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Paper Number

Experiences Linking Vehicle Motion Simulators to Distributed Simulation Experiments

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ABSTRACT

The Tank Automotive Research, Development and Engineering Center (TARDEC) has been at the forefront in developing the hardware and software for physics-based, ride motion simulation, for over 30 years. In order to share this capability with the simulation community, it is necessary to develop an interface to link these motion simulators with other DoD distributed simulations. Various technologies such as the Distributed Interactive Simulation (DIS), Network Data Delivery Service (NDDS™) and the High Level Architecture (HLA) have been used to try and accomplish this goal. The distributed simulations of interest are the Semi Automated Forces (SAF) ones such as, Modular SAF (ModSAF), OneSAF Test Bed (OTB) Version 1.0 and OTB Version 2.0. There have been five projects, which incorporated various levels of interoperability. These projects have provided extensive experience and many lessons learned to support the continuing effort to develop a more robust and flexible distributed simulation environment within the GVSL at TARDEC.

This paper will describe the current simulators and simulation environment at TARDEC, each of the five projects associated with developing a distributed simulation capability and the current ongoing effort to create a useful simulation federation consisting of the motion simulators and OTB Version 2.0. In order to develop this federation the Federation Development and Execution Process (FEDEP) is being used. The FEDEP is a generalized process for developing federations that has evolved from the activities and experiences of the simulation community.

INTRODUCTION

INTRODUCTION TO THE TARDEC PHYSICAL SIMULATION ENVIRONMENT – The TARDEC Ground Vehicle Simulation Laboratory (GVSL) has developed a unique capability with its RMS and CS/TMBS man-rated physics based vehicle motion simulators. These 6 degree-of-freedom (DOF) simulators provide the capability to recreate realistic vehicle ride motion characteristics within the laboratory. They can realistically simulate the motion, visuals and sound of a vehicle system. The simulators are currently configured for the following vehicles: HMMWV, M1, M2 and Stryker. These simulators are used to perform research into vehicle motion effects. They provide a controlled environment that is not affected by the kinds of variability that is found when performing testing in the field.

DESCRIPTION OF THE RMS AND CS/TMBS – The RMS and CS/TMBS are six DOF, man-rated, motion simulators used to perform research in the areas of military vehicle systems.

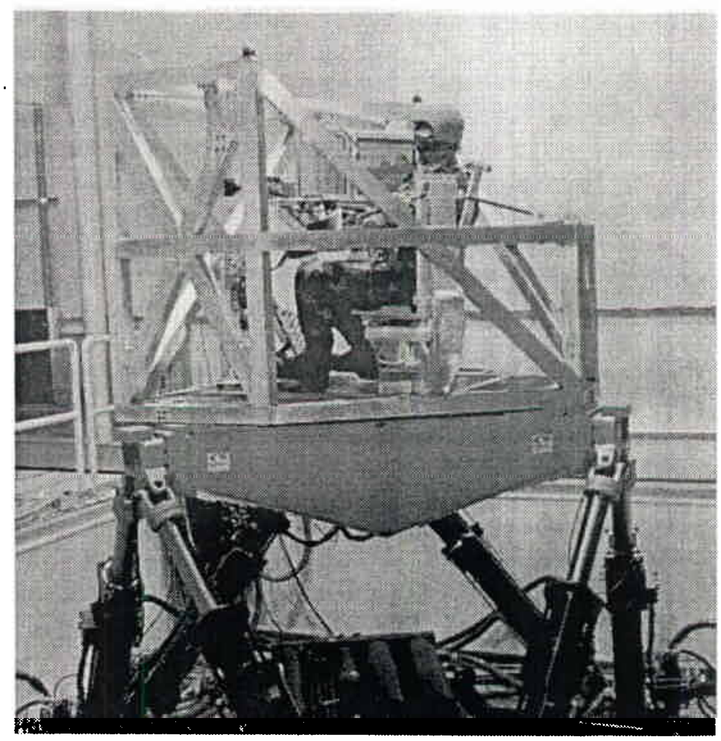

Figure 1. Ride Motion Simulator (RMS)

The RMS (Figure 1) is a reconfigurable simulator that is used to evaluate single person vehicle stations such as a driver or commander. The total system has a bandwidth of up to 40 Hz. The system is used for the following: Soldier-in-the-loop simulation, war-gaming exercises,

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **21 JUN 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Experiences Linking Vehicle Motion Simulators to Distributed Simulation Experiments**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Richard W. Jacobson**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **USA TACOM 6501 E 11 Mile Road Warren, MI 48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER **14068**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) **TACOM TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

crew station and component/development, and workload/task performance investigations.

The CS/TMBS (Figure 2) is also a reconfigurable simulator that is used to evaluate large, turret or crew stations. The system is capable of running with a fully active crew station. The CS/TMBS can support up to 25 tons. The total system has a bandwidth of up to 8 Hz. The system is used for the following: gun/turret drive characterization, control system algorithm development, turret system structure development, baseline vs. modified studies crew station and soldier/machine interface development.

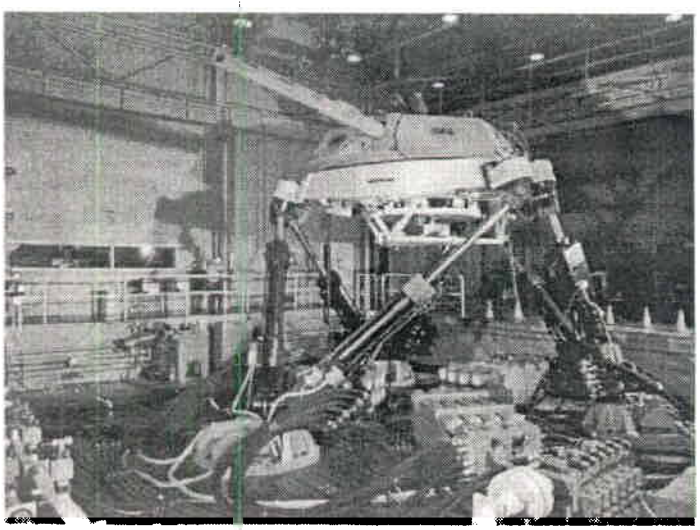

Figure 2. Crew Station/Turret Base Motion Simulator (CS/TMBS)

DISTRIBUTED SIMULATION – In order to make the RMS and CS/TMBS more available, it is necessary to have them participate in simulated military operations experiments, both locally and with other simulations/simulators around the country. In a "Distributed Simulation", different organizations can run different simulations/simulators and design experiments to evaluate things that affect military operations, like survivability, tactics, logistics, detectability, etc. These experiments may be configured between simulations running at the same installation, or they may involve systems in every corner of the country.

The Defense Modeling and Simulation Office (DMSO) initiated the standardization of simulation interoperability. This effort has produced the Institute of Electrical and Electronics Engineers IEEE Standard 1278 Distributed Interactive Simulation (DIS) and (IEEE) Standard 1516 for Modeling and Simulation (M&S) High Level Architecture (HLA). These two standards provide the framework that will allow legacy simulations to interoperate with current and future simulations. The DIS Standard 1278 was developed first and was a definition of the low level network protocols needed to communicate between simulations on a network. The experiences with DIS led to the development of the HLA Standard 1516 which describes a high level framework for the intercommunication of simulations. The focus of this paper will be on HLA.

A short description of HLA is necessary to provide a background in simulation interoperability. An HLA distributed simulation is called a Federation. The Federation consists of two or more Federates. A Federate is a single simulation. The list or description of all objects, attributes and interactions that is to be shared between all of the Federates in a Federation is called the Federation Object Model (FOM). Each simulation also has a list of the objects, attributes and interactions that it will share with the Federation. This is called the Simulation Object Model (SOM). The SOM is a subset of the FOM. All communication of data within a federation is done through the Run Time Infrastructure (RTI), which is a separate program from the Federates. The federation that is being developed within the GVSL consists of the RMS and an Army military combat simulation program called OneSAF Test Bed. OneSAF stands for One Semi Automated Forces.

In order to leverage all of the simulation work that has been done in the past, the Army is currently supporting an effort to combine its various Semi Automated Forces (SAF) simulations into a single simulation (OneSAF). Semi Automated Forces describes the simulations capability to create virtual forces, which exhibit the behaviors of real forces. This effort is progressing in phases in order to maintain existing simulation capabilities. This effort builds on the work done to develop Modular SAF (ModSAF). The current phase has produced the OneSAF Test Bed (OTB). OTB Version 2.0 has just been released. OTB is the recommended SAF to be used until the OneSAF Objective System (OOS) is completed in 2006.

VISION - In order to make RMS and CS/TMBS a better research tool, the TARDEC GVSL is developing the necessary simulation infrastructure to allow these simulators to link with other DoD simulations using HLA. As part of this effort an HLA federation is being developed which will consist of two federates the RMS and OTB Version 2.0. This federation will use the DMSO 1.3NGv6 HLA specification and Run Time Infrastructure (RTI). The development of the interoperability of HLA with the RMS and CS/TMBS will provide a more flexible and productive simulation environment. The past work on developing a distributed simulation environments for the RMS will be described in the next section.

LINKING TARDEC SIMULATORS INTO DISTRIBUTED SIMULATIONS

DESCRIPTIONS OF PAST WORK TO LINK THE RMS INTO DISTRIBUTED SIMULATIONS – Various projects within the GVSL have contributed to the knowledge of distributed simulation. There was an initial effort to use the DIS protocols. There was also some experience with a commercial software package called VR-Link, which is a program that aides in connecting simulatiors and virtual reality simulations. Two projects were performed to satisfy a mandate that Army simulations be HLA compliant. Two other projects provided insight into the process of creating distributed simulations. One project evaluated HLA as a possible method of providing interoperability, but it was rejected due to its limitations. The other project used HLA to communicate vehicle dynamics information into a OneSAF simulation.

RMS with Distributed Interactive Simulation (DIS) and ModSAF – During development of the initial code base for the RMS and CS/TMBS an attempt was made to implement the DIS protocol. A commercial-off-the-shelf (COTS) software package called VR-Link was used to provide an interface between the RMS and ModSAF, which it did very successfully. This implementation allowed the simulators to appear and move around within a ModSAF scenario. Unfortunately, there were issues within the C Object Oriented Programming System (COOPS) environment, which was being used for the RMS code development that prevented the two-way communication needed to provide full participation within a ModSAF scenario. The lesson learned from this effort was the limitations of the COOPS programming environment.

SOVAS and HLA – SOVAS [1] is a high fidelity, physics-based, real-time simulation of the dynamics of a ground vehicle. It can be used to determine vehicle handling characteristics and ride quality. It is one of the methods used to compute motions for the simulators in the GVSL. This project was established in order to satisfy a requirement for all Army simulations to be HLA compliant. It was decided at the start of this project to make SOVAS natively compliant rather than procure separate Gateway software like VR-Link.

SOVAS has achieved HLA compliance [1]. This was the first effort to make parts of the RMS and CS/TMSB supporting codes HLA compliant. The compliance test used the DMSO RTI 1.3NGv2 with a control and monitoring program and the SOVAS code as federates. The control program issued all of the commands necessary to test the HLA functionality of SOVAS.

The work on the SOVAS HLA compliance provided extensive experience about the complexity of the code necessary to meet HLA requirements. This project required over 12,500 lines of code. The HLA code does not only provide a framework for the communication of information about objects, attributes and interactions, but it also requires an extensive amount of bookkeeping about all of the data. Another important lesson learned was how firewalls, and network security in general, affect distributed simulations over the wide area. There was a lot of time spent trying to open up ports and protocols on the various firewalls in order to run the HLA certification testing between TARDEC and DMSO. This project took longer than expected, because of the network problems and the extra time needed to write the control and monitoring program.

First effort to implement HLA in the RMS software – After SOVAS achieved HLA compliance an effort was started by members of the GVSL to implement HLA capability into the RMS code. This project was established for the same reason as the SOVAS HLA project, to satisfy a requirement for all Army simulations to be HLA compliant. It was also decided to make the software natively compliant rather than purchase commercial software like VR-Link.

The existing DIS routines within the code were disabled. The RMS code base was modified to include all of the required functions required by the HLA Federation Rules. The data that was to be passed from the RMS software was position, velocity, acceleration and vehicle orientation. In order to test the modified RMS software a control and monitoring program, similar to the one used for the SOVAS HLA compliance testing was created. The control and monitoring program acts as a driver for the compliance testing process by sending requests to the RTI to activate responses from the RMS software. It also acts as a monitor to see if all of the federation interactions respond correctly. This implementation used the DMSO 1.3NGv2 RTI.

This project required an extensive amount of programming of the RMS code and the control and monitoring program. During certification testing it was found that the HLA code seemed to be very fragile. The code would hang and crash for no apparent reason. As with the SOVAS certification project it was found that the work always took longer than planned.

The Dynamic Reconfigurable Engineering Workstation (DREW) – The DREW [6] project was another effort by TARDEC that developed engineering level simulations that would provide interaction of vehicle simulators over the Internet. The project's main goal was to show how simulators could be used to perform design optimization studies from remote locations. This project evaluated HLA and Network Data Delivery Service (NDDS™) for its communications protocol. NDDS™ was selected because it provided more reliable update rates, message ordering and the monitoring of latencies. This kind of reliability was needed because of the need for high-speed update rates.

The project was a success, but it did not provide a link to DIS or HLA. Some type of HLA or DIS interface would have allowed the simulators to participate in other distributed experiments. It was observed during this project that the HLA/RTI needed additional time to mature and that this effort would make a good case for developing a real-time RTI with the features required by the DREW.

Vehicle Dynamics and Mobility Server (VDMS) – The VDMS provides a means of simulating, in real-time, high-fidelity, multi-body vehicle dynamics, off-road vehicle-soil interaction, collision detection and obstacle negotiation. It also includes the ability to apply autonomous control algorithms to a vehicle. The VDMS capabilities can be applied to a vehicle in a distributed experiment. The vehicle dynamics code used in this project is the same used for the RMS.

VDMS was used in the Fall 2001 Simulation Technology (SIMTECH) Research, Development & Engineering Center (RDEC) Federation Calibration Experiment (CalEx) [3]. The VDMS was used to evaluate the cross-country motion of up to ten robotic vehicles. In this experiment VDMS communicated with HLA through a Network Interface Unit (NIU) specifically developed for this project by the TARDEC Vetronics Technology Area and the dynamics code was developed from work from the National Advanced Driving Simulator and Simulation Center (NADS-SC) at the University of Iowa.

More recently VDMS was rewritten and used to support the Modeling Architecture for Technology, Research, and Experimentation (MATREX) and to support the Developmental Test Command (DTC) with the Virtual Proving Ground (VPG) [9]. The rewrite was necessary to provide a better capability for vehicle representation and to reduce the amount of computer resources required. VDMS provided an engineering level simulation of vehicle dynamics and drivetrain performance. The GVSL and the Vetronics Technology Area of TARDEC worked together to support these two projects. In the work with the Virtual Proving Ground [9] VDMS was used to provide vehicle positions and orientations for a Stryker vehicle. This data was communicated through an NIU to a simulated vehicle in OTB using the DIS protocol. A MÄK HLA Gateway was used to communicate the vehicle data to other participants within the Virtual Proving Ground.

The VDMS projects provided experience in the development of an NIU for HLA. It also provided an opportunity to make improvements in the dynamics part of the VDMS code.

RMS – OTB VERSION 2.0 COMMUNICATIONS USING HLA – This previous work with HLA and various technologies associated with the GVSL simulators showed that a more integrated HLA based simulation environment would help to reduce the effort needed to incorporate new technologies with the RMS and CS/TMBS. In order to provide this capability to the greatest audience the effort is being focused on OTB and its successor OneSAF Objective System (OOS). OOS is being developed to be the next generation Computer Generated Forces (CGF) that can represent and control a full range of operations and systems.

All of the past projects that have been described had specific and narrow objectives. In order to create a robust and flexible environment it is necessary to create a true HLA Federation. This is the reason that the FEDEP is being used. Many of the items in the FEDEP are not applicable to this project, but by formalizing the process it creates a framework that will allow future Federations to be generated much more easily.

There are many facets of the RMS environment that need to be understood and coordinated in order to make a complete link between the motion simulators and a distributed simulation environment such as OTB. Some of the information needed includes the following: vehicle characteristics, vehicle orientation, vehicle location within the terrain database, vehicle speed and direction, and how the terrain will be visualized within the simulator. In addition, there are the HLA aspects, which include: the Run Time Infrastructure (RTI) to be used, development of the Federation Object Model (FOM) and the Simulation Object Model (SOM) for each separate simulation within the distributed environment. These Object Models formally set forth all of the data to be shared within a distributed simulation.

Much of the preliminary work necessary for the creation of an integrated HLA interface for the RMS and CS/TMBS is already available. In order to validate that effort a federation consisting of the RMS and OTB Version 2.0 is being implemented. The Federation Development and Execution Process (FEDEP) version 1.5 is being used to plan and formally document this effort. The FEDEP version 1.5 is a 6 step process that has been developed by the simulation community to provide a way of organizing the activities that might be needed in putting together a distributed simulation. The following is a summary of the activities performed in each step of the FEDEP to create a distributed federation linking the RMS with OTB version 2.0:

Step 1: Define Federation Objectives – The Federation Objective is a force-on-force engagement at the platoon level with the RMS represented as a separate vehicle. This vehicle must be able to observe the engagement and be seen as a vehicle in the scenario. The RMS software must be capable of receiving information about instances of vehicles in OTB and display each individual vehicle accurately as well as their movement. Each vehicle that can be represented by the RMS will be tested with the OTB scenario.

Step 2: Develop Federation Conceptual Model –The Federation Conceptual Model provides more detail about each federate within the federation. The OTB Federate will be running the force-on-force scenario. This scenario will consist of a blue force M1A2 tank platoon moving to a defensive location and a red force will be a T80 tank platoon that will be attacking along a line that will intersect the blue defensive position. The RMS will be configured as one of four vehicles, HMMWV, M1, M2 or Stryker. The RMS vehicle will move with the blue force to the defensive position and then observe the red force approach and observe the engagement.

Step 3: Design Federation – A force-on-force scenario has been developed and tested in OTB version 1.0. The scenario will be configured in OTB version 2.0 using the Military Scenario Development Environment (MSDE). MSDE is part of the OTB version 2.0 software distribution. In order to have an RMS federate, it is now necessary to determine the capabilities of the RMS software. In order to support all of the HLA requirements, that have been defined in Step 1 and Step 2 the RMS will need to provide its location, velocity, direction and orientation. It will also have to be able to accept information about instances of other vehicles from OTB and display those vehicles in the correct location

Step 4: Develop Federation – Development of the federation will require detailed analysis of each federate in order to develop their Simulation Object Models. The Simulation Object Model is the list of data in a simulation that has been formatted in accordance with the HLA Object Model Template.

The following activities will be necessary to complete this step:
1) Determine all of the objects, attributes and interactions that need to be communicated from the RMS. This will be the Simulation Object Model (SOM) for the RMS software.
2) Select a suitable Federation Object Model (FOM) that is supported by OTB. This will also be the SOM for OTB.
3) Make sure that all of the data described by the RMS SOM is also in the OTB SOM/FOM.
4) Make the necessary modifications in the RMS software to satisfy HLA requirements.

Steps 5 & 6 – Integrate and Test Federation and Step 6: Execute Federation and Prepare Results – These steps consists of testing the Federation to correct any problems. Once the Federation has been successfully integrated it will be run several times with the RMS configured as a different vehicle. In addition the path that the RMS vehicle takes will be modified to test how well the RMS can drive within an OTB scenario.

CONCLUSION

Linking the RMS and CS/TMBS to other distributed simulations is an important capability. It will give researchers, testers and trainers another tool to use to provide the best equipment to the soldiers in the field.

The process of linking legacy software into a distributed simulation is a non-trivial task. The Federation Execution Development Process provides an excellent framework to guide these kinds of activities, however there is an extensive amount of detail that must be filled in by the user.

There have been many lessons learned about the development of HLA compliant simulations, specifically the need to provide sufficient time to write and test software. In addition the requirements for network communication must be addressed early in the project. Many of the projects required the development of additional software to provide an HLA capable simulation. The FEDEP is an excellent tool which can focus the effort to create a distributed simulation environment using HLA.

ACKNOWLEDGMENTS

The following members of the TARDEC GVSL and High Performance Computing Group provided invaluable assistance in the preparation of this paper: Pat Nunez, Kevin Hope, Martin Novak, Cesar Lucas, Scott Valentine, Mark Brudnak, Dr. David Lamb, Victor Paul, Stacy Budzik, Dr. Al Reid.

REFERENCES

1. Dr. David A. Lamb, "High Level Architecture and the SOVAS Modeling System: Lessons Learned While Achieving Compliance", 2002 Summer Computer Simulation Conference
2. Mark Brudnak, "TACOM-TARDEC Ground Vehicle Simulation Laboratory", unpublished presentation to the LSI SDD M&S Planning Meeting, October 9-10, 2002.
3. Mark Brudnak, Patrick Nunez, Alexander Reid, "Real-time, Distributed, Unmanned Ground Vehicle Dynamics and Mobility Simulation, SAE Paper 2002-01-1178, 2002 SAE World Congress, 2002.
4. Defense Modeling and Simulation Office (DMSO), "High Level Architecture Federation Developmeent and Execution Process (FEDEP) Model, Version 1.5, December 8, 1999,
5. Jake Borah, "Insights into Federation Development Issues", Tutorial at the 2003 Fall SIW.
6. Stacy Budzik, Patrick Nunez, Yiannis Papelis, Dario Solis, "Dual Use Vehicle and Heavy Equipment Virtual Proving Ground (VHEVPG)", IVSS-2002-MAS-05, NDIA 2nd Annual Intelligent Vehicle Systems Symposium, Traverse City, MI, June 2002.
7. Patrick Nunez, Alexander Reid, Randy Jones, Sally Shoop, "A Virtual Evaluation Suite for Military Ground Vehicle Dynamic Performance and Mobility", SAE Paper 2002-01-3049, 2002 SAE World Congress, 2002.

8. Mark Brudnak, IV.GC.2003.01 Execution Plan, High-fidelity Ground platform and Terrain mechanics Modeling (HGTM), as of Dec 9, 2002
9. Anthony Docimo, Gerald Hinkle, Geoff Sauerborn, "Vehicle Dynamics in the Virtual Proving Ground (VPG) Synthetic Environment Integrated Testbed (SEIT)", 04S-SIW-034, 2004 Spring Simulation Interoperability Workshop, April 18-23, 2004

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

CGF – Computer Generated Forces

COOPS – C Object Oriented Programming System

CS/TMBS – Crew Station/Turret Motion Base Simulator

DIS – Distributed Interactive Simulation

DMSO – Defense Modeling and Simulation Office

GVSL – Ground Vehicle Simulation Laboratory

Mbps – Mega bits per second

OneSAF – One Semi Automated Forces

OTB – OneSAF Test Bed

RMS – Ride Motion Simulator

SCRAMNet – Shared Common RAM Network

SOVAS – Symbolically Optimized Vehicle Analysis System

VDMS – Vehicle Dynamics and Mobility Server