Future Combat Systems (FCS) Networked Fires Integration with Lead Systems Integrator's (LSI) Unmanned Combat Demonstration (UCD) in the RDE Command First Application (1st App)

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ABSTRACT: *The Virtual Distributed Laboratory for Modeling and Simulation (VDLMS) Science and Technology Objective (STO) initiated a First Application (1st App) effort in 2003 to baseline the use of legacy distributed simulations within the RDE Command to support Future Combat Systems (FCS) and Objective Force experimentation. This paper discusses the lessons learned in connecting the Soldier-In-The-Loop (SITL) crew stations developed as part of the LSI's UCD with the Networked Fires experiment. The goal is to examine the feasibility of using Armed Reconnaissance Vehicles (ARVs) as forward observers for Networked Fires. Performance data will be measured identifying the ability to remotely manage the role of forward observer for Networked Fires from ARVs. While the 1st App event itself is classified, including specific results regarding the performance of Networked Fires, this paper will be an unclassified discussion, focusing on a small FCS tactical and technical performance thread for a proposed design.*

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1.0 BACKGROUND

To develop Future Combat Systems (FCS) and the Objective Force (OF) a fundamental change in the acquisition process is required. Systems and subsystems will need to be evaluated and integrated using a faster and less costly method than previous development efforts. Simulation, Modeling, Acquisition, Requirements and Training (SMART) principles will be relied upon heavily to accomplish the FCS and OF schedule and requirements. This paper discusses the reuse of simulation software development for analysis in three different programs supporting FCS. Participating organizations included government management, government research, Lead Systems Integrator (LSI), contractor other than LSI and academia. This team worked together to accomplish much in a short period of time using simulation and thus is an excellent example case of the SMART principles.

1.1 TARDEC Related Activities

The TARDEC Vetronics Technology Area is responsible for the research and development of technology to effectively integrate the Warfighter into ground combat vehicles. The scope of this activity includes: vehicle system architecture, warfighter machine interfaces (WMIs), automation, robotics and embedded simulation. In keeping with the Army's vision of a network centric force comprised of a system of manned and unmanned vehicles, the scope also includes integration of semi-autonomous robotic and or tele-operated vehicles and control of these unmanned vehicles from within manned vehicles.

To achieve some of these goals TARDEC is working on the Crew integration and Automation Testbed (CAT) Advanced Technology Demonstration (ATD) to demonstrate a multi-mission capable two-man crewstation platform concept. These concept crewstations have been integrated into a Light Armored Vehicle (LAV) modified Stryker variant chassis shown in Figure 1, to demonstrate a C-130-transportable chassis supporting the Army' s Objective Force (OF). This program focuses on an improved WMI design using indirect vision driving and automated decision aids, an advanced electronic architecture design/network topology, and embedded simulation. By demonstrating these advanced technologies and other capabilities, the CAT ATD will prove technology readiness to sufficiently transition and integrate hardware and software components into FCS.

Figure 1. Modified Stryker vehicle used in CAT ATD

CAT ATD uses embedded simulation technologies to reduce crew workload by improving training, virtual battlespace visualization and mission rehearsal. Embedded simulation also has potential for virtual test and evaluation. .

As part of the TARDEC Vetronics Technology Area, the Embedded Simulation (ES) team has been developing detailed models of ground combat vehicles to support man-in-the-loop simulation demonstrations of new system concepts for over a decade. Operating on vehicle crewstations, this software simulates sensors, weapons, robotic vehicles and provides an interface for the soldier to interact with these simulated systems. Building on an earlier version of the Embedded Simulation System (ESS), known as Vetronics Technology Testbed (VTT), the CAT ATD ESS configuration operates on two crewstations that have been installed in a LAV to produce appropriate crew task loading for mission scenarios to test crewstation design and demonstrate unmanned combat.

The ES team for the past two years has been developing the capability to model the intelligent agents within vehicles, either operators or automation, to provide a complete high-resolution, constructive simulation of advanced ground combat vehicle concepts. In FY 03 TARDEC, the ES Team and their support contractor, DCS Corporation, developed a dynamic Improved Performance Research and Integration Tool (IMPRINT) model that was capable of playing in a distributed simulation as part of the LSI's Unmanned Combat Demonstration (UCD). This constructive model of the LSI's Control Vehicle (CV)/Armed Reconnaissance Vehicle (ARV) concepts were used in the virtual demonstration and to support continued experimentation of CV/ARV concepts by the FCS LSI. The WMI for the CV/ARV crewstations and the constructive model of the CV/ARV were based on task modeling performed by Micro Analysis and Design under the Vetronics Technology Integration (VTI) contract. [1] [2]

1.2 LSI Related Activities

The UCD was one of nine technology demonstrations conducted during the Concept and Technology Development (CTD) phase of the FCS program. The objective of the FCS technology demonstrations was to identify and reduce risks associated with fielding an Initial Operating Capability (IOC) FCS equipped force in 2010. The goals for these technology demonstrations were to validate system interfaces, demonstrate successful system integration, support operational evaluation of the force, validate system and subsystem elements, establish fallback alternatives and validate modeling & simulation results.

Based on the guiding goals and objectives for the FCS CTD technology demonstrations, assessment of the Unmanned Ground Vehicle (UGV) technologies available in the government and industry, and an assessment of overall risk was required.

Understanding and calibrating a realistic span of control for a soldier is key to the successful control of robotic assets. The soldier's span of control or "workload" has a direct affect on force structure, system effectiveness, and system capabilities. Analysis of the soldier's use of the conceptual UGV systems can also be used to identify and verify realistic and achievable functional requirements for fielded systems. The UCD focused on workload analysis and the investigation of UGV operator workload issues including the ratio of operators to UGVs, identification of stressful situations, achievable levels of autonomy, maneuvers, communications, weapons engagement and Reconnaissance Surveillance and Target Acquisition (RSTA) applications. The ARV was chosen as the study vehicle because of its extensive capabilities required for FCS and the range of soldier control required to exercise these capabilities.

The UCD is using the CAT crewstations to control ARVs to show the capabilities of robotics in FCS scouting missions. The CAT and Robotics Follower (RF) ATD were the closest surrogate programs available to the LSI for the CV/ARV concept. Workload, robotics maturity and functional ability were addressed in the virtual environment and at Ft. Bliss in a UCD field demonstration.

2. LSI UCD Virtual Demonstration

The UCD virtual demonstration was a soldier-in-the-loop simulation exercise. This demonstration was conducted in a laboratory environment using the UCD Systems Integration Lab (SIL). The demonstration was held at the TARDEC facilities in Warren, Michigan over a three-week period. The first two weeks were used to make simulation runs involving a 1:1 soldier to ARV control ratio. The third week was used to gradually increase the soldier to ARV ratio from 1:1 to 1:4. Two crews of two soldiers each were used throughout the demonstration.

The heart of the UCD SIL is the ESS or B-Kit. The ESS provides the entire simulated virtual environment for the SIL. This virtual environment includes the simulation of all vehicles in the environment (mobility, sensors, weapons, and vehicle systems), the simulation of the natural environment (terrain, weather, day/night), and the simulation of the threat environment (vehicles, weapons sensors).

Because the ESS uses the actual crew station to vehicle interface, it can also be used as an embedded training system in the actual vehicle and to provide a virtual environment for more complete test and evaluation. This capability was used during the UCD live maneuver demonstration.

The soldiers operate the ARVs from two crew stations that are identical in form fit and function to those installed in the real surrogate CV. From these crew stations they can monitor and control all functions of the robotic assets available in the mission. This includes target acquisition and engagement, RSTA, autonomous mobility, teleoperation, command and control, mission planning and battlefield visualization.

Figure 2 CAT/UCD Crew Station

Each crew station provides a WMI consisting of three large touch screen multi-function displays, hard keys, keyboard, yoke and voice command interface. A view of the crew stations is shown in Figure 2.

The virtual demonstration was focused on workload analysis and the investigation of operator workload issues such as the ratio of operators to ARVs, identification of stressful situations, robotic vehicle maneuver, communication, level of autonomous operation, reconnaissance, and weapons engagement. The virtual environment allowed us to make a large number of simulation "runs" providing greater flexibility with respect to time, safety and system parameters that would not be afforded in a real world environment. Therefore, the virtual demonstration supported the live demonstration development. The virtual demonstration was used to support the live exercise scenario development, provide for system integration and capability verification, rehearse live demonstrations and provide the training of soldier crews.

The goal of these objectives was to reduce risk for the System Design and Development (SDD) phase of the FCS Program. As part of the Concept and Technology Development (CTD) phase of the FCS program the LSI was tasked with conducting demonstrations to prove high risk technologies were ready for SDD. The UCD was tasked to demonstrate the maturity of key robotics technologies. A key aspect of this effort was to collect data on the operator workload involved in controlling semi-autonomous robotic ground vehicles and experimentally determining the optimal ratio between the number of robotic vehicles and the number of operators assigned to control those vehicles. The TARDEC Vetronics group was tasked with supporting the UCD.

TARDEC developed a program plan which included a laboratory virtual demonstration and a field live fire demonstration. The demonstrations were based on the LSI's ARV and CV concepts operating as a robotics reconnaissance platoon. To conduct the demonstrations TARDEC capitalized on assets from the CAT and RF ATD and the VTI contract with General Dynamics. These consisted of two SIL CAT crewstations for the virtual demonstration, a Stryker vehicle with two CAT crewstations and a Stryker vehicle configured for unmanned operation for the live fire demonstration. AMRDEC's Cougar Turret was mounted on the robotic Stryker. For the virtual demonstration, TARDEC configured the two crewstations as ARV control stations operating in the back of a CV. The roles of the CV commander and driver were performed by computer-generated forces and verbal communications with test personnel. The ARVs were modeled as 5.5 ton wheeled vehicles equipped with semi-autonomous navigation systems and RSTA systems and armed with Objective Crew Served Weapons (OCSW) and Javelin like missiles. [3]

2.1 IMPRINT Modeling

To provide additional force structure to the experiment and for additional data an interactive IMPRINT model was developed. The overall architecture selected for the CV/ARV constructive model is illustrated in Figure 3. Figure 3 delineates the implementation of the constructive model as two distinct sub models: a vehicle model, and a human performance model (HPM). This partitioning was selected because it isolates the models of crewmembers and their interfaces to the vehicle from the model of the vehicle itself. The partitioned design allows the use of identical vehicle models to support virtual simulation (using manned crew stations) and constructive simulation (using computer models of each operator in a crew station). This flexible architecture allows for insertion of models at the correct resolution and fidelity to answer specific questions. The partitioning also makes it easier to assess the impact of the various crew and man-machine interface configurations on the overall performance of a vehicle with a given equipment configuration.

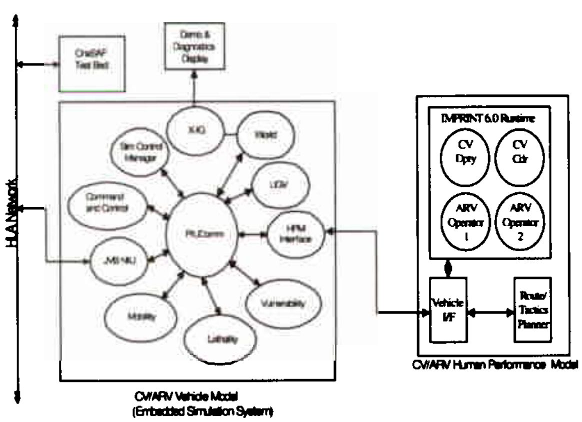

Figure 3 Vehicle Simulation Architecture

This overall architecture identifies two key interfaces, the interface between the vehicle model and the external synthetic battlefield using HLA, and the interface between the vehicle model and the HPM using the HPM Interface Control Document (ICD). [2]

2.2 UCD Virtual Demonstration Conclusions

Within the context of the simulation, the operators had no trouble controlling a single ARV. They also coordinated effectively during ARV mission planning and execution both independently and as a team.

No one task or event stood out as significantly higher workload than any other task. All of the operators characterized the workload as medium to light and generally uniform across tasks. None felt overloaded at any time when controlling a single ARV. When operating more than one ARV, the operators felt that the workload increased, but not to the extent that it was unmanageable. Mission planning at the beginning of the scenario was consistently reported as being overly taxing. The operators did not feel that this task was particularly difficult, but rather very time consuming.

All of the operators felt that they could control two ARVs simultaneously. Most operators felt that controlling three robotic vehicles was also manageable. One operator felt that his effectiveness would be reduced if he had to control three robots. Though the operators generally felt that they could operate three robots. There were numerous instances where operators were observed losing situational awareness (SA) on their other robots while they concentrated on a particular task with one robot. This was particularly true when multiple events occurred at once, such as receiving incoming fires while performing RSTA scan with an ARV. Despite the majority of operator opinions that controlling three robots was a manageable task, there was an observed drop in effectiveness when the third robot was added. This suggests that two robots per operator is perhaps a practical limit. This is also noted to be in the context of the simulation (see next item).

Simulation limitations created a lighter workload for the operators. This included uncoupled terrain, the immortality of the ARVs, the perfect communications environment, the simple behavior of the OPFOR, and the lack of physical motion effects. There was no non-traversable terrain anywhere in the scenarios, so teleoperation and cross-country maneuvering placed little workload on the operator. The ARVs could not be killed in the scenario, so there was no sense of urgency to move them from harm's way. Streaming video from the robots was available without interruption or time lag, causing less demand on the operator to process the information. The enemy targets were isolated, in the open, and did not move or shoot when the robots came into their vicinity. This also resulted in operators feeling little urgency to keep the robots from view of the enemy, and allowed them to take as much time as they needed to acquire RSTA information, target and engage enemy or call for indirect fires. Because the crewstations were static and operators did not wear gloves or other gear with the exception of the communications headset, it was not possible to explore the effects of motion sickness or the difficulty of operating controls while situated in a moving vehicle. Most of these factors were due to the inherent limitations of the simulated environment.

This environment provides the context under which the workload should be evaluated with respect to the virtual demonstration. Within this context, no operator had trouble controlling one ARV and they were able to effectively control two ARVs. However, if any of these factors are made more difficult, their ability to control two robots or even one robot will be affected. It is therefore not possible from this data to conclude with absolute certainty what the highest number of ARVs should be per operator.

The soldiers were allowed to operate the ARVs in any manner they thought reasonable to complete the assigned mission. There are no existing tactics, techniques and procedures (TTPs) for the use of robotic assets in a combat environment. The soldiers were given some guidance and possible strategies on the use of robotic capabilities. For the most part, the soldiers relied on strategies that they had learned for manned vehicles. In some cases, these strategies were valid. In other cases these strategies could have been different to take advantage of robotic capabilities. Significant work is required in the area of TTPs for robotic assets. This effort needs to occur as part of the design process of the assets. [3]

3.0 Capstone Demonstration

During March 2003 the CV/ARV crewstation participated in the FCS LSI Capstone Demonstration at Ft. Knox, KY. For this demonstration the crewstation was reconfigured to have one Reconnaissance and Surveillance Vehicle (R&SV) and one Armed Robotic Vehicle – Reconnaissance (ARV-R) acting as a reconnaissance detachment within a reconnaissance team supporting a combined arms battalion in Azerbaijan. The CV/ARV-R would acquire targets and then either engage with on board Javelin/OCSW weapons or pass that information to section leader for indirect fire support. If indirect fire was taken on a target, the CV/ARV-R would do Battle Damage Assessment (BDA).

3.1 Capstone Results

The UCD crewstations participated in all runs during demonstration week. This showed the ability for a soldier-in-the-loop (SITL) crewstation to perform in a large simulation exercise consisting of over 5000 entities. This allows for large simulations to have a small slice or section of the force to be run in higher resolution and to have SITL feedback on WMI design, tactics or functional capabilities for a given design.

4.0 VDLMS 1st App

During April 2003, the CV/ARV-R crewstation and HPM model participated in the RDECOM Virtual Distributed Lab for Modeling and Simulation (VDLMS) STO 1st App experiment in Huntsville, AL. For this demonstration, the crewstation and HPM model were reconfigured to have one Reconnaissance and Surveillance Vehicle (R&SV) and one ARV-R acting as a reconnaissance detachment within a reconnaissance team supporting a combined arms battalion in Azerbaijan. The ARV-R acquired targets and then either engaged with on board Javelin/OCSW weapons or made a Call for Fire (CFF) to NetFires. If a CFF was initiated from the CV, the ARV-R was required to either provide laser designation or periodic position updates of a target for PAM IIR or PAM SAL for missile guidance. The CV/ARV-R was responsible for doing BDA and then providing that message back to NetFires for further engagement if necessary.

The UCD crewstation's WMI was modified to send the required data in the CFF and provide a laser designation screen. The ESS was modified to pass entity data, CFF and laser designation PDU's to the federation.

4.1 VDLMS 1st App Results

The HPM vehicles participated in all record runs, with the crewstations participating in a majority of the runs. A majority of the missed runs were due to air conditioning problems in the Redstone Technical Test Center (RTTC) building where the UCD was housed. The crewstations were more susceptible to problems brought on by heat than the PCs running the HPM software.

Another issue that caused problems was schedule. The UCD virtual experiment was completed in January 2003. The UCD crewstations were shipped immediately to the Capstone Demonstration, which was completed in March. The UCD crewstations were then shipped immediately to 1st App for participation in the April experiment. The fact that other programs had schedule slippage namely UCD, CAT and Capstone; caused development and integration for 1st App do be delayed. When 1st App's schedule did not also slip this caused the UCD crewstations to not achieve full functionality. I do not think there was anything that TARDEC or 1st App could have done to alleviate these problems.

Finally, some general confusion on where to go and what to do by civilian operators because of their lack of military experience caused us some problems. The lack of military experience of TARDEC's technical personnel, and the fact that we were in a different building then our company commander, caused numerous confusion as to our platoon's military objectives. In the future, I would recommend getting current military and/or former military operators, and to have more and earlier meetings with the company commander to completely clarify the platoon's objectives and goals.

5.0 Lessons Learned

TARDEC learned numerous lessons in the performance of the UCD, Capstone Demonstration and VDLMS 1st App exercise. The significant lessons were:

1. It is feasible to use the same simulation system/subsystem models for multiple programs in a relatively short period of time.
2. As a subsystem in larger simulation demonstrations/exercises, such as Capstone and VDLMS 1st App, you are constrained to whatever schedule variations are forced upon the whole demonstration/exercise. This makes scheduling and planning fairly fluid, which in turn adds additional risk to research efforts (which are already inherently risky). The risk can be managed by dropping out of demonstration/experiments or reducing functionality, however in high profile programs management is not overly enthusiastic about either of these options. Hence, if you plan on doing multiple programs one after another, plan on your team working additional hours.
3. It is feasible to model and simulate in real-time the complex behavior of human operators within a combat vehicle using IMPRINT goal oriented task

networks interfaced to a high-resolution vehicle model.

4. The Human Performance Model (HPM) identified above can be validated using a Soldier-In-The-Loop (SITL) SIL. This model can then be used to fill out a more meaningful high-resolution task matrix behavior slice in an inherently constructive or lower resolution simulation experiment.
5. It is imperative that you have soldiers or persons with military experience operate SITL SIL and HPM decision making tools. While technical developers know how to operate the equipment and models, they struggle to understand the military context and jargon associated with maneuvers and engagements.

6.0 Conclusion

By utilizing the Army's Simulation, Modeling, Acquisition, Requirements and Training (SMART) strategy, much can be accomplished in a short period of time. However, work still needs to be done on how to best accomplish this and maximize the potential. Schedules and risk management of high profile programs are still problematic, and different approaches need to be undertaken to try and manage the fluidity of the multiple developments. However, with different approaches may come failure, and leaders within the Army are not too tolerant on that outcome.

7.0 References

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8.0 Author Biographies

PAUL BOUNKER is a Senior Project Engineer at the US Army's Tank-Automotive Research Development & Engineering Center, where he has been employed since 1994. He is currently the Team Leader of the Embedded Simulation (ES) Team. His research interests are in distributed simulation, virtual reality, advanced simulation architectures and intelligence modeling of vehicle systems. Mr. Bounker worked as a Project Engineer at the US Navy's Naval Aviation Depot in Norfolk, Virginia from 1989-1994. Mr. Bounker holds a BS degree in Electrical Engineering from Wayne State University in Detroit, Michigan.
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