15506

# Using Motion-Base Simulation to Guide Future Force Systems Design

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The U.S. Army Tank and Automotive Research, Development, and Engineering Center (TARDEC), in collaboration with the U.S. Army Research Laboratory (ARL), Human Research and Engineering Directorate, is using TARDEC's Ride Motion Simulator (RMS) to address design requirements for future force systems. Future force systems are envisioned to be lightweight, highly-mobile vehicles that will utilize complex information systems to ensure, for example, both Soldier survivability and system lethality. One of the major challenges and program risks identified by Future Combat Systems is that, in these future systems, Soldiers will need to be able to maintain their high levels of performance even when their vehicles are moving over terrain. This "motion effects" challenge involves a host of problems including, but not limited to: the presentation of critical information in an understandable way, the implementation of control devices that allow the successful completion of mission operations, and the reduction of potential disorientation and motion sickness, all of which will be adversely affected when Soldiers are bounced around in moving vehicles. Making decisions on how to deal with motion effects issues is all the more difficult because potentially crucial design choices must be made for vehicles whose ride characteristics are still unknown. Through the combined efforts of researchers at TARDEC and ARL, a systematic approach using motion-base simulation is being implemented to address some of these challenges.

## History

For the past twenty years, TARDEC's Ground Vehicle Simulation Laboratory (GVSL) has been developing simulation capabilities in the form of full motion-base simulators, reconfigurable crew workstations, models of many existing and theoretical ground combat vehicle models, and high-resolution dynamic terrain models. These facilities have

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produced a wealth of applied research and have fostered manned ground vehicle technology development. The GVSL produced numerous human factors assessments of crewstation component technologies such as control handles and display devices. Fully-powered turret systems stabilization experiments produced gun-turret drive improvements in the M2 Bradley Fighting vehicle. Recently the RMS was heavily utilized to evaluate HMMWV seats and restraints using combat-equipped Soldiers. TARDEC's GVSL operates three simulators of various sizes, which can potentially accommodate as many as nine Soldiers in a reconfigurable vehicle mock-up and are capable of generating complex six-degree-of-freedom motions of payloads up to 25 tons. Furthermore, GVSL has developed detailed models of ground combat vehicles including the Stryker, HMMWV, and a futuristic 24-ton tracked vehicle whose ride characteristics can be reproduced through high-fidelity computer simulations. These simulations also utilize dynamic terrain models that have been developed through programs such as the High Resolution Virtual Terrain Small Business Innovative Research and the High Fidelity Ground Platform and Terrain Mechanics Army Technology Objective. These models include environmental factors such as wind, mud, and snow, allowing for more realistic interactions between vehicles and the environment. For example, when a vehicle passing over a section of terrain compacts the soil, a second vehicle passing over the same terrain section will experience a different ride characteristic. The combination of platforms, vehicle models, and terrain models, allows a wide range of vehicles, terrains, and crew members (e.g., gunner, commander, or driver) to be simulated and recreated, giving researchers the capability to examine Soldiers' performance within highly-controlled, realistic operational environments (see Inset 1).

Over the past three years, TARDEC has teamed with ARL to specifically examine Soldier performance issues within these motion-base environments. Using a simulator and monitor control system developed to enable scenario design, operation, and data acquisition in an integrated fashion, researchers have been able to examine the influences of field of view on driving performance and the effects of ground vehicle motion on reach accuracy (see example below) for the Crew Integration and Automation Testbed - Advanced Technology Demonstrator (CAT-ATD) program. For the High Fidelity Ground Platform and Terrain Mechanics Modeling Army Technology Objective, TARDEC and ARL researchers have looked at issues including the effects of ground vehicle motion environments on Soldier performance for control-type tasks and have evaluated potential mitigations for motion sickness.

**Using simulation to suggest modifications of military standards**

Recently, in a joint project between the University of Michigan, TARDEC, and ARL, motion-base simulation was used to conduct research that supports refinements of design criteria stated in Military Standard 1472, which specifies the sizes of buttons for the design of Soldier-machine interfaces (MIL-STD 1472, Design Criteria Standard, Human Engineering, 1999). This project utilized TARDEC's mid-size motion-base platform, the RMS, which supports a reconfigurable cab large enough to allow simulation of a single-occupant crew station outfitted with vehicle controls, displays, and seats with restraints. In this experiment, the RMS was used to conduct research that aimed at determining the appropriate button size to use for Soldiers operating touch-screen displays while "on the move." The study, therefore, had a two-fold purpose: to examine how vehicle motions will affect Soldiers' ability to reach to and operate buttons on an interface, and to examine the operation of touch-screen interfaces, which are advantageous for their design flexibility but problematic because operators cannot feel when a button has been pressed. Participants were asked to press different-sized touch-screen and physical buttons in various locations around the RMS cab while they experienced a stationary and two different types of motion environments. The results obtained using an advanced motion-capture camera system showed that participants' performance was degraded in terms of both the timing and accuracy (see Figure 2a) of their reaching movements when The RMS cab was in motion compared to when it was stationary. This suggests that increasing button size should increase performance accuracy.

The results of this experimentation using motion-base simulation are consistent with anecdotal evidence derived from the CAT-ATD program. The CAT-ATD is a joint TARDEC – ARL program that examines advanced crew station design within field environments. Tests of crew stations in the CAT-ATD have suggested that application of touch-screen displays within motion environments requires larger buttons sizes and the location of buttons next to bezels that act as stabilization points for the operator (see Figure 2b). The combination of empirical evidence from the RMS study with the practical application of the CAT-ATD program suggests that either larger button sizes or another form of mitigation (i.e., stabilization points, modifying vehicle ride quality) will be required to obtain sufficient accuracy goals during "on-the-move" operations in future force systems.

This example shows how research results can be translated into design recommendations that have then been proven in actual field evaluations. What is particularly important about this example is that existing human engineering standards for interface designs that work well for Soldiers in stationary environments may need to be re-evaluated when Soldiers have to use them while in moving vehicles. Motion-based simulators like TARDEC's RMS provide a useful environment in which to examine these issues.

## Summary

The motion-base Ride Motion Simulator at TARDEC is being used to address Soldier performance issues for future systems design. The motion simulator provides a means for efficient, controllable and repeatable assessment to examine "motion effects" issues that will affect Soldiers as they perform their missions "on the move." Finding effective solutions to this challenge will be critical to the success of future force systems. Through the combined use of high-fidelity motion-base simulation and fielded prototypes such as the CAT-ATD, TARDEC and ARL are conducting the research necessary to obtain the right information, so that the best decisions can be made to produce the most effective systems for our Soldiers.

## References

U.S. Department of Defense (1999). *Design Criteria Standard, Human Engineering* (MIL-STD 1472F).

**Biographical Sketches**

Mr. Harry Zywiol is leader for the motion base technologies team for TARDEC's National Automotive Center. He has a B.S. in electrical engineering from the University of Michigan. He is Level III certified in systems planning, research, development and engineering, as well as Test and Evaluation and is an Acquisition Corp member.

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Dr. Susan Hill is an industrial engineer for ARL, Aberdeen Proving Ground, MD. She has a B.A. in Psychology from the College of William and Mary and a Ph.D. in Industrial Engineering and Operations Research, specializing in Human Factors, from Virginia Polytechnic Institute and State University.

*Figure 1.* Ride Motion Simulator in tank commander simulation. For illustration purposes, the crew station is opened, however, for testing purposes the crew station can be enclosed to replicate a "buttoned-up" environment.

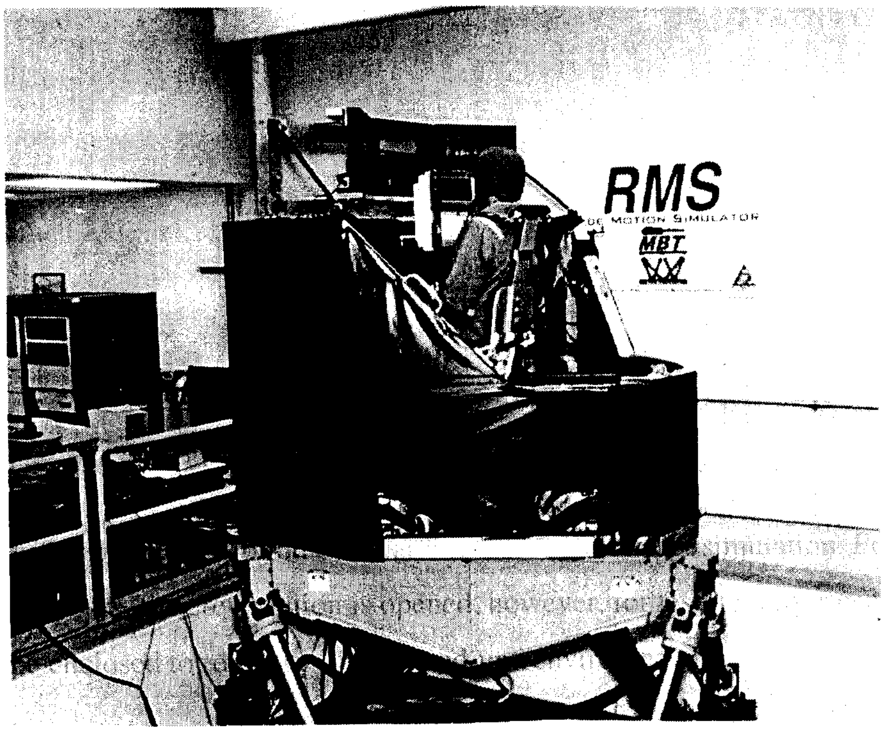
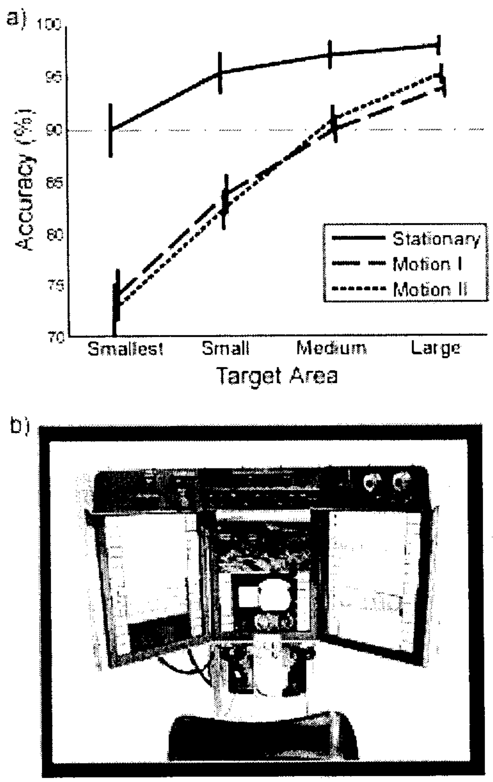


*Figure 2.* Increased button sizes needed for operating touch screens in motion environments. A) Data from RMS reaching study supports need to increase button size for operations occurring in motion environments. B) Increased button size supported in actual in field testing with CAT-ATD advanced crew station.



Inset 1

## The Necessity of Motion-Base Simulation

Assuring that future Solders will be able to perform while the vehicles are on the move is critical to the successful development of future force manned ground vehicles. Previous research has made it clear that motion effects issues can only be addressed by looking at Soldier performance in motion environments, because conclusions and design recommendations obtained in stationary environments may not provide optimal solutions. Three primary benefits of using motion-base simulators .to augment actual in-vehicle testing are:

*1) Laboratory Control*

**Better** definition and repeatability are two of the major advantages for research and assessment gained by using simulators. Motion-base simulators can be used to carefully define rich environments and precise scenarios that can be repeated exactly, which is difficult, if not impossible, in real-world environments. This is crucial to ensure the validity of experimental findings.

*2) Evaluation Prior to Construction*

**Faster** feedback on design decisions. One of the most difficult problems for future force systems design is to assess motion effects for vehicles that don't yet exist and, importantly, have yet unknown ride qualities. Using simulations, vehicle models can be constructed from known or proposed future vehicle parameters (e.g., suspension, drive, weight) and used to generate the predicted motions of future vehicle designs within motion-base simulators. Soldier performance can be examined, and important feedback can be provided early in the design process, before metal is bent.

*3) Efficient Use of Resources*

**Efficient** evaluation of design alternatives can be achieved. Simulation can provide both resource and time-effective (see #2, above) proving grounds for examining design alternatives, including Soldier-in-the-loop experimentation. Motion-base simulation offers the ability to solve many initial problems, such as vehicle motion effects, in a more effective manner by evaluating different design solutions before expensive prototypes are constructed and critical resources are spent in lengthy and costly field testing.