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THE VIRTTEX HUMAN RATING PROCESS

R. Curry, B. Artz, L. Cathey, P. Grant, and J. Greenberg

Ford Research Laboratory
P.O. Box 2053
MD 2115
Dearborn, MI 48124-2053
313-337-6479 (office)
313-248-9051 (fax)
rcurry4@ford.com

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ABSTRACT

Based on the VIRTTEX driving simulator's operational complexity and the intended use the facility, a safety review by a human-rating board (HRB) of experts was required. A human-rated system is one that incorporates design features, operational procedures, and adheres to other appropriate standards (i.e., ISO, ANSI, OSHA) necessary to safely accommodate human participants, maintenance and service personnel under both normal operation and in recovery from emergency situations. This paper details the human rating process established at Ford to certify VIRTTEX for human-in-the-loop experimentation. As part of this process the report describes the VIRTTEX systems being human rated, the tools and standards used to evaluate these systems, the HRB composition, the details of the documentation prepared for the HRB design review, the format of the HRB design review, and the approach used to resolve design review critical path issues. The time line for this process will also be outlined.

INTRODUCTION

Ford's VIRtual Test Track EXperiment (VIRTTEX) was designed to support three broad areas of research: Driver Safety, Driving Dynamics, and Consumer Insight. ***Driver Safety*** includes study of driver distraction, workload and active safety systems. ***Driving Dynamics*** applications use VIRTTEX to develop metrics and guidelines to aid vehicle engineers in the design of products that are fun to drive. ***Consumer Insight*** includes the evaluation of specific products for customer acceptability as well as the study of brand-specific attributes.

To support these research areas the following design objectives were developed for VIRTTEX:

Table 1: VIRTTEX Design Objectives

Design Objective	Comment
Simulate typical vehicle motions up to approx. +/-0.15 *g* lateral or longitudinal acceleration.	These acceleration levels account for about 90% of the vehicle miles driven in the US.
Simulate road vibrations up to the first mode of the un-sprung suspension masses.	To permit the analytical study of ride motion, no 'special effects' channels or actuators are used.
Provide a visual scene that requires the scanning of rear/side-view mirrors and can support common roadways and moderate traffic densities.	Special attention was paid to maintaining deterministic frame rates (at 60 *Hz*) and minimizing transport delays.
Provide a realistic cab environment for the driver. Allow interchangeable cabs to support different experiments.	Proper visual and motion simulation is only maintained at the driver's position.
Conceal the simulation motion system from the test participant as much as possible.	Non-technical test participants are often distracted by simulation equipment. We have designed our laboratory so that the motion system is not directly seen by the test participants.
Maintain a safe environment for the test participants and all other persons involved with the simulation.	This requirement underlies the design of virtually every subsystem in the VIRTTEX facility.

Based on these objectives and the intended use of the VIRTTEX driving simulator environment, a safety review by a human-rating board of experts was required.

HUMAN RATING PROCESS OBJECTIVES

The objectives for developing a human rating process for the VIRTTEX facility was to certify that the simulator design, its safety systems, the facility interfaces, the laboratory operating protocols, and methods for maintaining the highest level of safety were adequate for human-in-the-loop testing and maintenance/service personnel that will work with and around the system. Regarding the system design, performance data and safeguards were thoroughly examined on a system and sub-system level. This included the motion system, dome structure and components, the vehicle and its attachment to the motion platform, and life-critical facility structures such as simulator access bridges. Additionally, preventative measures such as start-up software diagnostics, system daily checks, and a routine maintenance schedule were reviewed. To complete the process, safety-relevant operating procedures, emergency preparedness, and the selection and handling of human participants for test drives and experimental purposes were also appraised.

PROCESS OVERVIEW

Because Ford has no standardized 'human-rating' process for reviewing simulators, best practices from NASA, the Department of Defense (DoD) and other resources were adopted.

The major steps (or milestones) completed on the way to receiving formal human-rating certification of VIRTTEX are outlined below:
Step #1: VIRTTEX life-critical systems safety integrity analyses.
Step #2: Literature search seeking viable human-rating sources.
Step #3: Selecting a human-rating board (HRB) of experts.
Step #4: Determining a process for implementing the safety assessment of VIRTTEX (e.g., design reviews, documentation, etc).
Step #5: Prepping the VIRTTEX team and setting up the design reviews.
Step #6: VIRTTEX Safety Assessment Report (SAR) drafts in advance of the design reviews.
Step #7: Addressing and documenting replies to all HRB critical-path issues in the SAR.
Step #8: The final SAR and HRB certification sign-off.

Based on the above steps, some obvious questions were posed:

- What or who are good sources for obtaining human-rating process documentation?
  - NASA (Human-in-the-Loop Simulators)
  - DOD flight, tank, and other human-in-the-loop simulators
  - Industrial vehicle simulators (i.e., Motorola, Johnson Controls)
  - NADS (National Advanced Driving Simulator)

- Who should be a member of the human-rating board?
  - Inside Ford: Health & Safety, Office of General Counsel (OGC), Human Factors, and Medical expertise
  - Outside Ford: Experienced and/or Academic simulator and human-vehicle interaction experts

- What VIRTTEX systems will be human rated?
  - Electro-Mechanical Safety Systems
  - Structural Design
  - Procedural Safety related to facility operations

- What tools will be used to analyze these systems?
  - Design and Process Failure Mode Effects Analyses (FMEAs)
  - Finite Element Analyses (FEAs)

- Safety Factor (SF) calculations in reference to yield strengths and loads
- System verification testing
- Adherence to appropriate standards (i.e., Ford, ISO, OSHA, ANSI, AISC, etc.)

More detail regarding answers to the above questions are covered in the following sections.

PROCESS FOUNDATION PRE-WORK

In developing this human-rating process, benchmarking of similar methodologies was done in order to establish a sound practice based on recognized credible sources. NASA is well known for its efforts to human-rate its many human-system integration vehicles and simulators, so this is where the search began. The DoD also maintains a number of simulator systems. Hence, resources provided to us by the TACOM (Tank and Army Command) were also key in embarking on defining a human rating process for VIRTTEX. We were also successful in obtaining a few other resources related to human-rating flight simulators.

Serving as the certification foundation, 13 Design/Process FMEAs were completed on the safety-related VIRTTEX sub-systems prior to initiating human-rating process. Sub-systems design FMEAs included the motion base, dome, access bridges, vehicle and its platform attachment, integrated safety system, operator's console, experimenter's station and other facility related life-critical components. Process FMEAs were done on procedures such as running a simulation and raising/lowering the access bridges.

As part of the safety assessment process, several analyses (i.e., FEAs and SF calculations) were completed on the structural integrity of many VIRTTEX sub-systems including the motion system, the dome, the vehicle buck and its attachment to the motion platform. System redundancy measures were also created to protect against hazardous equipment and human failure (i.e., life-safety systems and interlocks) in addition to documenting procedures to follow under several emergency situations. Performance verification tests were completed and documented on the motion system and life-safety systems. In addition, the team worked to identify and adhere to all applicable tools and standards that could be applied to the unique human-in-the-loop testing facility. Some of these standards included the Ford Robot Safety and ECPL (Energy Control and Power Lockout) Standards and the AISC (American Institute for Steel) yield strength standards. In order to achieve the highest level of safety, the team chose to abide by other self-imposed standards and tools including ISO guidelines on whole-body mechanical vibration (13090-1:1998, 2631-1:1997, MIL-STD 1472), and guidelines in the Handbook on Human Vibration and Handbook of Human Factors and Ergonomics.

DESIGN REVIEW PREPARATION

Human Rating Board Composition

The key element in successfully certifying the VIRTTEX facility was a human-rating board (HRB) of experts that contained members from inside and outside the Ford Community. Within Ford, we selected members from the user community (human factors and vehicle dynamics experts), Medical, OGC, and the Health & Safety office. External to Ford, nationally-recognized outside experts in simulation and human-vehicle interaction were sought adding more objectivity and credibility to the process.

Safety Assessment Report Preparation

The purpose of the VIRTTEX SAR was two-fold: It documents those VIRTTEX features that have been designed to support the safe use of the facility by researchers and test participants. Thus, it was used as a vehicle to convey this information to the HRB. In addition, it will serve as a reference document during the service life of the VIRTTEX facility and is the root source of the *VIRTTEX Protocol and Procedures* and the *VIRTTEX Operator and Observer Training Manuals* that are currently being completed as we bring the system, facility, and personnel up to speed.

Concerning the SAR contents, it begins by giving a general system and facility description. More detail follows outlining sub-system structural designs, performance, safety features, and interlocks. Life-safety systems verification tests are explained and a schedule of regular sub-system visual inspections and routine maintenance is presented. Subsequent sections address safety-relevant operational procedures and protocols, emergency preparedness, and the selection and handling of human participants for test drives and experimental purposes. The appendices provide additional detailed documentation in support of structural analyses FEAs, SF calculations, Integrated Safety System (ISS) flowcharted processes, participant informed consent and self-selection criteria, and memo responses to HRB critical issues.

THE HUMAN RATING REVIEW PROCESS

The VIRTTEX HRB was brought together on two separate occasions for all-day on-site forums that entailed a detailed design review and a follow-up session to address critical-path issues that arose from the design review. Between sessions and prior to certification, correspondence from the HRB and other involved parties (Ford Research Lab (FRL) Health & Safety, Building Services, OGC, Medical, Security, UAW, Dearborn EMS & Fire, and suppliers) was coordinated in the team effort that resulted in the successful human rating of the facility. The board provided guidance and input that was either incorporated into our safety procedures and processes and/or officially addressed in some form (i.e., additional analyses).

PROCESS RESULTS

Several protocols and tools have been established or created to maintain the highest level of health and safety in the VIRTTEX facility based on the human-rating process. These actions include:

- Establishing a daily checklist protocol that must be completed prior to running the VIRTTEX system.
- Working with FRL Building Services and suppliers to set up a routine maintenance schedule for this unique facility.
- Re-certification of VIRTTEX personnel every three years in synchrony with their First-aid and CPR training prerequisite.
- Working with Ford Medical to develop an evaluation process for participants that may experience adverse affects while driving the simulator.
- Establishing routine interlocks/safety switch checklist procedures for the facility.
- A "near miss" reporting procedure for VIRTTEX personnel.
- Setting up regular inspections by the Dearborn Fire Marshall.
- Coordinating regular site visits with Ford Research & Engineering Medical personnel to keep them apprised of facility modifications.
- A professionally produced VIRTTEX safety video used to consistently convey key information to all test-drive participants.
- Creation of a VIRTTEX Dome Evacuation Instruction Card used to clearly direct individuals on how to exit the dome via the emergency egress door.

PROCESS TIME LINE

In order to successfully human-rate the VIRTTEX facility, multiple entities had to work together over an extended period of time to design the safety sub-systems and create the policies and procedures documented in the official report the HRB signed off on for certification. Due to VIRTTEX's system and facility complexity, successful certification would not have been possible without the collaborative support and team work from a number of groups including external expertise and suppliers. If process foundational pre-work is included as part of the time line which occurred both prior to and in conjunction with the facility and system installation, approximately 9 months can be added to the time line presented below that high-lights human-rating process review milestones.

March 9th, 2001: The initial all-day design review forum took place. The next several weeks were spent refining the SAR, completing additional analyses, and preparing our results. This occurred in conjunction with efforts to complete the facility and system installation.

April 27th, 2001: The follow-up session to address critical-path issues raised at the design review occurred. The next few weeks were spent completing the final report for HRB sign off.

May 18th, 2001: Human-rating certification of the VIRTTEX facility was achieved when the board signed off on the official 92-page VIRTTEX Safety Assessment Report.

Final approval by the HRB signified that the simulator design, its safety systems, the facility interfaces, the laboratory operating protocols, and methods for maintaining the highest level of safety were adequate for human-in-the-loop testing and maintenance/service personnel that will work with and around the system.

SUMMARY

In establishing and documenting the process to human-rate the VIRTTEX facility, a new tool has now been created that can be used by other Ford facilities in an effort to attain the highest level of health and safety *prior to* operation. Additional process change was facilitated through this certification process in the cross-functional effort to develop and document safety policies and procedures for the VIRTTEX facility. Examples of some practices that have been put into place include the following:

For VIRTTEX Team members:

- A training certification requirement for VIRTTEX personnel.
- A daily facility checklist and standard operating procedures for test/experimental drives.

For Test-drive participants:

- Providing *informed consent* about the facility and experiment (when applicable) to all those who will drive/ride in the simulated environment.
- A professionally-produced safety video was made that consistently conveys the message that healthy & safety is of utmost importance. This video is shown to everyone who intends to drive/ride in the simulator, highlighting the safety features of the environment and proper interaction protocol.

For Maintenance/Service personnel:

- Diligence was taken in establishing several modes of communicating the state of the facility (protocols, signage, and highly visible work-log sheets) to all involved parties.

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ADDITIONAL ACRONYM DEFINITIONS

ANSI – American National Standards Institute
CPR – Cardio-Pulmonary Resuscitation
EMS – Emergency Medical Services
ISO – International Standards Organization
MIL-STD – Military Standard
NASA – National Aeronautics and Space Administration
OSHA – Occupational Safety and Health Act/Administration
UAW – United Auto Workers

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