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THE DEVELOPMENT AND EVALUATION OF A HIGH-FIDELITY SIMULATOR TRAINING PROGRAM FOR SNOWPLOW OPERATORS

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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

A customized training program incorporating high-fidelity simulation was developed for snowplow operators in a collaborative research project with the Utah Department of Transportation, the University of Utah, and General Electric Driver Development. Ratings of user acceptance of the training were very high, with drivers of all levels of experience indicating that the training helped them prepare for several issues critical to the safe and efficient operation of a snowplow. In the 6-month period following training, the odds of getting in an accident were lower for the group of drivers who received training compared with a matched control group who did not receive training and the estimated cost associated with each accident was also lower for the drivers who received training. In addition, the data indicate that fuel efficiency was greater for the trained drivers than for the control group.

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The Development and Evaluation of a High-Fidelity Simulator Training Program for Snowplow Operators[1]

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The safe operation of a snowplow requires a high level of expertise. Drivers often operate in very stressful situations, maneuvering 30 tons of equipment in tight quarters in blizzard conditions. Drivers often work long shifts, negotiate their vehicle in heavy traffic, on slippery roads with very limited visibility. For safe and efficient snow removal in urban settings, drivers often plow in a tight tandem formation and communicate heavily between vehicles. At the same time, the driver must manipulate the controls for the plow, the sander, the different communication devices, and maintain control of the vehicle. The driver must also have a high level of situation awareness, keeping in mind where his/her vehicle is in relation to the other vehicles on the roadway and making sure that the snow thrown by the plow does not come in contact with other vehicles, structures, or pedestrians. Drivers must develop a flexible plan for snowplow removal and in more urban settings must coordinate their activities with other members of their crew. Overall, the multitasking demands of a snowplow driver are very high and the skill set required to perform this task is comparable in many respects to those required of a skilled pilot flying an aircraft.

This report describes a collaborative research project between the Utah Department of Transportation (UDOT), the University of Utah, and General Electric Driver Development (GEDD). Following the lead of commercial aviation, where advanced high-fidelity simulator training has significantly improved the safety of airline travel, this research project was designed to determine the feasibility of using high-fidelity simulator training to improve the performance of UDOT maintenance operators (i.e., snowplow drivers).

[1] This project would not have been successful without the assistance of several key individuals. We would like to acknowledge the invaluable assistance provided by Todd Richins,, Roger Franz, Larry Limberis, Cindy Borland, Bonnie Bernardo, and Steve McCarthy at UDOT who provided the background information needed to develop the training program. In addition, several individuals at GEDD played key roles including Bryce Bruner, Darrel Rupp, and Dennis Blessinger. Joel Cooper from the University of Utah assisted in the task analysis and construction of the driving scenarios.

The psychological literature indicates that training can be optimized by combining *part-task training* and *variable priority training* techniques and both of these methods were incorporated in the current study. Part-task training is a method for taking a complex behavior, such as the safe and efficient operation of a snowplow, and decomposing it into to smaller more manageable units that can be practiced in isolation. Part-task training has been shown to be very effective in training an appropriate response to low frequency events, such as a tire blow-out or blade catching. On the other hand, variable priority training is a technique that focuses on multitasking by encouraging the flexible allocation of attention between several concurrent operations. With variable priority training, drivers are encouraged to pay attention to all the critical components of plowing, rather than over focusing on one element at the expense of another (thereby reducing the cognitive tunnel vision). Together, these two training techniques allow the development of skilled procedures that operate effectively in complex multitasking operations.

A list of the eight major tasks required to accomplish the objective of this research project is provided below. Also included in this report are six appendices that document several of the products developed during the project. Appendix 1 provides the informed consent document used in the project. Appendix 2 lists the major milestones in simulator software modification required to simulate snowplowing. The course syllabus used to train the 40 participants in the study group is given in Appendix 3. Appendix 4 provides the PowerPoint slides used in the lecture portion of the course. Appendix 5 provides a description of each of the accident/incidents that occurred during the 6 month interval following training. Appendix 6 provides several options for continuing the training, varying from options for continuing to outsource the training to options to purchase a simulator and develop in-house training at UDOT.

Task 1. Review specific UDOT needs for maintenance operator training

This task involved meeting with the Technical Advisory Committee (TAC) on several occasions to identify the training issues critical for UDOT winter maintenance operators. In addition, we met with expert drivers in the field to identify major problem areas. We also rode with the drivers on several occasions as they performed their snowplow operations. In addition, we evaluated existing database records on sources of accidents and incidents for UDOT winter maintenance personnel. From the aggregated information, we performed a detailed task analysis and *identified and scripted specific driving scenarios that could be built into the driving simulations (Task 3). We received ongoing feedback on the fidelity of the task analysis and driving simulations from expert UDOT drivers throughout the project.*

Task 2. Customize simulator software to model snowplow dynamics

This task involved modifying the simulator software to permit the simulation of a snowplow operating in a variety of winter conditions. Software development was done under subcontract with GEDD. The software modifications were specific to the MARK II high-fidelity motion-based simulator (and the TranSim VS) allowing the simulator to simulate a snowplow in winter driving conditions. The software modifications focused primarily on adding removable snow to the interstate and rural mountain roadways, adding a plow, sander, and optional wing to the vehicle (see Figures 5 and 6), and modeling the interactions of the snowplow with the snow/road surface. Additional software refinements were required to correctly represent lighting conditions. The major milestones for software modification are listed in Appendix 2, although many minor modifications to fine-tune the simulator are not indicated in the appendix. It is noteworthy that prior to this research project there was no simulation capability that allowed for the high-fidelity simulation of a snowplow operation.

Task 3. Develop specific driving scenarios based UDOT requirements

This task involved developing driving scenarios based on the information gathered in Task 1 and the software modifications performed in Task 2. These scenarios were initially developed and refined at the University of Utah and then ported to the MARK II for final refinement. At several points in the development process, expert UDOT drivers were asked to provide detailed feedback about the fidelity of the simulation. The end result of this task was a series of 18 customized scenarios (nine in urban interstate conditions and nine in rural mountain settings) that provided training on the critical issues of a) space management, b) speed management, c) crew communication, and d) fuel management.

Task 4. Develop customized training program to suit UDOT needs

This task involved developing a four-hour customized training program based on the specific UDOT needs identified in Task 1. Portions of this work were done under subcontract with GEDD in collaboration with the University of Utah. The training program drew upon material provided in existing GEDD training modules (e.g., "Space and Speed Management") and incorporated specific training on the issues that were identified in Task 1 as critical for UDOT snowplow drivers. The end product was an entirely new training module that incorporated both lecture and simulator training on the high fidelity MARK II motion-based simulator and the fixed-base TranSim VS simulator. The training syllabus is provided in Appendix 3 and the PowerPoint slides used in the lecture portion of training are presented in Appendix 4. Training focused on four key elements that were identified in Task 1: Space management, speed management, crew communication, and fuel management.

Task 5. Select participants for Study and Control groups

This task involved selecting eighty UDOT snowplow drivers to participate in the study. Half of the participants were assigned to the study group and received simulator training. The remaining drivers served as a control group. Study and control groups were matched in terms of age, years driving a snowplow, and prior driving history (e.g., rates of accidents, incidents, traffic tickets, and damage to maintenance equipment). A further requirement for participation in the study was that the participant was an employee at UDOT in their maintenance division (i.e., working as a snowplow driver).

Task 6. Provide advanced simulator training at GE Capital I-SIM facilities

This task involved providing training to 40 UDOT maintenance operators. The training session took 4 hours and was provided in groups of 4 drivers. Training took place in late October and early November of 2003. The training session was conducted at GEDD's facilities in Salt Lake City. At the end of training, drivers completed a 25 item questionnaire assessing various aspects of the simulator training. The *survey was designed to determine how well the training addressed the critical issues identified in the task analysis performed in Task 1.*

Task 7. Monitor driving performance over 6-month interval

This task involved monitoring the driving performance of the control and study participants for 6 months following the training interval (from November 2003 – April of 2004). We examined data from each driver on safety parameters (e.g., accidents), fuel management (e.g., MPG), and maintenance records to assess the effectiveness of training.

Task 8. Compare driving performance of Study and Control groups to determine effectiveness of training protocol (e.g., percentage reduction in traffic accidents).

This task involved using a between subjects statistical design to compare the study and control groups on the driving performance data collected in Task 7. Based on reports from the commercial trucking, we expected to find a reduction in accidents, a reduction in fuel consumption, and a reduction in maintenance costs.

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METHOD

Participants

Eighty maintenance workers from UDOT participated in the study. The participant's age, years with a commercial drivers license (CDL), years plowing, and years trucking are given in Table 1, and the correlation between these demographic variables is given in Table 2. An equal number of participants were selected from each of the 5 geographic regions in the state of Utah. The different regions represent urban interstate, mountain interstate, mountain 2-lane highway, and rural 2-lane highway roads and both city and rural town driving conditions. Half of the participants were assigned to the study group and the remaining participants served in the control group. Study and control groups were matched in terms of age, years driving a snowplow, prior driving history and geographic region of the state. A requirement for participation in the study was that the participant was an employee at UDOT in their maintenance division (i.e., working as a snowplow driver). The training session was conducted at GEDD facilities in Salt Lake City and lasted 4 hours.

Table 1: Participant demographic data

	Minimum	Maximum	Mean (sd)
Age	21	55	33.6 (9.3)
Years CDL	0	30	11.0 (9.0)
Years plowing	0	25	7.3 (7.1)
Years trucking	0	31	11.5 (9.8)

Table 2: Correlation between demographic variables listed in Table 1.

	Age	Years CDL	Years plowing	Years trucking
Age	-	0.598*	0.473*	0.658*
Years CDL	0.598*	-	0.773*	0.851*
Years plowing	0.473*	773*	-	0.723*
Years trucking	0.658*	851*	723*	-

* p<.01

Apparatus

Training was conducted at GEDD facilities in Salt Lake City, UT (located at 2961 West California Avenue, Salt Lake City). Simulator training was performed using both the Mark II and TranSim VS high fidelity driving simulators manufactured by GEDD.

The Mark II motion-based simulator, schematically represented in Figure 1 and pictured in Figure 2, combines a fully operational truck cab with LCD projection imaging on three screens to create a 180-degree field of vision. Two LCD side mirrors simulate the rear view from the truck cab. Audio and vibration systems add accurate driving noise and feel. Closed-circuit television allows observers to watch the driver from the operator console (Figure 3). Complete specifications of the Mark II are available from GEDD and the customized modifications for the current project are detailed in Appendix 2.

The TranSim VS, pictured in Figure 4 was used to train drivers on ways to optimize shifting to maximize fuel efficiency (e.g., progressive shifting, double clutching, timing, and appropriate gear selection). Complete specifications of the TranSim VS (and the newer TranSim III, see Appendix 6) are available from GEDD.

Procedure

The research project consisted of four key phases. The first phase involved performing a detailed task analysis that identified the major components to include in training. The second phase involved developing high-fidelity driving scenarios and PowerPoint slides that focused on the key components identified in the task analysis. The third phase involved the delivery of training to the 40 drivers in the study group. The fourth phase of the project involved collecting and analyzing driver performance measures for the study and control groups over a 6-month interval following the training. In the following paragraphs, we provide detail concerning the procedures used for each phase of the project.

Phase 1

The first phase of the project involved the development of a detailed task analysis of snowplow operations. We focused on critical training issues and proper procedures for plowing in winter conditions. On several occasions we met with the TAC to identify the operational issues for snowplow drivers, met with expert drivers in the field to identify major problem areas, and rode with the drivers as they performed their snowplow operations. In addition, we evaluated existing database records on sources of accidents and incidents. From the aggregated information, we identified and scripted specific driving scenarios that could be built into the driving simulations. We received ongoing feedback on the fidelity of the task analysis and driving simulations from expert UDOT drivers throughout the project.

Four key areas were identified for training: Space management, speed management, crew communication, and fuel management. Space management focused on helping the driver have good situation awareness of where their vehicle was in relationship to other vehicles, structures, and pedestrians (e.g., ahead, behind, left, right, above and below the vehicle). In addition, space management issues focused on knowing where the snow was being thrown, driving in tandem in urban settings to prohibit other vehicles from coming between the plowing team, and coordinating plowing operations. Speed management focused on the speed of the snowplow, situations for altering the driving speed, discussing strategies for changing the speed of the vehicle, computing stopping distances, the distance snow was thrown (driving faster tends to throw the snow farther), and the potential damage caused by the thrown snow. Also discussed in conjunction with space and speed management was "blade catching" situations where the plow blade acts to change the direction of the vehicle. Crew communication focused on issues of communicating over the different devices in the vehicle (e.g., state radio, CB radio, cell phone) with other members of the team and neighboring stations to coordinate plowing operations. In urban settings crew communication helps to coordinate tandem plowing (e.g., in tandem plowing, the lead driver is the eyes of the team, reporting oncoming obstacles, etc.). The fuel management component of training used the TranSim VS to train drivers on ways to optimize shifting to maximize fuel efficiency (e.g., progressive shifting, double clutching, timing, and appropriate gear selection).

Phase 2

The second phase of the project took the material identified in phase 1 and developed a series of high-fidelity driving simulator scenarios and PowerPoint lecture slides (included as Appendix 4). The driving scenarios consisted of 18 short plowing scenarios in urban interstate and rural mountain settings using the snowplow configurations presented in Figures 5 and 6. The driving scenarios were designed to capture critical components of plowing which could be practiced in isolation (i.e., part-task training) with scenarios later in the sequence focusing on combining the lessons learned in the earlier scenarios in multitasking situations (i.e., variable priority training). The course syllabus used for the 4-hour training is presented in Appendix 3. Inspection of the syllabus indicates that critical concepts were first introduced in lecture format, using PowerPoint slides, and then each concept was practiced in the driving simulator.

As training progressed, the multi-tasking demands increased and in the final driving scenario two drivers, using different simulators, were able to plow as a team in a virtual snowplowing environment.

Phase 3

The third phase of the project involved training 40 drivers using the curriculum developed in the second phase of the project. Drivers were trained in cohorts of 4 drivers at the in late October and early November of 2003. When participants arrived, they completed an informed consent document (Appendix 1). They then participated in the training curriculum detailed in Appendix 3. As noted in the appendix, training consisted of lecture (using PowerPoint), and practice of the concepts developed in lecture using the Mark II and TranSim VS driving simulators. The training was conducted at GEDD facilities in Salt Lake City, UT. One instructor (Dennis Blessinger) was responsible for delivering the training. At the end of the training session, drivers completed a 25 item questionnaire (Table 3) designed to assess various aspects of the simulator training.

Phase 4

The fourth phase of the project involved collecting and analyzing the accident and fuel efficiency data collected over the 6-month interval following training. The experimental design was a between subjects factorial with 40 participants assigned to the study group and 40 participants assigned to the control group. All analyses in this report used a one-tailed (directional) statistical test of the *a priori* hypothesis that simulator training improves driver efficiency. A significance level of $p<.05$ was adopted for all inferential tests.

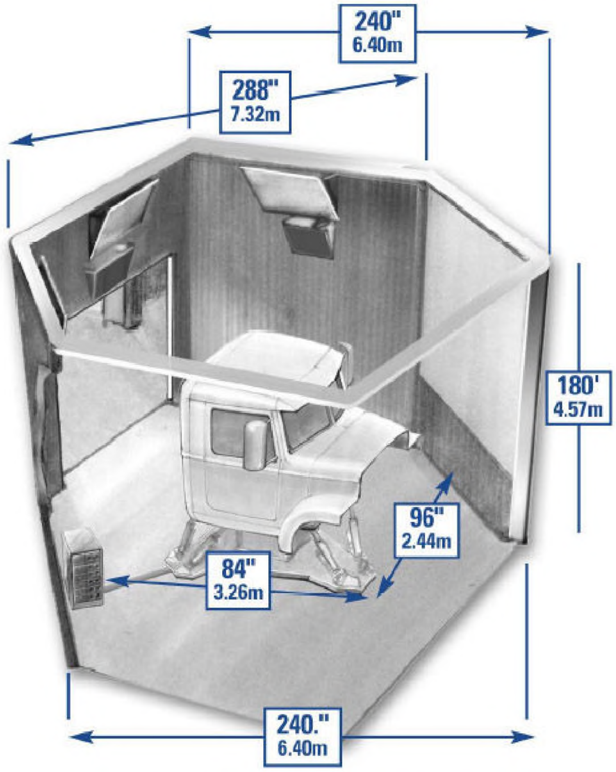


Figure 1. Schematic illustration of the Mark II motion-based simulator

Figure 2. The Mark II motion-based simulator

Figure 3. The operator console of the Mark II motion-based simulator

Figure 4. The TranSim VS simulator

Figure 5. Front view of simulated snowplow

Figure 6. Rear view of the simulated snowplow

RESULTS

Post-training survey

Immediately after the training session, participants completed a 25 item questionnaire assessing various aspects of training. The specific questionnaire items are presented in Table 3 and Figure 7 presents the average rating for each item along with the standard error for each item. Participants rated each item on a 5 point scale where a rating of 1 indicated strong disagreement, a rating of 3 was neutral, and a rating of 5 indicated strong agreement. Averaging across items (mean=4.5, sd=0.25) indicated considerable agreement, with ratings evenly centered between "agree" and "strongly agree". Inspection of the data indicates that for each item participant's ratings ranged between "agree" and "strongly agree" (questionnaire items 7 and 21 were slightly below "agree", but not significantly so). The standard error for each rating also indicates considerable consensus among participants.

Several items are worthy of note. First, participants found the snowplow training package very useful (average rating = 4.55), that the training should be part of UDOT training for all snowplow operators (average rating = 4.55), and that they would recommend this training for other snowplow drivers (average rating = 4.67). Second, as illustrated in Figure 8, only two correlations between the demographic variables and the rating of questionnaire items were significant, indicating that drivers of all levels of experience found the training to be useful. The first significant correlation was between age and item # 2 ("the classroom/lecture portion of the training was useful"), indicating a general trend for older drivers to rate the lecture portion of training higher than younger drivers. The second significant correlation was between years plowing and item # 24 ("the trainer understood your needs and issues"), indicating general trend for snowplow operators with less experience to rate this item higher than drivers with more plowing experience; however, in all cases ratings on this item ranged between "agree" and "strongly agree".

Overall, the ratings provide a strong indication that the drivers found the snowplow training package to be realistic, useful, well directed towards the learning objectives of speed management, space management, crew communication, and fuel management, and of sufficient quality that they recommended that this training should be part of UDOT training. Moreover, operators of all levels of experience found the course to be worthwhile. It is also useful to report that, although not formally part of the current research project, a separate cohort of 40 UDOT "Trans Tech" personnel with little or no snowplowing experience were also trained on the snowplow course (after the cohort from the current study reported very favorable ratings). The ratings of the Trans Tech drivers showed an identical pattern to those from the current study. In short, drivers of all backgrounds liked the training.

Figure 7. UDOT Snowplow Training Questionnaire (Exit Interview)

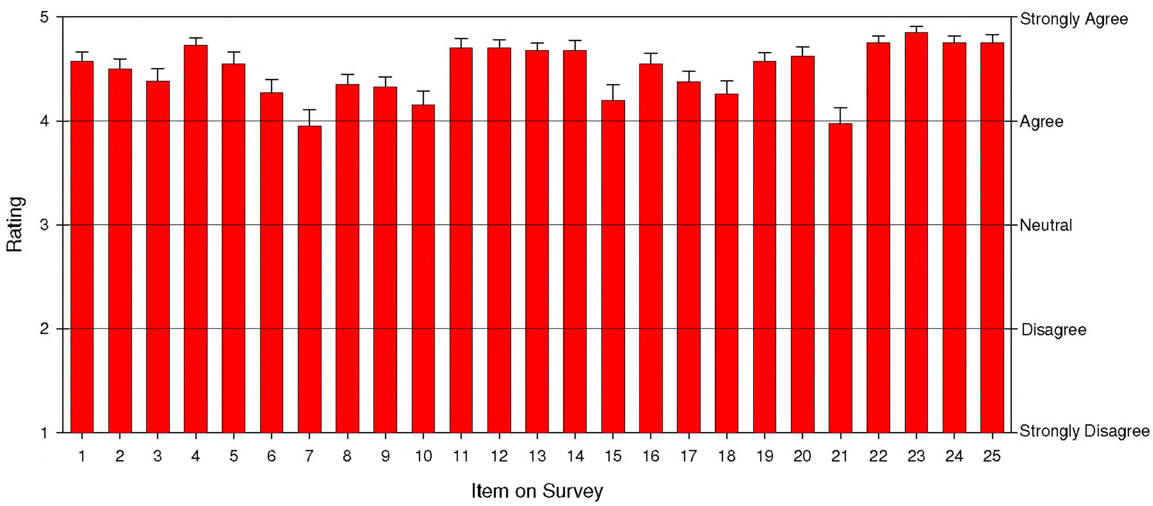
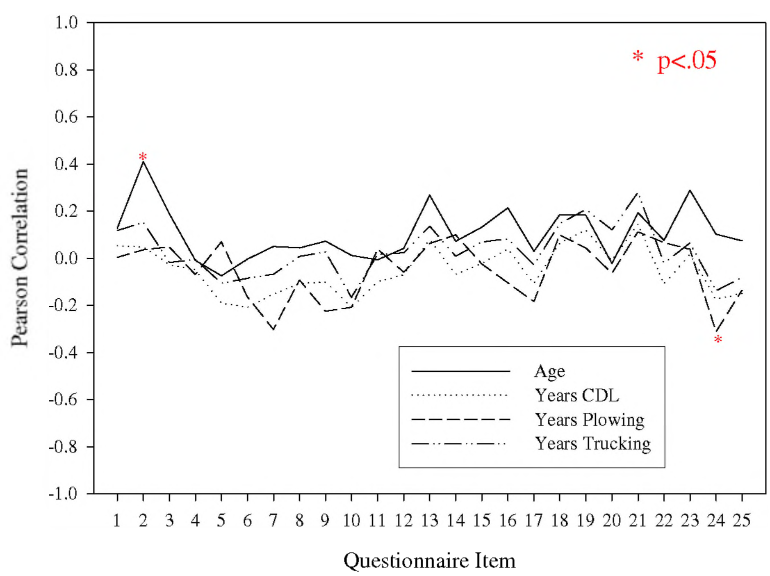


Table 3. Questionnaire Items

1) The snowplow training package was very useful.
2) The classroom/lecture portion of the training was very useful.
3) The training using the TranSim simulator for optimal shifting was very useful.
4) The simulations using the MARK II motion-based simulator were very useful.
5) This training should be part of UDOT training for all snowplow operators.
6) The training helped prepare me for dealing with non-routine situations.
7) The training helped prepare me for situations involving blade catching.
8) The training helped prepare me for situations involving passing cars.
9) The training helped prepare me for situations involving vehicles or pedestrians along the side of the road.
10) The training helped prepare me for situations involving plowing over structures.
11) This training explained why speed management is important for safe plowing.
12) This training explained why space management is important for safe plowing.
13) This training explained why good communication is important for safe plowing.
14) I would recommend this training for other snowplow drivers.
15) The course objectives satisfied my needs.

16) The driving simulations were realistic for the course objectives.
17) I practiced skills during the driving simulation part of the course that will be very useful on the road.
18) I practiced skills during the shifting simulation part of the course that will be very useful on the road.
19) The time spent in the lecture portion of the course was appropriate.
20) The time spent in the driving simulation portion of the course was appropriate.
21) The time spent in the shifting simulation portion of the course was appropriate.
22) The trainer had a good understanding of the course material.
23) The trainer worked well with the drivers.
24) The trainer understood your needs and issues.
25) The trainer gave very useful feedback.

Figure 8. Correlation of Demographic Variables with Questionnaire Items



Accident Rates

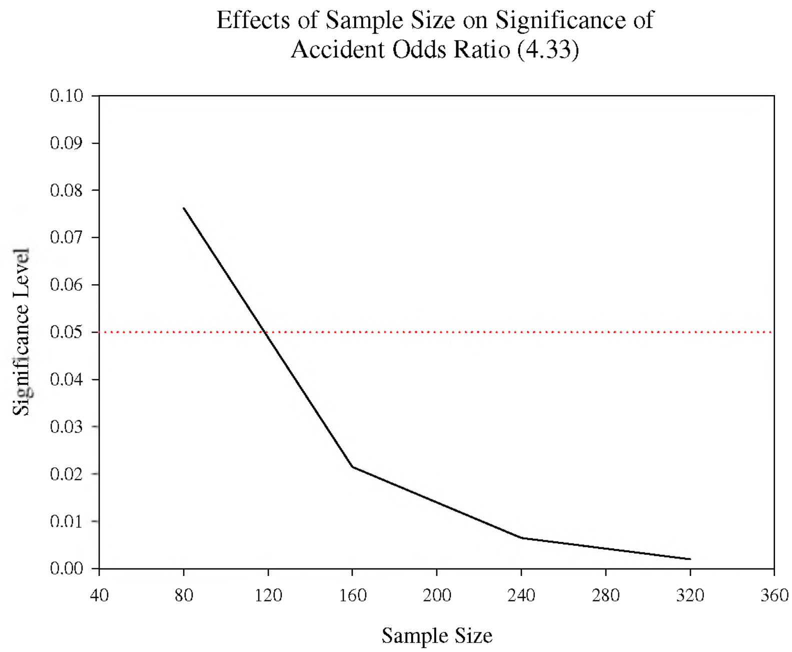
There were a total of 7 accidents over the 6 month interval following training (See Appendix 4 for detailed description). Three accidents were reported for drivers in the trained group; however, in Case # 3 and Case # 4 the trained driver was determined by UDOT to be not responsible for the accident. Four accidents were reported for drivers in the control condition. This results in the 2 X 2 contingency table (Table 4) in which the study group had one accident and the control group had four accidents.

Table 4. Accident rates for the study and control groups

	Accident	No Accident	
Study Group	1	39	40
Control Group	4	36	40
	5	75	80

The accident data were analyzed using logistic regression. Logistic regression is a statistical procedure specifically designed to deal with cases with few events (i.e., accidents) and has the advantage of providing an estimate of the odds ratio of an accident depending on training group. The obtained odds ratio was 4.33, indicating that there were fewer accidents in the study group than the control group. At first glance, the 4.33 odds ratio appears to indicate a substantial reduction in accident rates; however, a chi squared statistical test indicated that the effect was not significant given the sample size used in the study. The statistical test of the *a priori* prediction that training should result in a reduction in accident rates, was $\chi^2=2.05$, $p<.076$. It is evident that there was inadequate statistical power in the experimental design to detect differences between the study and control groups.

To determine the number of drivers needed to achieve statistical significance for the logistic regression tests, we simulated different sample sizes with the odds ratio (4.33) obtained in the current study. As evident in Figure 9, the effect of training becomes significant with 120 participants (60 in the study group and 60 in the control group) using a directional statistical test. That is, given the magnitude of the effect of training observed in the current study, UDOT would likely find a statistically significant reduction in accidents by training between 60 and 80 drivers. Furthermore, as the number of trained drivers increases, the magnitude of the odds ratio required to become statistically significant decreases. For example, if 250 drivers were trained, an odds ratio of 1.75 would be statistically significant (e.g., 25 accidents for drivers in control and 15 accidents for drivers who received training).



Insight can also be gained by considering the costs associated with each accident. The UDOT estimated costs differ for the study and control group. The aggregated cost of all accidents in the control group was $10,444, compared to $0 in the study group. Average cost of each accident in the control group was $2,611. Thus, it would appear that not only does the simulator training decrease the frequency of accidents, but it also reduces the costs associated with each accident. However, these cost estimates must be considered with caution, because it seems unlikely that any accident could result in a cost of $0.

Fuel Management and Maintenance

Based on earlier evidence from GEDD (Strayer & Drews, 2003) on the effectiveness of simulator training in commercial trucking sector, we expected that there would be a significant increase in fuel efficiency and a reduction in maintenance costs for those drivers who participated in training. Figure 10 presents the average monthly fuel use for drivers in the study and control groups, Figure 11 presents the average monthly usage for drivers in the study and control groups, and Figure 12 presents the median miles per gallon for drivers in the study and control groups. It is clear that there are distinct seasonal fluctuations in fuel consumption and usage, with the greatest use in the months of December, January, and February. Unfortunately, several factors make it difficult to evaluate the effectiveness of simulator training on fuel management and maintenance costs in the current study. The major problem was that there was not a unique assignment of vehicles to drivers. On many occasions more than one driver would use a vehicle during a storm and in some regions vehicles would occasionally change stations during the season, making it difficult to associate specific vehicle parameters with a unique driver (hence even the distinction between study and control groups in Figures 10, 11, and 12 contains an unknown amount of error). To complicate matters further, examination of the fuel records indicates that on many occasions the fuel card assigned to one vehicle was used to fill several vehicles (e.g., two vehicles in the same shed with the similar miles driven for a one-month interval would have vastly different fuel consumption rates i.e., 0 vs. 1137 gallons). In sum, neither the maintenance data nor the fuel data are of sufficient quality to afford a precise comparison between the study and control groups.

Figure 10. Fuel Usage By Month for Study and Control Groups

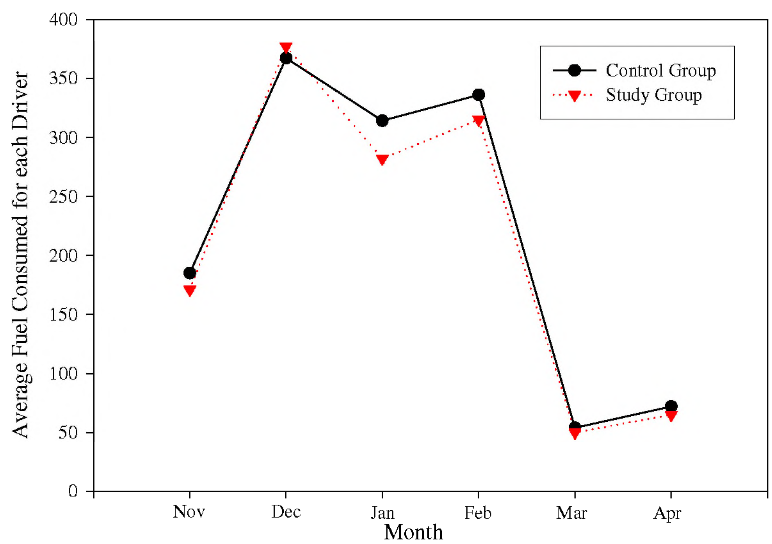


Figure 11. Vehicle Usage By Month for Study and Control Groups

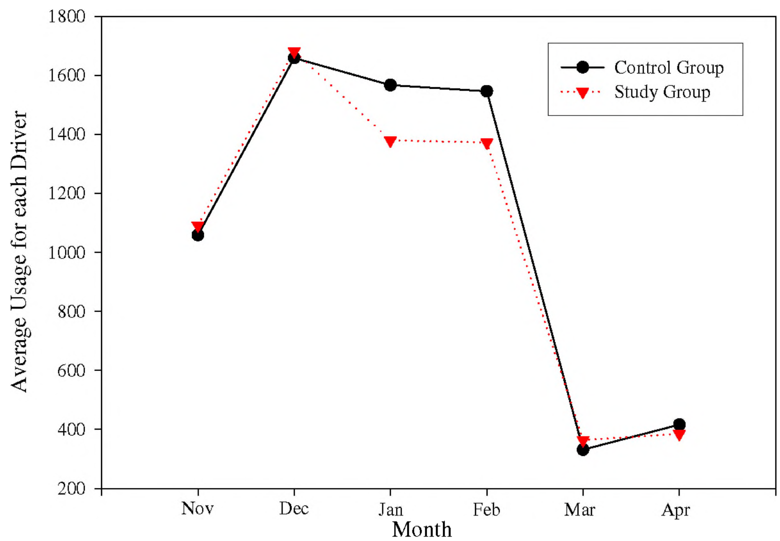
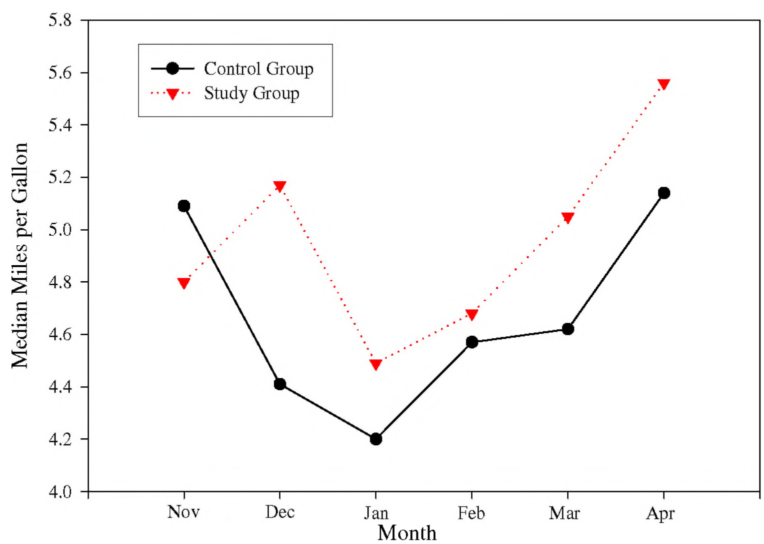


Figure 12. Fuel Efficeincy By Month for Study and Control Groups



Nevertheless, we performed a statistical analysis on the fuel efficiency data for the drivers with non-zero entries in fuel usage to see if there was any difference between the study and control groups.[2] The analysis revealed both an effect of month, $F(4,28)=3.7$, $p<.01$, and a difference in fuel efficiency between the study (mean 4.96,

[2] Note that due to missing data, the month of November was too noisy to include in the analysis, that the data from several drivers were lost due to missing values, and the data that were included in the analysis still have unknown levels of noise due to problems assigning fuel usage to vehicles/drivers.

sd=0.38) and the control groups (mean 4.67, sd=0.37), $F(1,31)=3.8$, $p<.05$. The difference represents a 6.2% improvement in fuel efficiency for those drivers who received simulator training. However, these data must be considered with caution, because of aforementioned problems in correctly assigning fuel usage to drivers/vehicles.[3]

Despite the fact that the data related to the effectiveness of training on fuel management and maintenance contains an unknown amount of noise in the current study, the evidence from the commercial trucking side is quite compelling. Indeed, there is every reason to expect that the benefits of training observed on the commercial side will be similar for UDOT drivers. For example, in the GEDD funded study evaluating simulator training (Strayer & Drews, 2003), drivers hauling mining materials in the Price Utah area exhibited clear and sustained benefits from training. Overall, simulator training increased fuel efficiency of the Price drivers by an average of 2.8%. Statistical analysis indicated that the improvement was significant, $F(1,39)=14.23$, $p<.01$, establishing that the fuel management program improves performance on this important dimension. Moreover, the Price drivers who exhibited the worst pre-training fuel efficiency exhibited the greatest benefits from simulator training. Although there are importance differences between UDOT maintenance operators and the drivers in the Price study, both share similarities in driving in mountainous conditions hauling heavy loads on well established routes. In any event, to more definitively evaluate the effectiveness of simulator training for UDOT drivers on fuel management and maintenance, more precise record keeping associating drivers to vehicles will required.

Conclusions and Recommendations

A customized training program incorporating high-fidelity simulation was developed for UDOT maintenance operators in a collaborative research project with the University of Utah and GEDD. Ratings of user acceptance of the training were very high, with drivers indicating that the training helped them prepare for several issues critical to the safe operation of a snowplow. Drivers of all levels of experience reported that the training was very useful and should be part of UDOT training. In the 6-month period following training, the odds of getting in an accident diminished for the group of drivers who received training compared to a matched control group who did not receive training (albeit a larger sample size would be required for this benefit to become

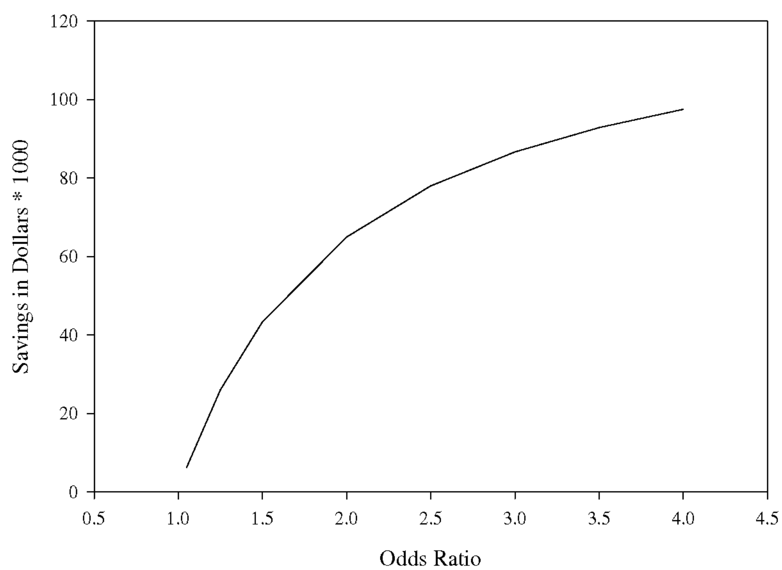
[3] On the other hand, any random assignment error in classifying drivers/vehicles into the control or study group should have the effect of washing out the training effect. Thus, the fact that there are differences between the study and control groups suggests that the effects are, in fact, quite substantial.

significant). Moreover, the estimated cost associated with each accident was lower for the study group than for the control group. Difficulties correctly assigning a specific driver to a specific vehicle during the 6 month post-training interval limit a complete assessment of the effects on fuel management and vehicle maintenance; however, the data that were analyzable from the current study indicate that fuel efficiency increases with training and data from the commercial sector provide compelling evidence for these improvements.

Overall, the snowplow simulator training program offers a number of attractive benefits for UDOT, including a reduction in the frequency of accidents, a decrease in the cost associated with each accident, and an increase in fuel efficiency. To estimate the savings of the training program, we examined the 2003 UDOT accident data and found that there were 50 accidents in which a snowplow was involved and the average cost of each accident was $2,600. Figure 13 plots the estimated savings to UDOT for different odds ratios, using the following equation.

Total Savings = (Frequency of accidents * Cost per accident) – ((Frequency of accidents/ Odds Ratio) * Cost per accident)

Figure 13. Projected Annual Savings From Reduced Accidents

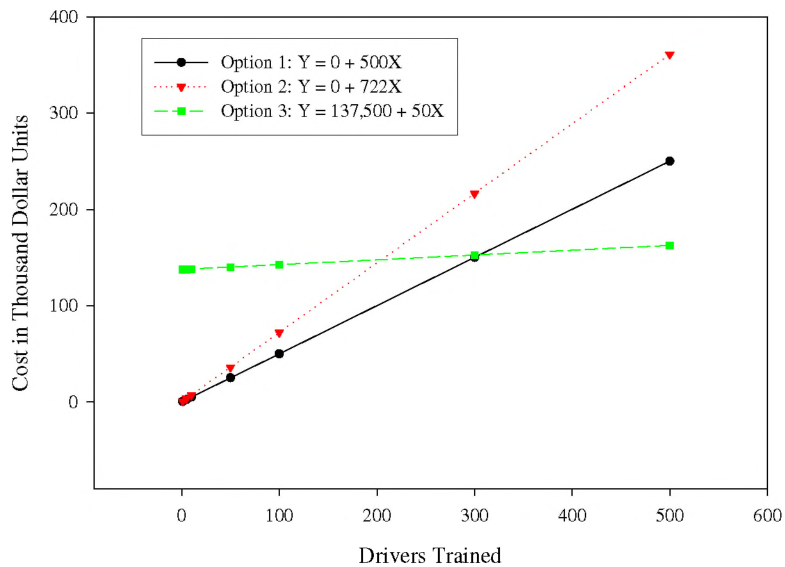


In addition, we can use the improvement in fuel efficiency to estimate the benefit to UDOT in fuel costs with training. In 2003, UDOT fuel expenses associated with snowplow maintenance operations were $800,000. Using the 2.8% estimate in fuel efficiency from the commercial trucking study by GEDD (Strayer & Drews, 2003), this would result in a savings of \$22,400. Using the less reliable 6.2% estimate in improvement obtained in the current study, this would result in a savings of \$49,600. We cannot know for certain what the savings to UDOT will be; however, a reasonable assumption is that it will fall somewhere between \$22,400 and \$49,600 per year.

To estimate the costs of training we used the information provided in Appendix 6 to derive the cumulative cost per driver for the three options provided by L3 (formerly GEDD).[4] In option 1, UDOT drivers commute to the Salt Lake City training facility. Training cost per driver is \$400, and we estimated a cost of \$100 for the time and expenses associated with UDOT workers commuting to and from the facility. Thus, the function relating the cumulative cost of training to the cost per driver is $Y = 0+500X$, where X is the number of drivers trained and Y is the predicted cumulative cost. In option 2, UTOD drivers are trained by L3 at on-side UDOT locations. Training cost per driver is \$722 (i.e., (6000+500)/9 = 722), thus the function relating the cumulative costs of training to the cost per driver is $Y = 0 + 722X$. Finally, in option 3 UDOT drivers are trained by UDOT staff, using simulator facilities purchased and operated by UDOT. In this option, the simulator and trailer purchase costs are \$137,500 and we estimated a cost of \$50 per driver for the costs of the UDOT trainer (includes salary and expenses moving the simulator to remote sites). Thus, the function relating the cumulative costs of training to the cost per driver for option 3 is $Y = 137{,}500 + 50X$.

[4] Note that in these estimates we did not include the lost revenue associated with the 4 hours that the driver was in training, as this should be a constant across the training options. Moreover, we assume in the analysis that the quality and duration of training is equivalent for the three options.

Figure 14. Estimated Cumulative Cost Per Driver



In Figure 14, the three functions are plotted and it is clear that option 1 is the cheapest of all options until at least 300 drivers have been trained, at which point the payoff from the purchase of the simulator would make option 3 the most cost effective option. However, for option 3 to be effective, the UDOT trainers will need to deliver the same quality training package that was delivered by GEDD. Moreover, it will be important to track the changes in driver performance over time to determine the overall effectiveness of the program implemented by UDOT.

Appendix 1: Informed Consent

Department of Psychology

TITLE: ADVANCED SIMULATOR TRAINING FOR UDOT WINTER MAINTENANCE OPERATORS

Principal Investigator: David L. Strayer, Ph.D.

Consent Form for Participation in a Research Project

BACKGROUND:

You are invited to take part in a research study. Before you decide to take part in this study, it is important for you to understand why this research is being done and what it will involve. Please take your time to read the following information carefully. Ask us if there is anything that is not clear or if you would like more information. The proposed research will evaluate the utility of using GE Driver Development's advanced simulator training to improve the performance of winter maintenance crews operating on Utah roadways.

STUDY PROCEDURE:

This study is a pilot program to test the utility of using GE Driver Development's advanced simulator training facilities (located at 2961 West California Avenue, Salt Lake City) to provide training for winter maintenance operators. One group of operators will receive a four (4) hour training program in the driving simulator practicing safe driving practices, correct operation of the equipment, and appropriate snow removal techniques. A control group, matched on age and driving history, will serve as a baseline. We will assess the effectiveness of training over the following six month period. We will collect paper and pencil ratings from you concerning the effectiveness of training and we will also collect measures of fuel consumption and breaking data over the 6 months following training. Based on reports from the commercial trucking industry, we predict that the simulator training program will result in a reduction in traffic accidents, decreased maintenance costs, and a reduction in fuel consumption.

Please note that participation in the study will not affect your job status in any way and that no information will be provided to UDOT that identifies your performance in the study.

RISK:

The personal risks in the experiment are similar to those of ordinary life; however, as with amusement rides, some people may experience minor motion sickness from the simulator (e.g., dizziness).

BENEFITS:

The study will help us understand the effectiveness of GE Driver Development's advanced simulator training to improve the performance of winter maintenance crews.

ALTERNATIVE PROCEDURES:

There are no alternative procedures, but you have the option of not participating in the study.

CONFIDENTIALITY:

We will keep all the research records that identify you private to the extent allowed by the law. All data will be coded by a randomly assigned subject number, kept in a secured database, and only the principal investigator, the co-investigator, and data entry staff will have access to raw the data. The summary data (averages values and standard deviations) will be presented in publications, technical reports, and conference presentations; however, no records indicating your identity will be made public. No information concerning your individual performance in the study will be provided to UDOT. The data will be kept on record for at least 5 years after publication of all technical documents, whereupon the data will be destroyed. However, representatives from the University of Utah may inspect and/or copy the records that identify you.

PERSON TO CONTACT:

Dr. David Strayer, phone (801) 581-5037

INSTITUTIONAL REVIEW BOARD:

If you have questions regarding your rights as a research subject, or if problems arise which you do not feel you can discuss with the Investigator, please contact the Institutional Review Board Office at (801) 581-3655.

VOLUNTARY PARTICIPATION:

It is up to you to decide whether or not to take part in this experiment. If you decide to take part in this experiment you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving any reason.

COSTS AND COMPENSATION:

There are no costs other than your time for participation in this study. There is no financial compensation for participation in the study.

RIGHT OF INVESTIGATOR TO WITHDRAW:

You may withdraw from the study at any time without penalty. The investigators can also withdraw you without your approval.

CONSENT:

Please initial box

1. I confirm that I have read and understand the information sheet dated _______ for the above study and have had the opportunity to ask questions.

☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.

☐

3. I agree to take part in the above study and that I will be given a signed copy of the consent form to keep.

☐

_______________________________ Date _______________

Signature of Participant

_______________________________ Date _______________

Researcher or Staff

Appendix 2. U of U/UDOT Snow Plow Simulator - Detailed Specification

Last Updated: Oct. 10th, 2003 – Bryce Brunner

Deliverables:

Vehicle Configurations:

Num	Vehicle	Vdd Name	Plow State	Wing State	Blade Heading	Diagram
1	*10 Wheeled Dump truck (Automatic)*	*sp_auto_plow_right*	*Down*	*In*	*right*	 *A U T O*
2	*10 Wheeled Dump truck (Automatic)*	*sp_auto_plow_left*	*Down*	*In*	*left*	 *A U T* O
3	*10 Wheeled Dump truck (Automatic)*	*sp_auto_plow_wing_right*	*Down*	*Out*	*right*	 *A U T O*
4	*10 Wheeled Dump truck (Automatic)*	*sp_auto_plow_wing_left*	*Down*	*Out*	*left*	 *A U T O*
5	*10 Wheeled Dump truck (13 speed Manual)*	*sp_man13_plow_right*	*Down*	*In*	*right*	 *13 S P D*
6	*10 Wheeled Dump truck (13 speed Manual)*	*sp_man13_plow_left*	*Down*	*In*	*left*	 *13 S P D*
7	*10 Wheeled Dump truck (13 speed Manual)*	*sp_man13_plow_wing_right*	*Down*	*Out*	*right*	 *13 S P D*
8	*10 Wheeled Dump truck (13 speed Manual)*	*sp_man13_plow_wing_left*	*Down*	*Out*	*left*	 *13 S P D*

Note: removed vehicles with blade up and wing up, added left and right blade heading configurations.

Visual Databases:

Num	Name	Description
1	Snow Freeway	24 Miles of Snow covered divided Freeway
2	Mountain Pass	18 Miles of 2 lane road

Structures:

Num	Structure	Database	Comment
1	Bridges	Mountain Pass	Provide reduced friction through scenario
2	Overpasses	Snow Freeway	Add new underpass to section of freeway to give appearance of overpass conditions
3	Blind Curves	Mountain Pass	Currently exists

4	Downgrades	Mountain Pass	Currently exists
5	On/Off ramps with Gore	Snow Freeway	Add gore area to snow freeway (concrete area in “Y”” section of off ramp.)

Conditions:

Num	Name	Description
1	Night and daytime driving	Currently exists
2	Reduced visibility	Currently exists
3	Obscured view out of right mirror because of wing	Need to add to visual vehicle model. *(U of U to determine if obstruction is caused by wing or rooster tail of snow.)*
4	Snowing (light and heavy)	Need to make current heavy snow more dense
5	Icy patches	Can be created in scenarios or through OpCon
6	Snow covering roadway (lane markers visible in left rear view mirror)	Add placable/removeable snow to Mountain Pass and Snow Freeway
7	Snowplow rooster tail (snow thrown farther as MPH increases)	Add to visual vehicle model as a component of speed.
8	Blade catching – if driver hooks blade, vehicle thrown left or right	Can be created in a scenario *(Implementation and training utility questionable – tabled as future item.)*

Overall Comments:

- Vehicles will be created with plow and/or wings in up and down states. Driver will not have ability to raise or lower plow/wing while driving in the initial version.
- Plows should be able to run in tandem as either a lead or follow vehicle.
- When plows are run in tandem outside plows should feel the effects of additional snow in their lane.

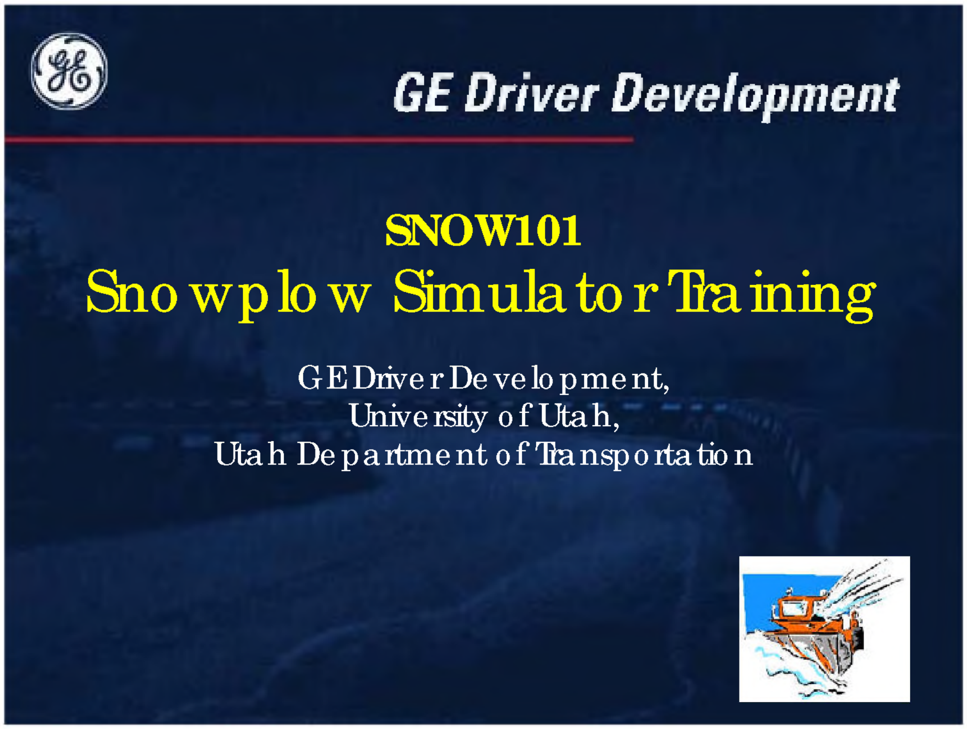
Appendix 3: Syllabus for Simulator Training

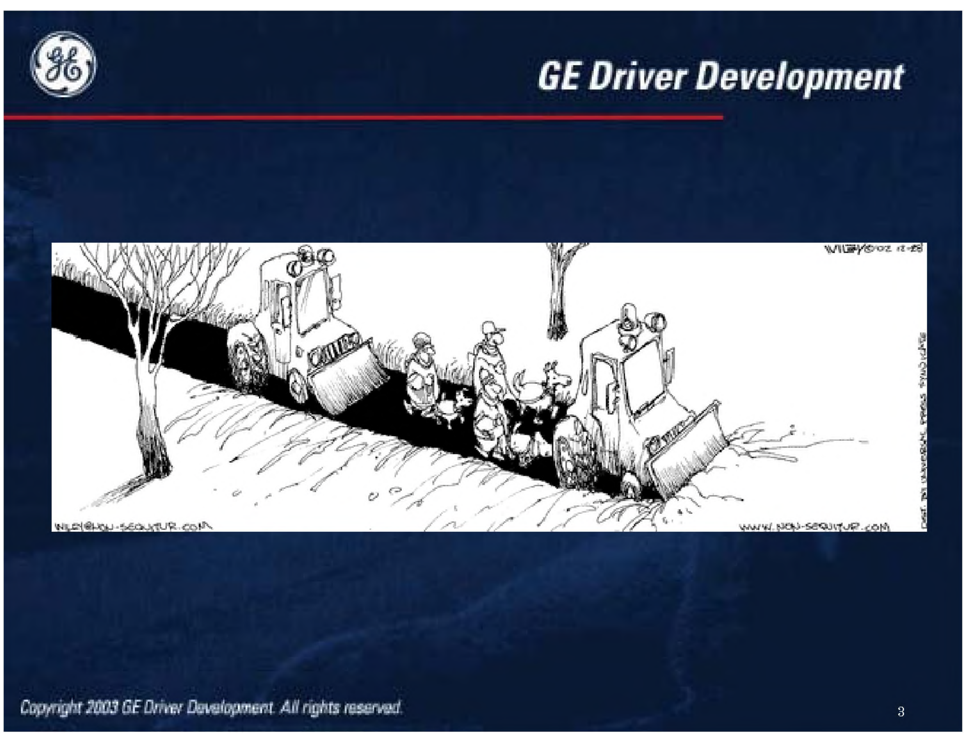
Time	Topic	Training Delivery
15 minutes	Welcome: • Introductions: self and participants ***(PPT #)*** • Purpose of Course o PPT 1 Slide UDOT Claims Data ***(PPT#)*** ▪ Contact with other vehicles ▪ Contact with stationary property ▪ Snow over structure ▪ Passing & Throwing Snow ▪ Passing same/opposite direction ▪ Merging at ramps o Maintenance Data ***(PPT#)*** ▪ Equipment Damage ▪ Running into back of truck ▪ Backing (damaging spinner) o Hitting Islands/ PPM • Review Course Objectives /Agenda/Driver Self Assessment ***(PPT #)*** 1. Demonstrate ability to effectively apply fuel management strategies through shifting techniques. 2. Demonstrate understanding and application of SIPDE, as well identifying cues and avoiding instances of and recovery in the event of tire/blade catch. 3. Demonstrate space management skills in tandem snow plowing settings as lead and following driver in both urban highway one-way and mountain two-way traffic. Also demonstrate space management skills in backing and turning snowplows. 4. Demonstrate skills required to effectively communicate, while plowing, with other drivers to optimize plowing coordination and sequencing and avoid obstacles. 5. Demonstrate speed management skills in tandem snow plowing settings as both lead and following driver in both urban highway one-way and mountain two-way traffic.	Instructor Led 
25 Minutes	**Fuel Management/Shifting Techniques** Instructors explain basic fuel management screen to students and what will be reviewed on summary screen. Instructor: • Define progressive shifting as it applies to a specific engine/trans • Review concepts and summary screen with participant. • Demonstrate progressive shifting and determine your individual fuel economy improvement **Participants conduct 3 drives with instructor coaching**	TranSim Basic
20 minutes	**Introduction To Mark II** U of U Scenario 1 Snowplow 4 minute.	Mark II 

Time	Topic	Training Delivery
15 minutes 30 minutes	**Discuss SIPDE** ***(PPT #)*** 1. What is SIPDE? i. Scan ii. Identify iii. Predict iv. Decide v. Execute 2. How does each element impact your driving? III. Conduct U of U Scenarios a. Scenario 6 b. Scenario 3 Conduct one replay drive and review SIPDE concepts with participants.	Instructor Led Mark II
20 min.	**Space Management** ***(PPT #)*** A. What are the components of space management? ***(PPT#)*** 1. Six Sides of Vehicle (handout) B. Calculating Stopping Time C. Applying Timed-Interval Method D. Factors Determining How Well Vehicles Maneuver E. Merging Guidelines Handout Stopping Distance Chart Optimal Plowing/ Coordination Timing • Tandem Formations • Communication • Other? *(5 minutes on the tandem plowing example slide and 5 minutes discussing other circumstances they may encounter)*	Instructor Led
30 minutes	**Conduct U of U Scenarios** a. Scenario 10 b. Scenario 2 Conduct one replay drive and review Space/SIPDE concepts with participants.	MarkII
20 min.	**Speed Management** ***(PPT#)*** A. Stopping distances and reaction times (*Formula for Distance Traveled use Reaction Time Chart as Handout)* B. Speed & Stopping Distance Determination C. Speed and snow throwing distance D. Maximum Speed, 35 MPH (Recommendations coming from Stan)	Instructor Led

Time	Topic	Training Delivery
	D. Speed and blade catching E. Load and gear selection awareness on downgrades/upgrades F. Merging and passing G. Speed and traffic considerations *(emphasize plowing complexity rises proportional to traffic density.)*	
20 min	**Advanced U of U Scenarios** a. Scenario 4 --Coach/review Speed/SIPDE while driving --Conduct replay with student. Allow student to assess their performance and compare with trainer's.	Mark II 
15 min.	**Crew Communication** Advanced U of U Scenario #9	Mark II 
10 min.	**Wrap Up and Summary** ***(PPT #)*** A. Review Key points from course and objective B. Questions?	Instructor Led 
220 Total minutes		

Appendix 4: PowerPoint slides 1-22 used during training





GE Driver Development

Types of UDOT Claims

- Contact with snowplow (space issue)
- Snow over structure (speed issue)
- Contact with stationary property (space issue)
- Passing throwing snow (speed issue)
- Passing in same direction (space issue)
- Merging at ramps (space issue)

4

GE Driver Development

Some Specific UDOT Incidents

- Plow clipped mirror at stop light
- Driver was cleaning inside shoulder and hit abandoned vehicle
- Driver hit attenuator with wing
- Vehicle lost control on slick roads and spun out in front of plow
- Cleaning the gore, collided with semi-trailer

5

GE Driver Development

Maintenance Issues

- Fixing damaged plows (e.g., shear bolts)
- Running into the back of other trucks
- Backing (tearing spinner off while turning around)
- Damaging islands, signs, delineators, etc.

6

GE Driver Development

Fuel Management

- UDOT fuel expenses $800K/year
- Proper shifting skills
- Improved efficiency, reduced costs
- Reduced idle time (30% of run time is in idle)
- Improved safety

7

GE Driver Development

SIPDE Golden Rules

- Know Your Route
- Know Your Equipment
- Anticipate Hazards
- Manage Your Fatigue
- Be Aware of Changing Weather
- Visibility

8

GE Driver Development

Stopping the Plow

- Drive in to 'virgin' snow
- Drop blade
- Use dirt on should of road for traction
- Jake brake?

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GE Driver Development

Lead Driver in Tandem

- Lead truck is the eyes of those following
- Lead truck dictates the speed but factors to considered are:
  - Snow conditions and visibility of 'following' drivers
  - Road conditions
  - Experience of 'following' drivers
  - Traffic density
- Lead driver must always be aware of what is happening to the team behind

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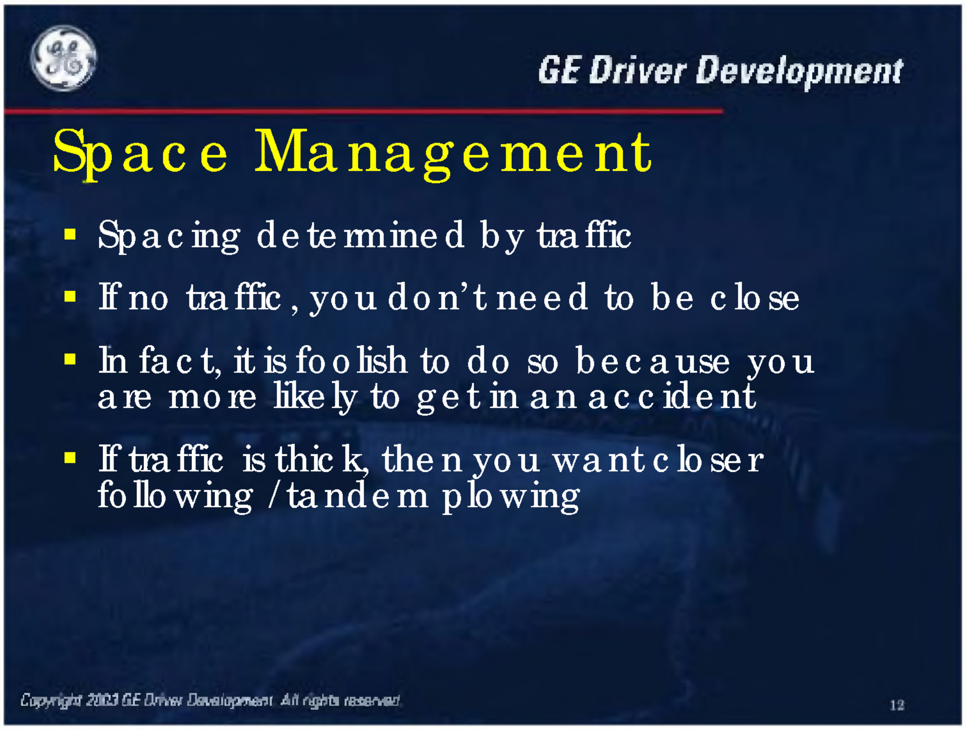
GE Driver Development

Drivers Following in Tandem

- Second truck should ask lead to slow if they can't keep up (for whatever reason)
- Visibility
- Confidence (Comfort Zone)
- Snow volume
- Traffic

11


GE Driver Development
Space Management
Spacing determined by traffic
If no traffic, you don't need to be close
In fact, it is foolish to do so because you are more likely to get in an accident
If traffic is thick, then you want closer following /tandem plowing
Copyright 2003 GE Driver Development. All rights reserved.
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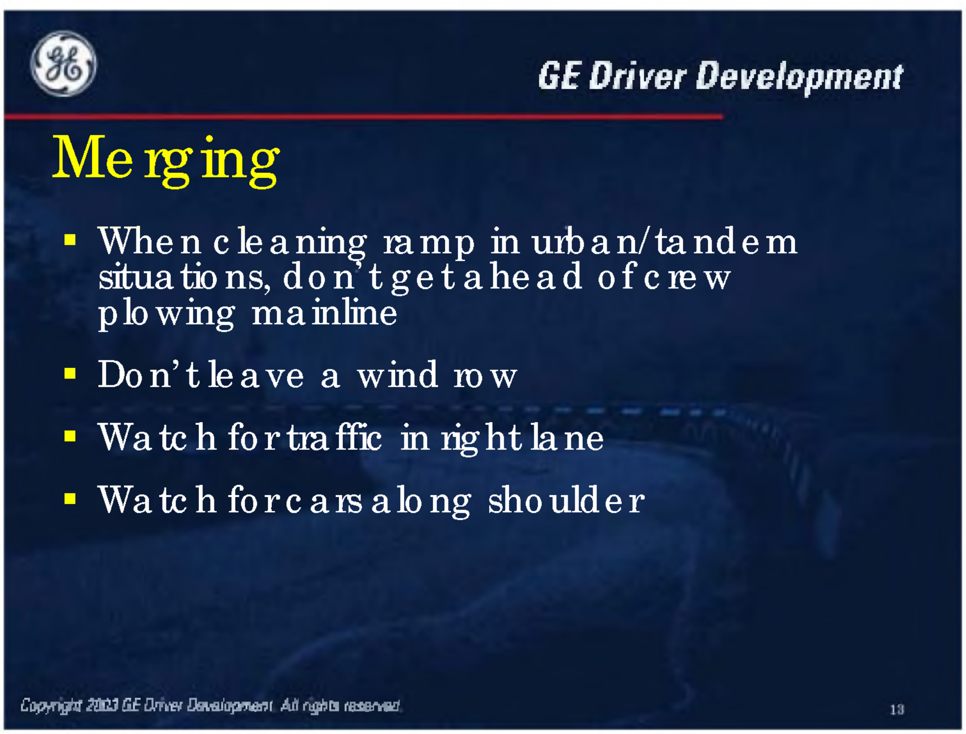
GE Driver Development
Merging
When cleaning ramp in urban/tandem situations, don't get ahead of crew plowing mainline
Don't leave a wind row
Watch for traffic in right lane
Watch for cars along shoulder
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13

GE Driver Development

Rules of Thumb for Speed

- Last plow in platoon
- Along sidewalks
- Turning
- Winging back
- U-turns
- Plowing structures

GE Driver Development

Rules of Thumb for Speed

- Limited visibility (high winds, blowing snow)
- Heavy urban traffic
- Max speed for heavy snow
- Clean-up throwing snow over Jersey barrier
- Max speed down-hill
- Max speed with clear roads

GE Driver Development

Situations to Decrease Speed

- Over structures
- When parked cars are present
- When people are present
- Along fences
- If there are plowable pavement markers

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GE Driver Development

Hazard Recognition

- Blade catching
- Snow drifts
- Cattle guards
- Debris on roads
- Railroad crossings
- Manhole covers
- Icy patches

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GE Driver Development

Visibility

- Whiteout conditions
- Wipers icing up
- Blow by (from plow)
- Use centerline in mirror to *position the plow*

GE Driver Development

Crew Communication

- Lead truck alerts others of traffic/obstacle hazards
- Last truck alerts others of troublesome traffic approaching the plowing team
- Following trucks alert truck ahead when it is out of salt/sand
- Lead truck can advise last truck when to clear gore

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GE Driver Development

Crew Communication

- Communicate with dispatch on state radio
- Coordinate with neighbor stations
- Communicate over CB
- Communicate with team
- Communicate with partners

GE Driver Development

Fatigue

- This is when accidents happen
- Structures sneak up on you
- Not aware of where wind row is going
- Let people know you are tired
- Take a break – in a safe place
- Don’t put yourself or others at risk

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GE Driver Development
Best Practices
Overcommunication between drivers is always best
Don't exceed comfort zone
Don't leave a wind row
Don't let lanes get snow packed
Don't forget to breath ☺
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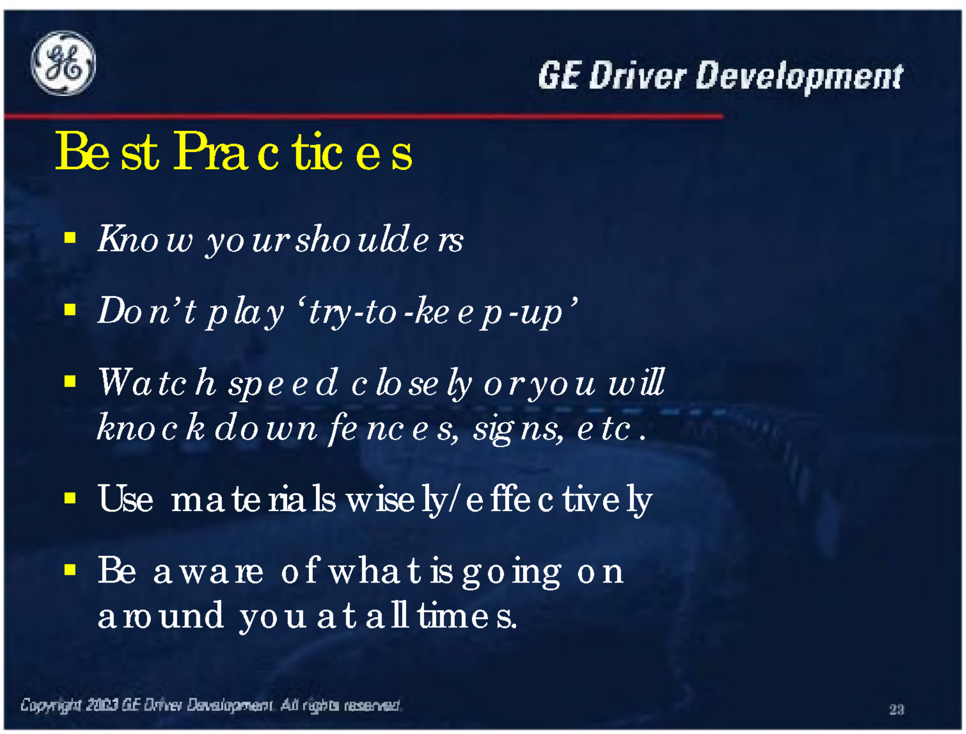
22


GE Driver Development
Best Practices
Know your shoulders
Don't play 'try-to-keep-up'
Watch speed closely or you will knock down fences, signs, etc.
Use materials wisely/effectively
Be aware of what is going on around you at all times.
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Appendix 5. Accidents reported in the 6-month interval following training

Case:	1
Group:	Control
Date:	12/11/2003
Region:	4
Cost:	$3,883
Description:	The UDOT driver turned off SR-89 onto Marxville road to check the condition of a stop sign. He was looking at the stop sign in the side mirror, looked up and saw a vehicle coming from the other direction. He was traveling at approximately 5 MPH and was coming to a stop. The vehicle traveling in the opposite direction started to come to a stop when the two vehicles struck head-on.
Case:	2
Group:	Control
Date:	12/27/2003
Region:	1
Cost:	$1,450
Description:	The UDOT driver plowing and sanding in the inside lane decided to move to the outside lane. The other vehicle was along side the snowplow on its right and was somewhat obscured (in blind spot) and low profile. The UDOT driver signaled and moved right, colliding the plow blade into the left front of the other vehicle as it was passing in the outside lane.
Case:	3
Group:	Study*
Date:	12/27/2003
Region:	2
Cost:	$500
Description:	The UDOT driver 3 states he and three other snowplows were traveling SB on I-15. Driver 1 was in the lead then Driver 2 then Driver 3 then Driver 4. Driver 3 stated a pickup traveling SB cut between Driver 1 and Driver 2 to take the ramp to I-215. Driver 2 had to stop to keep from hitting the pickup. Driver 3 could not stop in time to avoid hitting Driver 2's truck. Driver 3 hit the back of Driver 2's sander causing damage. *Driver 2 was trained, Driver 3 (responsible for accident) was not
Case:	4
Group:	Study
Date:	01/07/2004
Region:	1
Cost:	$1,300
Description:	The lead snowplow truck with sander stopped on the shoulder of the

	roadway to stage for a multi-plow sweep. The following snowplow pulled up behind the lead truck and made contact between the plow-blade and the sander causing damage to the sander. The following driver (who was not in either the trained or control group) was the cause of the accident.
Case:	5
Group:	Control
Date:	02/03/2004
Region:	3
Cost:	$5,000
Description:	The UDOT driver was the second plow in tandem east bound on Sr. 92. The lead plow blade hit a trench plate inadvertently exposing a latent trench. The transverse plates were hidden by snow cover. There was insufficient traffic control and no warning of the hazard. The plow drove into the exposed trench at approximately 30 MPH. The collision caused extensive damage to both the plow blade, front wing and the vehicle driving mechanism. The UDOT vehicle was disabled and required transport. UDOT had no knowledge of the covered trench.
Case:	6
Group:	Study
Date:	02/04/2004
Region:	4
Cost:	$0
Description:	UDOT driver was east bound completing the 4th & 5th pass with the wing plow in the down position. A semi-truck passed on the left side, employee was watching as semi truck passed when he realized that he was too far to the right. As a result he could not move to the left due to the semi truck and struck an ET-200 guardrail end section with the wing plow. He tried to move to the left and was unable to do so in time.
Case	7
Group:	Control
Date:	02/09/2004
Region:	3
Cost:	$161.10
Description:	UDOT driver was northbound on Sr 189. He was plowing the center provisional lane. He said that his vision was obscured by slush thrown onto his windshield. As the visibility improved he observed a raised center island approaching. He swerved to the right into the inside North bound lane. He said, that he was unable to completely avoid colliding with the island because of the traffic volume. The plow blade removed three sections of concrete slab from the island.

Appendix 6: Options for UDOT training provided by L3 (formerly GEDD)[5]

Option 1

L3 trains at the SLC site	$400 per trainee/course (max 8 per day/one (1) instructor)

Option 2

L3 trains at UDOT locations:	$6000 per day (max 9 trainees/day)(one (1) instructor) $1.50/mile in-state relocation fee for each trailer move (min $500)

Option 3

UDOT purchases simulators:	$98,000 per VS III unit (inc. 1 year warranty)(multi-unit discount available) $5000/unit/year extended warranty $4500 per unit to install in trailer for transportation *(L3 must do the install to protect warranty)*

Figure 15. The TranSim VS III

[5] GEDD was recently acquired by L3 Com. However, the simulator facilities and training staff have not changed with the change in corporate ownership.