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IVSS-2003-MAS-XX

A Ground Vehicle Simulation Design to Study Driver Display Concepts

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ABSTRACT

The Tank Automotive Research, Development and Engineering Center's (TARDEC) Motion Base Technologies (MBT) team develops and applies simulation capabilities for the evaluation of emerging vehicle technologies. Currently, the MBT team is configuring its Ride Motion Simulator (RMS) [1] to investigate vehicle-driving performance using two indirect vision display methods. The investigation will focus on a driving simulation comparing three, flat-panel displays with a Head Mounted Display (HMD). This study will involve several subjects who will drive a modeled Stryker vehicle across a rendering of Aberdeen Proving Ground's (APG) Churchville terrain. Subjects will drive across different segments of the course at various speeds with each display type. Measures of driving performance will be taken and compared for each display type.

This paper describes the design of this simulation, which includes the development, and integration of many subsystems working together in order to meet the experiment objectives. There are numerous subsystems that will be discussed further in this paper including; vehicle dynamics, head mounted and flat panel displays, head tracker, sound, visual overlays, data acquisition, RMS motion and washout algorithm, terrain and visual database, experiment and protocol design, RMS driver console and control loading. The effort directly supports the use of high-fidelity driving simulators for vehicle design and occupant feedback in order to adapt new technology to the soldier.

INTRODUCTION

High fidelity driving simulator development and application has been steadily growing in the past few years. This is due to increased demand for full-scale ground vehicle simulations in order to reduce costly prototype development and testing as well as the desire to rapidly bring new vehicle systems to the user. A number of crew-centered technologies being developed today require studies be performed on simulators to ensure the technology design is proven. Some of these technologies involve trade studies for driver controls and display systems for indirect driving. Indirect driving is a technique where the vehicle driver views are displayed on display screens rather than directly looking through windshields or vision blocks. Cameras, appropriately placed on the exterior of the vehicle, produce either a video or enhanced image of the outside environment that is displayed on a screen for the vehicle driver. Indirect vision systems in military vehicles can result in vehicle designs that are safer for the crew since a direct line of sight for the driver is not required. Head mounted displays, for driving purposes, carry the indirect display one step further in that the driver is more immersed in the scene. Data can be displayed within the scene as well as providing the driver with additional navigation or other information. A head or eye tracker can render the scene per the direction of the driver's head or eyes. Different head mounted displays are available for various applications. The simulation described in this paper was designed to determine driver performance measures between using flat panels versus a head mounted display for the indirect driving function.

SIMULATION REQUIREMENTS

To be an effective aid for vehicle and crew station developers, a driving simulator should contain a number of simulation subsystems. Most high-end and several mid-level driving simulators contain motion bases for enhanced cueing, as well as visual, and cab control loading subsystems [2]. For the work described in this paper, the following subsystems were selected for development; flat panel display, head mounted display, motion, protocol, driver console, vehicle dynamics, terrain and visual database, audio, data acquisition, and integration. Furthermore, these subsystems must be seamlessly integrated in a synergistic simulation for smooth and real-time operation. The requirements determined for this project are described below.

FLAT PANEL DISPLAYS – The display should mimic the target vehicle application that is the current two-man crew initiative for Future Combat Systems and other applications.

HEAD MOUNTED DISPLAY – A wide Field-Of-View (FOV) for vehicle driving combined with good resolution is required. A head-tracking device to determine head angular motion is required.

MOTION – A motion base simulator to produce motion cues for the driver is required.

PROTOCOL – An experiment design to determine driver performance for each display system is required.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **02 JUN 2003**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **A Ground Vehicle Simulation Design to Study Driver Display Concepts**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Meldrum, AnnMarie; Paul, Victor J.; Reid, Alexander; Zywiol, Harry J. Jr**	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **USATACOM 6501 E 11 Mile Road Warren, MI 48307-5008**	8. PERFORMING ORGANIZATION REPORT NUMBER **13866**
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 **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**9**	

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

DRIVER CONSOLE – A console with driver's steering wheel, accelerator and brake pedals, gear select, seat with restraint are required to provide the basic controls for driving.

VEHICLE DYNAMICS – A vehicle model that reacts properly to road and driver inputs. This model provides the motion states that ultimately produce the cues for the visuals, motion base, and audio systems.

DATABASE – A database that offers a variety of driving conditions including sweeping turns, hills, and cross-country is required.

AUDIO - Within own vehicle sounds produced at an appropriate sound pressure level are required.

DATA ACQUISITION - A data acquisition system that records and enables analysis of key variables is required.

INTEGRATION – Software is integrated such that the simulation has low latency but is flexible to permit data acquisition.

These subsystems are described in depth here.

FLAT PANEL DISPLAYS

The RMS cab, often referred to as the "Wheeled Vehicle Cab" shown in Figure 1, consists of a space frame with three, large rear projection screens for its display system.

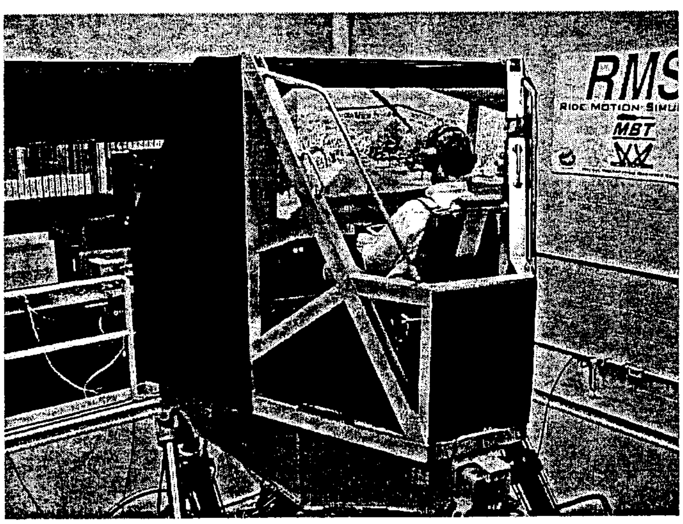

Figure 1. RMS Wheeled Vehicle Cab

This display system is comprised of three JVC D-ILA® Model DLA-S15 Series light valve projectors. These projectors provide SXGA resolution at 1365 x 1024 native resolution. A brightness value of 1500 ANSI lumens with a contrast ratio of more than 350:1 allows operation of the display even in standard room lighting. The Computer Generated Imagery on the screens is displayed by an Evans and Sutherland ESIG-HD/3000® system. This system allows for simulation of an out-the-window view.

The Army has a requirement for sophisticated, highly integrated crew stations for future combat vehicles. In support of this effort, TARDEC is developing the Crew Integration and Automation Testbed (CAT) Advanced Technology Demonstrator (ATD). The purpose of the CAT-ATD is to investigate and research new crew interfaces, automation, and integration technologies that are required to operate and support future combat vehicles. The experiment in this paper attempts to reproduce essential elements of the CAT-ATD display system for driving purposes. A concept of the system is depicted in Figure 2.

The RMS cab was configured to produce the CAT-ATD indirect view consisting of three 21-inch diagonal displays, providing a total FOV of 120° HFOV x 30° VFOV. Each display renders the indirect view and driver instrument and gauge readings.

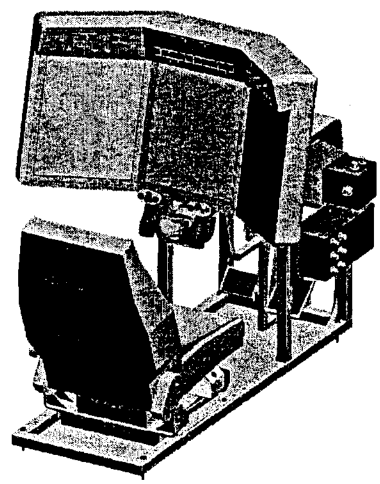

Figure 2. Concept CAT-ATD Crew Station

Vital driving information (speed, direction and transmission gear) has to be relayed to the driver during the tests. For this experiment, there are two different sets of symbology. For the flat panels, it was desired to replicate as much of the proposed CAT-ATD symbology as possible. The size, position and layout of this symbology were determined not appropriate for the HMD so it was decided to use a heads-up-display technique and overlay this information upon the visual scene. Specialized software and hardware is used to create and display both types of symbology.

The symbology was developed using a software package called VAPS from eNGENUITY Technologies in Montreal, Canada. VAPS allows the designer to layout a display, properly position it, and update its properties. Thus, a digital speedometer, compass and gear-select were created in VAPS and linked to the real-time simulation environment via a SCRAMNet® reflective memory network. This allowed the symbology display to get updated vehicle speed, heading and power train gear information in real-time. A rendering of the symbology design is shown in Figure 3. The indirect view is rendered in a 14.4 inch diagonal view on the top portion of the design, while the symbology is rendered on the bottom portion.

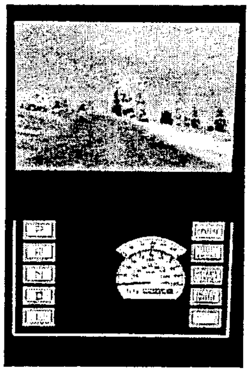

Figure 3. Symbology Design

Once this display was complete, it needed to be mixed and overlaid with the visual scene from the ESIG 3000HD. To achieve this, a RGB Spectrum® Synchromaster® 550 was used. This device allows for the input of two video signals, the desired background and symbology. It then uses a real-time chromakeying technique to overlay the symbology upon the background and outputs the resultant video signal. The resolution, sync and timing of the output video signal can be adjusted to drive either the HMD or the flat-panels.

HEAD MOUNTED DISPLAYS

HMDs, rendering a synthetically generated environment, offer a greater level of immersion than the traditional flat panels to the user. The MBT team selected a Kaiser ProView™ XL 50 for use in the GVSL CAT-ATD experiments. See Figure 4. The decision was based on the need for a HMD with the largest field of view possible, yet economical in cost. The XL 50 features full-color XGA stereo-scopic performance with 1024H x 768V resolution. It has a 50° diagonal field of view, (30° V x 40° H), a resolution of 2.3 arcmin per color pixel and transmission is non see-through. The optical modules are mounted on the same ergonomically designed headband system used on all ProView™ HMDs [5].

Figure 4. Kaiser ProView™ XL 50 Error!

For this experiment, it is crucial to detect and measure the test subject's head motion. The reason is twofold: 1) to determine where the subject is looking, allowing for the appropriate scene to be rendered, and 2) to determine how the test subject's head is moving in the dynamic environment of the RMS, which affects the image the participant sees.

There are numerous head-tracking devices commercially available. Several use a magnetic field to measure the head movement. This type was deemed impractical because of the large amount of metal in the laboratory due to the predominately aluminum RMS cab. MBT Engineers, instead, chose an InterSense IS-300 Pro Orientation Tracker. See Figure 5. The IS-300 is an inertial 3-DOF orientation tracking system. It obtains its primary motion sensing using a miniature solid-state inertial measurement unit, called an InertiaCube™, which senses the angular rate of rotation, gravity and the earth's magnetic field along the three perpendicular axes. The angular rates are integrated to obtain the orientation (yaw, pitch, and roll) of the sensor. The InertiaCube is mounted to the top of the HMD. This head tracker virtually eliminates the jitter common to other systems. This has been a major deficiency and source of simulator sickness in immersive head mounted display applications. It offers a fast response with an update rate of up to 500 Hz, for very low latency tracking. The tracker offers smooth, steady response, even in noisy, metal-cluttered environments. The tracker has an unlimited range such that there is little setup, no line-of-sight constraints and virtually unlimited operating range. With a 50-millisecond prediction algorithm, this helps to reduce latency delays when coupled with an image generator [6].

A second InertiaCube™ was mounted to the motion base motion so its angular motion could be accounted for. For the simulation, relative head motion is desired to be calculated per equation (1).

Relative head motion = Head motion (measured) – RMS Base motion (1)

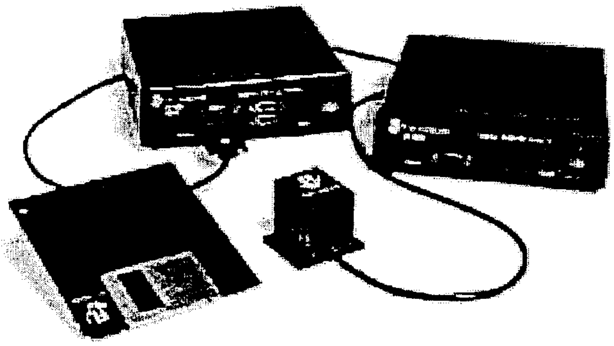

Figure 5. InterSense IS-300 Pro Head-Tracker

MOTION BASE

The motion base selected for the design is the 6 degree-of-freedom hydraulic Ride Motion Simulator [1]. It is capable of producing the ride dynamics of the Stryker in the Aberdeen Proving Grounds scenario for the simulation. The motions of the simulated vehicle will extend far beyond the limited travel of the motion base (several miles as opposed to several feet). Therefore, an algorithm is needed to transform the actual vehicle motion into excursions which remain within the capability of the motion base. This algorithm attempts to present angular rate and linear specific forces to the driver as these are generally accepted as the most important motion cues [7].

PROTOCOL DESIGN

A protocol was written for this experiment by the MBT team and the U.S. Army Research Laboratory, Human Research and Engineering Directorate (HRED). The protocol introduces the background to the study, the overall objective, and summarizes what the experiment is about. It describes all the equipment being used and the roles and responsibilities of all involved. HRED developed the human factor aspects of the experiment and provided an experiment design and copies of subjective questionnaires to be administered to the subjects. The MBT team is responsible for conducting the experiment, managing all integration of all subsystems, collecting the data and writing a technical report. HRED will train and test subjects on their tasks, administer questionnaires, conduct statistical analysis of the experimental results and co-author a technical report with the MBT team. The data analysis portion by HRED will consist of the driving performance data and will be considered as a fixed factorial 2x4x2 experiment (number of displays x vibration levels x road turns), analyzed for correlated measures in separate multivariate analyses of variance for levels and turns.

DRIVER CONSOLE

A driving console was designed and built for the RMS cab to allow real-time man-in-the-loop driving on the simulator. This console consists of a HMMWV instrument panel, brake and accelerator pedals and a steering wheel mounted to a steel framework. Inside the framework, a servo-controlled torque motor receives commands from the vehicle dynamics model to provide the appropriate steering feedback to the driver. In addition, the torque motor's internal encoder reports the driver's steer input to the vehicle dynamics model. To create realistic brake feel, the brake pedal was attached to a dual spring apparatus with each spring having a different spring constant. This allowed for a non-linear break force typical in ground vehicles. A potentiometer was also mounted to the pedal to provide brake pedal position to the vehicle dynamics model. Accelerator pedal feel was accomplished by mounting an automobile throttle body assembly to the framework and attaching its cable to the accelerator pedal. The throttle position sensor was used to provide throttle position to the vehicle dynamics model. In addition to the above framework, a pedestal was fabricated for the HMMWV gear shifter. Five miniature optical switches were used to determine the shifter position and send that information to the vehicle dynamics model.

VEHICLE DYNAMICS

In the fall of 2001, TACOM's Vetronics group conducted a series of indirect driving experiments utilizing their VTT crew station in the back of a M2/M3 Bradley Fighting Vehicle. An effort is underway to move the next generation of that crew station into a variant of the Stryker 8x8 wheeled vehicle. Because of this, the MBT team decided to use a wheeled 8x8 for this experiment. Because of its ease of use and real-time performance, Real-time Technologies Inc.'s SimCreator was selected and utilized for model creation.

SimCreator is a graphical modeling environment that allows users to "wire-up" components to create models of systems and run them in real-time either locally or distributed across different machines located on a network. Users can choose from a number of predefined components or create their own components in order to create their model. The General Vehicle Dynamics System (GVDS) component of SimCreator allows for easy creation of high fidelity, real-time vehicle dynamics models by providing a core dynamics engine and multi-body dynamics components to quickly assemble complex representations of ground vehicle systems [4]. SimCreator can generate C code that interfaces with the GVSL's real-time simulation environment and provides real-time vehicle dynamics for RMS experiments.

The real-time dynamics model is a somewhat generic 8x8 model with Stryker Infantry Carrier Vehicle (ICV) characteristics. See Figure 6. Actual Stryker data were gathered and incorporated into the model. The model construction was a joint effort between Real-time Technologies (RTI) and TARDEC.

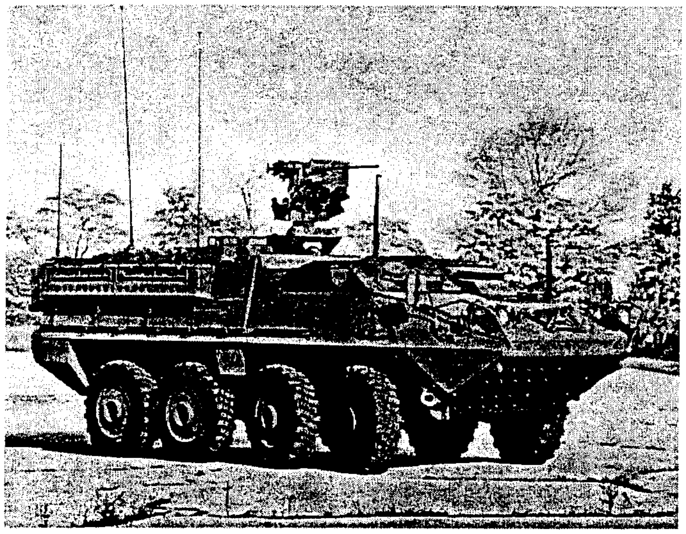

Figure 6. Stryker Infantry Carrier Vehicle (ICV)

The ICV is modeled as nine separate rigid bodies and a power-train component. The rigid bodies consist of a primary "hull" body and eight wheel station bodies. The hull body represents the mass and inertia properties of the ICV while each wheel station models the suspension, tire and damping data. Steering is achieved by a system of constraint equations derived from the vehicle's steering geometry. The power train is built from several predefined power train components from within SimCreator. It requires several inputs from the upper level of the model (individual wheel torques, acceleration pedal position, brake pedal force, and gear selection). With these inputs, the power train is able to return engine torque, engine speed, and wheel velocity back to its parent components.

The real-time vehicle dynamics model runs at a rate of 500 Hz on an SGI Origin® 2000 workstation. The model receives gear selection, acceleration, brake and steer commands from the operator controls located on the RMS. The dynamics model in turn provides its position on the database (x, y and z), its orientation (heading, pitch and roll), its global body accelerations (all 6 DOF), vehicle speed, engine RPM and steer torque back to various processes within the simulation.

TERRAIN AND VISUAL DATABASES

In order to create a realistic driving simulation, the driver needs to feel as if they are piloting an actual vehicle across some given terrain; they need to control where they are going, hear what is going on around them, feel the motion of the vehicle and see where they are going. The terrain and visual databases play a big role in achieving this, especially the latter two items. A distinction is made between these two types of databases because they are used for different aspects of the simulation, and at times, are separate and unique collections of data.

The visual database is exactly what one would expect: a visual representation of the world from the perspective of the test subject. The terrain database provides the surface information (elevation, soil characteristics, surface normals, etc.) to the real-time dynamic model in order to realistically stimulate the vehicle dynamics.

Visual databases are typically constructed to represent areas of interest to the modeler, war-gamer, tester, game player or a host of other users. They are rendered in real-time (30 Hz or better) using an image generator (IG) computer. IGs range from simple PCs with a graphics card to large, custom built systems with high-end capability. The building block of the visual database is the polygon, which can represent a portion of ground, vehicle, building, tree or any type of object which will be displayed by the IG. One thing all IGs have in common is that there is a limit to the number of polygons that they can render in 30 Hz real-time. Typically, the more money you spend, the more polygons you can render in real-time.

Most visual databases are constructed using thousands upon thousands of polygons. While the IG is designed to neglect polygons that are not in the field-of-view, it still may have to sort through thousands that are in the field-of-view before it can render an image in real-time. Because of this limit to the number of polygons that an IG can render in real-time, terrains are usually built to a fairly low level of resolution, with terrain polygon sizes usually approaching 30 meters or larger.

Due to the rough construction of the visual databases, there is extremely little high-frequency ground content to help the virtual terrain realistically represent an actual cross-country terrain. This does not bode well for use in a motion based, driving simulation environment where both visual features and terrain elevation information need to both be at the highest resolution possible in order to immerse the test subject into the simulation. There are a few approaches that one can take regarding this dilemma: build a smaller visual data base but at a very high resolution; build a regular database with high resolution in particular areas of interest; or have a totally separate terrain database that is correlated to the visual one. Each choice brings with it challenges when in a motion simulation environment. For our experiment, we chose the second approach.

A rendering of the selected Churchville B course is shown in Figure 7. The initial database information was provided from the Virtual Proving Ground group at APG. The University of Iowa modified the database to increase the fidelity of the roads and increase the number of features. This took care of our visual requirements. Next, we needed to be able to send terrain elevation information to the vehicle dynamics model in order to "feel" the terrain.

Figure 7. Visual Representation of APG's Churchville B Course

The GVSL's current terrain query directly queries a polygonal dump of the OpenFlight representation of the visual database. With this approach, the terrain query is able to get elevation and normal information at any point on a polygon without the burden of a massive terrain file. This technique also reduces the amount of process start-up time during simulation run time.

AUDIO GENERATION

Audio cues provide lots of information in a simulation, especially a driving type, and assist in immersing the participant into the virtual world of the simulation. Information such as vehicle engine speed, the relative position of other objects in the simulation can be derived from the direction and volume of audio sounds. For this experiment, the MBT team used the Vega™/Audioworks2™ software from Multigen-Paradigm Simulation. The Audioworks2 software renders sounds in a spatially correct environment. It includes an audio rendering component that models the physical properties of sound such as Doppler shift, range attenuation and propagation delay.

For our experiment, only a sound representing engine noise was required for the simulation. To capture the most realistic sound possible, the base engine audio recordings were taken from an actual Stryker ICV running at the Army Corps of Engineers', Waterways Experiment Station located in Vicksburg, Mississippi. This base engine sound is positioned with the vehicle model and moves with it in the virtual environment. The sound is also varied by rising or lowering both the pitch and volume of the engine sound based on a normalized value of the engine RPM value. The raw RPM value comes from the vehicle dynamics model's power train component and is normalized by the audio process. As the participant accelerates the vehicle, the engine sound gets higher in pitch and louder in volume. Because the sound is based on engine RPM and not vehicle speed, the participant will also hear the sound vary as the power train model shifts gears.

Sounds can also be assigned to and moved with other objects (other vehicles, etc.) or be based on events in the simulation (weapons firing, explosions, collisions, etc.) to further increase the experience for the simulation participant.

DATA ACQUISITION

The focus of the data collection activity is to capture data that, after analysis, will show any differences in driver performance while using the two different display methods. The ARL test protocol called for four separate driver performance measures and several subject questionnaires in order to achieve this. The performance measures were: road following accuracy, speed of travel, forward/lateral acceleration and steering wheel reversals. In addition, the MBT team added the 6 platform accelerations (x, y, z, roll, pitch and yaw) of the RMS in order to measure the dynamic environment in which the participant was subjected to and to monitor the simulator's performance.

Some of the performance measures can be determined directly at run-time (speed of travel and forward/lateral acceleration) while others will have to be extracted from other data collected. In order to measure road following accuracy, the visual database is coded with a terrain type to reflect roadway/non-roadway. At runtime, this terrain type will be determined with each terrain query by the vehicle dynamics model. Post-run data reduction and analysis will yield the road following accuracy. Steering reversals will be determined by post-processing data from the encoder on the steering wheel, which gives the exact position of the steering wheel during the run.

In order to collect all of the data, a real-time simulation data recorder was developed. This data recorder has the ability to record any variable internal to the distributed simulation such as vehicle dynamics model variables or terrain query results and write them to a file. In an effort to keep all of the data collected time-correlated, a method was needed to take externally measured data and record it with the internal simulation data. This will be achieved by outputting the six RMS accelerations through its controller's analog outputs. Those signals will then be re-digitized by another computer that places the information onto the SCRAMNet® reflective memory ring. Once the signals are on the SCRAMNet®, they are visible to the real-time data recorder and can be captured with the other data.

Because this method involves outputting analog signals and re-digitizing them, this process has to occur at a higher rate than the real-time data recorder in order to account for latencies and maintain the desired time correlation. A summary of all of the data to be collected can be found in Table 1.

Channel Name	Source
Steering Position	Steering Wheel Encoder
On Road Status	Terrain ID from terrain query
Vehicle Speed	Vehicle dynamics model
Vehicle forward acceleration	Vehicle dynamics model
RMS fore-aft acceleration	RMS Controller
RMS lateral acceleration	RMS Controller
RMS vertical acceleration	RMS Controller
RMS roll acceleration	RMS Controller
RMS pitch acceleration	RMS Controller
RMS yaw acceleration	RMS Controller

Table 1. Data Acquisition Channels

Once all of the data is collected, it will be reduced and an ANalysis Of VAriance (ANOVA) will be conducted to look at difference, if any, in driving performance. The ANOVA, along with analysis of the subject questionnaires, will be used to determine if the HMD display method should be further explored for use in ground vehicles.

INTEGRATION

This simulation is comprised of many different components. Several components run as separate processes and are distributed across several machines linked on a network. This results in a large effort to integrate the different pieces of the simulation and ensure that they all receive and provide all of the necessary information in a scheduled, deterministic fashion. Many elements of this simulation had already been integrated previously in the GVSL's real-time simulation environment (motion, washout, sound, dynamics, and visuals) [1]. There were several new components however. The most challenging of these were the HMD/head tracker items.

In operation, the HMD provides the occupant with an immersive scene in the direction the driver is looking. In actual vehicle operation, the HMD scene can be electronically coupled to remote external vehicle cameras pointed in the direction of the driver's head. Measuring the driver's head movement requires a head tracker, which measures head rotation described earlier. As the occupant rotates their head, the head tracker measures rotational positions and writes those positions to the SCRAMNet® reflective memory. A separate process on another machine takes those rotations and adds them (or subtracts them depending on their direction) to the movement of the vehicle dynamics model. The result forms the eye point position in the simulation.

CONCLUSION

The simulation design presented in this paper offers the researcher or vehicle designer a flexible, yet high-fidelity laboratory simulator to address any number of crew station design issues. Currently, an experiment protocol is being planned that employs the flat panel versus head mounted display as an independent variable. Driver performance measures will determine how well each display system works in a cross-country scenario.

It is possible the simulation design may also be used to investigate a number of other crew station design issues such as;

- Performance and subjective comparisons between joystick, yoke, and steering wheels for driving.

- The optimum display method and determination of what of data and visual information should be presented in a head mounted display.

- Whether an eye tracker combined with a head tracker is required to render the scene to the driver.

Army researchers are exploring the ground vehicle simulation design for use in robotic applications and other tasks. Tele-operating an unmanned ground vehicle (UGV) when both control and robotic vehicle are in motion presents a number of challenges for the control operator. This is because the operator is continuously experiencing different and therefore conflicting (de-coupled) visual and motion cues. The tele-operation task coupled with command and control tasks could present situations too difficult for the soldier to handle. To create a tele-operations scenario using a simulator, it is important to reproduce the de-coupled motion and visual cues properly. The simulator system described in this paper is capable of de-coupling the visuals with the motion. Therefore the Ride Motion Simulator, configured as a driving simulator, can help precisely determine what soldier degradations might occur and also help to explore mitigating techniques to reduce performance loss.

Other Army researchers are considering using the simulator designs presented in this paper for soldier effects in soft soil, snow and ice conditions. It is hoped that understanding the physics of mobility technology in these types of ground surfaces will be more understood in this work.

This paper described the essential simulator design created by the Ground Vehicle Simulation Laboratory at TACOM-TARDEC to enable vehicle designers to create next generation vehicles. The Army is currently developing the simulation science and technology necessary to ensure these vehicle designs are optimized to fit the design to the soldier.

REFERENCES

1. Paul, V., Meldrum, A., "Motion Base Simulation as a Tool to Evaluate Emerging Vehicle Technologies." NDIA IVSS-2003-MAS-02, 2nd Annual Intelligent Vehicle Systems Symposium, 2002.

2. Weir, D. H. and Clark, A. J., "A Survey of Mid-level Driving Simulators", SAE 950172, International Congress and Exposition, Detroit, MI.

3. Oldaugh, D, "High Mobility Multi-Wheeled Vehicle Simulation Console Design and Fabrication for the Ride Motion Simulator", Kettering University Thesis, March, 2002.

4. Romano, R. A., "Real-Time Multi-Body Dynamics Using a Modular Modeling Methodology, SAE 2003-01-1286, International Congress and Exposition, Detroit, MI.

5. Kaiser Electro Optics, ProView™XL Owner's Manual, 1999.

6. InterSense, Inc., User Manual for IS-300 and IS-300 Pro Systems, 1999.

7. Romano, R. A., "A New Approach to Motion Control Logic For Ground Vehicle Simulators, Image Conference, Scottsdale, AZ, 1996.
