

**Implementation of the WTI  
DriveSafety 500C Driving Simulator Laboratory**

by

Michael J. Kelly

Research Director

And

Suzanne Lassacher

Research Associate

Western Transportation Institute  
College of Engineering  
Montana State University

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## 2. EXECUTIVE SUMMARY

Collection of data related to driving hazards and unsafe conditions is dangerous and time consuming if done on actual highways or test tracks. Because of the changing nature of environmental conditions and traffic, it is impossible to maintain the full control of driving scenarios necessary for experimental precision. This can be accomplished safely and easily in a simulation laboratory designed to collect detailed measures of driver performance during high fidelity, realistic driving scenarios.

A high fidelity driving simulator has been implemented at the Western Transportation Institute to support testing of driver performance and behavior in the safety and controlled environment of the laboratory. WTI selected and purchased a DriveSafety DS500C Vection simulator. This simulator features five visual channels providing approximately 140-degrees of view plus rear-view mirrors. The visual simulation allows the driver to drive through scenarios including rural and urban roadways, buildings, traffic signs and signals, other vehicles, trees, rain, snow, fog, darkness, and even animals in the roadway. Auditory displays provide a realistic sound environment. A driving cab contains the driver seat and all fully functional displays and controls. An automated performance measurement system collects a broad range of data on the driver's control inputs and performance. An operator station allows the researcher to program and control the research scenarios.

This report describes the criteria by which this model of simulator was selected, describes the process of installation and initial operation, describes the activities necessary to initiate a program of driver performance research, and provides a summary of critical lessons that should be taken into account by other organizations considering such an investment.

### 3. INTRODUCTION

The Western Transportation Institute acquired the high-fidelity driving simulator in January 2004. The simulator allows WTI to conduct research on driver performance and behavior in the safety and controlled environment of the laboratory. Collection of data related to driving hazards and unsafe conditions is dangerous and time consuming if done on actual highways or test tracks. Due to the changing nature of environmental conditions and traffic, it is impossible to maintain the full control and repeatability of driving scenarios necessary for experimental precision. This can be accomplished safely and easily in a simulation laboratory designed to collect detailed measures of driver performance during high fidelity, realistic driving scenarios.

Exploratory research on new traffic engineering practices and devices often cannot be performed in real world traffic scenarios. A research simulator will allow testing and development of prototype and notional systems before they can be fielded. The laboratory economically supports research in safety, control theory, psychology, driver fatigue, and other topics that are difficult to study in low fidelity laboratory simulations or on the real roadways.

The simulation laboratory will be available to support data collection for a large number of projects related to animal/vehicle interactions, infrastructure design, safety, and other areas involving driver response to realistic driving scenarios.

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## 4. PURCHASING PHASE

Driving simulators are available with a broad range of capabilities. These range from the large-scale National Driving Simulator at the University of Iowa down to simulation software designed for a desktop computer with, perhaps the addition of a gaming-quality steering wheel and pedals.

WTI began the procurement process by developing a list of requirements for our simulator. Some of these are described below:

Fixed Base. High end driving simulators simulate the accelerations experienced by a real-world vehicle by tilting the driving cab in various directions. This requires a relatively complex hydraulic system beneath the simulator cab. The initial purchase and maintenance of the hydraulic system can be a major investment. Furthermore, all moving elements of the simulator need to be structurally hardened to withstand the movements and vibrations. A large body of research in the aviation simulation environment has shown only a marginal benefit for the full motion system. WTI chose to specify a fixed-base simulator with an under-seat vibration system.

Driver Cab. Fixed-base driving simulators can be purchased with one of four levels of fidelity of the driver's station. At the lowest level is a desktop simulator in which the driver sits on a standard desk chair and interacts with the simulation through gaming-quality steering wheel and controls. One step above that is a driver cab containing an actual vehicle seat, instrument panel, and more realistic steering wheel and pedals. Another step more realistic is a cab consisting of the driver station of an actual vehicle with all of the vehicle behind the front seats removed and all of the vehicle controls being fully functional. At the highest level of fidelity is a full vehicle with only the engine and drive train removed. While providing some advantages of realism, the full vehicle driver station was not practical for our application because of limitations on the dimensions of the laboratory space and building corridors through which the equipment would have to be delivered. WTI chose to specify a built-up cab consisting of the driver station of an actual sedan.

Visual System. Simulator visual systems may consist of a single screen directly in front of the driver or a wraparound system of screens providing up to a 180-degree visual field. Because of the importance of peripheral vision to driving safety, WTI selected a wraparound visual system. Wraparound systems frequently utilize front projection systems with (usually) three large screens. These front projection systems, however, require a laboratory with larger dimensions than available at WTI. We, therefore, chose a visual system that included five 36-inch plasma monitors in a semicircle around the front of the cab and provided approximately a 140-degree forward field of view.

Compatibility with Other Centers. To maximize the collective success and impact of driving simulation research, it is important for the various research centers to be able to exchange lessons-learned, research scenarios, data and results. This goal can best be accomplished when the centers are performing research on comparable instrumentation, under comparable conditions, and using similar measurement methods. WTI determined that it was important to select a simulator of the same or comparable model to facilities used by colleagues at other highway research institutions.

Candidate Systems. Our survey of the simulator market identified two systems that would meet a majority of our criteria, the General Electric I-Sim and the DriveSafety 500C Vection.

- Both of these simulators are fixed-base.
- The I-Sim has a much lower fidelity driver cab while the DriveSafety 500C uses the driver station of a Saturn sedan with all controls functionally active.
- The visual systems are very similar.
- The DriveSafety 500C is designed for research purposes while the I-Sim is primarily a training tool.
- The DriveSafety 500C is used by a large percentage of university and industry research laboratories and there is a large and active user's group dedicated to information exchange.
- The I-Sim is slightly less expensive.

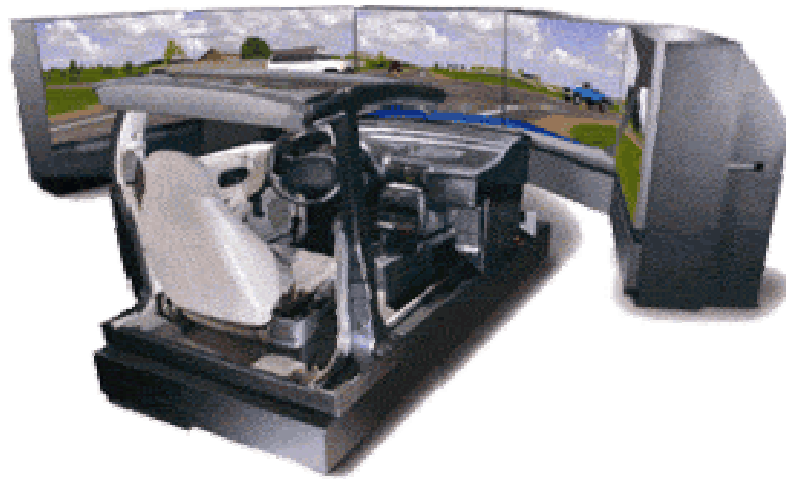
Based on these considerations, WTI selected the DriveSafety 500C Vection simulator with built-up cab (BUC) and five-channel plasma monitor visual system for procurement.



## 5. INSTALLATION PHASE

The DriveSafety 500c Simulator is a high-fidelity system that has been designed for research. It uses Vection simulation software and HyperDrive scenario software. Installation of the driving simulator took place at the end of January 2004. DriveSafety came to Bozeman and did the initial set up of the simulator and provided training for staff on simulator operation and scenario development.

The following hardware components were installed: six Dell Optiplex GX 270 computers, one Dell Dimension 4600 computer, one quarter cab of a Saturn sedan, a control loader, One UPS power supply, 5 Toshiba flat screen displays, a sound device, and a surge protector. The five Toshiba LCD screens provide 140 degrees of view. Each screen is controlled by a dedicated Linux based computer. Communication to each screen is controlled by a main computer. Six Dell Optiplex GX270s are used for this purpose.



**Figure 1: DriveSafety 500c Driving Simulator**

## 6. TESTING PHASE

The Dell Dimension 4600 computer (also called the HyperDrive computer) is a Windows XP Pro box that runs the HyperDrive scenario control software. The scenario control software allows the user to develop simulated virtual “worlds”. The user may populate the virtual “world” with static and dynamic entities such as buildings, signs, pedestrians, animals, landscaping elements, bicyclists, and other vehicles. The scenario designer may also control the roadway environment such as road friction, weather, time of day (night vs. day), traffic signals, etc. Realistic sounds may also be included in the scenarios.

High resolution graphics (800 x 600 pixels) are used to display the scenario on each of the five display channels. The displays run in real-time and have a 60Hz refresh rate with a 48msec latency. Highway design standards were applied to the roadway and traffic control models. The scenario author may choose from 256 vehicles ranging from passenger cars to construction vehicles to populate the roadways of the scenario. Ambient traffic is programmed to obey traffic rules such as adhering to the posted speed limit and obeying all traffic signs and signals. Behaviors for ambient traffic may be scripted to create distractions and conflicts.

Scenarios are transferred from the HyperDrive computer to the host computer. The host computer then communicates with each of the remaining Linux based Dell OptiPlex GX270s which are used to control one of the five displays (also called “channels”).

Data for 40 performance measures may be collected at rates between 1Hz and 60Hz. Custom data collection variables may be specified by the scenario author. The collected data is stored on the HyperDrive computer and analyzed using a statistical package or an off-the-shelf spreadsheet application such as Microsoft Excel.

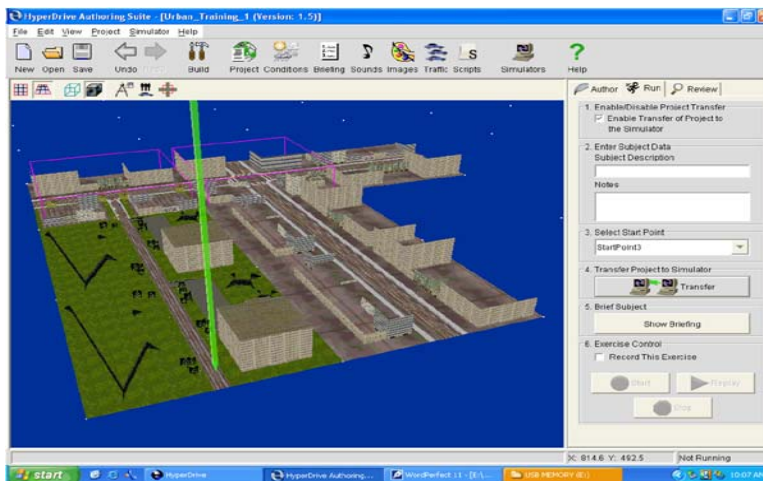


Figure 2: HyperDrive scenario development software.

## 7. CONCLUSIONS AND LESSONS LEARNED

A simulator procedures manual was also developed by WTI (see Appendix). This manual outlines startup and shutdown procedures, subject screening, experimental protocols, human subject research approval, subject recruitment guidelines, etc. Many of these procedures were adapted from those that have been found successful by other research centers using similar models of driving simulators. Colleagues at other centers suggested that we develop a close relationship with the MSU Human Subjects Committee and educate them concerning our approaches to reducing the risk of participation in our experiments. The procedures manual was, therefore, prescreened by our HSC which was then able to label our planned research program as "minimal risk".

After installation of any complex, custom-built system such as the simulator, a shakedown period is expected to identify and correct initial hardware and software problems. During the initial setup, problems were encountered with the control loader by the Drive Safety representative. He was eventually able to resolve the issue in such a way that the simulator would run. Shortly thereafter, we began to have trouble with one of the display monitors. We were unable to display anything on a particular channel. This took the better part of a month to resolve.

New problems surfaced in March. The scenarios would load and then inexplicably, the simulator would "crash" reverting from the scenario to the splash screen. This was the beginning of a series of problems that have yet to be fully resolved. We have worked extensively with Drive Safety to resolve these ongoing problems. To date the following have been done:

- 1) All pins on one connector on the control loader were replaced
- 2) Power supply on the control loader was replaced.
- 3) Full software upgrades to newer versions have been performed twice.
- 4) Additional network card installed and system formatted for remote access purposes.
- 5) Original Firebolt network card replaced with a tested card.

Overall, approximately one person-month of WTI staff time has been spent working with DriveSafety to resolve these ongoing simulator issues. DriveSafety plans to replace the control loader with a new control loader as soon as one is available. Apparently, our current control loader was one of the first developed and manufactured by a new vendor. It is important to note that when the simulator is functioning properly, it runs very well.

Many lessons have been learned. It is necessary to set aside time for the scenario developers and data analysts to familiarize themselves with the software they will be using to develop the scenarios and analyze the data collected. Ample time must be allotted for scenario development, training, testing, and data analysis. As with any piece of equipment, things can and do go wrong: funding needs to be allocated for simulator maintenance and troubleshooting.

Expectations for the simulator's capabilities need to be realistic. Researchers who choose to use the simulator for research purposes need to remember that while many "real" situations can be recreated in the simulator, some of the actual look and feel will vary. One such example is the driver's perception of speed and distance in the simulator. The driver may not feel that he/she is

actually driving at the speed registered on the speedometer. Drivers tend to underestimate distances, often stopping, for example, one or two car lengths before a stop signal or crosswalk.

We found that scenario description standardization is needed: i.e. which components (traffic, signals, signage, etc.) identify a scenario as urban, rural, etc. It would be helpful if there were standards on data collection and analysis. It would also be useful to know what general recommendations have been made regarding subject demographics (number of representatives from various age groups, etc.).

## 8. RECOMMENDATIONS

General recommendations include the development of standards for simulator scenario development, testing, and protocol. Expectations of the simulator's capabilities need to be kept realistic. Adequate time for development, testing, and analysis needs to be allotted to gather the best, not comprehensive data.

An opportunity to thoroughly test and evaluate the simulator in the setting where it will be used would be extremely advantageous and efficient. The vendor should do a site visit and consult face-to-face with the client and see where and how the simulator will be used. Recommendations can then be made for lab setup and requirements such as air flow and remote access to the simulator can be addressed proactively as opposed to reactively.

Certain environmental aspects should be taken into consideration when installing and operating a complex and multi-component system such as a simulator. Adequate airflow is most important. Seven computers generate a substantial amount of heat. It is important to keep the room cool for the comfort of the subjects and to protect the equipment. The room that houses the simulator should be equipped with independent air temperature controls and be sufficiently sound-proofed so as not to disrupt the working environment.



**Figure 3: Photo of simulator running a scenario.**

## **9. APPENDIX**

See included Simulator Procedures Manual.

Project Data/ Driving Simulator/ Documents/ Simulator\_Procedures\_Manual.doc