of the Crew Commanders (CC) and Gunners (GNR). These data indicate that the HMD version of the SMI implemented in this initial evaluation posed significant challenges for the Crew Commander.

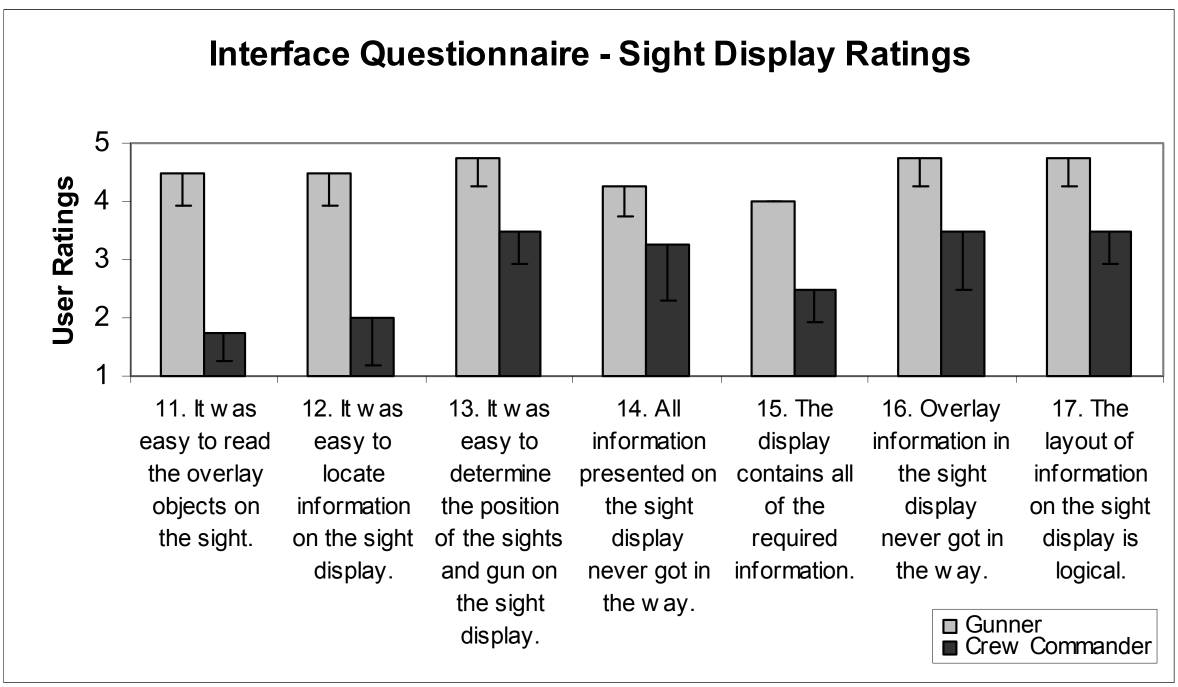

Figure 6: Sight Display Usability Ratings.

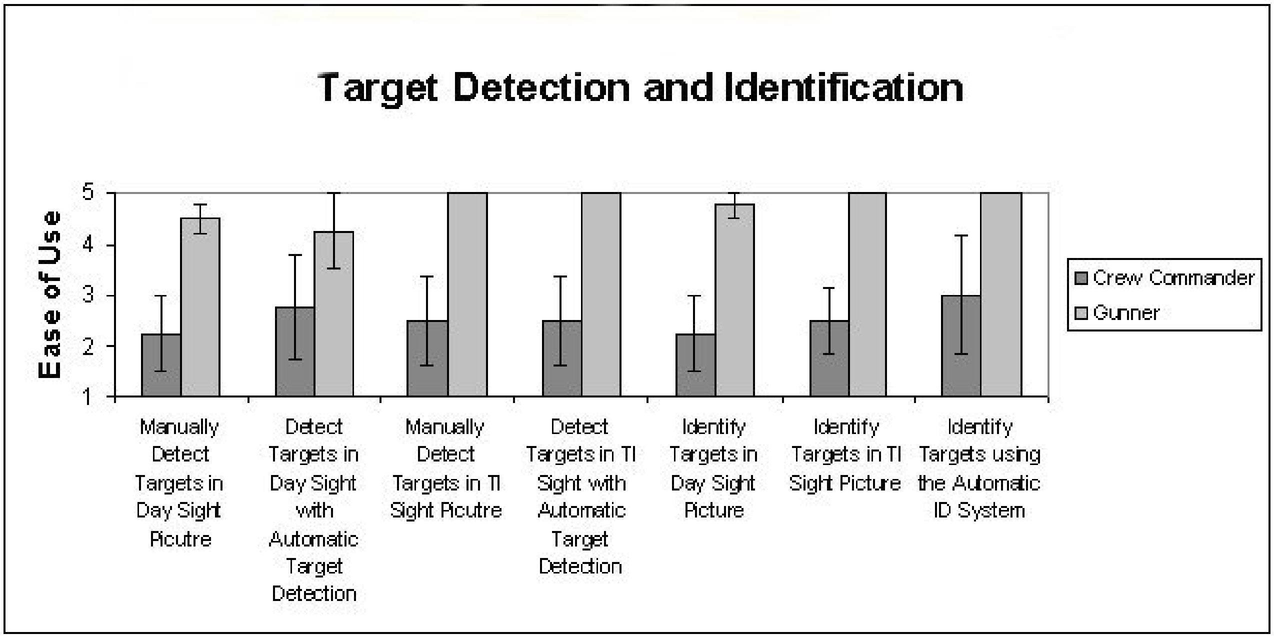

Figure 7: Target Detection and Identification Ratings.

These Crew Commander challenges using the HMD immersive view are further explained in Figure 8, which plots ease of use ratings from very low (1) through borderline (3) to very high (5). These data illustrate a number of significant conclusions of the SMI implementation using the HMD, including:

- The HMD had borderline usability when the vehicle was static and the head tracker was used to rotate the sight picture (mag levels of x1 and x4).
- The HMD had higher usability when the vehicle was static and the head tracker was eliminated from sight control with only the joysticks controlling the sight (mag levels x14 and x25).
- The HMD was not usable when the vehicle was moving. This was the result of a number of factors, including HMD movement on the wearer's head, significant neck fatigue, and extreme vertical image movement. Early assessments indicate this was a result of the large and heavy experimental nature of the HMD itself, and only a preliminary integration into the virtual vehicle.
- It was difficult to orient and navigate in the immersive display as the user had to constantly look down to view the map. This early version of the system did not include digital data over laid on the sight display (borders, routes, phase lines, boundaries, objectives), and it quickly became clear that such information fusion is essential in an immersive environment.

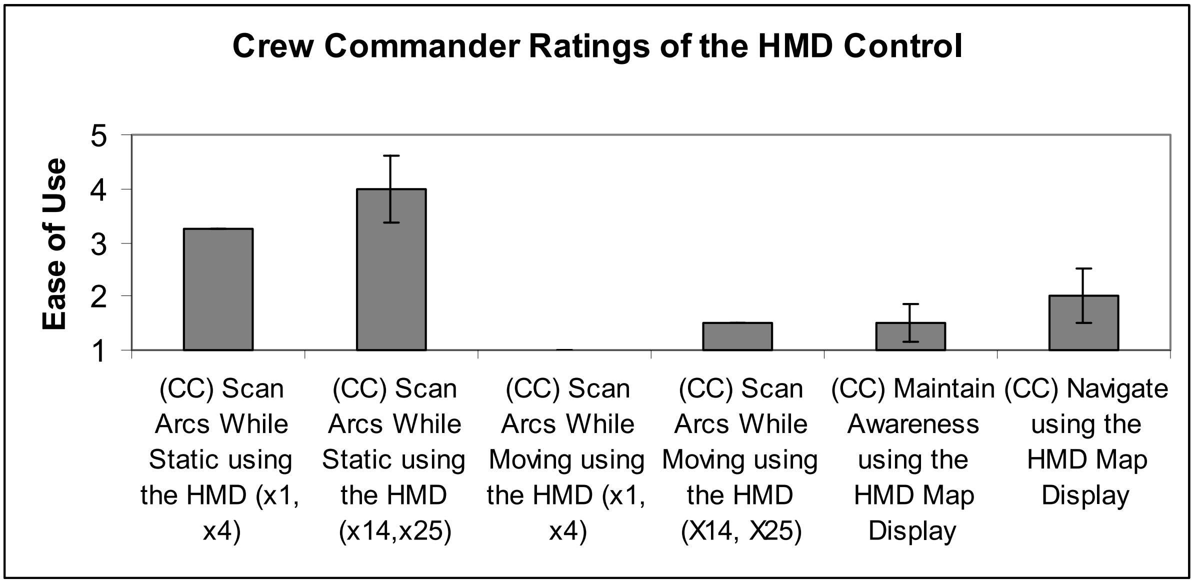

Figure 8: HMD Usability Ratings.

Crew Commander workload ratings were found to be higher than ever experienced in lab evaluations on previous systems, which was due to the challenges of using the HMD implementation tested.

This first evaluation provided a series of data that demonstrated that Direct Voice Input was very easy to use under a full range of engagement conditions, and it will continue to be employed throughout the follow on versions of the system.

Key features from the first lab evaluation with high utility, such as ATDR, DVI, and Computer Engage, will be continually refined in later builds. The HMD will be enhanced with map data fusion onto the sight picture, and its integration with the virtual system will be improved; the next evaluation will re-test the HMD usefulness and usability, but the final version of the system may warrant a flat panel or concave display implementation if the HMD is not successful.

CONCLUSIONS

The Multi-Mission Effects Vehicle Technology Demonstration Project will evaluate a concept for a revolutionary future vehicle, capable of rapid short and medium-range target engagement using information from organic and remote sensors. MMEV TD will evaluate crew and system performance and determine future crew requirements, explore coalition interoperability with the US Army Objective Force, help define a Future Force framework and evaluate its performance in realistic scenarios, and contribute crucial requirements information for purchase of future combat vehicles and for defining the future Army.

The first build of MMEV demonstrated that basic advanced technologies can improve Situation Awareness and engagement performance, showed the advantages of collaboration between air and ground assets, and provided basic experience with the creation of an HLA federation. Completion of the integration of real technologies, and their evaluation in a field trial, will validate the performance of key technologies and the use of a virtual environment to assess crew and system performance.

The work to date has not significantly begun to answer the questions posed at the start of this paper. However, the MMEV TD project will feature increasing complexity and capability in technology modelling, SMI design, simulation technology, performance monitoring, and HLA implementation. Future evaluations will allow detailed exploration of the multi-mission concept, and provide answers to the key questions.