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Simulator Technology

Analysis of Applicability to Motor Vehicle Travel

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SIMULATOR TECHNOLOGY

ANALYSIS OF APPLICABILITY TO MOTOR VEHICLE TRAVEL

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EXECUTIVE SUMMARY

In excess of 44,000 people are killed, and many more seriously injured or maimed each year in automobile and truck accidents. The dollar cost paid by everyone - in the form of insurance premiums and taxes - is enormous. It is clearly in the national interest to conduct basic research to fully understand the causes of these accidents, and to develop acceptable means to substantially reduce both the number and severity of automobile, truck, bus, and other roadway accidents.

Air travel, which was considered risky or unsafe in the 1930s, 40s, and 50s, has made extensive use of simulators since WWII to conduct basic research, to train, to certify, and to license, all with the objective of making air travel safer. Air travel is indeed much safer now than a few decades ago, and the application of simulators is generally credited as a significant factor in this improved safety. Motor vehicle travel, on the other hand, is not nearly as safe as air travel, and simulators have not been widely or extensively used for research, training, certification, or licensing.

Simulators have not been widely used with respect to vehicle travel in the past because they were cost prohibitive and, in many instances, technically limiting. However, recent advances in technology have changed, and are continuing to change, this assessment. High fidelity driving simulators ranging in price from several thousand to a few million dollars are becoming readily available. The availability of such simulators suggests that those with an interest in, or a responsibility for, motor vehicle travel may conduct basic research, train, certify, and license during the next 30 years via simulators in a manner similar to that which has been experienced in air travel for the past 50 years.

The purpose of this report, therefore, is to answer the question: Can simulator technology be applied to motor vehicle travel in a way that will reduce the accident rate, dramatically improve quality, and/or reduce cost as suggested.

This report begins with the identification of specifically how a motor vehicle simulator may be utilized to reduce the accident rate; to increase the quality of licensing and/or certification without increasing costs; and to provide lower cost, higher quality vehicle - highway systems. Specific identified motor vehicle simulator utilizations include research; development and evaluation of training, screening, certification, and licensing systems/programs; and highway and automobile design and design evaluation.

Utilizations identified in this report are based on contributions from diverse sources around the world, including state and local governments; Canadian, Netherlands, Swedish, and German government researchers; university researchers; private researchers; simulator manufacturers; and automobile designers (Ford; GM). The utilizations suggested include currently funded programs (if a simulator were available today, it would definitely be used today), planned near future programs, and suggested programs.

Each utilization requires a specific level of simulator fidelity (and therefore cost). Thus a set of basic simulator characteristics/requirements was developed for each utilization. It is evident from the summary tables that substantial benefit may be obtained from any of a variety of simulator fidelity levels (i.e., cost levels).

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INTRODUCTION

Background

Substantive research leading to highway vehicle accident reduction has traditionally been constrained or severely limited by the inability to economically conduct highly controlled experiments in a safe environment. Off-highway instrumented driving ranges and vehicles have afforded significant research opportunities, but these opportunities are limited by the inability to present hazardous or highly stressful situations, to control weather conditions, to provide a wide variety of scenarios and situations, to change or control the environment including alternative highway designs and signing, and to select or vary specific vehicle properties. Likewise, on-highway experiments using instrumented vehicles or traffic measurement systems afford significant research opportunities, but these opportunities are also limited by the same restrictions as the off-highway experiments plus the inability to control the traffic and other individuals. Simulators at almost every level of fidelity and cost also provide significant research opportunities, but the opportunities have, until recently, been limited by unfavorable cost vs. fidelity vs. research capability factors, and, in many instances, the inability to provide adequate visual (system) fidelity at any cost.

In addition to their role in research, simulators are a valuable design and evaluation tool. They may be used, for example, to evaluate vehicle controllability - such as various 4-wheel steer algorithms, antilock brakes, and active suspension systems -, head-up displays, intelligent vehicle-highway systems, highway design, signs-signals-markings, and many other design features and driver-vehicle-highway systems. However, simulators have not been widely used as a design and/or evaluation tool due to cost and fidelity limitations.

During the 1980s, significant advances in computer technology coupled with the advent of relatively inexpensive graphics processors and readily available graphics software lead to truly high fidelity, substantially lower cost visual system technology for highway vehicle simulators. Simulator fidelity levels that were unachievable a decade ago are now readily achievable, and cost vs. fidelity vs. research capability that were unfavorable as recently as five years ago now appear potentially favorable.

It, therefore, behooves us as a society to evaluate, or re-evaluate, the cost and efficacy of highway vehicle simulators as a research, licensing, training, and design tool to conduct the basic research, design, development, and evaluation needed to significantly reduce our accident rate and associated costs, and to obtain minimal cost designs/systems consistent with safety and public preference.

Overview

To answer the question: can simulator technology be applied to motor vehicle travel in a way that will reduce the accident rate, dramatically improve quality, and/or reduce cost, specific existing and potential uses and applications of simulators in motor travel research, design, development, evaluation, licensing, and certification programs were identified. Those applications that will in all likelihood contribute significantly to accident reduction, to helping assure safe designs as technology advances, and/or to helping to assure minimal cost consistent with safety and public preference were selected for inclusion in this report. The fact that a large number of specific applications were identified indicates simulator technology may be applied to motor vehicle travel to reduce the accident rate, improve quality, and/or reduce costs consistent with safety and public preference.

Detailed simulator characteristics needed to support each specific simulator utilization were then developed. Realistic characteristics in light of current technology may be interpreted as a feasibility statement relative to the application of simulators to motor vehicle travel.

Methodology

The strategy for determining the need, potential utilization, benefit, and complexity of a driving simulator (or complex of simulators) is:

Step 1: Identify the need: Identify, verify, and validate specific utilization and research that, given appropriate resources, would almost definitely be executed.

Step 2: Specify, in detailed characteristics, physical resources needed to execute the identified utilization and research. Physical resources include appropriate simulator needs, library needs, unique and standard software (e.g., to gather experimental data on simulators, sensor suite, etc.); physical resources as defined does not include funding for research projects.

To accomplish step 1, each of the 100 individuals on the A3B06 mailing list and other known appropriate individuals* were asked to identify specific utilization and research - i.e., needs - pertaining to vehicle operation, highway design, or operator behavior that they and/or their organization would accomplish given appropriate resources. Results of this solicitation were reviewed, refined, and augmented in an iterative process via phone, via mail, and via a subcommittee meeting attended by 15 interested, participating individuals. The results of this process are presented in the section entitled "Simulator Utilization."

The solicitation also requested respondents to characterize the physical resources they thought necessary to support the specific research. Emphasis was placed on detailed simulator characteristics. After the utilization was refined, four individuals, each from a different organization and each an expert in simulator design as well as utilization/application, developed detailed simulator characteristics for each utilization. The characteristics are based on the initial inputs from potential users plus the expertise and experience of the four individuals developing the final tables. The results of this effort are presented in the section entitled "Simulator Characteristics and Requirements."

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*Because certain individual experts have been involved in feasibility studies and other related analyses for the proposed National Advanced Driving Simulator (NADS), either as employees of U.S. Department of Transportation or under contract to U.S. DOT, all U.S. DOT employees and all NADS related contractor personnel were excluded from participating in this survey and analysis.

SIMULATOR UTILIZATION

To determine whether or not simulator technology can be applied to motor vehicle travel, numerous users and potential users - researchers, engineers, training/licensing/certification personnel, vehicle roadway designers, etc. - were asked to state how they would use a simulator in their daily work, if a simulator were available. They were also asked to indicate requisite simulator characteristics/fidelity level for each application. Responsible personnel from state and local governments, researchers from foreign governments, university researchers, private researchers, and automobile designers responded to the solicitation for potential simulator utilization with specific, focused, currently funded projects, planned future projects, and suggested projects. For example, both Canadian and Florida officials described currently funded utilizations of a simulator (if one existed) relative to aging drivers, highway and automobile designers described utilization of a simulator to evaluate upcoming designs and design features, and almost every respondent described utilization of a simulator for sorely needed basic research. Thus there are numerous on-going and near future funded projects where the principals indicated they would definitely use a driving simulator if a suitable simulator was available, and numerous suggested projects which are intended to lead to minimal cost products consistent with safety and public preference and/or which will lead to a significant accident reduction.

The editors of this document grouped, expanded, and elaborated these suggested utilizations into a structured set of utilizations tabulated in Table I. A description of each utilization in Table I follows.

Group I: Driver Related Utilization

A driving simulator can be very beneficial to researchers, instructional/training system development specialists, licensing agencies, special certification agencies/groups, vehicle designers, tire designers, and legislators to study and characterize human behavior relative to driving, to develop and validate training, licensing, certification, and screening programs, and to develop and validate legislation to reduce accidents. This group of potential utilizations lists a few of the many vehicle operator studies that could be conducted on a driving simulator with the goal of substantially reducing the accident rate and severity by improved quality training, improved quality licensing and certification, and appropriate legislation.

I-1. Driver Behavior Studies

Very little is known about driver behavior - especially under limit or stress or hazardous conditions. This unfortunate fact is attributable to the actuality that safe, economically feasible means to study driver behavior under limit, stress, or hazardous conditions have generally not been available. A properly designed and implemented driving simulator can provide the means to study driver behavior under a variety of conditions. The items suggested below are examples of the types of behavioral studies that should be accomplished to help understand driver behavior with the goal of significantly reducing accident rate and severity.

A. Braking and Steering Behavior; and Motion Perception

Knowledge of driver braking and steering behavior is essential to the design of safe vehicles and highways. Currently, engineers designing vehicles and highways base critical decisions on informal observations, personal experience, and a mixture of supported and, too often, unsupported statements in the literature.

In this utilization, a series of studies would be conducted in a driving simulator to fully characterize human behavior relative to steering and braking. The characterization would include numerous factors, such as age and occupation, that may affect inherent aptitude, attentiveness, attitude, etc., that in turn affect braking and steering behavior.

Additionally, this utilization would include extensive studies on motion perception while driving. Motion perception is known to affect steering and braking behavior as well as other factors such as stress.

B. Risk Perception and Decision Making

Risk of death, serious injury, or substantial inconvenience is inherent in driving. Most individuals make decisions, such as whether or not to drive in a specific state of fatigue or intoxication, what constitutes a safe speed and driving strategy in a particular situation, etc., based on risk perception. Very few people will drive such as to intentionally cause death, serious injury, or substantial inconvenience to themselves or to other people, but numerous people can be observed daily driving in what is generally considered an unsafe manner.

In this utilization, a driving simulator would be used to learn how drivers perceive and respond to risk. With the understanding of human behavior resulting from these studies, methods and programs to substantively improve risk perception and response can be developed. Such programs should lead to a substantial reduction in the accident rate.

C. Workload

Casual observation of vehicle and highway trends reveals that tasks are being added to the driving workload without consideration for overloading the driver. For example, consider an individual trying to orient himself in a strange town via an onboard intelligent map display while driving 45 MPH on a congested parkway with fixed signs, one or two variable message displays presenting critical information, partially obstructed views, and traffic signals in unknown locations. Is he/she overloaded? Is the probability of an accident high?

The purpose of this utilization of a driving simulator is to conduct a number of studies that will result in an understanding of the workload facing drivers and on the workload limits of drivers. This research data can then be used by engineers in the design of vehicles and highways to limit the workload to a safe level, by appropriate government and private organizations to evaluate new technology relative to its effect on workload, and by cognizant agencies to develop programs to teach drivers how to recognize and avoid work overload.

D. Hazard Perception

Risk perception and hazard perception are closely related. Research into hazard perception, in this utilization of a driving simulator, would characterize human perception of whether or not potential hazards exist, and if so, what is the threat posed by the perceived hazard(s), for a very large number of typical driving situations.

The results of these studies would be used to design hazard awareness education programs/modules and to influence the design of hazard alerting devices being considered for vehicles and highways.

E. Effects of Stressors

It is generally understood that stress may be a temporary condition that can adversely impact a driver's performance. Stress can be induced by vehicle factors (e.g., malfunctioning vehicle system, or an unfamiliar vehicle); roadside factors (e.g., adverse weather conditions, unfamiliar roads, high traffic volumes); or driver factors (e.g., personal or family problems, time pressure, etc.). This utilization is to study the consequences of various types of stress, and to develop and test strategies to mitigate the adverse impacts of stress.

F. Driving Characteristics of Classified Groups

There have been, and continue to be, numerous drug and alcohol studies and aging driver studies. Studies of physically and mentally impaired drivers are being considered, and a few are being executed. Nearly all of the studies have been severely limited by lack of a device to safely and economically conduct scientific experiments.

In this utilization, a driving simulator would be used to safely conduct a complete, methodical, thorough study and characterization of classes of drivers thought to differ substantively from the driving population as a whole. Classes suggested by respondents to this survey include:

a. Aging and effects of aging
b. Selected subsets of mentally impaired
c. Selected subsets of physically impaired
d. Effects of alcohol

e. Effects of various drugs - both legal and illegal
f. Teenagers
g. Effects of long-term captivity (POWs, Civil Prisons)
h. Inexperienced at various specific age groups (late 20s, midlife, elderly)

G. Social Interactions

Social interactions have often been accused or suspected contributors to accidents, but very little research has been conducted to investigate the effects on driver performance and behavior resulting from the driver's interaction with other people while driving. "Other occupant" may refer to other occupants of the driver's vehicle, or may refer to the interpersonal communication that may occur over a cellular telephone or CB while driving. The extent that other individuals may distract the driver, or divert his/her attention from the driving task, or to the extent that such interpersonal communication may cause stress, is an important, yet overlooked, aspect of driver performance. This utilization of a driving simulator is to conduct rigorous studies of the affect of social interactions on driver behavior.

H. Multiple Driver Situations

Very few studies have been conducted involving multiple driver situations - especially those which may result in an accident. This utilization of a driving simulator would involve studying and defining the behavior of drivers when they must interact with, and/or react to, other drivers. Two, three, four or more vehicles may be involved; and multiple vehicle types (car; large/small truck; bus) may be involved. Ordinary as well as potential accident situations may be studied. It is to be emphasized that this utilization is to study and define operator behavior under situations such that the ultimate result will be to improve vehicle and highway design.

I-2. Driver Performance Measures for Driver-Vehicle-Highway Systems Evaluation

Currently, safe or unsafe performance can not be predicted in most driver-vehicle-highway systems. A theory of driving and valid models that would enable engineers to evaluate alternative systems do not exist. The items suggested below are the types of studies that should be accomplished to give engineers the tools necessary to evaluate and predict the relative safety of driver-vehicle-highway systems.

A. Driver Performance Measures

There is considerable interdependency between the driver the vehicle, and the highway relative to safety measures, yet a set of driver performance measures that discriminates safe and unsafe driver-vehicle-highway systems does not exist. For example, the recognition-response time required to avert an accident is dependent on the braking, suspension, and steering system in the vehicle, and on the road surface and available alternative paths of travel in the highway design. Or, the ease of controlling a vehicle (i.e., the vehicle steering and suspension system) in a specific environment (i.e., highway design) affects stress which affects performance. The question is: What driver performance measures discriminate the relative safety of driver-vehicle-highway systems.

This utilization of a driving simulator is to test theories concerning performance measures that will discriminate the relative safety of driver-vehicle-highway systems with the ultimate goal of providing an evaluation tool for engineers.

B. Develop and Validate a Theory of Driving

The performance of ships at sea and aircraft in the air, including the human operator, have been expressed by mathematical models and evaluated analytically via proven theories. Equivalent analytical tools are nonexistent for automobile, truck, and bus driving.

These analytical tools are invaluable in the design, development, and evaluation of systems. These tools significantly reduce the design and development costs, and increase the efficacy of safe systems at minimal cost. The utilization suggested here for a driving simulator is to develop and validate a theory of (automobile, truck, bus) driving that will analytically predict the performance of driver-vehicle-highway systems.

I-3. Design of Driver Screening and Licensing Tests

Simulators are rapidly becoming an economically viable means to conduct a wide range of driver tests including standard licensing, specialized licensing, testing of persons recovering from illness or injury, and preroad test screening. Simulators hold the potential for quality tests as well as economically viable tests. A general purpose driving simulator is considered an excellent tool to develop and validate quality tests.

Currently, driving skills are tested in a vehicle in either on-highway tests or off-highway driving ranges. The skills tested are severely limited by safety and cost considerations as well as the limited scenarios, tasks, and skills inherent in on-highway and driving range tests.

Simulation offers the potential to measure most driving skills in various tasks in a variety of scenarios. A general purpose driving simulator, in this utilization, would be used to:

1. Evaluate (and develop) alternative tasks and alternative scenarios with selected tasks to stimulate the desired response (performance) in the potential operator being tested.

2. Validate proposed or hypothesized skill measurement systems - scenario; task; data; analysis of data - as an accurate, fair assessment of an individuals specific skill level.

3. Develop specifications and requirements for the minimal cost simulator which will produce the desired results for the specific application.

The general purpose driving simulator would be used by federal, state, and local agencies; rehabilitation organizations; major employers; and other organizations to develop and validate tests before investing large sums of money in equipment and/or subjecting the public to a potentially unfair or invalid test. Numerous specific applications were suggested by respondents to this survey. These applications include:

A. An inexpensive reliable means to prescreen elderly (and other potentially unsafe) drivers before administering the road test for operator licensing. (Note: This application implies the states responding would continue with the current road test as opposed to replacing the current road test with a simulator.)

B. Prescreen personnel (especially new-hires) to determine training needs:

   a. Police, fire, ambulance vehicle operation
   b. DEA and FBI driver training
   c. Individuals recovering from serious injury or illness
   d. Physically and mentally impaired
   e. Professional (commercial) drivers

C. Vehicle operator licensing tests

   a. Initial
   b. Recurrent

D. Vehicle operator certification tests

   a. Emergency vehicle operators
   b. Law enforcement vehicle operators

E. "Fit to Drive" - i.e, medical certification of an individual's "fitness" to drive. Includes individuals recovering from illness or injury and physically or mentally impaired individuals.

F. An inexpensive, reliable, portable means to test for drug or alcohol intoxication.

In each application, the concerned organization would identify the skills to be tested as well as possible tasks, scenarios, and measurements of the skills. Additional alternative tasks, scenarios, and measurements of the skills would also be suggested by simulator staff personnel and via the driving simulator library and technical support staff (ref. Tables III and IV and text). The organization would evaluate alternatives and validate the selected alternative via the driving simulator. The driving simulator support staff would indicate the minimal cost simulator requirements and specifications as discussed in Section IV.

I-4. Vehicle Training Systems and Programs.

Simulators are rapidly becoming an economically viable means to teach and even hone driving skills. Additionally, skills not heretofore taught for safety reasons or because the environment, task, and/or scenario could not be created, can now be taught via driving simulators.

However, such a simulator usually represents a large dollar investment to government, university, and private organizations. It is only prudent to validate the training system before making such an investment. Also, minimal cost simulator specifications and requirements for a simulator to support the applicable training objectives should be validated before investing in a simulator.

A general purpose driving simulator in this utilization would, therefore, be used to:

1. Validate entire training systems which make extensive use of a driving simulator.
2. Validate the efficacy of a simulator with specific characteristics relative to specific training objectives.
3. Generate minimal cost simulator specifications and requirements to support the training program under consideration.

Specific applications suggested by respondents to this survey include:

A. Emergency vehicle (fire, ambulance, police) operator training systems.
B. Law enforcement (DEA, FBI, police) driver training programs.
C. Rehabilitation driver training programs.
D. Special driver training programs for elderly, physically impaired, mentally impaired, "high risk drivers", and other subsets of the general population with special training needs.

In each application, the concerned organization would conduct the proposed training program using the driving simulator and evaluate the efficacy of the training system using standard techniques. In developing the training system, the driving simulator library and support staff (ref. Tables III and IV and text) would help Instructional Development personnel envision and select scenarios and tasks to teach specific skills. Upon completion of the validation efforts, the driving simulator support staff would indicate the minimal cost simulator requirements and specifications to support the specific training objectives as discussed in Section IV.

I-5. Skill Transfer: Vehicle - Vehicle

As advanced in-vehicle instrumentation systems and intelligent driver-vehicle interfaces become more commonplace in vehicles of all types, information that is central to the driving task will be increasingly managed through this interface. Likewise, substantive differences among vehicles in vehicle control may result as various amounts of automatic control, four wheel steer, and other control systems are implemented. More so than today, drivers who transfer from one vehicle to another may encounter problems due to differences in the design and implementation of these man-machine interfaces.

The purpose of this utilization of a driving simulator is to investigate the nature and extent of potential problems associated with drivers transferring from one vehicle to another when either or both vehicles contain intelligent instruments, different control systems, or other substantive differences that may adversely affect the driving task. These studies are intended to establish the degree of standardization in: (1) the format or content of auxiliary instruments that will be necessary to minimize the potentially dangerous effects of negative transfer of skill in cars in which auxiliary information is integral to the performance of the driving task; and (2) various systems affecting the controllability of vehicles. These studies should include the many organismic factors to be considered in the study of skill transfer, including age.

Group II: Vehicle Related Utilization

A driving simulator will be very beneficial to researchers, automobile, bus, and truck designers, and government personnel to study characteristics of, and proposed changes to, automobiles, trucks, and buses that may affect driving performance. This group of potential utilizations lists a few of the many vehicle studies that could be conducted on a driving simulator with the goal of improving driver performance as a result of improved vehicle design and thereby reducing accidents.

Most of the studies suggested in this group should be executed under both normal and limit driving scenarios plus intermediate points. This suggests multiple simulators of varying complexity/fidelity or cost; or it suggests that significant benefit can be obtained from a presumed less expensive simulator that is limited to normal driving scenarios.

II-1. Directional Control Studies

Directional control studies involve vehicle characteristic that affect it's steering or braking behavior.

A. Directional Control System Design

The primary goal of these studies would be to assess the influences of vehicle properties in safety-related driving situations and to develop design characteristics with potential for improving the vehicle handling qualities and mitigating the hazards of risky driving situations. The emphasis would be on vehicle system design characteristics and would involve vehicle performance measures such as lateral acceleration, response time, stopping distance or deceleration performance, steering gain for steady turns, rollover threshold, obstacle evasion capability, etc. For example, one might analyze how sensitive rollover threshold is to various vehicle or tire design characteristics, or one could compare several vehicles in terms of their rollover potential.

A second goal would be to relate the vehicle design characteristics and performance measures to the driver's subjective perceptions.

B. Directional Control Device Development

Conceptual vehicle control strategies can be implemented on a 'generic' vehicle handling model to assess fundamental benefits of new technologies. Currently, development of new control strategies is largely restricted to objective analytical modeling. The benefits to the driver are difficult to quantify until hardware is available. Driving simulation offers an opportunity to evaluate both objective performance and subjective perceptions at a much earlier stage in the design process. At later stages in the design, actual steering, braking, or powertrain hardware could be installed and tested in the simulator.

1. New Devices: Some of the newer technologies include four-wheel steer, traction control, active suspensions, antilock brakes, etc. Simulators allow a number of different design concepts to be evaluated in a variety of different scenarios, including slippery road surfaces, at a very early design stage.

2. Development and Evaluation of Primary Controls for Disabled Drivers: Primary controls (throttle, brake, and steering) for disabled drivers are becoming increasingly sophisticated, with the potential of "drive-by-wire" systems using a variety of interfaces for driver input. Control gain is always a key issue, even with the more traditional control modifications. Much research and development is needed.

C. "Unexpected" Changes in Vehicle Dynamic Behavior

The purpose of this utilization is to investigate potential human factors problems associated with unanticipated changes in vehicle configuration or the driving control loop. These "unexpected" changes may either be accidental failures or design intent.

1. Failure Mode Evaluations: As vehicle technology becomes more sophisticated, there are more failure modes to consider and an increasing potential for adverse subsystem interactions. Evaluating the effects of failure modes on a driver's ability to control the vehicle are studies ideally suited for a driving simulator because of safety concerns for the test drivers.

2. Transient Performance with Active and Adaptive Control Systems: Some researchers have advocated the concept of adaptive control in which vehicle subsystems assume some level of automatic control of driving functions when driver workload

is judged to be too high. A far less radical approach is active control in which vehicle control subsystems such as steering, suspension, handling, braking, etc., change their response characteristics as a function of driving profile (speed, road condition, weather, illumination, etc.). Active and adaptive control alters the relationship between driver and vehicle in fundamental ways. There is some concern that the loss of direct control or of consistent control of the driving task can lead to degraded performance rather than to improved performance.

II-2. Longitudinal Vehicle Control Studies

Longitudinal Vehicle Control studies involve the fore/aft control of a vehicle. In some cases the longitudinal motion may be fully or partly under automatic control. How the driver interacts with these controls is a key concern.

A. Powertrain

Driving simulators to date have not adequately reproduced frequencies needed for powertrain studies of performance feel, driveline oscillation, tip-in clunk, shift quality, etc. Such studies are excellent candidates for driving simulators, as are studies of self-activating all-wheel drive systems or fully electronic throttle control systems.

B. Automated Car Following and Braking

"Smart" cruise controls automatically keep a vehicle at a fixed distance behind a lead vehicle without any driver throttle or brake inputs. The driver must steer his vehicle, and can, at anytime, assume full control of the vehicle. While a limited amount of braking may be included with smart cruise controls, it is also possible to fully (and automatically) brake the vehicle to avoid a collision. Careful evaluation of these controls is required.

II-3. Vibration and Noise Studies

Several noise and vibration issues are of major concern relative to improving driver performance. A driving simulator incorporating vibration activators will allow more realistic representation of road feel and ride quality, and also permit more realistic evaluations of interior control operability. Representative noise and vibration studies that impact driving performance and therefore safety include:

A. Heavy Truck Cab Design

Vibration is a particular concern in heavy trucks because of their very stiff suspensions. Vibration can affect control operability and may induce driver fatigue. Evaluation of various cab vibration isolation devices and their effect on road feel is an important concern.

B. Seat Assessment

Seat dynamic response properties affect driving comfort and fatigue. Evaluations of different seats or of individual seat design parameters and their interaction with vibration can be made.

C. Sound Quality

Vibration-induced noise affects subjective perception of vibration magnitude. Some sounds are helpful, others are not. Noise cancellation technologies offer the capability of selective reduction of undesirable sounds. On the other hand, helpful sounds typically associated with gas-powered vehicles may not be present in electric vehicles. Is it necessary to generate these sounds or to provide the information in some other way? A driving simulator can be a useful tool for evaluating these issues.

II-4. Aids for Path-Keeping or Path-Finding

Many devices and systems are under development which will augment driver sensory capabilities or provide information to assist in making decisions about vehicle path. These devices need to be evaluated in normal and limit driving scenarios in various weather conditions. The following are examples of devices and systems that need to be thoroughly evaluated by responsible U. S. Department of Transportation, vehicle designers, and researchers, and which can be readily evaluated via a properly designed driving simulator.

A. Augmented Vision Systems and Head-Up Displays (HUD)

HUDs have already been introduced into vehicles, but additional research concerning the capabilities and limitations of this technology for motor vehicle applications is needed.

Augmented vision systems which enhance driver's capability to see at night, in fog, etc., are under development. This information could be displayed head-up or head-down. Issues of interest include display format and symbology, cue conflicts, false alarms, distance perception, etc.

B. Navigation or Route Guidance Devices

Navigation, route guidance, and in-car signing devices are important aspects of the Intelligent Vehicle Highway System (IVHS) programs now under development. Key issues with these devices include information content and format of driver displays.

C. Lighting & Visibility

These devices represent the conventional aids to hazard detection currently on vehicles - headlighting systems, signaling systems, direct and indirect (mirror) viewing systems and conspicuity enhancements for heavy trucks. There is a continuing need to evaluate new design concepts for these systems.

D. Hazard Alerting Devices

These devices convey warnings of impending collision (to the front, side, or rear), rollover, jackknife, slippery road, drowsiness or fatigue, etc. Some studies of interest with these devices include:

1. Behavioral Adaptation to Alerting Devices: A proliferation of warning indicators will accompany the development of intelligent driver interfaces. There is some potential that drivers will come to rely on these devices to keep them alert or to provide critical conflict information that may be better acquired through active search and surveillance. The purpose of this project is to determine the potential role of behavioral adaptation to these alerting devices.

2. Warning Effectiveness: The purpose of studies in this utilization of a driving simulator is to evaluate the effectiveness of various warning schemes on mitigating the hazard. Consideration must be given to understandability, false alarms, misses, timing of the warning in relation to the impending hazard, etc.

II-5. Human Factors Evaluations of Vehicle Interiors

Driving performance, and therefore safety, is affected by vehicle interior design, especially under heavy task loading. Thus, the purpose of the following studies in this set of utilizations of a driving simulator is to evaluate driver performance versus task loading with alternative interior designs. Small amplitude vertical ride motions, though not essential, can increase the realism of some evaluations. Suggested studies include:

A. Secondary Controls and Convenience Devices

These include communication devices such as cellular phones, entertainment systems (e.g., radios), vehicle status displays - which may contain diagnostic or prognostic information, office equipment (e.g., computers), etc. Some of these devices may share a single display. Some may use voice for input or output. Understandability, operability, distraction, and workload are key concerns with these devices.

B. Display Quantification

It is important to develop appropriate methods for quantifying the characteristics of auxiliary displays that bear on the nature and degree of intrusion of drivers' visual attention to the driving task. With the introduction of intelligent auxiliary displays in automotive interfaces, it is important to determine the critical factors affecting the potential for such displays to intrude on the driving task and to develop appropriate metrics for quantifying the extent of which prototype displays conform to good human engineering principles.

C. Systems Evaluation of Interior Layouts

A systems evaluation of interior control and display layouts for hand and foot controls, doors, seat controls, and instrument panels can be conducted in a driving simulator under realistic task loading scenarios. Objectives focus on functional characteristics and spatial organization.

In early design stages, functioning controls or displays are often not available. However, mock-ups of instrument panel, door, or steering column-mounted controls can still use a simulator as part of the layout, reach, readability, and findability evaluations.

Simulator requirements for these tasks focus on task-loading and perceived realism, rather than on modeling accuracy.

Group III: Environment Related Utilization

A driving simulator will be very useful to researchers and highway designers to study the various design features associated with highway design, and to evaluate proposed new highway designs and proposed modifications to existing highways before construction begins. This group of utilizations lists a few of the many environment studies that could be conducted on a driving simulator with the goal of significantly reducing highway (including signing) costs as well as the national accident rate and severity.

III-1. Highway Design

Utilization of a driving simulator for highway design includes basic research to develop an understanding of design parameters with respect to human behavior; evaluation of proposed highway designs; and analysis and evaluation of alternative solutions to "high accident" sections of roadway.

Highway design, due to a lack of resources, frequently neglects to adequately consider the needs and limitations of the drivers for whom these systems are intended. For example, traffic control devices may compete for the driver's attention with other traffic control devices, or be located such that they cannot be seen until there is insufficient time available to the driver to take appropriate action, or where they cannot be seen under certain lighting or weather conditions. A driving simulator, in these utilizations, would be used by researchers to gain an understanding of human behavior with respect to highway design, by traffic engineers to better design/redesign and plan highways and to test them from the driver's perspective before implementation, and by government agencies to analyze high accident sections of roadway.

A. Signs, Signals, and Markings

Signs, signals, and markings include:

1. Roadway delineation
2. Information
3. Traffic control

Driver interpretation of signs, signals, and markings, and a lack of commonality among jurisdictions are major unresolved issues. Roadway delineation and official signage continue to be implicated in law suits involving accidents. Several states and local jurisdictions have reported major sign design errors that were necessarily corrected at a cost of hundreds of thousands or, in some cases, millions of dollars per error. Signs, signals, and markings should be analyzed separately for parameters such as contrast, letter size, conspicuity, visibility in various weather conditions, etc., and they should be considered in the aggregate as a subset of the overall highway design whereby they compete for the drivers attention, affect the instantaneous work load, must allow adequate response time, and should not be obstructed from the driver's view regardless of weather conditions, time of day, and time of year.

This utilization of a driving simulator should eliminate the potential for costly design errors, and improve the overall design quality to the point of a significant reduction in the accident rate. To accomplish this objective, a methodical, well thought out series of tests would be conducted on a properly designed driving simulator. Each test or subset of tests would address specific issues such as interpretation, size, visibility in adverse weather, etc. Highway designers, using this fundamental knowledge, would then use a driving simulator to test and verify the efficacy, readability, placement, and safety of alternative proposed designs and/or to analyze existing designs. Evaluation would include different weather conditions, times of day, and times of year tests as well as different age groups, experience levels, temporal driver characteristics, etc.

B. Horizontal and Vertical Curvature

Curvature affects controllability, visibility, monotony, and other driving factors. Curvature should usually be considered in conjunction with weather, time of day, and lighting. This utilization of a driving simulator will permit researchers to study the relationship between curvature and driver performance, and for highway designers to evaluate the efficacy and safety of proposed and/or existing designs relative to curvature.

C. Lane and Shoulder Width

Lane and shoulder widths are critical safety and cost considerations for each specific section of roadway. In this utilization of a driving simulator, highway designers would evaluate the safety associated with alternative lane and/or shoulder widths for specific sections of roadway, and based on the results of their evaluation, design the minimal cost roadway consistent with safety.

D. Median and Barrier Design

Median and barrier design are also critical safety and cost considerations, and they impact the overall aesthetics of the highway. In this utilization of a driving simulator, highway designers would evaluate the safety and aesthetic appeal - both total highway and median/barrier strip - of alternative designs, and based on the results of their evaluation, generate minimal cost designs consistent with safety and desired overall aesthetics.

E. Illumination

A disproportionally large percentage of all accidents take place at night on roads that are not illuminated. Many of these accidents involve pedestrians. Nighttime traffic volumes are likely to continue to increase, because more shopping and entertainment facilities remain open late at night and shift work is likely to become more common (especially in cities). At the same time, the ageing driver population is increasing, a group known to have deteriorating night vision. Manufacturers continue to develop new lighting devices with different characteristics of intensity, beam pattern, and color temperature. In this utilization, a driving simulator would be used to determine general illumination requirements for various sections and types of roadways, to determine general guidelines for transitioning from one illumination level to another, and for evaluating proposed designs.

F. Surrounding Environment

Research has shown that drivers will choose certain routes in preference to others because of scenic vistas or other "pleasant" roadside environments. Likewise, anecdotal evidence points to the avoidance of certain roads because of unpleasant roadside developments. With renewed interest being shown in the US on the environment and scenic beauty, research is necessary to understand the issues and their consequences - both political and safety. In this utilization, a driving simulator would be used to conduct basic research to understand the affect of scenic vistas and aesthetics on driver attitudes and performance, and to evaluate proposed highway designs for both public acceptance and safety.

G. Traffic Interactions

The interaction of vehicles in the traffic stream is an issue of continuing concern, both from the perspective of "traffic conflicts" (often used as surrogate measures of accident risk prediction) and for other safety issues brought about by such interactions. For example, the driver's view of the road and other traffic may be obscured by other vehicles - especially large buses and trucks (including doubles and triples), or by changes to the driver's own vehicle, such as darkly tinted windows. Concerns about merging and intersecting traffic on a variety of road configurations, weather and visibility conditions, vehicle factors, and driver factors continue to have widespread interest aimed at a reduction of such potential "traffic conflicts". In this utilization, a driving simulator would be used by highway designers to evaluate proposed alternative designs, by researchers to study human behavior relative to traffic interactions, and by government agencies to analyze existing known problem areas.

H. Tunnels

Drivers frequently complain of their inability to see beyond the tunnel entrance/exit when entering/exiting a tunnel, of adaptation to radical changes in illumination level between inside and outside tunnel areas, and of visual effects that adversely affect driving performance. In addition, data shows that many drivers refuse to utilize tunnels because of claustrophobic-type fears. In this utilization of a driving simulator, researchers would conduct studies to understand both physiological and behavioral response to entering/exiting tunnels under various conditions and to driving through tunnels, and tunnel designers/highway engineers would test and verify all aspects of a proposed tunnel design, including illumination, signage, interchange design, etc., before beginning construction.

I. Pre-Construction Overall Design Review

As new roads and highways are built, and as existing roads are redesigned to improve their safety and capacity, the availability of a simulator could be an invaluable resource tool for the designer. Despite the best engineering judgement and expertise, there is no substitute for the ability to preview the integrated design elements of a complex roadway from the driver's eye-point, before the road is built. Inherent roadway design characteristics, as basic as horizontal and vertical curvature, line and shoulder width, gore and ramp design, median and barrier design, and the placement of necessary roadside structures, will, for the life of the roadway, effect that roadway's safety and capacity. A driving simulator, as a resource tool for highway designers, will help to ensure the safest possible highway designs and public acceptance of these designs before the highways are built, and the simulator will help assure minimal cost consistent with safety and public acceptance.

III-2. Construction Zone Safety

Traffic conflicts and accidents in construction zones continue to be disproportionally high because the temporary and sudden changes in traffic patterns, traffic flow, and speed violates the driver's expectancy. This is especially true along high-speed limited access freeways. Despite the constant improvement in signs and markings, the introduction of new technology such as portable changeable message signs and special purpose lighting, and the increasing attention to worker safety, traffic conflicts and accidents in construction zones are a serious extant problem. In this utilization, a driving simulator would be used for basic experimental research of alternatives and warrants for specific features at construction zone sites, and it would be used to evaluate existing and future sites.

A. Temporary Traffic Control Devices

Many special purpose traffic control devices including barricades, flashers, specialized lighting, pavement markings, and temporary (including changeable message) signage serve the purpose of alerting motorists to the construction zone, informing them of the safest path around the zone, and protecting construction workers and equipment. New devices are frequently introduced, often without a research base to determine their effectiveness or proper utilization. A driving simulator would be used to evaluate specific devices and general site designs, and to develop general guidelines for safe site designs.

B. Conspicuity of Personnel and Construction Vehicle Movement

Movement of workers and equipment in construction zones occasionally causes drivers to erroneously perceive the movement as an accident threat and therefore unnecessarily brake, and on other occasions causes an accident because personnel/equipment moved into the path of traffic and the lead driver did not correctly perceive the movement as an accident threat and therefore did not brake sufficiently or in time. In this utilization of a driving simulator, research would be conducted to understand drivers' perception of motion and impending motion in work zones, and alternative designs to improve safety and reduce "false alarms" would be evaluated.

III-3. Effects of the Natural and Built Environment

Many aspects of the design and appearance of the roadside environment can affect driver behavior, performance, and attitude. Structures designed by highway designers for highway use may have unintended side effects. For example, the transition zones and entrances to highway tunnels can bring about claustrophobic reactions in certain drivers; the increasing construction of noise barriers adjacent to freeways in many suburban areas can likewise cause unintentional reactions of confinement, both among motorists and adjacent property owners. Certain roadside developments that are not directly under the control of highway designers may also impact the motorist. Outdoor advertising signs, particularly the changeable-message type, may distract the driver's attention or compete for that attention with official highway signs. Roadside development may be so pleasant (distant mountain or water vistas; spectacular city skylines) or so unpleasant (industrial factories, salvage yards, dumps) that the driver's attention is inadvertently drawn to the roadside vista at the expense of the driving task. A driving simulator capable of reproducing these visual scenarios in the laboratory will serve to support research into mitigation measures and other efforts intended to promote safe travel.

III-4. Effects of Weather on Visibility

Although problems such as vehicle control (steering and stopping) in rain, snow, and ice are issues to be addressed, this utilization of a driving simulator is concerned with the reduced visibility that may exist during weather conditions such as rain, snow, dust storms in desert areas, and fog which plagues specific sites throughout the country. To date, efforts to provide localized fog and dust measurement systems have proven largely ineffective, as have systems of warning signs, both fixed and of the chargeable message type. The problem is one of the extremely localized nature of such phenomena both in time and location. A driving simulator, therefore, should be well suited for research into ways to understand and mitigate the adverse affects of these weather conditions on driver performance.

III-5. Underground Highway Systems

In the 1970s, the US DOT undertook a major effort to better understand all aspects of highway tunnel design and construction. Ever increasing traffic in urban areas, concerns about air quality, the cost of right-of-way acquisition, and community impacts due to highway placement all contributed to concerns which lead to consideration of underground urban roadways as an alternative to the problems associated with above ground roadways. These concerns and problems have not been overcome in the 1990s - indeed they continue today with even greater urgency. A number of major underground highway projects which include substantial underground highway networks with interchanges are in the planning and design stages. Unfortunately, society's knowledge of the design features of major underground facilities is limited. We have some empirical data from on-the-road studies, and considerable anecdotal evidence from observation that indicates drivers behave differently when entering, exiting, or driving through tunnels than they do on open highways. A simulator is necessary to understand the impact on driver performance, attitude, and behavior of the design features of underground, enclosed roadways. Thus, this utilization of a driving simulator would be to conduct the necessary preliminary research to determine the viability of underground systems from the driver's perspective. A driving simulator would be used extensively to further develop and define requisite design features including illumination, signage, lane and roadway delineation, intersection design, etc.

<u>Group IV: General Utilizations</u>

With the advent of low cost, high fidelity driving simulator capabilities, driving simulators are expected to find widespread use during the next three decades. This group of utilizations lists a few of the many general driving simulator studies that could be conducted on a general purpose driving simulator with the goal of assuring proper design and application of driving simulators during the coming decades, and with the goal of understanding the causes of accidents so that means can be developed to eliminate various causes and reduce the effects of unavoidable causes.

IV-1. Simulator Design Studies for Developing Other Simulators

The cost of driving simulators is decreasing dramatically while fidelity is increasing even more dramatically. Thus, widespread use of simulators for training, licensing, prescreening, and research by the early 21st century can be reasonably assumed. Currently, rigorous tools and procedures to specify the best level of fidelity for specific applications/simulators or to determine cost-benefit trade-offs for specific applications/simulators do not exist. A maximum fidelity driving simulator with variable fidelity capability could be used to develop simulator requirements for specific objectives and applications.

In this utilization, various federal, state, and local agencies as well as major university and private research centers considering a simulator, or procurement of several simulators, would develop their best effort draft of simulator requirements and specifications based on available technical expertise plus the technical expertise - personnel and literature - resident at such a maximum fidelity driving simulator facility. The simulator would then be downgraded -mostly via software commands - to replicate the fidelity and features of the draft simulator requirements/specifications. Tests would then be conducted to verify the efficacy of the simulator design or specifications, including its appropriateness for its intended tasks and its cost-benefit performance.

It is also conceivable that this suggested utilization of a driving simulator may include the development of tools and/or procedures to specify, or aid in specifying, the optimal simulator for specific applications.

IV-2. Skill Transfer: Simulator - Vehicle

When simulators are used for training, there is always the question of skill transfer from the simulator to the actual platform during the training system development and early usage phases. When simulators are used for testing, there is always a question of validity - do individuals perform on simulators with the same level of skill as they do on actual platforms? A very high fidelity driving simulator is an excellent tool to study simulator-vehicle skill transfer for both students and experienced drivers for various levels of simulation fidelity. This knowledge would be invaluable in preventing the misuse of simulators, in assuring that a proper simulator is selected/specified for the application at hand, and in educating individuals responsible for using/not using simulators in specific applications.

IV-3. Simulator Sickness

Simulator sickness continues to frustrate simulator designers and users. Simulator sickness compromises research data, diminishes training value, and precludes licensing applications. Thus it would be extremely beneficial to understand simulator sickness so that it can be avoided in simulator design. This application of a driving simulator is, therefore, to conduct extensive basic research with the goal of understanding simulator sickness.

IV-4. Accident Reconstruction and Analysis

Air travel is dramatically safer today than it was in the 1940s, 50s, and 60s. A major reason for this improved safety is that DOT and NTSB reconstructed accidents and, based on detailed accident analyses, developed means to eliminate most of the causes and to reduce the hazards associated with unavoidable causes. This detailed analysis and correction philosophy should be applied to automobile, truck, and bus driving as well.

This utilization of a driving simulator suggests that appropriate agencies such as the U. S. Department of Transportation should develop an ongoing program to reconstruct and analyze large numbers of motor vehicle accidents with the objective of developing means to substantially reduce the national accident rate and severity. Reconstruction would necessarily include a faithful high fidelity simulation of all vehicles and people involved, of the specific weather and lighting conditions, and of the vehicle/tire and roadway conditions.

SIMULATOR CHARACTERISTICS and REQUIREMENTS

Overview

Table I includes over 50 specific utilizations of driving simulator technology to make vehicle travel safer and/or to improve quality and reduce costs. The next question is what level of fidelity is required for each of the 50 utilizations, and what support resources are necessary in order for nonsimulator literate researchers, designers, etc., to obtain maximum benefit from a driving simulator.

Appendix A contains a set of detailed simulator characteristics and requirements as described below for each utilization in Table I. The characteristics and requirements in Appendix A are summarized in Table II for ease of overviewing. There are also additional characteristics and requirements that apply to any utilization. These additional characteristics and requirements are tabulated in Table III and discussed in the following paragraphs.

While developing the simulator requirements, a number of relevant questions or issues were raised - such as availability and affordability of a requisite simulator to a researcher or state/local government agency. These questions/issues are tabulated in Table IV and discussed in the following paragraphs.

Table V provides an overview of simulator fidelity - i.e., the cost drivers - versus utilization or benefit. Excluding software development (which includes the equations of motion), the major cost drivers will be the motion system, the visual system, and the extent of cockpit variations (including time to change cockpits). Table V, therefore, groups the Table I utilizations by gross levels of motion fidelity (cost), visual fidelity (cost), and cockpit changeability (cost) requirements. Thus Table V provides insight relative to cost-benefit trade-offs, individual simulator requirements for a multisimulator complex, and potential utilization that will be sacrificed versus fidelity (cost) reductions if, due to funding limitation or etc., a less than maximum fidelity simulator is implemented. Table V is discussed more fully in the subparagraphs that follow.

Detailed Simulator Characteristics and Requirements

The major subsystems associated with a simulator are:

- Visual System
- Perceived Motion
- Motion
- Equations of Motion (Software)
- Miscellaneous - Sensor/Data Gathering; Biomedical; Environmental; etc.
- Tactile
- Audio: Sound
- Cab: Cockpit
- Control Station

A typical simulator specification addresses the characteristics and requirements of each of these major subsystems in detail. Accordingly, this report includes a gross overview and a detailed overview of the requirements and characteristics for each of these subsystems, except the control station, for each utilization (in Table I) in Table II and Appendix A respectively. General control station simulator requirements applicable to all/any utilization(s) in Table I are provided in Table III.

It is to be emphasized that good simulator specification and design involves "fooling" the senses. It is a well-known fact in simulator design that tactile fidelity and motion sensation and fidelity are strongly influenced by visual stimulation. Likewise, motion and visual cues are often more important than the motion and visual per se. Vibration is also a distractor that reduces visual system requirements for the same level of visual system fidelity. And there are many, many more cross modal affects that are part of competent simulator specification and design. It is beyond the scope of this report to accommodate these design practices in the requirements and characteristics; therefore, the requirements and characteristics in this report should be viewed as gross order of magnitude guidelines subject to modification by prudent simulator design.

Likewise, Table III highlights a few of the general requirements considered important to nonsimulator literate researchers, designers, etc. It is beyond the scope of this report to address command, control, and monitor station requirements in any level of detail beyond Table III.

Relevant Issues

Extreme concern was strongly expressed by most of the survey respondents over such issues as availability of a driving simulator to small organizations/private researchers, adequate supporting resources, sustained adequately funded research (both in-house and contract), etc. Table IV tabulates the issues raised by survey respondents. The need to address and resolve these issues as a prerequisite to a successful driving simulator program can not be over emphasized; and, of course, if the program is to be successful, the aggregate resolution must be conducive to executing the utilizations tabulated in Table I.

Simulator Requirements (Cost) vs. Utilization

Table V is included in this report to convey the potential simulator utilization (benefit) that will be lost if selected high cost requirements/characteristics are deleted from a driving simulator, and to provide a guide for selecting simulators for a multisimulator driving simulator complex.

The major cost drivers in a driving simulator are expected to include equations of motion, instrumentation and data gathering, scenario libraries, visual system, motion system, control computer complex, major variations in cockpit, etc. Three of these, motion system, visual system, and extent of cockpit variations, have been selected to illustrate utilization gained/sacrificed for various subsystem fidelity (cost) combinations which can be equated to a few different cost plateaus.

A given cost plateau may be achieved including/excluding different combinations of fidelity or requirements. For example, two simulators, each with a different level of visual and motion fidelity and cockpit changeability, may cost the same. Table V will, therefore, also assist in evaluating which simulator features to keep/delete if funds are limited.

CONCLUSIONS

1. The application of simulator technology to motor vehicle travel should contribute to a substantially reduced accident rate, a reduced potential for accidents brought about by technological advances, to dramatically improved quality of highways while simultaneously reducing costs, lower cost, higher quality vehicle - highway systems, and a significantly higher quality licensing process without increased cost.

2. The conduct of each of the 54 specific utilizations identified in this report, including subsets, is a necessary (but not sufficient) requirement to achieve these benefits from simulator technology.

3. A simulator capable of accomplishing all of the 54 identified utilizations would be a maximum fidelity simulator.

4. Substantial benefits can be obtained from a variety of less than maximum fidelity simulators. Table V provides a foundation for a fidelity/cost-benefit analysis, and Tables II and V may be used as guidelines for selecting/specifying research simulators.

5. State governments as well as automobile designers indicated they have currently funded and/or planned future projects whereby they would use today, if it were available, and will use in the future, if it is available, a properly designed and implemented driving simulator.

6. A large quantity of potential simulator utilizations was presented in this report. Although no attempt was made to estimate the number of simulator hours required to accomplish these suggested utilizations, the editors, based on their experience, feel the utilizations suggested in this report alone would require well over three decades (60,000 simulator hours) to accomplish.

7. In view of large number of simulator hours required to accomplish the suggested utilizations and considering the various levels of fidelity required for various utilizations, a simulator complex consisting of one host computer system and several simulators, each with selected fidelity (cost) for each simulator subsystem, would be the most cost effective total system to achieve all the utilizations identified in this report. In addition, a multi-simulator complex would dramatically shorten the time required to accomplish the utilizations and thereby achieve the benefits listed in item 1. Table V may be used as a guide for selecting the fidelity of each simulator in a multisimulator complex.

TABLE I

POTENTIAL UTILIZATION OF A NATIONAL DRIVING SIMULATOR

GROUP I - Driver Related Utilization

I-1. Driver Behavior Studies

- A. Braking and Steering Behavior; and Motion Perception
- B. Risk Perception and Decision Making
- C. Workload
- D. Hazard Perception
- E. Effects of Stressors
- F. Driving Characteristics of Classified Groups
- G. Social Interactions
- H. Multiple Driver Situations

I-2. Driver Performance Measures for Driver-Vehicle-Highway Systems Evaluation

- A. Driver Performance Measures
- B. Develop and Validate A Theory of Driving

I-3. Design of Driver Screening and Licensing Tests

- A. Prescreen Elderly (and Other Potentially Unsafe) Drivers
- B. Prescreen Personnel
- C. Vehicle Operator Licensing Tests
- D. Vehicle Operator Certification Tests
- E. "Fit-To-Drive" Tests/Certification
- F. Portable Drug/Alcohol Intoxication Test

I-4. Vehicle Training Systems and Programs

- A. Emergency Vehicle
- B. Law Enforcement
- C. Rehabilitation Driver Training Programs
- D. Special Driver Training Programs

I-5. Skill Transfer: Vehicle - Vehicle

TABLE I (Cont'd.)

<u>GROUP II - Vehicle Related Utilization</u>

II-1. Directional Control Studies

- A. Directional Control System Design
- B. Directional Control Device Development
    - 1. New Devices
    - 2. Development and Evaluation of Primary Controls for Disabled Drivers
- C. Unexpected Changes in Vehicle Dynamic Behavior
    - 1. Failure Mode Evaluations
    - 2. Transient Performance with Active and Adaptive Control Systems

II-2. Longitudinal Control Studies

- A. Powertrain
- B. Automated Car Following and Braking

II-3. Vibration and Noise Studies

- A. Heavy Truck Cab Design
- B. Seat Assessment
- C. Sound Quality

II-4. Aids for Path Keeping and Way Finding

- A. Augmented Vision Systems and Head-Up Displays (HUD)
- B. Navigation or Route Guidance Devices
- C. Lighting and Visibility
- D. Hazard Alerting Devices
    - 1. Behavioral Adaptation of Alerting Devices
    - 2. Warning Effectiveness

II-5. Human Factors Evaluations of Vehicle Interiors

- A. Secondary Controls and Convenience Devices
- B. Display Quantification
- C. Systems Evaluation of Interior Layouts

TABLE I (Cont'd.)

GROUP III - Environment Related Utilization

III-1. Highway Design

A. Signs, Signals, and Markings
B. Horizontal and Vertical Curvature
C. Lane and Shoulder Width
D. Median and Barrier Design
E. Illumination
F. Surrounding Environment
G. Traffic Interactions
H. Tunnels
I. Pre-Construction Overall Design Review

III-2. Construction Zone Safety

A. Temporary Traffic Control Devices
B. Conspicuity of Impending Personnel and Vehicle Movement

III-3. Effects of Natural and Built Environments

III-4. Effects of Weather

III-5. Underground Highway Systems

GROUP IV - General Utilization

IV-1. Simulator Design Studies for Developing Other Simulators

IV-2. Skill Transfer: Simulator - Vehicle

IV-3. Simulator Sickness

IV-4. Accident Reconstruction and Analysis

TABLE II: GROSS LEVEL OF FIDELITY (COST) VS UTILIZATION

POTENTIAL UTILIZATION OF A NATIONAL DRIVING SIMULATOR

GROUP I - DRIVER RELATED UTILIZATION	VISUAL	PM	MOTION	EOM	TACTILE	AUDIO	COCKPIT
I-1. Driver Behavior Studies							
A. Braking and Steering Behavior; and Motion Perception	H	H	MH	H	H	H	G
B. Risk Perception and Decision Making	H	M	M	M	M	M	G
C. Workload	H	L	L	M	M	ML	G/I
D. Hazard Perception	H	L	L	M	M	M	G
E. Effects of Stressors	H	MH	MH	M	Y	H	G
F. Driving Characteristics of Classified Groups	H	MH	MH	M	Y	H	G
G. Social Interactions	M	ML	L	ML	Y	M	G
H. Multiple Driver Situations	H	M	M	ML	Y	M	G/I
I-2. Driver Performance Measures for Driver-Vehicle-Highway Systems Evaluation							
A. Driver Performance Measures	H	MH	H	M	Y	M	G
B. Develop and Validate A Theory of Driving	H	H	H	H	Y	H	G
I-3. Design of Driver Screening and Licensing Tests							
A. Prescreen Elderly (and Other Potentially Unsafe) Drivers	H	L	M	M	H	MH	G
B. Prescreen Personnel	H	L	M	M	H	MH	G
C. Vehicle Operator Licensing Tests	H	L	M	M	H	MH	G
D. Vehicle Operator Certification Tests	H	L	M	M	H	MH	G
E. "Fit-To-Drive" Tests/Certification	H	L	M	M	H	MH	G
F. Portable Drug/Alcohol Intoxication Test	H	L	M	M	H	MH	G
I-4. Vehicle Training Systems and Programs							
A. Emergency Vehicle	H	H	H	H	H	MH	G
B. Law Enforcement	H	H	H	H	H	MH	G
C. Rehabilitation Driver Training Programs	MH	M	ML	M	H	M	C(LIM)
D. Special Driver Training Programs	MH	M	ML	M	H	M	C(LIM)
I-5. Skill Transfer: Vehicle - Vehicle	M	M	M	L	Y	MH	C

TABLE II: GROSS LEVEL OF FIDELITY (COST) VS UTILIZATION (Cont'd.)

POTENTIAL UTILIZATION OF A NATIONAL DRIVING SIMULATOR

GROUP II - VEHICLE RELATED UTILIZATION	VISUAL	PM	MOTION	EOM	TACTILE	AUDIO	COCKPIT
II-1. Directional Control Studies							
A. Directional Control System Design							
B. Directional Control Device Development	H	MH	H	H	H	H	C
1. New Devices	MH	MH	H	H	H	H	G
2. Development & Evaluation of Primary Controls for Disabled Drivers							
C. Unexpected Changes in Vehicle Dynamic Behavior							
1. Failure Mode Evaluations							
2. Transient Performance with Active and Adaptive Control Systems	H	H	H	H	H	H	G
II-2. Longitudinal Control Studies							
A. Powertrain	M	MH	H	M	Y	M	G
B. Automated Car Following and Braking	M	MH	H	M	Y	M	G/I
II-3. Vibration and Noise Studies							
A. Heavy Truck Cab Design	M	M	M	ML	Y	H	C
B. Seat Assessment	M	M	M	ML	Y	H	C
C. Sound Quality	M	M	L	L	Y	H	C
II-4. Aids for Path Keeping and Way Finding							
A. Augmented Vision Systems & Head-Up Displays (HUD)	H	L	L	L	N	M	G
B. Navigation or Route Guidance Devices	M	L	L	L	N	N	G
C. Lighting and Visibility	H	L	L	L	N	M	G
D. Hazard Alerting Devices	M	MH	M	ML	Y	M	C/I
1. Behavioral Adaptation of Alerting Devices							
2. Warning Effectiveness							
II-5. Human Factors Evaluations of Vehicle Interiors							
A. Secondary Controls and Convenience Devices	M	L	L	L	N	ML	G/I
B. Display Quantification	M	L	L	L	N	ML	G/I
C. Systems Evaluation of Interior Layouts	M	L	L	L	N	ML	G/I

TABLE II: GROSS LEVEL OF FIDELITY (COST) VS UTILIZATION (Cont'd.)

POTENTIAL UTILIZATION OF A NATIONAL DRIVING SIMULATOR

GROUP III - ENVIRONMENT RELATED UTILIZATION	VISUAL	PM	MOTION	EOM	TACTILE	AUDIO	COCKPIT
III-1. Highway Design							
A. Signs, Signals, and Markings	H	L	L	L	Y	L	G
B. Horizontal and Vertical Curvature	H	L	ML	ML	Y	L	G
C. Lane and Shoulder Width	MH	L	ML	ML	Y	L	C
D. Median and Barrier Design	MH	L	L	M	Y	L	G
E. Illumination	H	ML	L	L	Y	L	G
F. Surrounding Environment	MH	L	L	L	Y	L	G
G. Traffic Interactions	H	ML	L	M	Y	ML	G
H. Tunnels	H	L	L	L	Y	L	G
I. Preconstruction Overall Design Review	H	ML	M	M	Y	ML	C
III-2. Construction Zone Safety							
A. Temporary Traffic Control Devices	H	L	MH	M	Y	L	G
B. Conspicuity of Impending Personnel and Vehicle Movement	H	L	MH	M	Y	L	G
III-3. Effects of Natural and Built Environments	H	L	L	L	Y	L	G
III-4. Effects of Weather	MH	ML	ML	M	Y	L	G
III-5. Underground Highway Systems	H	L	ML	M	Y	L	C

TABLE II: GROSS LEVEL OF FIDELITY (COST) VS UTILIZATION (Cont'd.)

POTENTIAL UTILIZATION OF A NATIONAL DRIVING SIMULATOR

GROUP IV - GENERAL UTILIZATION	VISUAL	PM	MOTION	EOM	TACTILE	AUDIO	COCKPIT
IV-1. Simulator Design Studies for Developing Other Simulators	H	H	H	M	Y	H	C
IV-2. Skill Transfer: Simulator - Vehicle	H	H	H	M	Y	H	C
IV-3. Simulator Sickness	H	H	H	H	MH	M	G
IV-4. Accident Reconstruction and Analysis	H	H	H	H	Y	L	C

H = High Level of Fidelity (Cost)
M = Medium Level of Fidelity (Cost)
L = Low Level of Fidelity (Cost) -- includes both very simple systems and no system (i.e., not required)
Y/N = Yes/No, is/is not required
G = Generic
G/I = Generic cab with changeable instrument panel
C = Changeable cab and instrument panel

TABLE III

General Simulator Requirements

This table contains simulator features which should be incorporated in a driving simulator independent of utilization/detailed specifications.

1. User friendly system for administering tests and collecting data.
2. Provide standard data collection modules.
3. Ability to repeat tasks without additional tasks similar to aircraft pilots repeating take-offs without flying around and landing in between take-offs.
4. Resident technology support staff to help design and implement the various projects.
5. Ability to incorporate and to protect proprietary software models (e.g., steering system, suspension, control strategy etc.)
6. Ability to incorporate and to protect proprietary hardware (e.g., instrument panels).
7. Protection of proprietary data and results.
8. Ability to easily and readily reconfigure the hardware and software to meet specific needs - such as using antilock braking, various control/warning/display systems, environment, signs, etc. well as various vehicles.
9. The design of vehicle dynamic model should be highly modular and parameterized. User should be able to build the vehicle of his choice using high level screen input to modify generalized data bases describing the vehicle characteristics. No simulation source code modification should be necessary.
10. Formats of summary graphic data displays used by the simulator should be able to be created by the user. This should include full access to all simulation variables without the need to change source code. (Implies display routines are data base driven.)
11. The software should allow for the preparation and storage of preplanned and automatically executed scenarios so that experimental repeatability is enhanced. Also, the scenario descriptions should allow for free format comments which can be inserted for documentation of experiment purpose, etc. A data base/keywording facility could enhance the usefulness of looking over what has already been done for deciding what to do in the future.

TABLE III (Cont'd.)

12. The software should allow for the saving of free format operator's comments to enhance the transferability of data and for maximizing capture of the sense of the experiment.

13. Standard sensor, transducers, etc., electrical and mechanical interface for vehicle cab to interface with the simulator circuits. Must publish and maintain detailed interface specifications.

14. Provide an inventory of selectable standardized, basic simulator features/configurations, such as vehicle designs and dynamics; driving routes; roadside elements; weather conditions; signs and markings; other vehicles; etc., for use by researchers who do not require, and perhaps cannot afford, the development of customized features and configurations to support their specific needs.

15. Computer equipment used for data collection and analysis must be compatible with computer equipment that is commonly available to the anticipated user population.

16. A driving simulator facility should include (limited) off-line data validation and analysis capability. The next step in some experiments is dependent on the results of the proceeding step; this capability would enable researchers to modify their experiment plan based on results as the experiment progresses.

TABLE IV

Relevant Issues

There are a number of issues which are critical to any decisions concerning the development, utilization, and cost-effectiveness of a driving simulator that are beyond the scope of this report. Issues raised by survey respondents are listed below.

1. Establishment and maintenance of public, fair, consistent user scheduling and prioritization considerations and standards.

2. Long-term commitment for adequate funding sufficient to support meaningful research projects. Such a commitment must include maintenance, operations, enhancements/modifications, data storage and retrieval, etc.

3. Establishment and maintenance of public, fair, consistent user fees which are affordable by researchers, whether sponsored by DOT, other government agencies, universities, non-profit or profit-making private organizations, including industry proprietary research design and development.

4. Convenient, central location of host facility. Location should also be in a moderately or less expensive area re. motel and restaurant costs.

5. Hours of utilization. Policies must be established to permit flexible time-of-day, and hours-per-day access. Such policies must include considerations of cost, security, availability of support, maintenance, subject availability, and research study design requirements.

6. Time, expense, and design for switchover and reconfiguration when changing projects.

7. Rigorous validation of a driving simulator.

8. Development and maintenance of a technical library with information and data on simulation and measurement of vehicle, operator and roadway performance. This library should be accessible to all users and potential users of a driving simulator, and should include all research data resulting from use of a driving simulator (proprietary data excluded). Library contents should be available on popular databases for remote access.

9. Continued support and funding of simulator-based research at independent facilities, especially those with special or novel capabilities, notwithstanding future larger facilities.

TABLE V: SIMULATOR FIDELITY/COST VS POTENTIAL UTILIZATION			
FIDELITY (COST)			
MOTION	VISUAL	COCKPIT	UTILIZATION (TABLE I)
H	H	C	IV-1. Simulator Design Studies for Developing Other Simulators IV-2. Skill Transfer: Simulator - Vehicle IV-3. Simulator Sickness IV-4. Accident Reconstruction and Analysis
		G/I	None
		G	I-2A. Driver Performance Measures I-2B. Develop and Validate A Theory of Driving I-4A. Training: Emergency Vehicle I-4B. Training: Law Enforcement II-2C. Unexpected Changes in Vehicle Dynamic Behavior
	MH	C	None
		G/I	None
		G	II-1B. Directional Control Device Development
	M	C	II-1A. Directional Control System Design
		G/I	II-2A. Powertrain II-2B. Automated Car Following and Braking
		G	None
	L		None
MH	H	G	I-1A. Braking and Steering Behavior; and Motion Perception I-1E. Effects of Stressors I-1F. Driving Characteristics of Classified Groups II-2A. Powertrain II-2B. Automated Car Following and Braking
M	H	C	III-1I. Preconstruction Overall Design Review
		G/I	I-1H. Multiple Driver Situations
		G	I-1B. Risk Perception and Decision Making I-3A. Prescreen Elderly (and Other Potentially Unsafe Drivers) I-3B. Prescreen Personnel I-3C. Vehicle Operator Licensing Tests I-3D. Vehicle Operator Certification Tests I-3E. "Fit-To-Drive" Tests/Certification I-3F. Portable Drug/Alcohol Intoxication Test
	M	C	I-5. Skill Transfer: Vehicle - Vehicle II-3A. Heavy Truck Cab Design II-3B. Seat Assessment
	L		None

TABLE V: SIMULATOR FIDELITY/COST VS POTENTIAL UTILIZATION (Cont'd.)			
FIDELITY (COST)			
MOTION	VISUAL	COCKPIT	UTILIZATION (TABLE I)
ML	H	C	III-5. Underground Highway Systems
ML	MH	C	I-4C. Rehabilitation Driver Training Programs I-4D. Special Driver Training Programs III-1C. Lane and Shoulder Width
ML	MH	G	III-4. Effects of Weather
L	H	C	None
L	H	G/I	None
L	H	G	I-1C. Workload I-1D. Hazard Perception II-4A. Augmented Vision Systems an Head-Up Displays (HUD) II-4C. Lighting and Visibility III-1A. Signs, Signals, and Markings III-1B. Horizontal and Vertical Curvature III-1E. Illumination III-1G. Traffic Interactions III-1H. Tunnels III-3. Effects of Natural and Built Environments
L	MH	G	III-1D. Median and Barrier Design III-1F. Surrounding Environment
L	M	C	II-3C. Sound Quality
L	M	C/I	II-5A. Secondary Controls and Convenience Devices II-5B. Display Quantification II-5C. Systems Evaluation of Interior Layouts
L	M	G	I-1G. Social Interactions II-4B. Navigation or Route Guidance Devices
L	L		None

H = High
M = Medium
L = Low
G = Generic Cockpit Including Instrument Panel
G/I = Generic Cockpit with Changeable Instrument Panel
C = Changeable Cockpit

APPENDIX A

DETAILED SIMULATOR REQUIREMENTS FOR EACH UTILIZATION

Table I includes 54 major utilizations plus several specific subsets and numerous nonspecific subsets. A driving simulator sensory stimulation system, equations of motion, and cockpit must satisfy numerous detailed requirements in order to be useable for any specific utilization. These detailed requirements should consider cross modal effects, measured data, and the experience gained on various (aero-space) simulators. This level of detail is beyond the scope of this report.

However, the committee is including in this report an overview of the sensory stimulation, equations of motion, and cockpit requirements for each of the 54 major utilizations. It is particularly hard to indicate visual and motion requirements because of the numerous "simulator tricks" and cross modal effects. Thus, the reader is cautioned to view the contents of this appendix as a gross preliminary indication of requirements to be modified by prudent simulator design rather than absolute numbers ready to be plugged into a formal specification - especially the visual and motion system parameters.

Table A lists the contents: Table A.0 through Table A.41. Table A-0 is a three-page table explaining the requirements (parameters and units of measure) for the simulator(s). Tables A.1 through A.41 are sets of three-page tables, one for each utilization. Each table contains the overview requirements for the stated utilization. (Note: In a few cases, one table suffices multiple utilizations; thus, there are 41 rather than 54 tables.)

TABLE A: SIMULATOR REQUIREMENTS	
TABLE	UTILIZATION
Table A.0	Units of Measure
Table A.1	I-1A: Braking and Steering Behavior; and Motion Perception
Table A.2	I-1B: Risk Perception and Decision Making
Table A.3	I-1C: Workload
Table A.4	I-1D: Hazard Perception
Table A.5	I-1E: Effects of Stressors
Table A.6	I-1F: Driving Characteristics of Classified Groups
Table A.7	I-1G: Social Interactions
Table A.8	I-1H: Multiple Driver Situations
Table A.9	I-2A: Driver Performance Measures
Table A.10	I-2B: Develop and Validate A Theory of Driving
Table A.11	I-3A-F: Design of Driver Screening and Licensing Tests
Table A.12	I-4A,B: Vehicle Training Systems and Programs: Emergency; Law Enforcement
Table A.13	I-4C,D: Vehicle Training Systems and Programs: Rehabi-tation and Special
Table A.14	I-5: Skill Transfer: Vehicle - Vehicle
Table A.15	II-1A: Directional Control System Design
Table A.16	II-1B: Directional Control Device Development
Table A.17	II-1C: Unexpected Changes in Vehicle Dynamic Behavior
Table A.18	II-2A,B: Longitudinal Control Studies
Table A.19	II-3A,B: Vibration and Noise: Heavy Truck; Seat
Table A.20	II-3C: Sound Quality
Table A.21	II-4A,C: Aids for Path Keeping: Vision/HUD; Lighting
Table A.22	II-4B,D: Aids for Path Keeping: Navigation; Hazard Alerting
Table A.23	II-5A,B,C: Human Factors Evaluations of Vehicle Interiors
Table A.24	III-1A: Signs, Signals, and Markings
Table A.25	III-1B: Horizontal and Vertical Curvature
Table A.26	III-1C: Lane and Shoulder Width
Table A.27	III-1D: Median and Barrier Design
Table A.28	III-1E: Illumination
Table A.29	III-1F: Surrounding Environment
Table A.30	III-1G: Traffic Interactions
Table A.31	III-1H: Tunnels
Table A.32	III-1I: Preconstruction Overall Design Review
Table A.33	III-2A: Temporary Traffic Control Devices
Table A.34	III-2B: Conspicuity of Impending Personnel & Vehicle Movement
Table A.35	III-3: Effects of Natural and Built Environments
Table A.36	III-4: Effects of Weather
Table A.37	III-5: Underground Highway Systems
Table A.38	IV-1: Simulator Design Studies for Developing Other Simulators
Table A.39	IV-2: Skill Transfer: Simulator - Vehicle
Table A.40	IV-3: Simulator Sickness
Table A.41	IV-4: Accident Reconstruction and Analysis

Table A.0: Table A -- Requirements Table -- Units of Measure

PARAMETER	UNIT OF MEASURE/SPECIFICATION
Visual System	
Overall Fidelity	High Medium Low
Field of View	~ 200° ~ 120° ~ 60°
Brightness	Bright Medium Low ~ Motion Picture ~ Home TV ≪ Home TV
Contrast	High Medium Low ≥ 16 S/G ~ 12 S/G ≥ 8 S/G
Daytime Scenes	Yes/No
Nighttime Scenes	Yes/No
Special Effects	List (e.g., fog, sun glare, etc.)
Resolution	VH 4 arc min High Medium Low ~ 6 arc min ~ 13 arc min ~ 20 arc min
Moving Models	Number + Fidelity
Scene Content	Dense/Urban; Sparse/Rural
Perceived Motion	
Lateral Displacement	Multiple lane; 2 lane; w/in lane serpentine
Vertical Displacement	TBD
Skidding	Yes/No and type
Fish-tailing	Yes/No and elaborate
Instability/Vehicle Dynamics	Yes/No and elaborate
Motion System	
Asynchronous Random Bumping	Yes/No
Synchronous Bumping	Yes/No (e.g., crossing RR tracks)
Pitch Associated with Braking	Yes/No
Acceleration - Cues	List magnitude, type of event, and axis ($X, Y, Z, \theta, \phi, \psi$)
- Sustained	List magnitude, type of event, and axis ($X, Y, Z, \theta, \phi, \psi$)
Displacement: Lateral (Y axis) Longitudinal (X axis) Vertical (Z axis) Roll (θ axis) Pitch (ϕ axis) Yaw (ψ axis)	List magnitude and/or event
Vibration	Frequency content/bandwidth, DOF
Vibration as a Distraction	Yes/No
Equations of Motion: Vehicle Model	
Simple; Basic Limited Vehicle Dynamics Sophisticated, Accurate Vehicle Dynamics	} Select one
Include Effects of Road Conditions; Weather	Yes/No and specify
Tactile	
Control Loading	Yes/No & Indicate SW, Brake, etc.;bandwidth
Engine Vibration	Yes/No (Yes implies cognizance of engine status)
Audio: Sound	Indicate Directional Accuracy Needed
Road Noise	Yes/No
Own Vehicle Noise	Yes/No
Warning	Yes/No
Wind Noise	Yes/No
Cab: Cockpit	
Vehicle Type(s)	Specify (Compact, Full Size, Van, Pick-up Truck, etc.)
Manual; Automatic	Select
Instrument Panel - Generic, Fixed - Changeable	} Select; elaborate
Technology Related - Information System - Heads-up Display - Other	} Yes/No - elaborate as appropriate
Miscellaneous Requirements	
Unique Control & Monitoring	Specify
Output Data	Specify

TABLE A.1

Utilization: I-1A: Braking and Steering Behavior; and Motion Perception

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	Motion perception is the driving factor for high fidelity.
Field of View	200°	
Brightness	High	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	None	
Resolution	High	
Moving Models	Few; Low Fidelity	
Scene Content	Various	
Perceived Motion:		
Lateral Displacement	ML; 2L; Serpentine	
Vertical Displacement	Yes	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s²; 300°/s²; 200°/s²
- Sustained	None	
Displacement:		
Lateral	~ 10′	
Longitudinal	~ 15′	
Vertical	~ 2″	
Roll	~± 30°	
Pitch	~± 20°	
Yaw	~±120°	
Vibration	Minimal	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather	Road Conditions	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic; Various	A lot can be learned with a generic only cab; some additional information can be gathered with specially configured cabs.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/R	
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		Possible medical harness; head and/or eye position indicator.

TABLE A.2

Utilization: I-1B: Risk Perception and Decision Making

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
<u>Visual System:</u>		
Overall Fidelity	High	Dependent on user population and degree of perception.
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	High	
Moving Models	Several; HiFi	
Scene Content	Various	
<u>Perceived Motion</u>:		
Lateral Displacement	ML; 2L; Serpentine	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
<u>Motion System:</u>		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	Minimal	
- Sustained	Not Required	
Displacement:		
Lateral	~ 5'	
Longitudinal	~ 5'	
Vertical	-	
Roll	~± 10°	
Pitch	~± 10°	
Yaw	~± 90°	
Vibration	Yes	
Vibration as a Distraction	Yes	
<u>Equations of Motion:</u> <u>Vehicle Model</u>		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	Yes	
<u>Tactile:</u>		
Control Loading	Yes	
Engine Vibration	Yes	
<u>Audio: Sound</u>		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
<u>Cab: Cockpit</u>		
Vehicle Type(s)	Generic	
Manual; Automatic	Manual	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/R	
<u>Miscellaneous Requirements</u>		
Unique Control & Monitoring		
Output Data		

TABLE A.3		
Utilization: I-1C: Workload		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	High	
Moving Models	Various	
Scene Content	Various	
Perceived Motion:		
Lateral Displacement	ML; 2L	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Minimal	
- Sustained	No	
Displacement:		
Lateral	Not Required/Minimal	Some motion may add workload stress.
Longitudinal	Not Required/Minimal	
Vertical	Not Required/Minimal	
Roll	Not Required/Minimal	
Pitch	Not Required/Minimal	
Yaw	Not Required/Minimal	
Vibration	Minimal	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		

TABLE A.4		
Utilization: I-1D: Hazard Perception		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Various
Resolution	Very High	
Moving Models	Yes	Various
Scene Content	Various	
Perceived Motion:		
Lateral Displacement	Minimal	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	Yes	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Minimal	
Warning	Minimal	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Changeable	Will require extensive versatility and variation.
Technology Related - Information System Heads-up Display Other	HUD; Alerting Devices; Communi-cations; etc.	
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.4 (Continued)		
Utilization: I-1D: Hazard Perception		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Motion System:		
Asynchronous Random Bumping	No	
Synchronous Bumping	Minimal	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	Minimal	
- Sustained	Not Required	
Displacement:		
Lateral	Not Required	
Longitudinal	Not Required	
Vertical	Not Required	
Roll	Not Required	
Pitch	Not Required	
Yaw	Not Required	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic	Additional cabs will provide same additional information.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/A	
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.5		
Utilization: I-1E: Effects of Stressors		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	Less fidelity may add to stress.
Field of View	200° w/Rear	
Brightness	High	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	Very High	4-6 Arc Min./L.P.
Moving Models	7	
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	2L	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	Yes	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	10 Hz - 100 Hz	
Vibration as a Distraction	30 Hz - 70 Hz	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Sedan: Generic	
Manual; Automatic	Automatic	Some experiments may require manual.
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/R	
Miscellaneous Requirements		
Unique Control & Monitoring Output Data	Medical Harness	

TABLE A.6		
Utilization: I-1F: Driving Characteristics of Classified Groups		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	Other than real-world may contaminate results.
Field of View	200° Forward + 3 rear	Full F.O.V. needed to assess visual influence
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Weather and time-of-day.
Resolution	Very High	
Moving Models	7 Minimum	Provide real-world scenes.
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	2L	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	Yes	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	10 Hz - 100 Hz	
Vibration as a Distraction	30 Hz - 70 Hz	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	Steering to 50 Hz; Brake; Accel, Gear Shift
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	All Types	
Manual; Automatic	Both	
Instrument Panel - Generic, Fixed Changeable	Changeable	Reconfigurable for selected experiment.
Technology Related - Information System Heads-up Display Other	Yes	As required for experiment.
Miscellaneous Requirements		
Unique Control & Monitoring Output Data	Medical Harness	Eye Tracker

TABLE A.7		
Utilization: I-1G: Social Interactions		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	200° w/Rear View	
Brightness	Bright	May have affect on driver attitude.
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	As required by experiment.
Resolution	MH	
Moving Models	7	
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	2L	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	Low Level
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	Minimal
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	± 5′	
Vertical	-	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 360°	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion:		
Vehicle Model	✓	
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	As in real vehicle, may affect driver attitude.
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Sedan	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/A	
Miscellaneous Requirements		
Unique Control & Monitoring	Medical Harness	
Output Data		

TABLE A.8

Utilization: I-1H: Multiple Driver Situations

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200° Forward + 3 rear	F.O.V. needed to assss visual influence.
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Weather and time-of-day.
Resolution	Very High	
Moving Models	7 Minimum	
Scene Content	Dense	Provide real-world scenes.
Perceived Motion:		
Lateral Displacement	2L	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Minimal	
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	N/R	
Vertical	± 2 inches	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 90°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion:		
Vehicle Model		
Simple; Basic	√	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	√	
Tactile:		
Control Loading	Yes	Steering to 50 Hz; Brake; Accel, Gear Shift
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)		Generic for each standard size vehicle.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Changeable	Reconfigurable for selected experiment.
Technology Related - Information System Heads-up Display Other	No	
Miscellaneous Requirements		
Unique Control & Monitoring Output Data	Medical Harness	Eye Tracker

TABLE A.9		
Utilization: I-2A: Driver Performance Measures		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200° w/Rear	
Brightness	Bright	Maximum attainable.
Contrast	High	Maximum attainable.
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	Very High	Maximum attainable.
Moving Models	7	
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	ML	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	Yes	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	10 Hz - 100 Hz	
Vibration as a Distraction	30 Hz - 70 Hz	
Equations of Motion:		
Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	√	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	√	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Minimal	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/A	
Miscellaneous Requirements		
Unique Control & Monitoring	Full medical harness	
Output Data		

TABLE A.10

Utilization: I-2B: Develop and Validate A Theory of Driving

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200° + 3 RV	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Weather; Time-of-Day.
Resolution	Very High	
Moving Models	Yes	At least 7.
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	ML	
Vertical Displacement	Yes	
Skidding	Yes	Not essential unless specifically trying to determine how these actions are handled. However, there are a lot of other driving situations to explore so that a simulator without these would still be quite useful for this purpose.
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	No	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	Yes	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	10 Hz - 100 Hz	
Vibration as a Distraction	Minimal	
Equations of Motion: Vehicle Model		
Simple; Basic Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	Steering to 50 Hz; Brake; Accel, Gear Shift
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	Manual may be rquired to complete theory.
Instrument Panel - Generic, Fixed Changeable	Generic	Except a reconfigurable panel will be required if theory includes extensive detail relative to instruments.
Technology Related - Information System Heads-up Display Other	N/R	
Miscellaneous Requirements		
Unique Control & Monitoring	Medical Harness	Eye Tracker
Output Data		

TABLE A.11		
Utilization: I-3A-F: Design of Driver Screening and Licensing Tests		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	No	
Special Effects	Possibly	
Resolution	High	
Moving Models	Yes	Typical Traffic
	Various	Typical Urban, Rural, Interstate, etc.
Scene Content		
Perceived Motion:		
Lateral Displacement	ML; 2L	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Small Amount	
Acceleration - Cues/Onset	Minimal	
- Sustained	No	
Displacement:		
Lateral	± 3 ft	
Longitudinal	± 2'	Need for longitudinal motion is a candidate for experimental verification.
Vertical	No	
Roll	± 10°	
	± 15°	
Pitch	± 90°	
Yaw		
	Yes	
Vibration	Yes	
Vibration as a Distraction		
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		Current popular system.
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		Requires driver skills assessment software.

TABLE A.12

Utilization: I-4A, B: Vehicle Training Systems and Programs: Emergency; Law Enforcement

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	Very High	Include high speed, urban.
Moving Models	Yes	
	Varied	
Scene Content		
Perceived Motion:		Include high speed sperpentine.
Lateral Displacement	ML; 2L; Serpentine	
Vertical Displacement	Yes	
Skidding	Yes	
Fish-tailing	Yes	Very High Fidelity
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s²; 300°/s²; 200°/s²
- Sustained	Limited	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	360°	
Vibration	Minimal	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	Generic for Type/Use of Vehicle.
Technology Related - Information System Heads-up Display Other		Only to extent of standard equipment.
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.13		
Utilization: I-4C, D: Vehicle Training Systems and Programs: Rehabilitation and Special		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
<u>Visual System:</u>		
Overall Fidelity	Medium-High	
Field of View	~200°	
Brightness	High	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	High	
Moving Models	Yes	
Scene Content	Varied	
<u>Perceived Motion</u>:		
Lateral Displacement	w/in lane; 2L	Limited: Normal snow, ice, wet pavement.
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	No	
<u>Motion System:</u>		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	Limited
Acceleration - Cues/Onset	Limited	
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	± 5′	
Vertical	± 2″	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	Yes	
<u>Equations of Motion:</u> <u>Vehicle Model</u>		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	Limited	
<u>Tactile:</u>		
Control Loading	Yes	
Engine Vibration	Yes	
<u>Audio: Sound</u>		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
<u>Cab: Cockpit</u>		
Vehicle Type(s)	Varied	Include special controls.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
<u>Miscellaneous Requirements</u>		
Unique Control & Monitoring		
Output Data		

TABLE A.14		
Utilization: I-5: Skill Transfer: Vehicle - Vehicle		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	~200°	
Brightness	Medium	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Minimal	
Resolution	Medium-High	
Moving Models	Yes	At least 5.
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	w/in lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	No	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Minimal	
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	± 5′	
Vertical	± 2″	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Various	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed		
Changeable	Changeable	
Technology Related - Information System	Yes	
Heads-up Display		
Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.15		
Utilization: II-1A: Directional Control System Design		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	~200°	
Brightness	Medium	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	No	
Special Effects	No	
Resolution	High	
Moving Models	Yes	Limited; Simple
Scene Content	Simple, but varied	
Perceived Motion:		
Lateral Displacement	ML; 2L; Serpentine	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	Duplicate actual based on measured data
- Sustained	No	
Displacement:		
Lateral	10 M	
Longitudinal	10 M	
Vertical	.2 M	
Roll	± 30°	
Pitch	± 20°	
Yaw	360°	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	√	
Include Affects of Road Conditions; Weather	√	
Tactile:		
Control Loading	Yes	Very accurate
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Various Types	Generic by basic size/vehicle type
Manual; Automatic	Manual; Automatic	
Instrument Panel - Generic, Fixed	Generic	
Changeable		
Technology Related -		
Information System		
Heads-up Display		
Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.16

Utilization: II-1B: Directional Control Device Development

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium-High	
Field of View	~200°	
Brightness	Bright	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	No	
Special Effects	No	
Resolution	High	
Moving Models	Yes	Limited; Simple
Scene Content	Simple, but varied	
Perceived Motion:		
Lateral Displacement	ML; 2L; Serpentine	
Vertical Displacement	No	
Skidding	Yes	Only when associated with snow or ice.
Fish-tailing	No	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	Realistic values
- Sustained	No	
Displacement:		
Lateral	10 M	
Longitudinal	10 M	
Vertical	No	
Roll	± 30°	
Pitch	± 20°	
Yaw	± 90°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	Accurate
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic	May be desireable to include multiple vehicle types.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		

TABLE A.17		
Utilization: II-1C: Unexpected Changes in Vehicle Dynamic Behavior		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	No	
Special Effects	No	
Resolution	High	
Moving Models	Yes	
Scene Content	Varied, but simple	
Perceived Motion:		
Lateral Displacement	2L; ML; Serpentine	
Vertical Displacement	No	
Skidding	Yes	Snow; Ice
Fish-tailing	Yes	Snow; Ice
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	Very Realistic
- Sustained	No	
Displacement:		
Lateral	10 M	
Longitudinal	10 M	
Vertical	.2 M	
Roll	± 30°	
Pitch	± 20°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	Very Realistic
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.18		
Utilization: II-2A, B: Longitudinal Control Studies		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	60°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Weather and Time-of-Day
Resolution	High	
Moving Models	7	
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	w/in Lane; 2L	
Vertical Displacement	No	
Skidding	Yes - Miminal	
Fish-tailing	Yes - Minimal	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; .5g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	No	
Displacement:		
Lateral	5 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	10 Hz - 100 Hz	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	Steering to 50 Hz; Brake; Accel; Gear Shift
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	All Types	
Manual; Automatic	Manual; Automatic	
Instrument Panel - Generic, Fixed Changeable	Changeable	Reconfigurable for selected experiment.
Technology Related - Information System Heads-up Display Other	N/R	
Miscellaneous Requirements		
Unique Control & Monitoring Output Data	Yes	

TABLE A.19		
Utilization: II-3A, B: Vibration and Noise: Heavy Truck; Seat		
Parameter	Requirement/ - Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	60°	
Brightness	Medium	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Minimal	
Resolution	Medium	
Moving Models	5	
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	Yes	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ	.1g; .1g; 2g; 50°/s²; 50°/s²
- Sustained	No	
Displacement:		
Lateral	± 18 inches	
Longitudinal	± 18 inches	
Vertical	± 6 inches	
Roll	± 10°	
Pitch	± 10°	
Yaw	N/R	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	√	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	√	Rough Road
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Minimal	
Warning	No	
Wind Noise	Minimal	
Cab: Cockpit		
Vehicle Type(s)	All Types	
Manual; Automatic	Manual; Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/R	
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.20		
Utilization: II-3C: Sound Quality		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	60°	
Brightness	Medium	May have affect on driver attitude.
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	As required by experiment.
Resolution	Medium	
Moving Models	7	
	Dense	
Scene Content		
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	No	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	No	
Yaw	No	
Vibration	10 Hz - 100 Hz	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	No	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	Relate to sound.
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	Vehicle noise & vibration directly related.
Other Vehicle	No	
Warning	No	
Wind Noise	Minimal	
Cab: Cockpit		
Vehicle Type(s)	Various	
Manual; Automatic	Manual; Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	N/R	
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		

TABLE A.21		
Utilization: II-4A, C: Aids for Path Keeping: Vision/HUD; Lighting		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
<u>Visual System:</u>		
Overall Fidelity	High	
Field of View	200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Fog; Dust; Rain; Snow
Resolution	Very High	
Moving Models	5-10	
Scene Content	Various	
<u>Perceived Motion</u>:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
<u>Motion System:</u>		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	No	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	No	
Yaw	No	
Vibration	Minimal	
Vibration as a Distraction	Yes	
<u>Equations of Motion:</u> <u>Vehicle Model</u>		
Simple; Basic	√	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	Yes	
<u>Tactile:</u>		
Control Loading	Minimal	
Engine Vibration	Minimal	
<u>Audio: Sound</u>		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
<u>Cab: Cockpit</u>		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other	As Required	
<u>Miscellaneous Requirements</u>		
Unique Control & Monitoring		
Output Data		

TABLE A.22		
Utilization: II-4B, D: Aids for Path Keeping: Navigation; Hazard Alerting		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
<u>Visual System:</u>		
Overall Fidelity	Medium	
Field of View	60°	
Brightness	Medium	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Fog; Dust; Snow; Rain
Resolution	High	
Moving Models	No	
Scene Content	Various	
<u>Perceived Motion</u>:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
<u>Motion System:</u>		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	θ; ϕ; ψ	100°/s^2; 100°/s^2; 100°/s^2: Add to realism of alerting device
- Sustained	No	
Displacement:		
Lateral	No	
Longitudinal	No	
Vertiçal	No	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 120°	
Vibration	Yes	
Vibration as a Distraction	Yes	
<u>Equations of Motion:</u> <u>Vehicle Model</u>		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
<u>Tactile:</u>		
Control Loading	Minimal	
Engine Vibration	Yes	
<u>Audio: Sound</u>		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
<u>Cab: Cockpit</u>		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable		Generic Panel with specific devices under test added.
Technology Related - Information System Heads-up Display Other		
<u>Miscellaneous Requirements</u>		
Unique Control & Monitoring		
Output Data		

TABLE A.23		
Utilization: II-5A, B, C: Human Factors Evaluations of Vehicle Interiors		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium	
Field of View	60°	
Brightness	Medium	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	No	
Resolution	Medium	
Moving Models	Yes	
Scene Content	Dense	
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	Not critical.
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	No	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	No	
Yaw	No	
Vibration	Minimal	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	No	
Tactile:		
Control Loading	Minimal	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Changeable	
Technology Related - Information System Heads-up Display Other		As required by devices being evaluated.
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.24		
Utilization: III-1A: Signs, Signals, and Markings		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~120°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	Very High	
Moving Models	No	
Scene Content	Varied	
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	Minimal	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	No	
Yaw	Minimal	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Yes	
Other Vehicle	Minimal	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.25		
Utilization: III-1B: Horizontal and Vertical Curvature		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
<u>Visual System:</u>		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	High	
Moving Models	No	
Scene Content	Rural; Pkwy; Interstate	
<u>Perceived Motion</u>:		
Lateral Displacement	w/in Lane	
Vertical Displacement	Minimal	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
<u>Motion System:</u>		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	± 5'	Displacement is required for driver/ cab orientation only; displacement is not required for sensation of driving.
Longitudinal	No	
Vertical	± 6 inches	
Roll	No	
Pitch	± 20°	
Yaw	± 180°	
Vibration	Minimal	
Vibration as a Distraction	No	
<u>Equations of Motion: Vehicle Model</u>		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
<u>Tactile:</u>		
Control Loading	Yes	
Engine Vibration	Minimal	
<u>Audio: Sound</u>		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
<u>Cab: Cockpit</u>		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
<u>Miscellaneous Requirements</u>		
Unique Control & Monitoring		
Output Data		

TABLE A.26		
Utilization: III-1C: Lane and Shoulder Width		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium High	
Field of View	~200°	
Brightness	Medium	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	High	
Moving Models	Yes	
Scene Content	Varied	Include turning lanes
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	± 5'	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	No	
Yaw	± 180°	
Vibration	Minimal	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	But must include side suction forces.
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	Yes	
Warning	No	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Various	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		

TABLE A.27

Utilization: III-1D: Median and Barrier Design

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Visibility and definition in rain, snow fog
Resolution	High	
Moving Models	Minimal	
Scene Content		Mostly divided highway variations.
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	No	
Yaw	± 30°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.28		
Utilization: III-1E: Illumination		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	No	
Nighttime Scenes	Yes	Need very high fidelity with right illumination.
Special Effects	Yes	Fog, Rain, Snow.
Resolution	Very High	
Moving Models	Yes	Represent moderate traffic; include on-coming vehicles.
Scene Content	Urban; Rural	Various nighttime scenes/scenarios.
Perceived Motion:		
Lateral Displacement	ML; 2L; w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	Minimal	
Longitudinal	No	
Vertical	No	
Roll	Minimal	
Pitch	Minimal	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.29		
Utilization: III-1F: Surrounding Environment		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	Medium High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	No	
Special Effects	No	
Resolution	High	
Moving Models	Few	
Scene Content	Rural; Parkway	Emphasize surrounding environment.
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement: Lateral Longitudinal Vertical Roll Pitch Yaw	Not Required	
Vibration	Minimal	
Vibration as a Distraction	OK	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.30

Utilization: III-1G: Traffic Interactions

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Rain, Fog.
Resolution	Medium High	
Moving Models	Yes	Lot of traffic - traffic conflicts.
Scene Content	Urban; Interstate (Merge)	Emphasis on intersections and merge.
Perceived Motion:		
Lateral Displacement	2L; w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Y; θ, ψ	Y and θ minimal; ψ realistic.
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	No	
Vertical	No	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		

TABLE A.31		
Utilization: III-1H: Tunnels		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	-	Enter/Exit Tunnel Day/Night; Rain, Fog, Snow
Nighttime Scenes	-	
Special Effects	-	
Resolution	Very High	
Moving Models	Yes	
Scene Content	Tunnels	Driving through; Entering; Exiting
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	Minimal	
- Sustained	No	
Displacement:		
Lateral	± 5'	
Longitudinal	No	
Vertical	No	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 90°	
Vibration	No	
Vibration as a Distraction	Yes	
Equations of Motion:		
Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Yes	Tunnel Noise
Own Vehicle Noise	No	
Other Vehicle	Yes	Tunnel Noise
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.32		
Utilization: III-1I: Preconstruction Overall Design Review		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Rain; Fog
Resolution	High	
Moving Models	Yes	
Scene Content	Urban; Eval; Inter-state	
Perceived Motion:		
Lateral Displacement	2L; ML; w/in Lane	
Vertical Displacement	Minimal	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	Y; θ, ψ	Minimal
- Sustained	No	
Displacement:		
Lateral	± 5'	
Longitudinal	No	
Vertical	± 6 inches	
Roll	± 20°	
Pitch	± 10°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Various Generic	Generic cockpit for each standard size vehicle
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.33		
Utilization: III-2A: Temporary Traffic Control Devices		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Fog; Rain
Resolution	Very High	
Moving Models	Yes	Limited Traffic
Scene Content	Urban; Eval; Interstate	Construction Zone
Perceived Motion:		
Lateral Displacement	w/in lane; 2L	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Y; θ, ψ	Swerving and Serpentining
- Sustained	No	
Displacement:		
Lateral	± 5'	
Longitudinal	No	
Vertical	No	
Roll	± 20°	
Pitch	± 10°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	No	
Own Vehicle Noise	No	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.34

Utilization: III-2B: Conspicuity of Impending Personnel and Vehicle Movement

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Fog; Rain
Resolution	High	
Moving Models	Yes	Limited Traffic; Construction Equipment; Construction Personnel
Scene Content	Urban; Rural; Inter-state	Construction Zone
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Y; θ, ψ	Swerving and Serpentining
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	No	
Vertical	No	
Roll	± 20°	
Pitch	± 10°	
Yaw	± 180°	
Vibration	Yes	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	No	
Own Vehicle Noise	No	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring Output Data		

TABLE A.35		
Utilization: III-3: Effects of Natural and Built Environments		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	-200°	
Brightness	Bright	
Contrast	Medium	
Daytime Scenes	Yes	
Nighttime Scenes	No	
Special Effects	No	
Resolution	High	
Moving Models	Minimal	
Scene Content	Rural; Urban; Inter-state	
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	No	
- Sustained	No	
Displacement:		
Lateral	No	
Longitudinal	No	
Vertical	No	
Roll	No	
Pitch	± 5°	
Yaw	± 30°	
Vibration	Minimal	
Vibration as a Distraction	Yes	
Equations of Motion: Vehicle Model		
Simple; Basic	✓	
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.36		
Utilization: III-4: Effects of Weather on Visibility		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
<u>Visual System:</u>		
Overall Fidelity	Medium-High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Fog; Dust; Rain; Snow
Resolution	High	
Moving Models	Yes	Traffic: Ahead and Oncoming
Scene Content	Urban; Rural; Inter-state	Include mountains
<u>Perceived Motion</u>:		
Lateral Displacement	w/in Lane; 2L	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
<u>Motion System:</u>		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	Y; ϕ	Vehicle braking and acceleration
- Sustained	No	
Displacement:		
Lateral	No	
Longitudinal	± 36"	
Vertical	No	
Roll	No	
Pitch	± 15°	
Yaw	± 20°	
Vibration	Minimal	
Vibration as a Distraction	No	
<u>Equations of Motion:</u> <u>Vehicle Model</u>		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
<u>Tactile:</u>		
Control Loading	Yes	
Engine Vibration	Minimal	
<u>Audio: Sound</u>		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
<u>Cab: Cockpit</u>		
Vehicle Type(s)	Generic	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
<u>Miscellaneous Requirements</u>		
Unique Control & Monitoring		
Output Data		

TABLE A.37		
Utilization: III-5: Underground Highway Systems		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	~200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes		
Nighttime Scenes		
Special Effects		
Resolution	Very High	
Moving Models	Yes	Merging; Intersecting; Oncoming; Ahead Traffic
Scene Content	Complex Tunnels	
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	No	
Fish-tailing	No	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Minimal	
Synchronous Bumping	No	
Pitch Associated with Braking	No	
Acceleration - Cues/Onset	Minimal	
- Sustained	No	
Displacement:		
Lateral	± 5′	
Longitudinal	No	
Vertical	No	
Roll	± 10°	
Pitch	± 10°	
Yaw	± 90°	
Vibration	Minimal	
Vibration as a Distraction	No	
Equations of Motion:		
Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	No	
Warning	No	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Various Generic	Generic cockpit for each standarad size vehicle.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.38		
Utilization: IV-1: Simulator Design Studies for Developing Other Simulators		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200°+ 3 Rear	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	Fog; Dust; Rain; Snow; Sun Glare, etc.
Resolution	Very High	
Moving Models	Numerous	
Scene Content	All	
Perceived Motion:		
Lateral Displacement	ML; LL; w/in Lane	
Vertical Displacement	Yes	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	Yes	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	Yes	
Vibration as a Distraction	Yes	Controllable
Equations of Motion: Vehicle Model		
Simple; Basic	✓	Selectable
Limited Vehicle Dynamics	✓	Selectable
Sophisticated, Accurate Vehicle Dynamics	✓	Selectable
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	Highly accurate; capable of degrading
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Various	
Manual; Automatic	Manual; Automatic	
Instrument Panel - Generic, Fixed Changeable	Changeable	
Technology Related - Information System Heads-up Display Other	Insertable	
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.39

Utilization: IV-2: Skill Transfer: Simulator - Vehicle

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	No	
Resolution	High	
Moving Models	3-5	
Scene Content	Urban; Rural; Inter-state	
Perceived Motion:		
Lateral Displacement	w/in Lane	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	No	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.5g; .6g; 300°/s^2; 200°/s^2; 200°/s^2
- Sustained	Yes	
Displacement:		
Lateral	± 5′	
Longitudinal	± 5′	
Vertical	± 8 inches	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	Yes	
Vibration as a Distraction	Minimal	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics	✓	Include unique features such as 4-wheel steer.
Sophisticated, Accurate Vehicle Dynamics		
Include Affects of Road Conditions; Weather	✓	
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Various	
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Changeable	
Technology Related - Information System Heads-up Display Other	Yes	Include all relevant systems.
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.40

Utilization: IV-3: Simulator Sickness

Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	Primarily Daytime Scenes
Special Effects	No	
Resolution	Very High	
Moving Models	Yes	
Scene Content	Various	
Perceived Motion:		Perceived motion requirements are dependent on particular maneuvers being studied.
Lateral Displacement	w/in Lane	
Vertical Displacement	Yes	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	Yes	
Pitch Associated with Braking	Minimal	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	Realistic (.8g; .8g; .1g; 300°/s^2; 300°/s^2; 200°/s^2)
- Sustained	No	
Displacement:		
Lateral	10 M	
Longitudinal	30 M	
Vertical	1 M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	Yes	10 - 100 Hz
Vibration as a Distraction	Yes	10 - 100 Hz
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Yes	
Audio: Sound		
Road Noise	Yes	
Own Vehicle Noise	Yes	
Other Vehicle	No	
Warning	No	
Wind Noise	Yes	
Cab: Cockpit		
Vehicle Type(s)	Various Generic	Generic for each standard size vehicle.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		

TABLE A.41		
Utilization: IV-4: Accident Reconstruction and Analysis		
Parameter	Requirement/ Specification (See Table A.0 for Units of Measure)	Comments - Clarification - Rationale
Visual System:		
Overall Fidelity	High	
Field of View	200°	
Brightness	Bright	
Contrast	High	
Daytime Scenes	Yes	
Nighttime Scenes	Yes	
Special Effects	Yes	
Resolution	Very High	
Moving Models	Yes	
Scene Content	All	
Perceived Motion:		
Lateral Displacement	ML; 2L; w/in Lane	
Vertical Displacement	No	
Skidding	Yes	
Fish-tailing	Yes	
Instability/Vehicle Dynamics	Yes	
Motion System:		
Asynchronous Random Bumping	Yes	
Synchronous Bumping	No	
Pitch Associated with Braking	Yes	
Acceleration - Cues/Onset	X; Y; Z; θ, ϕ, ψ	.8g; .8g; 1g; 300°/s^2; 300°/s^2; 200°/s^2
- Sustained	Limited	
Displacement:		
Lateral	10M	
Longitudinal	30M	
Vertical	± 1M	
Roll	± 30°	
Pitch	± 30°	
Yaw	Unlimited	
Vibration	Minimal	
Vibration as a Distraction	No	
Equations of Motion: Vehicle Model		
Simple; Basic		
Limited Vehicle Dynamics		
Sophisticated, Accurate Vehicle Dynamics	✓	
Include Affects of Road Conditions; Weather		
Tactile:		
Control Loading	Yes	
Engine Vibration	Minimal	
Audio: Sound		
Road Noise	Minimal	
Own Vehicle Noise	Minimal	
Other Vehicle	Yes	
Warning	Yes	
Wind Noise	No	
Cab: Cockpit		
Vehicle Type(s)	Various Generic	Generic for each standard size vehicle.
Manual; Automatic	Automatic	
Instrument Panel - Generic, Fixed Changeable	Generic	
Technology Related - Information System Heads-up Display Other		
Miscellaneous Requirements		
Unique Control & Monitoring		
Output Data		