

Automated Vehicle Simulator to Enhance Connected Vehicle Message Delivery

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Disclaimer Page

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| 16. Abstract <p>Connected Vehicles (CVs) facilitate new safety applications such as warnings for wrong way driving and blind spots, however it is still unclear what the best methods are for alerting drivers with this information. Autonomous Vehicles (AVs) will encounter issues similar to CVs in that different information may need to be provided to a passenger so that they are able to maintain situation awareness of the vehicles operation and trust in the underlying technology. The primary objective for this project was to investigate multimodal AV and CV displays for future vehicles to safely and quickly alert drivers of upcoming automation related vehicle warnings. This objective was accomplished through a multi-phased approach including simulation test bed development, test bed demonstration and evaluation with stakeholders, testbed modifications from evaluations, and development of an experimental plan. This document includes technical information regarding tasks associated with this effort and its main subtasks, ending with recommendations for human-in-the-loop experimentation to advance the science and implementation of automated vehicle messages.</p> | | | |
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Executive Summary

Connected Vehicles (CVs) facilitate new safety applications such as warnings for wrong way driving and blind spots, however it is still unclear what the best methods are for alerting drivers with this information. Automated vehicles (AVs) will encounter issues similar to CVs in that different information may need to be provided to a passenger so they are able to maintain situation awareness of the vehicles operation and trust in the safety of the underlying technology.

The primary objective for this project was to investigate multimodal AV and CV displays for future vehicles to safely and quickly alert drivers of upcoming automation related vehicle warnings. This objective was accomplished through a multi-phased approach including simulation test bed development, test bed demonstration and evaluation with stakeholders, testbed modifications from evaluations, and development of an experimental roadmap.

In order to empirically investigate upcoming AV and CV displays, a useful testbed for human-in-the-loop experiments is required. The University of Central Florida's (UCF) Institute for Simulation and Training (IST) created the Florida Department of Transportation Connected and Automated Vehicle Simulator (FDOT-CAVS) in support of this goal. Following an iterative development processes, researchers created mock-ups, prototypes, and finally experiment ready simulations. At each phase of the cycle, requirements, specifications, and performance was evaluated with stakeholders from the FDOT for verification and validation. In order to further refine this simulation to support human-in-the-loop experimentation, researchers exhibited it at the 2015 Florida Automated Vehicles Summit (FAVS), where experts and stakeholders were encouraged to experience the simulation devised by the team and to provide criticisms and suggestions for future modifications.

Overall, volunteers at the FAVS responded positively to the simulation platform and provided feedback used for further simulation improvement and identification of possible research issues. This feedback was then applied to modify simulation software and serve as a starting point in development of a research plan. This research plan includes a review of the literature to clearly identify the state-of-the-art in AV/CV research, gaps in the state-of-the-art, and how to move beyond the state-of-the-art in gap areas. This technical report summarizes the described efforts in more detail and includes the simulation development process, FAVS evaluation, research plan, and other technical documents.

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List of Abbreviations and Acronyms

| | |
|-----------|--|
| AV | Automated Vehicle |
| CV | Connected Vehicle |
| DSRC | Dedicated Short-Range Communications |
| FAVS | Florida Automated Vehicles Summit |
| FDOT-CAVS | Florida Department of Transportation – Connected and Automated Vehicle Simulator |
| IST | Institute for Simulation and Training |
| UCF | University of Central Florida |
| UMTRI | University of Michigan’s Transportation Research Institute |
| V2V | Vehicle-to-Vehicle |
| V2I | Vehicle-to-Infrastructure |

Chapter I - Introduction

Increased vehicle safety is a driving force in the development of automated vehicle (AV) and connected vehicle (CV) technologies. As U.S Transportation Secretary Anthony Fox stated in a public address at the beginning of 2014, "Vehicle-to-vehicle (V2V) technology represents the next generation of auto safety improvements, building on the life-saving achievements we've already seen with safety belts and air bags," (Naylor, 2014). Unlike safety belts and air bags that are designed to protect motor vehicle occupants in the event of an accident, CVs will be designed to avoid catastrophes all together by providing early warnings about impending danger. While not every possible situation can be avoided or foreseen while commuting in a motor vehicle, CVs have the potential to prevent many of the common accidents that do occur through improved driver situation awareness. Accidents that occur from situations such as vehicle following, lane changing or passing, turning through intersections while crossing oncoming traffic, or running red lights and stops signs will no longer jeopardize the safety of fellow motor vehicles on the road. Moreover, AV technologies are expected to take safety further than CV systems, with estimated annual savings of \$1.3 trillion according to Morgan Stanley reports on the economic benefits of driverless cars. Specifically, it is expected that there will be an estimated savings of \$507 billion due to a reduction of accident costs, (Morgan Stanley, 2015).

The National Highway Traffic Safety Administration released a report in 2014 on the readiness for V2V communication that thoroughly describes the need for CVs, the economic impact they will have, and most importantly, the amount of lives they will save (National Highway Traffic Safety Administration, 2014). Currently, the technology that is a focus for CV success is dedicated short-range communications (DSRC) because it offers the latency, accuracy, and reliability needed for vehicle-to-vehicle communication. At the University of Michigan's Transportation Research Institute (UMTRI), projects such as the Multipath SPAT Broadcast and IntelliDrive are dedicated to improving CV communication (Robinson & Dion, 2013), but more work is needed regarding the interaction component with the driver. Meaning, although the CVs will provide warnings for potential danger, less is known on how those warnings should be displayed, how often they should be initiated, and if they should change depending on the driving conditions (e.g. night driving, storms).

With V2V and V2I technologies increasing the volume of data available, it is critical that the method in which the vehicle delivers information does not overload drivers. An abundance of research has shown that increased volume and complexity of information results in adverse impacts on decision making performance (Iselin, 1998; Miller, 1956; Streufert S. C., Complexity and complex decision making: convergences between differentiation and integration approaches to the prediction of task performance, 1970; Streufert S. , 1973) and threaten the benefits of in-vehicle support systems (Carsten & Nilsson, 2001; ECMT, 1995; Rumar, 1990). Moreover, older drivers are a growing segment of the population, and it is well known that cognitive and physiological capabilities diminish with age (Rakotonirainy & Steinhardt, 2009). However, there

is a lack of fundamental research on how age may affect acceptance and understanding of CV messages.

It is therefore clear that efforts are needed regarding the interaction component between the CV and driver. Meaning, although the CVs will provide warnings for potential danger, less is known on how those warnings should be displayed, how often they should be initiated, if they should change depending on the driving conditions (e.g. night driving, storms), and how age impacts ability of drivers to perceive CV messages. The primary objective for this project was to investigate multimodal CV and AV displays for future vehicles to safely and quickly alert drivers of upcoming automation related vehicle warnings. This objective was accomplished through a multi-phased approach including simulation test bed development, test bed demonstration and evaluation with stakeholders, testbed modifications, and development of an experimental plan.

Chapter II - Simulation Development

In order to produce a useful testbed for human-in-the-loop experiments for future investigations, the University of Central Florida's (UCF) Institute for Simulation and Training created the Florida Department of Transportation Connected and Automated Vehicle Simulator (FDOT-CAVS). Simulation development followed an iterative design process, with several meetings held between project stakeholders (UCF and FDOT) to review plans and formalize requirements.

1. Requirements and Specifications

On May 26, 2015, a kickoff meeting was held over the phone between project stakeholders Ed Hutchinson, Tanner Martin, Daniel Barber, David Metcalf, John Lambert to review the overall project tasks and initial simulation design requirements. The initial prototype mockup of the simulator, Figure 1, was presented and highlighted key features and requirements for the simulation including:

- 1 Large immersive main display for high fidelity 3D visualization of drivers perspective
- 2 Steering wheel with ability for manual and computer driven operation (i.e. simulator able to move steering wheel when emulating autonomous driving mode)
- 3 Gas and brake pedals
- 4 Interactive center console
- 5 Standard Gaming PC
- 6 Surround sound speakers
- 7 Portable for data collection and demonstration at different locations
 - a. Must be able to disassemble within 2 hours and transport using equivalent of a mini-van or larger



Figure 1 : Initial prototype rendering of AV Simulator.

In addition to the hardware specifications presented, an initial scenario was discussed to demonstrate AV and CV capabilities of the simulation for review at a future meeting in advance of the Florida Automated Vehicles Summit (FAVS). At this meeting, project stakeholders reviewed proposed system capabilities and discussed additional modifications. Upon conclusion of the meeting, the hardware plan for the simulation was approved, and it was determined the initial scenario would be a 5-10 minute autonomous driving scene within a downtown/business district concluding with the vehicle entering a highway on ramp. Additional factors for this scene included the simulated car following rules of the road and dealing with normal traffic.

2. Simulator Prototype

1.1 Hardware

Following the kickoff meeting, the simulator was designed from a commercial arcade cabinet using a ruggedized desktop PC and 55” curved flat-panel display. The platform incorporated a force-feedback enabled steering wheel with weighted pedals, enabling both manual and computer controlled features. A second, touch-enabled monitor acted as the center console for the simulated vehicle. A full list of the hardware used for the simulation is described in Table 1.

Table 1 : Hardware purchased for FDOT-CAVS.

| | |
|---|---|
| Chicago Gaming Redline GT Gaming Cabinet: | A commercial arcade cabinet which serves as the base of the simulator. Includes steering-wheel and pedals |
| ViewSonic TD2220 Touch Monitor: | 22" touch monitor which serves as the center console screen |
| Samsung UN55JU6700 Curved 55-Inch 4K Ultra HD Smart LED TV: | 55" Curved Flat-screen TV used as the primary display for the simulator |
| Custom-Built PC: | A custom PC featuring an Intel I7 Quad-core 4GHz processor, an NVIDIA GTX970 graphics card with 4 gigabytes on-board memory, 16 gigabytes of DDR3 |

| | |
|---|--|
| | 1600 RAM, and a Samsung 850 EVO 500 GB SSD hard-drive |
| Microsoft Wireless All-In-One Media Keyboard: | Wireless media keyboard for experimental control and convenient stowage during experimentation |
| Various Cables: | 1 HDMI cable, 2 USB Male-to-female extension cables, 3 standard 3-conductor PC power cables |

The center console featured an interactive display including a functional web-browser and navigation interface. The main simulation and visuals were developed using the Unreal Game Engine and the center console using the C++ programming language. Figure 2 provides an overview of the assembled system.



Figure 2 : Version 1.0 of the FDOT-CAVS. This testbed is an advanced simulator used for measuring human experiences with connected vehicles. Top Left: A side view of the complete simulator system demonstrated on October 10, 2015. Right: The complete interactive dashboard console display showing the web-browser and navigation panes. Bottom-left: A view from the main screen of the simulator as the car approaches an intersection.

1.2 Simulation Scenario

The initial simulation scenario demonstrated an ability to emulate a driverless car navigating through a commercial downtown district. Within the scenario, the vehicle took a route through a downtown area, taking several left and right turns to moving towards a highway onramp, changed lanes, and finally entered the freeway. During execution, the vehicle obeyed traffic laws such as maintaining safe distances to traffic, stopping at red lights, and waiting for gaps in traffic when making left and right turns onto connecting roadways. Moreover, the physical steering wheel of

the simulation turned in conjunction with behaviors of the vehicle, indicating when it is turning left, right, or adjusting for slight turns. Finally, to showcase how a driverless car would handle an “off-normal” event, the simulation triggers an SUV backing up at the toll booth for the highway onramp, forcing the driverless car to respond accordingly by stopping before the SUV collided, Figure 3.



Figure 3 : SUV reversing at toll booth, forcing driverless car to react.

As shown in Figure 2, there is also an interactive center console display available for users to monitor state information of the vehicle. On this console is an interactive map visualizing the position of the vehicle, route it is following, and surrounding buildings and roads composed of imagery typical of a modern GPS navigation system. Finally, a fully functional web browser covers the top half the console to support studies where a user may interact with multimedia while in a driverless car.

1.3 Simulator Review

Upon completion of the prototype AV Simulation, on September 28, 2015 it was demonstrated to FDOT stakeholders to verify that it met requirements described in the proposal and discussed during the kickoff meeting, identify additional modifications, and finalize scenario events for the FAVS data collection event in December 2015. Attending this meeting was Ed Hutchinson, Tanner Martin, and David Sherman. Overall response to the simulation was positive, and the following key modifications were requested for incorporation prior to the FAVS for the next version of the simulation:

- 1 Develop two scenarios which include both city and highway driving
- 2 Two events for driverless vehicle to respond to:
 - a. Jaywalking pedestrian, walking into street from occluded field of view
 - b. Sudden stop on highway

- 3 Ability to manually drive vehicle at start of one scenario to engage/immerse participants in the scenario
- 4 Updated media/entertainment display for center console, with the ability to automatically play video or audio clips when the vehicle hits a specific point in a scenario
 - a. Specifically, trigger playback of video as vehicle enters highway onramp to distract participants prior to sudden stop on highway
 - b. FDOT was to provide video clip for scenario
- 5 Update virtual dashboard in car to display speed and other virtual sensor data
 - a. Indicate turn signals
 - b. Speedometer
 - c. Gear
 - d. Detection of traffic, pedestrians, obstacles

On October 20, 2015 the AV simulation was also demonstrated for Assistant Secretary Richard Biter with Ed Hutchinson. At this meeting Secretary Biter was shown the previously reviewed scenario to capture his response and feedback, Figure 4. Response to the simulator was positive, with no other additional feedback regarding modifications in addition to those identified at the September 28 meeting.



Figure 4 : FDOT site visit demonstration and review of AV simulator. Top Left: attendees from left to right, Andrew Best, Richard Biter, David Metcalf, John Lambert, Ed Hutchinson, Daniel Barber.

3. FAVS Simulation

Following simulator prototype review meetings, identified modifications were made to the testbed to prepare for evaluations at the FAVS. Only software modifications were made to the platform, with no additional hardware changes. The secondary touch display application was modified to house a more complete interactive console including simulated climate controls, a functional web-browser, updated navigation interface, and a media player. This display also provided “hooks” to communicate with 3D simulation to enable triggering of arbitrary video clips defined in XML script files. The Unreal Game Engine-based simulation was also updated to add a start screen to select a scenario, updated in-car dash, and support other events as identified during prior review meetings. Figure 5, provides an overview of the updated simulator system.



Figure 5 : Version 2.0 of the FDOT-CAVS. Top Left: A side view of the complete simulator system. Right: The complete interactive dashboard console display showing the routing and media player panes. Bottom-left: A view from the main screen of the simulator as the car approaches a parking garage. The dashboard iconography replicates (with permission) that of the Tesla Model S.

The simulation experience contained two distinct driving scenarios that demonstrated driverless vehicle research concepts. In each vignette, the user navigated a simulated city with other vehicles, pedestrians, and typical traffic patterns. During each run, the simulator presented users with combinations of driving hazards including jaywalking, sudden slowdowns, traffic jams, and vehicles running red lights (see Figure 6).



Figure 6 : Hazardous Road Conditions. Top Left: The driverless car stops as a pedestrian walks across the street. Top Right: The driverless car navigates heavy traffic in the busy downtown. Bottom Left: Traffic on the highway abruptly slows to a crawl as the police car activates its sirens. Bottom Right: The driverless car brakes abruptly as another car runs a red light.

In Scenario 1, the vehicle began stationary in a parking lot in connected vehicle mode (i.e. manual driving). A user would then drive the car around the parking lot to familiarize themselves with the driving profile of the car and the iconography of the virtual dashboard and center console. Once the user was ready, they exited the parking lot and the vehicle switched to autonomous mode. The car proceeded through a simulated downtown district where the autonomous vehicle had to avoid hazards such as vehicles running red-lights and pedestrians jaywalking across the busy city streets (see Figure 6). The car then turned onto the highway.

Once on the highway, the vehicle played a video on the in-dash media player (Figure 5) which distracted the user. During the video, the car made a sudden stop as traffic slowed for an emergency vehicle. Warning tones played as the brakes of the vehicle screeched the car to a safe speed. Once traffic cleared, the car exited the scenario. In the future, responses to surprises such as a sudden stop will measure situation awareness in the pilot of the vehicle.

The second scenario was a practical mirror of the first. The vehicle began on a long segment of highway and made several lane changes at high speed as it approached the downtown exit. During the maneuvers, a video played through the in-dash media player, and a sudden stop occurred as in Scenario 1. Once the vehicle exited the highway, it encountered similar hazards in the downtown area. As the vehicle exited downtown (towards the parking lot from Scenario 1), the scenario ended. Scenario two served to highlight the simulator's highway driving capabilities and messaging capability, as well as the ability to use the simulated city to test a number of routes, destinations, and hazards.

Once the design of the simulator and the scenarios were created, the researchers exhibited the simulator at the 2015 Florida Autonomous Vehicles Summit (FAVS) to get feedback. Researchers chose the FAVS as a feedback site because of the concentration of industry professionals and stakeholder personnel present. The simulator was demonstrated to transportation engineers, Florida Department of Transportation personnel, sensor technology manufacturers, university researchers, automotive industry representatives, and members of the general public.

Chapter III - Experts Community Data Collection

During the exhibition portion of the FAVS, researchers invited visitors to experience the two simulated scenarios outlined in the previous chapter. The total simulation time took roughly ten minutes per person, five minutes per scenario. During their drive, volunteers provided performance feedback and reactions to the various aspects of the simulation. Researchers encouraged participants to pay specific attention to the vehicle's handling and the interactive elements of the console and messaging. After their drive, several volunteers stayed at the booth to further discuss their impressions and opinions on the simulator. Researchers took note of comments and suggestions. The following sections provides an overview of these comments with the full list of comments in Appendix A.

1. Vehicle Performance Analysis

The response to the simulator was overwhelmingly positive. As revealed by some of the following comments from attendees.

“The graphics of this simulator are very impressive.”

“I am really eager to see how different demographic groups respond to this simulation.”

“The center console and navigation display feels like a real car. The experience feels authentic.”

Computationally, the simulator functioned as expected with virtually no stutters or lag in the simulation. In nearly all cases, the autonomous vehicle navigated in a consistent, plausible fashion and the volunteers believed that the traffic situation was typical and consistent with their own driving experience.

Some volunteers expressed concerns on the handling of the vehicle when in CV (manual) mode. These volunteers perceived that the CV did not handle ‘correctly’ at high speeds. They asked researchers to focus on a looser steering scheme which prevented over-steering when the vehicle was moving at speeds above 40 miles per hour. In low speeds, volunteers were satisfied with steering, but some suggested that a higher idle power might feel more appropriate. In the current simulated car, idling in drive will not move the car forward. A user must push the gas pedal for the vehicle to move; some volunteers perceived this feature to be overly conservative.

In addition, some volunteers expressed concern about the tightness of the steering when in AV mode at high speeds as well. In particular, users on the highway suggested they would feel more comfortable if the autonomous car relaxed its lane center adherence. The vehicle rigidly follows the centerlines of the highway, which causes it to make more corrections than a human when dealing with banked sections on the highway. This made some users uncomfortable. A few volunteers also noted that the autonomous vehicle is very conservative and courteous in its driving, occasionally to the frustration of its pilot. This complaint is common of autonomous vehicles but merits investigation as part of ongoing research (Richtel & Dougherty, 2015).

2. Vehicle Experience Analysis

Vehicle performance aside, researchers requested feedback on the experience of being driven by the autonomous car, interacting with the navigation system, and the connected vehicle warning tones / messaging. Again, feedback was very positive overall. Users felt that the interactive navigation system accurately represented real systems and enjoyed the web-browser and media portions of the console system. Users felt the simulator was visually impressive and the modelled scenarios were realistic in their scope.

Volunteers responded that the warning tones were appropriate in volume and timbre, but they were not always sure why the vehicle was warning them. A small number felt that the vehicle's decisions were not clear to them as it navigated and warned them of changing conditions. Users also appreciated the 'radar' screen showing nearby vehicles but some admitted they were not sure of the meaning of the color scheme.

Chapter IV - Simulation Modifications and Documentation

For the next phase of the project, the research team modified the simulator to support the feedback received and analyzed at the FAVS. The following section described in detail changes made to the simulation to improve the overall user experience and to support additional data collection requirements for human-in-the-loop experimentation.

1. Vehicle Performance Improvement

When in CV drive mode (manual), the vehicle idles forward without the user intervening. Researchers loosened the steering curve of the vehicle at speeds above 40 miles per hour to reduce oversteering. Researchers also constructed a connected-vehicle training course for familiarizing participants in human-in-the-loop experiments with the steering profile of the car at various speeds and iconography included within onboard and center panel displays.

2. Vehicle Experience Improvement

Researchers loosened the vehicle's AV autonomous lane following algorithms at high speeds as well to provide a more comfortable lane-switching and banked-turn experience on the highways of the simulated city. Additionally they investigated methods by which the vehicle can take greater advantage of opportunities presented by changes in traffic, such as clearance in adjacent lanes. Where possible, the autonomous navigation algorithm will behave more consistent with expectations of passing and red-light stopping behaviors.

Experts and volunteers expressed the most concern over the clarity of the vehicle's driving decisions and warnings. Researchers developed a CV training course to familiarize subjects participating in future human-in-the-loop experiment (or demonstrations) with the various alerts (e.g. tones, icons) they will encounter. The appropriate level of transparency, tones, and warning icons is a principle investigation of this project.

Chapter V - Experimental Roadmap

Discussions between FDOT and UCF personnel, meetings at outreach events, and a review of the literature were performed to identify AV scenarios and capabilities to evaluate a drivers understanding of status displays, emergency messages, and trust in AV technologies. Specific measures of interest for AV technologies included a performance such as a driver's ability to accurately interpret AV messages, reduction of collisions, and subjective measures as provided through workload, usability, and trust in automation. UCF then identified a roadmap consisting of three consecutive studies to drive creation of protocols, data analysis plans, and publications for human-in-the-loop studies leveraging the CAV Simulation described in Chapters II and III.

1. Review of the Literature

Overall, the literature revealed a number of connected vehicle studies incorporating a variety of different messages, with in-vehicle alerts ranging from email and text to intersection violation warnings (e.g. vehicle running stop sign). The National Highway Traffic Safety Administration (NHTSA) has identified several new messages CVs could make available including Intersection Movement Assist, Left Turn Assist, Emergency Electronic Brake Light, Forward Collision Warning, Blind Spot Warning/Lane Change Warning, and Do-Not-Pass Warning (U.S. Department of Transportation, 2014). Of all identified messages, Forward Collision Warnings (FCW) were the most commonly studied. Within this topic area, researchers studied effects on driver behavior, a driver's engagement in a secondary task, and older and younger drivers' responses to FCW systems.

Koustanai (2012) believed that drivers could more effectively use and develop trust in a FCW system with proper training and exposure. To test these hypotheses, their team executed a simulation-based study consisting of 28 participants some of which received hands on training with the FCW systems, some participants only read the FCW manual, and the remaining participants had no familiarity with the system. The results showed that drivers with hands on training demonstrated more effective interactions, had no collisions, better reactions in most situations, and increased trust (Koustanai, Delhomme, & Mas, 2012).

Muhrer et al. (2012) conducted a laboratory study regarding driving and gaze behavior while using a FCW and FCW+ (FCW with autonomous braking) system while performing a secondary task. A total of 30 participants ranging in age from 30-40 years old received training on how to use the FCW+ system. The Surrogate Reference Task (SuRT), (Mattes, 2003), acted as the secondary task, and was used to examine visual attention allocation; however, drivers were told to only perform the secondary task when they felt safe to do so. In this experiment, a substantial number of accidents occurred in critical

situations without FCW+, but no accidents occurred in critical situations during the use of FCW+. Researchers also discovered that driving with the FCW system did not lead to more engagement in the secondary task. Therefore, a FCW or a FCW+ system could help reduce countless vehicle accidents and not cause driver distractions.

A study conducted by Cotte et al. (2001) was one of the few studies that researched the impact of AV technologies on elderly drivers. Researchers had 62 participants ranging in age from 30-40 and 65 to 81 years old. Using a driving simulator, participants were instructed to drive 50 MPH with a focus on avoiding collisions. Participants were told that the warning system was not always accurate, and auditory warnings were delivered if they drove too fast, too slow, or were at risk of a forward collision. If drivers drove too fast or too slow a female's voice reminded them to drive at least 50 MPH. If drivers drove over 57 MPH a police siren went off. The collision warning was a male voice that said, "Brake, brake, brake, brake." The results of the study determined that overall there were no differences between age groups. Researchers did however notice a significant effect when comparing drivers who did and did not receive the warnings. Drivers that received the warning drove much slower than drivers who did not receive a warning.

In general, a common theme across all studies reviewed was to test different modalities for message delivery. Three modalities are available to alert drivers of safety issues – auditory, visual, and tactile. However, there is no specific research that shows whether one modality (or combination thereof) is more effective in preventing an accident, nor is the implementation format within a modality consistent within studies. This is clearly shown in previously described study of Cotte et al. (2001) which employed voiced auditory messages (e.g. "slow down") and cues (e.g. police siren). Furthermore, trust is a common concern reported by both researchers and drivers. For example, researchers have tried increasing the level of trust in AV technologies by either giving drivers prior training with the technology (Koustanai, Delhomme, & Mas, 2012) or allowing drivers to use technology that shares in their driving goals. An example study testing shared driving goals was Verberne et al. (2012), where different Adaptive Cruise Control (ACC) either matched the drivers goals (i.e. energy efficiency, comfort, speed, and safety) or did not, and how that description affected trust. Overall, researchers have conducted numerous studies over the last ten to fifteen years to answer many questions regarding AV technologies; however, with a large focus in recent years on ACC and FCW, there is still a significant amount of research yet to be done to support more recently identified AV messages.

With AV research focused primarily on FCW, a significant lack of research on connected vehicles involving older adults was revealed. The majority of the studies conducted with AVs had a maximum participant age range of approximately fifty years old. There is not enough research done to determine how older drivers would perceive or react to a AV messages. Therefore, in addition to growing research on different types of

messages, much of the research conducted with AV technology should be expanded to elderly drivers. This factor is particularly needed since research shows that AV research with collision warnings are more likely to benefit older drivers because it helps them compensate for age-related sensory and cognitive changes (Cotte, Meyer, & Coughlin, 2001).

Beyond age related research, an area that requires significant focus is modality. Many researchers conducted studies primarily with audio messages (either spoken messages or cues and sounds); however, audio messages may be ineffective if there is a lot of noise in the vehicle or if the driver is driving with their windows down (Singer, Lerner, Walrath, & Gill, 2015). Continued research is needed to determine which of the three modalities would be best suited to alert drivers of a variety of safety messages. For example, do drivers respond better to an audio message versus a tactile message, or both? Perhaps, depending on the urgency of the safety messages, drivers should receive all three modality alerts.

In addition to researching effects of older drivers and modalities, with research focused primarily on FCW, lateral drift, and lane change/merge crash warnings, it can be said that there are a number of safety messages lacking basic research warnings (Sayer, et al., 2011; Fitch, Bowman, & Llaneras, 2014). Research to date has not focused on alerts for impending/future events including emergency vehicles, wrong way driving, intersection movement assist, and intersection violation warning, especially across different age groups. Moreover, with inclusion of more AV warnings and messages we must be cognizant of overloading drivers. An abundance of research has shown that increased volume and complexity of information results in adverse impacts on decision making performance (Iselin, 1998; Miller, 1956; Streufert S. , 1970; Streufert S. C., Effects of information relevance on decision making in complex environments, 1973) and threaten the benefits of in-vehicle support systems (Carsten & Nilsson, 2001; ECMT, 1995; Rumar, 1990). Table 2 below lists AV messages most likely to benefit from additional research as described, with each safety warning having the potential to significantly impact the number of vehicle accidents and fatalities that occur every year.

Table 2. Table of key AV messages for future research.

| MESSAGE | DESCRIPTION |
|--------------------------------|--|
| Curve Speed Warning | Alerts driver to slow down for upcoming turn or changes in road |
| Intersection Movement Assist | Alerts driver that it is unsafe to enter the intersection due to conflicting traffic |
| Intersection Violation Warning | Alerts driver they are about to commit a violation at an intersection |

| | |
|-------------------------------|---|
| Pedestrian/Bicyclist Presence | Alerts driver to a pedestrian or bicyclist presence |
| Wrong-way Driving | Alert driver that someone is driving the wrong-way down a road/coming right at them |

2. Future Research

As technology has become more sophisticated, the car industry is becoming increasingly interested in developing connected and autonomous vehicles. Compared to traditional driving, use of AV technology will involve human factors issues, such as losing situation awareness, being overloaded or distracted by AV safety messages, and trust issues to the system. Based on the information gathered in the literature review, most previous work only focused on basic messages in traditional modalities. Also, age effects of interacting with AV technology was not considered. Therefore, future work should be done in an effort to close those research gaps. To help fill gaps identified, the following series of studies are recommended.

Study 1

This study will investigate individual differences (e.g. age, gender) in the impact of AV technology on driver performance compared to a baseline (no AV messages). Participants in at age groups, (i.e. young drivers, adult drivers, and senior drivers), will be recruited to understand the effects of age when interacting with and without AV technology. Specifically, we will apply at least two types of AV safety messages, such as intersection violation warning and emergency vehicle alert. This study will test how much those AV technology could facilitate driver in different ages in terms of improving driving performance, enhancing traffic efficiency, and preventing accidents.

Study 2

This study will focus on the modalities of how the connected vehicle’s safety messages are delivered. Traditionally, on board messages are delivered either visually or with audio technology. This study will test other modalities, such as tactile messages, to determine if other modalities are more beneficial and effective over traditional ones. This study will also compare different age groups similar to Study 1, while attempting to improve upon/augment AV safety messages previously investigated.

Study 3

This study will test the impact of additional AV safety messages on driving performance. Additional types of AV safety messages may include collision warnings, lane departure, and traffic conditions in combination with AV messages investigated in Study 1 and 2. Since too much information or inappropriate messages may distract or overload the drivers, inappropriate safety messages may be detrimental to driving performance. Experimentation is needed to understand the influence of multiple AV safety messages in different scenarios, such as highway driving and local driving. Study 3 will test a variety of AV safety message in highway and local driving scenarios using at least a college study population.

Chapter VI - Conclusion

In summary, while AV research has advanced significantly over the last ten years, there are still a lot of unanswered questions and gaps in the research. As shown through the presented review of the literature, the dominant research areas for automated messages revolve around forward collision and lane assist which are all onboard a single vehicle. With an evolving infrastructure and new communication technologies enabling advanced V2V and V2I capabilities, academia, industry, and government organizations must work to further new AV message types to realize safety potentials. Without proper understanding of how to implement new AV messages, like intersection violation warning, there will be a missed opportunity to save lives while informing developers of driverless systems. Moreover, additional efforts are needed to evaluate best practices for delivery of this information. During the last 15 years, a rapid expansion in the use of robotics for military applications resulted in vendors creating different interfaces for control of each platform. This led to different training requirements for use of each robot, single-use instrumentation and control devices, and increased costs. Addressing this and other interoperability challenges lead to the creation of new standards to ease access, training, and integration of aerial and ground vehicles such as the Joint Architecture for Unmanned Systems (JAUS), (Wikipedia, 2015; Barber, Davis, Nicholson, Chen, & Finkelstein, 2008). In order to prevent similarly disparate methods of AV signaling across manufacturers and vehicle types, research is needed to identify best practices and guidelines that meet safety requirements for all drivers across different generations. With the development of the FDOT-CAV presented here, our intention is to close a portion of that research gap by conducting studies on key questions that have not been addressed such as the affect AV technology has on older drivers, the importance of communicating safety messages to drivers, and the best modality/modalities to be used for that purpose. Through a systematic and empirical evaluation, the best practices for future vehicles can be identified, with the intent of improving safety for all drivers.

References

- Barber, D., Davis, L., Nicholson, D., Chen, J. Y., & Finkelstein, N. (2008). The Mixed-Initiative Experimental Testbed for Collaborative Human Robot Interactions. *26th Army Science Conference*, (pp. 483-489). Orlando, FL USA.
- Carsten, O., & Nilsson, L. (2001). Safety assessment of driver assistance systems. *European Journal of Transportation and Infrastructure Research*, *1*, 225-224.
- Cotte, N., Meyer, J., & Coughlin, J. F. (2001). Older and Younger Drivers' Reliance on Collision Warning Systems. *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting* (pp. 277-280). Minneapolis: HFES.
- ECMT. (1995). Statement of principles of good practice concerning the ergonomics and safety of in-vehicle information systems. *In New Information technologies in the Road Transport Sector: Policy Issues, Ergonomics and Safety* (pp. 35-42). The European Conference of Ministers of Transport.
- Fitch, G. M., Bowman, D. S., & Llaneras, E. (2014). Using Wizard of Oz Technique to Evaluate Connected Vehicles: Distracted Driver Performance to Multiple Alerts in a Multiple-Conflict Scenario. *Proceedings of the Transportation Research Board 93rd*. Washington DC: Transportation Research Board.
- Iselin, E. R. (1998). The effects of information load and information diversity on decision quality in structured decision task. *Accounting Organizations and Society*, *13*(2), 147-164.
- Koustanai, A., Delhomme, P., & Mas, A. (2012, October). Simulator Training with a Forward Collision Warning System: Effects on Driver-System Interactions and Driver Trust. *Human Factors*, *54*(5), 709-721.
- Mattes, S. (2003). The lane change task as a tool for driver distraction. *Quality of Work and Products in Enterprises of the Future*, 57-60.
- Miller, G. A. (1956). The magic number of seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, *63*, 81-97.
- Morgon Stanley. (2015, January 23). *Autonomous Cars: The Future Is Now*. Retrieved February 24, 2016, from Morgon Stanley: <http://www.morganstanley.com/articles/autonomous-cars-the-future-is-now>
- Muhrer, E., Reinprecht, K., & Vollrath, M. (2012, October). Driving with a Partially Autonomous Forward Collision Warning System: How do Drivers React? *Human Factors*, *54*(5), 698-708.
- National Highway Traffic Safety Administration. (2014). *Preliminary Statement of Policy Concerning Automated Vehicles*. Washington, D.C., USA: United States Department of Transportation.
- Naylor, N. (2014, February 3). *National Highway Traffic Safety Administration*. Retrieved 01 06, 2016, from U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles: <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles>

- Rakotonirainy, A., & Steinhardt, D. (2009). In-vehicle Technology Functional Requirements for Older Drivers. *Proceedings of the First International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. Essen, Germany: ACM.
- Richtel, M., & Dougherty, C. (2015, September 1). *Google's Driverless Cars Run Into Problem: Cars With Drivers*. Retrieved from New York Times: http://www.nytimes.com/2015/09/02/technology/personaltech/google-says-its-not-the-driverless-cars-fault-its-other-drivers.html?partner=rss&emc=rss&_r=1
- Robinson, R., & Dion, F. (2013). *Multipath SPAT Broadcast Project*. Lansing, MI, USA: Michigan Department of Transportation.
- Rumar, K. (1990). The basic driver error: late detection. *Ergonomics*, 1281-1290.
- Sayer, J., LeBlanc, D., Bogard, S., Funkhouser, S., Bao, D., Buonarosa, M. L., & Blankespoor, A. (2011). *Integrated Vehicle-Based Safety Systems Field Operational Test Final Program Report*. Washington D.C.: U.S. Department of Transportation National Highway Traffic Safety Administration.
- Singer, J., Lerner, N., Walrath, J., & Gill, M. (2015). *Warning and Message Perception under Ambient Noise Conditions: On-Road Experiment Report under Crash Warning Interface Metrics 3 Program*. Washington, DC: US Department of Transportation.
- Streufert, S. (1970). Complexity and complex decision making: convergences between differentiation and integration approaches to the prediction of task performance. *Journal of Experimental Social Psychology*, 6(4), 494-509.
- Streufert, S. (1973). Effects of information relevance on decision making in complex environments. *Memory & Cognition*, 1(3), 224-228.
- Streufert, S. C. (1970). Complexity and complex decision making: convergences between differentiation and integration approaches to the prediction of task performance. *Journal of Experimental Social Psychology*, 6(4), 494-509.
- Streufert, S. C. (1973). Effects of information relevance on decision making in complex environments. *Memory & Cognition*, 1(3), 224-228.
- U.S. Department of Transportation. (2014, 10 14). *V2V Communications Fact Sheet*. Retrieved from Vehicle-to-Vehicle Communications: http://www.safercar.gov/staticfiles/safercar/v2v/V2V_Fact_Sheet_101414_v2a.pdf
- Verberne, F. M., Ham, J., & Midden, C. J. (2012, October). Trust in Smart Systems: Sharing Driving Goals and Giving Information to Increase Trustworthiness and Acceptability of Smart Systems in Cars. *Human Factors*, 54(5), 799-810.
- Wikipedia. (2015, 01 06). *JAUS*. Retrieved from Wikipedia: <https://en.wikipedia.org/wiki/JAUS>

Appendices

Appendix A Summary of FAVS Comments

Table 3 : Summary of visitor and guest comments on the simulator demonstrated at the FAVS.

| Comment | Context |
|---|--|
| I would have run that yellow light. The car stops too conservatively at lights. | In regards to the driverless car's strict rule to stop for yellow lights, even in cases where the car may have safely crossed the light. |
| The vehicle is very hard to control at this speed. | In regards to the simulated car's tight steering at high velocities. |
| The vehicle appears to be having trouble staying in the middle of its lane. | In regards to the driverless car's tendency to correct frequently on the highway |
| The graphics of this simulator are very impressive | A user remarking on the visual quality of the downtown area of the simulated city. |
| So, I can play with my phone while the car drives itself? that is really neat. | Comments on the advantages of such an autonomous vehicle |
| I'm not sure I trust this car to make good decisions | A user commenting on transparency of the driverless car on the highway |
| I am really eager to see how different demographic groups respond to this simulation | In regards to the potential of this form of human-in-the-loop testing |
| I would be interested to see how this simulator integrates with existing sensors and automation technology. | In regards to the potential of integrating real sensor data into the simulated vehicle. |
| My kids would love this! | In regards to the general excitement value of piloting the connected car. (This was the most common comment). |
| The console display feels very realistic. | A user remarking on the level of detail of the center console. |
| The vehicle drives like a truck in some respects. Even though I am in drive, I must hit the gas to go. | In regards to the driverless car's low idle power. |
| I am unsure why the car is beeping at me. | In regards to the vehicle's warning tones |
| The center console and navigation display feels like a real car. The experience feels authentic. | |
| The traffic patterns feel believable in the simulator. | |

Appendix B Task 1 Report

Task 1: Summary of AV Simulation Development

Institute for Simulation and Training, University of Central Florida

1. Background

Increased vehicle safety is a driving force in the development of Automated Vehicles (AV) and Connected Vehicles (CV) technologies. As U.S Transportation Secretary Anthony Fox stated in a public address at the beginning of 2014, "Vehicle-to-vehicle technology represents the next generation of auto safety improvements, building on the life-saving achievements we've already seen with safety belts and air bags," (Naylor, 2014). Unlike safety belts and air bags that are designed to protect motor vehicle occupants in the event of an accident, CVs will be designed to avoid catastrophes all together by providing warnings about impending danger. While not every possible situation can be avoided or foreseen while commuting in a motor vehicle, CVs have the potential to prevent many of the common accidents that do occur with improved driver situation awareness. Accidents that occur from situations such as vehicle following, lane changing or passing, turning through intersections while crossing oncoming traffic, or running red lights and stops signs will no longer jeopardize the safety of fellow motor vehicles on the road. Moreover, AV technologies are expected to take safety in further than CV systems, with estimated annual savings of \$1.3 trillion according to Morgan Stanley reports on the economic benefits of driverless cars. Specifically, it is expected that there will be an estimated saving of \$507 billion due to a reduction of accident costs.

The National Highway Traffic Safety Administration released a report in 2014 on the readiness for vehicle-to vehicle communication that thoroughly describes the need for CVs, the economic impact they will have, and most importantly, the amount of lives they will save (National Highway Traffic Safety Administration, 2014). Currently, the technology that is a focus for CV success is dedicated short-range communications (DSRC) because it offers the latency, accuracy, and reliability needed for vehicle-to-vehicle communication. At the University of Michigan's Transportation Research Institute (UMTRI), projects such as the Multipath SPAT Broadcast and IntelliDrive are dedicated to improving CV communication (Robinson & Dion, 2013), but more work is needed regarding the interaction component with the driver. Meaning, although the CVs will provide warnings for potential danger, less is known on how those warnings should be displayed, how often should they be initiated, and if they should change depending on the driving conditions (e.g. night driving, storms).

3. Project Objective(s)

Connected Vehicles (CVs) facilitate new safety applications such as warnings for wrong way driving and blind spots, however it is still unclear what the best methods are for alerting drivers with this information. Automated vehicles (AVs) will encounter issues similar to CVs in that different information may need to be provided to a passenger so that they are able to maintain situation awareness of the vehicles operation and trust in the underlying technology. The primary objective for this project is to investigate multimodal AV and CV displays for future vehicles to

safely and quickly alert drivers of upcoming automation related vehicle warnings. This objective will be accomplished through a multi-phased approach including simulation test bed development followed by data collection with human participants performed throughout the state of Florida and at UCF. Findings from this effort will result in requirements and recommendations for how to implement connected vehicle displays for ease of use and increased safety.

2. AV Simulation Development

The purpose for this task was to develop a test platform focused on automated vehicle technologies that is able to simulate a vehicle with AV and CV capabilities within scenarios relevant to the Florida Department of Transportation (FDOT) (e.g. self-driving to user selected destination). The final deliverable for this task was a demonstration of a simulation to FDOT stakeholders to gather additional feedback prior to the expert data collection and demonstration at the Florida Automated Vehicle Summit (FAVS).

4. Project Kickoff

On May 26, 2015, a kickoff meeting was held over the phone between project stakeholders Ed Hutchinson, Tanner Martin, Daniel Barber, David Metcalf, John Lambert to review the overall project tasks and initial simulation design plans. The initial version of the simulator, Figure 1, was presented and highlighted key features and requirements for the simulation including:

- Large immersive main display for high fidelity 3D visualization of drivers perspective
- Steering wheel with ability for manual and computer driven operation (i.e. simulator able to move steering wheel when emulating autonomous mode)
- Gas and brake pedals
- Interactive center console
- PC
- Surround sound speakers
- Portable for data collection and demonstration at different locations
 - Must be able to disassemble within 2 hours and transport using equivalent of a mini-van or larger



Figure 7: Initial mockup of AV Simulator.

In addition to the hardware specifications presented, an initial scenario was discussed to demonstrate AV/CV capabilities of the simulation for review at a future meeting in advance of the Florida Automated Vehicles Summit (FAVS). At this meeting, project stakeholders would review systems capabilities and discuss additional modifications. Upon conclusion of the meeting, the hardware plan for the simulation was approved, and it was determined the initial scenario would be a 5-10 minute autonomous driving scene within a downtown/business district concluding with the vehicle entering a highway. Additional factors for this scene would include following rules of the road and dealing with normal traffic.

5. Driverless and Connected Vehicle Simulator (DCVS)

Following the kickoff meeting, the final simulator as designed from a commercial arcade cabinet using a ruggedized desktop PC and 55” curved flat-panel display. The user drives using a force-feedback enabled steering wheel and weighted pedals, enabling both manual and computer controlled features required. A second, touch-enabled monitor provides the center console of the vehicle. The center console features a completed interactive console display included a functional web-browser and navigation interface. The main simulation and visuals were developed using the Unreal Game Engine and the center console using the C++ programming language. Figure 2 provides an overview of the simulator system.



Figure 8: The FDOT DCVS is an advanced simulator used for measuring human experiences with connected vehicles. Top Left: A side view of the complete simulator system demonstrated on October 10, 2015. Right: The complete interactive dashboard console display showing the web-browser and navigation panes. Bottom-left: A view from the main screen of the simulator as the car approaches an intersection.

The simulation scenario demonstrates the ability to emulate a driverless car navigating through a commercial downtown district. Within the scenario, the vehicle takes a route through a downtown area, taking several left and right turns to move towards a highway onramp, changes lanes, and finally enters the freeway. During execution, the vehicle obeys traffic laws such as maintaining safe distances to traffic, stopping at red lights, and waiting for gaps in traffic when making left and right turns onto connecting roadways. Moreover, the physical steering wheel of the simulation turns in conjunction with behaviors of the vehicle, indicating when it is turning left, right, or adjusting for slight turns. Finally, to showcase how a driverless car would handle an “off-normal” event, the simulation triggers an SUV backing up at the toll booth for the highway onramp, forcing the driverless car to respond accordingly by stopping before the SUV collided, Figure 3.



Figure 9: SUV reversing at toll booth, forcing driverless car to react.

As shown in Figure 2, there is also an interactive center console display available for users to monitor state information of the vehicle. On this console is an interactive map visualizing the position of the vehicle, route it is following, and surrounding buildings and roads composed of imagery typical of a modern GPS navigation system. Finally, a fully functional web browser covers the top half the console to support studies where a user may interact with multimedia while in a driverless car.

3. AV Simulation Review Meetings

Upon completion of the prototype AV Simulation, on September 28, 2015 it was demonstrated to FDOT stakeholders to verify that it met requirements described in the proposal and discussed during the kickoff meeting, identify additional modifications, and finalize scenario events for the FAVS data collection event in December 2015. Attending this meeting was Ed Hutchinson, Tanner Martin, and David Sherman. Overall response to the simulation was positive, and the following key modifications were requested for incorporation prior to the FAVS:

- Develop two scenarios which include both city and highway driving
- Two events for driverless vehicle to respond to
 - Jaywalking pedestrian, walking into street from occluded field of view
 - Sudden stop on highway
- Ability to manually drive vehicle at start of one scenario to engage/immerse participants in the scenario
- Updated media/entertainment display for center console, with the ability to automatically play video or audio clips when the vehicle hits a specific point in the scene
 - Specifically, trigger playback of video as vehicle enters highway onramp to distract participants prior to sudden stop on highway
 - Video clip to be provided by FDOT
- Update virtual dashboard in car to display speed and other virtual sensor data
 - Indicate turn signals

- Speedometer
- Gear
- Detection of traffic, pedestrians, obstacles

On October 20, 2015 the AV simulation was also demonstrated for Assistant Secretary Richard Biter with Ed Hutchinson. At this meeting Secretary Biter was shown the previously reviewed scenario to capture his response and feedback, Figure 4. Response to the simulator was positive, with no other additional feedback regarding modifications in addition to those identified at the September 28 meeting.



Figure 10: FDOT site visit demonstration and review of AV simulator. Top Left: attendees from left to right, Andrew Best, Richard Biter, David Metcalf, John Lambert, Ed Hutchinson, Daniel Barber.

4. Conclusion

In conclusion, an initial version of a Driverless and Connected Vehicle Simulator (DCVS) was developed based on initial proposed plans and discussions with FDOT stakeholders. This simulation was then reviewed on two separate occasions and determined the project was on track, and additional modifications and scenarios to system in support of community feedback data collection were identified. These features, documented here will be incorporated into the DCVS and demonstrated the FAVS in December 2015.

5. References

- National Highway Traffic Safety Administration. (2014). *Preliminary Statement of Policy Concerning Automated Vehicles*. Washington, D.C., USA: United States Department of Transportation.
- Naylor, N. (2014, February 3). *National Highway Traffic Safety Administration*. Retrieved 01 06, 2016, from U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles: <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles>
- Robinson, R., & Dion, F. (2013). *Multipath SPAT Broadcast Project*. Lansing, MI, USA: Michigan Department of Transportation.

6. Appendix 1: Simulator Hardware

Below is a List of the hardware used in the FDOT-DCVS

| | |
|---|---|
| Chicago Gaming Redline GT Gaming Cabinet: | A commercial arcade cabinet which serves as the base of the simulator. Includes steering-wheel and pedals |
| ViewSonic TD2220 Touch Monitor: | 22" touch monitor which serves as the center console screen |
| Samsung UN55JU6700 Curved 55-Inch 4K Ultra HD Smart LED TV: | 55" Curved Flat-screen TV used as the primary display for the simulator |
| Custom-Built PC: | A custom PC featuring an Intel I7 Quad-core 4GHz processor, an NVIDIA GTX970 graphics card with 4 gigabytes on-board memory, 16 gigabytes of DDR3 1600 RAM, and a Samsung 850 EVO 500 GB SSD hard-drive |
| Microsoft Wireless All-In-One Media Keyboard: | Wireless media keyboard for experimental control and convenient stowage during experimentation |
| Various Cables: | 1 HDMI cable, 2 USB Male-to-female extension cables, 3 standard 3-conductor PC power cables |

Appendix C Task 2 Report

Task 2: Summary of Florida Autonomous Vehicle Demonstration

Institute for Simulation and Training, University of Central Florida

1. Background

1. Motivation

Increased vehicle safety is a driving force for in vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) to facilitate creation of advanced connected vehicles (CV). As U.S Transportation Secretary Anthony Fox stated in a public address at the beginning of 2014, "Vehicle-to-vehicle technology represents the next generation of auto safety improvements, building on the life-saving achievements we've already seen with safety belts and air bags," (Naylor, 2014). Unlike safety belts and air bags that are designed to protect motor vehicle occupants in the event of an accident, CVs will be designed to avoid catastrophes all together by providing new warnings to drivers. While not every possible situation can be avoided or foreseen while commuting in a motor vehicle, CVs have the potential to prevent many common accidents that occur through improved driver situation awareness (SA), enabling them to avoid accidents from situations such as vehicle following, lane changing or passing, turning through intersections while crossing oncoming traffic, or running red lights and stops.

The National Highway Traffic Safety Administration (NHTSA) released a report in 2014 on the readiness for vehicle-to vehicle communication that thoroughly describes the need for CVs, the economic impact they will have, and most importantly, the amount of lives they will save (National Highway Traffic Safety Administration, 2014). Currently, the technology that is a focus for CV success is dedicated short-range communications (DSRC) because it offers low latency, accuracy, and reliability needed for V2V communication. At the University of Michigan's Transportation Research Institute (UMTRI), projects such as the Multipath SPAT Broadcast and IntelliDrive are dedicated to improving CV communication (Robinson & Dion, 2013). Combined with radar, cameras, and other sensors, V2V technologies allow cars to "see" around corners and "through" traffic resulting in an abundance of data previously unavailable to increase driver SA (U.S. Department of Transportation, 2014).

With V2V and V2I technologies increasing the volume of data available, it is critical that the method in which the vehicle delivers information does not overload drivers. An abundance of research has shown that increased volume and complexity of information results in adverse impacts on decision making performance (Iselin, 1998; Miller, 1956; Streufert S. , 1970; Streufert S. C., 1973) and threaten the benefits of in-vehicle support systems (Carsten & Nilsson, 2001; ECMT, 1995; Rumar, 1990). Moreover, older drivers are a growing segment of the population, and it is well known that cognitive and physiological capabilities diminish with age (Rakotonirainy & Steinhardt, 2009). However, there is a lack of fundamental research on how age may affect acceptance and understanding of CV messages. It is therefore clear that efforts are needed

regarding the interaction component between the CV and driver. Meaning, although the CVs will provide warnings for potential danger, less is known on how those warnings should be displayed, how often should they be initiated, if they should change depending on the driving conditions (e.g. night driving, storms), and how age impacts ability of drivers to perceive CV messages.

2. Data Collection at FAVS

In order to produce a useful testbed for human-in-the-loop experiments, the University of Central Florida's Institute for Simulation and Training created the Florida Department of Transportation Connected and Driverless Vehicle Simulator (FDOT-DCVS) (details in Section 2.1). Before beginning human-in-the-loop experimentation, researchers exhibited the simulator at the 2015 Florida Autonomous Vehicles Summit (FAVS). Experts and stakeholders were encouraged to experience the simulations devised by researchers at UCF and to provide criticisms and suggestions (discussed in Sections 3.1 and 3.2).

Researchers chose the FAVS as a feedback site because of the concentration of industry professionals and stakeholder personnel present. The simulator was demonstrated to transportation engineers, Florida Department of Transportation personnel, sensor technology manufacturers, university researchers, automotive industry representatives, and members of the general public. The feedback generated by the various attendees will provide the backbone of the modifications needed for the next stage of research for the project.

2. Data Collection Methods

This section describes the simulator itself, the setup at the FAVS, and the method by which commentary and performance were given.

3. Connected and Driverless Vehicle Simulator

The simulator is designed from a commercial arcade cabinet using a ruggedized desktop PC and 55" curved flat-panel display. The user drives using a force-feedback enabled steering wheel and weighted pedals. A second, touch-enabled monitor provides the center console of the vehicle. The center console features a complete interactive console display including simulated climate controls, a functional web-browser, a navigation interface, and a media player. Figure 1 provides an overview of the simulator system.

The simulation experience contains two distinct driving scenarios to demonstrate driverless vehicle research concepts. In each case, the user navigates a simulated city with other vehicles, pedestrians, and typical traffic patterns. In each case, the simulator presents users combinations of driving hazards including jaywalking, sudden slowdowns, traffic jams, and vehicles running red lights (see Figure 2).

In Scenario 1, the vehicle begins parked in a parking lot in connected vehicle mode (i.e. manual driving). The user drives the car around the parking lot to familiarize themselves with the driving profile of the car and the iconography of the virtual dashboard and center console. Once the user is ready, they exit the parking lot and the vehicle switches to autonomous mode. The car proceeds through a simulated downtown where the autonomous vehicle must avoid hazards such as vehicles

running red-lights and pedestrians jaywalking across the busy city streets (see Figure 2). The car then turns onto the highway.



Figure 11: The FDOT DCVS is an advanced simulator used for measuring human experiences with connected vehicles. Top Left: A side view of the complete simulator system. Right: The complete interactive dashboard console display showing the routing and media player panes. Bottom-left: A view from the main screen of the simulator as the car approaches a parking garage. The dashboard iconography replicates (with permission) that of the Tesla Model S.

Once on the highway, the vehicle plays a video on the in-dash media player (Figure 1) which distracts the user. During the video, the car must make a sudden stop as traffic slows for an emergency vehicle. Warning tones play as the brakes of the vehicle screech the car to a safe speed. Once traffic clears, the car exits the scenario. In the future, responses to surprises such as a sudden stop will measure situation awareness in the pilot of the vehicle.

The second scenario is a practical mirror of the first. The vehicle begins on a long segment of highway and makes several lane changes at high speed as it approaches the downtown exit. During the maneuvers, a video plays through the in-dash media player, and a sudden stop occurs as in Scenario 1. Once the vehicle exits the highway, it encounters similar hazards in the downtown area. As the vehicle exits downtown (towards the parking lot from Scenario 1), the scenario ends. Scenario two serves to highlight the simulators highway driving capabilities and messaging capability, as well as the ability to use the simulated city to test a number of routes, destinations, and hazards.

4. FAVS Feedback Collection

During the exhibition portion of the FAVS, researchers invited visitors to experience the two simulated scenarios outlined above. The total simulation time took roughly ten minutes per person, roughly five minutes per scenario. During their drive, volunteers provided performance feedback and reactions to the various simulation aspects. Researchers encouraged participants to pay specific attention to the vehicle's handling and the interactive elements of the console and messaging. After their drive, several volunteers stayed at the booth to further discuss their impressions and opinions on the simulator. Researchers took note of comments and suggestions.



Figure 12: Hazardous Road Conditions. Top Left: The driverless car stops as a pedestrian walks across the street. Top Right: The driverless car navigates heavy traffic in the busy downtown. Bottom Left: Traffic on the highway abruptly slows to a crawl as the police car activates its sirens. Bottom Right: The driverless car brakes abruptly as another car runs a red light.

3. FAVS Simulator Analysis

5. Vehicle Performance Analysis

The response to the simulator was overwhelmingly positive. Computationally, the simulator functioned as expected with virtually no stutters or lag in the simulation. In nearly all cases, the autonomous vehicles navigated in consistent, plausible fashion and the volunteers believed that the traffic situation was typical and consistent with their own driving experience.

Some volunteers expressed concerns on the handling of the connected vehicle. These volunteers perceived that the connected vehicle does not handle ‘correctly’ at high speeds. They asked researchers to focus on a looser steering scheme which prevented over-steering when the vehicle was moving at speeds above 40 miles per hour. At low speeds, volunteers were satisfied with steering, but some suggested that a higher idle power might feel more appropriate. In the current

simulated car, idling in drive will not move the car forward. A user must push the gas pedal for the vehicle to move; some volunteers perceived this feature to be overly conservative.

In addition, some volunteers expressed concern about the tightness of the autonomous vehicle's steering at high speeds as well. In particular, users on the highway suggested they would feel more comfortable if the autonomous car relaxed its lane center adherence. The vehicle rigidly follows the centerlines of the highway, which causes it to make more corrections than a human when dealing with banked sections on the highway. This made some users uncomfortable. A few volunteers also noted that the autonomous vehicle is very conservative and courteous in its driving, occasionally to the frustration of its pilot. This complaint is common of autonomous vehicles but merits investigation as well (Richtel & Dougherty, 2015).

6. Vehicle Experience Analysis

Vehicle performance aside, researchers requested feedback on the experience of being driven by the autonomous car, interacting with the navigation system, and the connected vehicle warning tones / messaging (Appendix 2: Summary of Simulator Comments). Again, feedback was very positive overall. Users felt that the interactive navigation system accurately represented real systems and enjoyed the web-browser and media portions of the console system. Users felt the simulator was visually impressive and the modelled scenarios were realistic in their scope.

Volunteers responded that the warning tones were appropriate in volume and timbre, but they were not always sure why the vehicle was warning them. A small number felt that the vehicle's decisions were not clear to them as it navigated and warned them of changing conditions. Users also appreciated the 'radar' screen showing nearby vehicles but some admitted they were not sure of the meaning of the color scheme.

4. Plan for Simulation Improvement

7. Vehicle Performance improvement

For the next phase of the current project, the research team will adjust the driving profile of the vehicle to be more consistent with user expectations of a four-door sedan. In particular, when in drive, the vehicle will idle forward without the user intervening. Researchers will loosen the steering curve of the vehicle at speeds above 40 miles per hour to reduce oversteering. Researchers will also construct a connected-vehicle training course for familiarizing participants in human-in-the-loop experiments with the steering profile of the car at various speeds and iconography.

Researchers will loosen the vehicle's lane following algorithms at high speeds as well to provide a more comfortable lane-switching and banked-turn experience on the highways of the simulated city. They will additionally investigate methods by which the vehicle can take greater advantage of opportunities presented by changes in traffic, such as clearance in adjacent lanes. Where possible, the autonomous navigation algorithm will behave more consistent with expectations of passing and red-light stopping behaviors.

8. Vehicle Experience Improvement

Experts and volunteers expressed the most concern over the clarity of the vehicle's driving decisions and warnings. Researchers will use the connected-vehicle training course to familiarize subjects in a human-in-the-loop experiment with the various tones they will encounter. The appropriate level of transparency, tones, and warning icons is a principle investigation of this project and researchers will explore these design options further in part three of the current effort.

5. Conclusion

Volunteers at the Florida Autonomous Vehicles Summit responded positively to the Florida Department of Transportation Driverless and Connected Vehicle Simulator and many expressed interest in the project's future. Researchers gained understanding of the many ways the simulator accurately represents the driving experience and its current deficiencies. Exhibiting the simulator provided vital insights on how drivers' perceptions of the vehicle vary and the most important points for improving the simulation. Based on this feedback, researchers are developing the necessary capability to finalize the simulator and begin human-in-the-loop testing with participants in a controlled study.

6. References

- Carsten, O., & Nilsson, L. (2001). Safety assessment of driver assistance systems. *European Journal of Transportation and Infrastructure Research, 1*, 225-224.
- ECMT. (1995). Statement of principles of good practice concerning the ergonomics and safety of in-vehicle information systems. In *New Information technologies in the Road Transport Sector: Policy Issues, Ergonomics and Safety* (pp. 35-42). The European Conference of Ministers of Transport.
- Iselin, E. R. (1998). The effects of information load and information diversity on decision quality in structured decision task. *Accounting Organizations and Society, 13*(2), 147-164.
- Miller, G. A. (1956). The magic number of seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review, 63*, 81-97.
- National Highway Traffic Safety Administration. (2014). *Preliminary Statement of Policy Concerning Automated Vehicles*. Washington, D.C., USA: United States Department of Transportation.
- Naylor, N. (2014, February 3). *National Highway Traffic Safety Administration*. Retrieved 01 06, 2016, from U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles: <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles>
- Rakotonirainy, A., & Steinhardt, D. (2009). In-vehicle Technology Functional Requirements for Older Drivers. *Proceedings of the First International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. Essen, Germany: ACM.
- Richtel, M., & Dougherty, C. (2015, September 1). *Google's Driverless Cars Run Into Problem: Cars With Drivers*. Retrieved from New York Times:

- http://www.nytimes.com/2015/09/02/technology/personaltech/google-says-its-not-the-driverless-cars-fault-its-other-drivers.html?partner=rss&emc=rss&_r=1
- Robinson, R., & Dion, F. (2013). *Multipath SPAT Broadcast Project*. Lansing, MI, USA: Michigan Department of Transportation.
- Rumar, K. (1990). The basic driver error: late detection. *Ergonomics*, 1281-1290.
- Streufert, S. (1970). Complexity and complex decision making: convergences between differentiation and integration approaches to the prediction of task performance. *Journal of Experimental Social Psychology*, 6(4), 494-509.
- Streufert, S. C. (1973). Effects of information relevance on decision making in complex environments. *Memory & Cognition*, 1(3), 224-228.
- U.S. Department of Transportation. (2014, 10 14). *V2V Communications Fact Sheet*. Retrieved from http://www.safercar.gov/staticfiles/safercar/v2v/V2V_Fact_Sheet_101414_v2a.pdf

7. Appendix 1: Simulator Hardware

Below is a List of the hardware used in the FDOT-DCVS

| | |
|---|---|
| Chicago Gaming Redline GT Gaming Cabinet: | A commercial arcade cabinet which serves as the base of the simulator. Includes steering-wheel and pedals |
| ViewSonic TD2220 Touch Monitor: | 22" touch monitor which serves as the center console screen |
| Samsung UN55JU6700 Curved 55-Inch 4K Ultra HD Smart LED TV: | 55" Curved Flat-screen TV used as the primary display for the simulator |
| Custom-Built PC: | A custom PC featuring an Intel I7 Quad-core 4GHz processor, an NVIDIA GTX970 graphics card with 4 gigabytes on-board memory, 16 gigabytes of DDR3 1600 RAM, and a Samsung 850 EVO 500 GB SSD hard-drive |
| Microsoft Wireless All-In-One Media Keyboard: | Wireless media keyboard for experimental control and convenient stowage during experimentation |
| Various Cables: | 1 HDMI cable, 2 USB Male-to-female extension cables, 3 standard 3-conductor PC power cables |

8. Appendix 2: Summary of Simulator Comments

| Comment | Context |
|---|--|
| I would have run that yellow light. The car stops too conservatively at lights. | In regards to the driverless car's strict rule to stop for yellow lights, even in cases where the car may have safely crossed the light. |
| The vehicle is very hard to control at this speed. | In regards to the simulated car's tight steering at high velocities. |
| The vehicle appears to be having trouble staying in the middle of its lane. | In regards to the driverless car's tendency to correct frequently on the highway |
| The graphics of this simulator are very impressive | A user remarking on the visual quality of the downtown area of the simulated city. |
| So, I can play with my phone while the car drives itself? that is really neat. | Comments on the advantages of such an autonomous vehicle |
| I'm not sure I trust this car to make good decisions | A user commenting on transparency of the driverless car on the highway |
| I am really eager to see how different demographic groups respond to this simulation | In regards to the potential of this form of human-in-the-loop testing |
| I would be interested to see how this simulator integrates with existing sensors and automation technology. | In regards to the potential of integrating real sensor data into the simulated vehicle. |
| My kids would love this! | In regards to the general excitement value of piloting the connected car. (This was the most common comment). |
| The console display feels very realistic. | A user remarking on the level of detail of the center console. |
| The vehicle drives like a truck in some respects. Even though I am in drive, I must hit the gas to go. | In regards to the driverless car's low idle power. |
| I am unsure why the car is beeping at me. | In regards to the vehicle's warning tones |
| The center console and navigation display feels like a real car. The experience feels authentic. | |
| The traffic patterns feel believable in the simulator. | |

Appendix D Draft User Guide

Driverless and Connected Vehicle Simulation Manual

Institute for Simulation and Training, University of Central Florida

1 Background

The simulator is designed from a commercial arcade cabinet using a ruggedized desktop PC and 55" curved flat-panel display. The user drives using a force-feedback enabled steering wheel and weighted pedals. A second, touch-enabled monitor provides the center console of the vehicle. The center console features a complete interactive console display including simulated climate controls, a functional web-browser, a navigation interface, and a media player. Figure 1 provides an overview of the simulator system.



Figure 13: The FDOT DCVS is an advanced simulator used for measuring human experiences with connected vehicles. Top Left: A side view of the complete simulator system. Right: The complete interactive dashboard console display showing the routing and media player panes. Bottom-left: A view from the main screen of the simulator as the car approaches a parking garage. The dashboard iconography replicates (with permission) that of the Tesla Model S.

The simulation experience contains two distinct driving scenarios to demonstrate driverless vehicle research concepts. In each case, the user navigates a simulated city with other vehicles, pedestrians, and typical traffic patterns. In each case, the simulator presents users combinations of driving hazards including jaywalking, sudden slowdowns, traffic jams, and vehicles running red lights (see Figure 2).



Figure 14: Hazardous Road Conditions. Top Left: The driverless car stops as a pedestrian walks across the street. Top Right: The driverless car navigates heavy traffic in the busy downtown. Bottom Left: Traffic on the highway abruptly slows to a crawl as the police car activates its sirens. Bottom Right: The driverless car brakes abruptly as another car runs a red light.

In Scenario 1, the vehicle begins parked in a parking lot in connected vehicle mode (i.e. manual driving). The user drives the car around the parking lot to familiarize themselves with the driving profile of the car and the iconography of the virtual dashboard and center console. Once the user is ready, they exit the parking lot and the vehicle switches to autonomous mode. The car proceeds through a simulated downtown where the autonomous vehicle must avoid hazards such as vehicles running red-lights and pedestrians jaywalking across the busy city streets (see Figure 2). The car then turns onto the highway.

Once on the highway, the vehicle plays a video on the in-dash media player (Figure 1) which distracts the user. During the video, the car must make a sudden stop as traffic slows for an emergency vehicle. Warning tones play as the brakes of the vehicle screech the car to a safe speed. Once traffic clears, the car exits the scenario. In the future, responses to surprises such as a sudden stop will measure situation awareness in the pilot of the vehicle.

The second scenario is a practical mirror of the first. The vehicle begins on a long segment of highway and makes several lane changes at high speed as it approaches the downtown exit. During the maneuvers, a video plays through the in-dash media player, and a sudden stop occurs as in Scenario 1. Once the vehicle exits the highway, it encounters similar hazards in the downtown area. As the vehicle exits downtown (towards the parking lot from Scenario 1), the scenario ends. Scenario two serves to highlight the simulator's highway driving capabilities and messaging

capability, as well as the ability to use the simulated city to test a number of routes, destinations, and hazards.

2 Simulator Execution

2.1 Powering on the Simulator

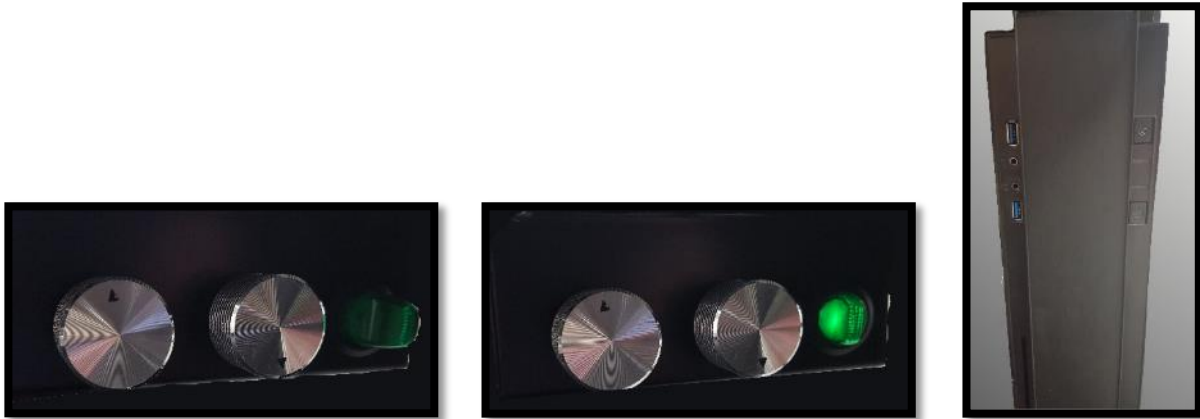


Figure 15: The power switch and pc are located under the right front speaker, near the bottom of the center console. *Left:* The power switch in the "Off" position. *Center:* The power switch in the "On" position. *Right:* The PC which powers the simulation. The power button on the PC is the bottom right button.

To power on the simulator, first make sure the power strip in the rear is plugged in. The total power usage of the simulator is low enough to occupy a standard power outlet. Next, ensure the green toggle switch under the right speaker is in the "On" position. Press the power button on the PC to power it up (Figure 3).

2.2 Launching the Simulation



Figure 16: Launching the Application. From Left. *First:* The Center Panel icon launches the navigation and entertainment interface. *Second:* The DriverlessCar Icon launches the DCVS. *Third:* The Loading screen for the simulator. *Fourth:* The main menu of the simulator offers three options: Play Scenario 1, Play Scenario 2, or Exit the program.

Once the computer has booted, Windows may require you to log into the PC, to do so use the user name FDOT and password FDOTfdot99.

Once you login, click on the FDOT console display icon on the desktop. (Figure 4). This will launch the center console application on the secondary display. Once the console application has launched. Double click the FDOT DCVS icon on the desktop. The loading screen will appear and then the main menu of the application. From here, you can click to play Scenario 1, to play Scenario 2, or to exit the program (see Figure 4).

2.3 Running a Scenario

To run a scenario, click on its title in the main menu. The screen will fade to black and fade back in once the scenario is ready. In scenario 1, the user (pilot) will have control of the vehicle until they leave the parking lot. The vehicle will then drive through the city to the highway. Scenario 2 is entirely automated. The vehicle begins on the highway and drives towards the parking lot.

2.4 The Pause Menu

While a scenario is running, pressing the escape key (ESC) will open the pause menu (Figure 5). From the pause menu, one can choose to resume the current scenario, restart the current scenario or return to the main menu. The last option controls what will happen when the scenario ends. If the option reads "Looping On", the scenario will restart when the end is reached. If the option reads "Looping off" the simulator will return to the main menu once the scenario is complete.

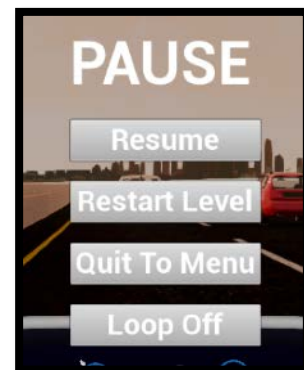


Figure 17: The Pause Menu

2.5 The Center Console Display



Figure 18: Center Console Display

The center console display (Figure 6) provides several areas of interaction. The navigation tab can be zoomed by "pinching" the screen with two fingers or clicking on either of the magnifying glass icons. The map can be locked or unlocked from the car by clicking the lock button. The web-browser is also interactive. Users may click on links to load different pages (internet connection required). Users can also interact with the climate controls, however these do not control any aspect of the surrounding climate.

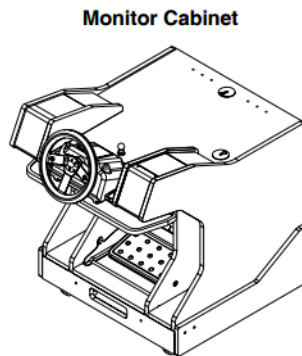
Clicking on the Controls icon in the bottom left corner of the center console screen will open the Configuration window. To exit the center console, click the "Exit Application" icon in this menu. No other options in this menu should be altered while operating the simulator.

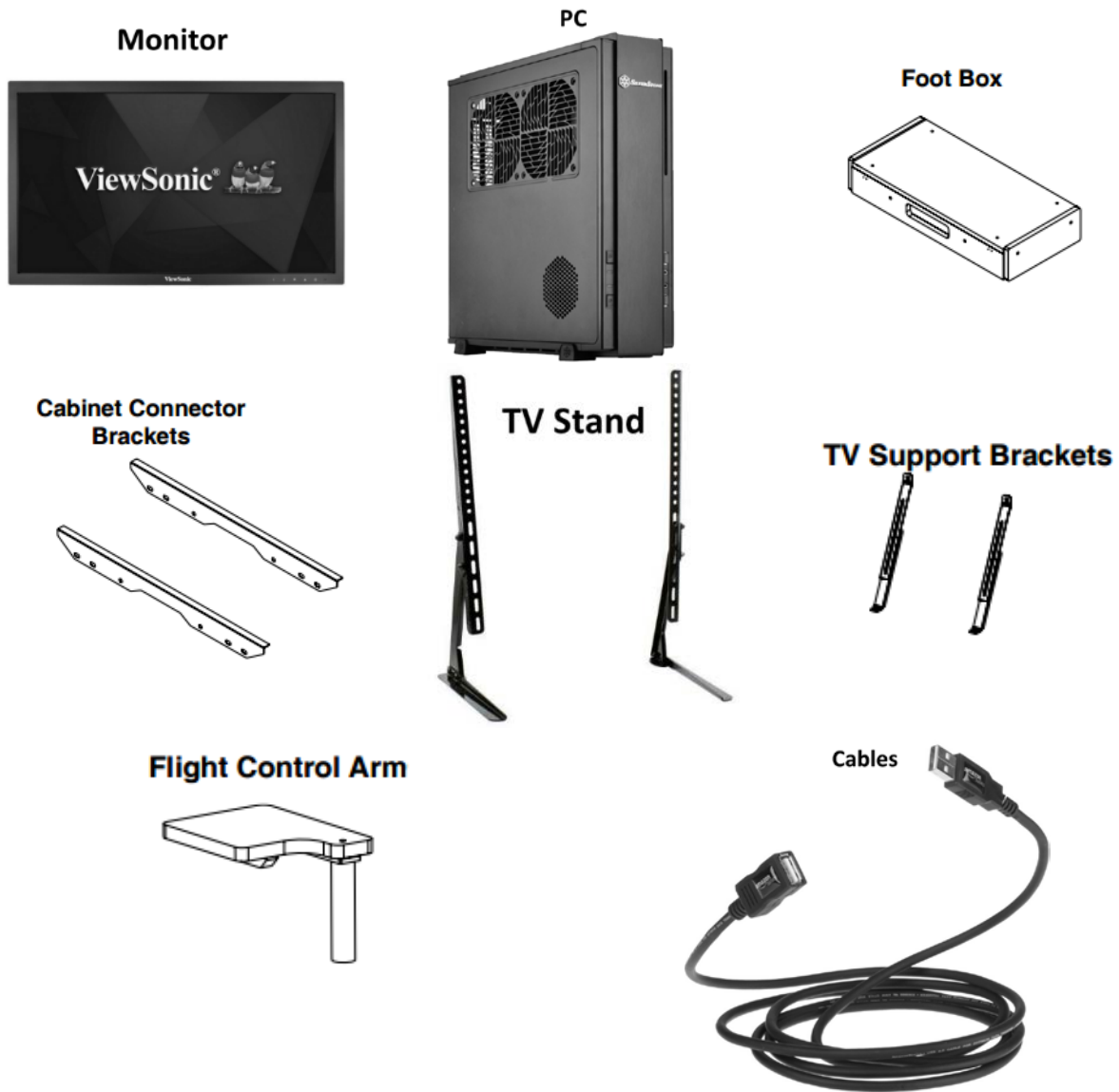
3 Simulator Assembly

For this, take a few pictures of the simulator and mark what each piece is. Basically, how to put together and break down, and pack in a van.

3.1 Parts

Below is a list of all major parts/components needed in the simulator's assembly.





The mounting hardware required for assembly.

- 4x M6x30 Screws (PH #1)
- 4x M8x30 Screws (PH #1)
- 2x Square Spacers
- 8x Cap Screws (3/16" hex)
- 8x Nuts (7/16" Wrench)
- 12x 1/4-20 x 1-3/4" Socket Cap Screws

3.2 Tools

A list of the tools required for assembly is listed below.

- Philips #1 Screwdriver

- Philips #2 Screwdriver
- 5mm Allen Key/Hex Wrench
- 3/16" Allen Key/Hex Wrench
- 1/2" (Socket)Wrench
- 7/16" (Socket)Wrench

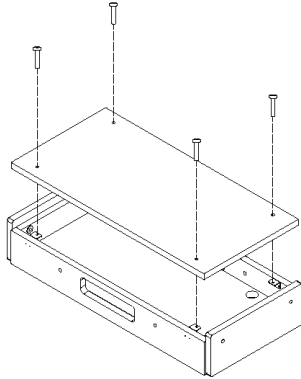
3.3 Assembly Instructions

In the subsequent sections you will find step-by-step instructions on how to assemble all the major components of the simulator into a working unit. Ensure you have all of the appropriate mounting hardware and tools before beginning the process. Follow the four steps outlined in order to guarantee proper assembly.

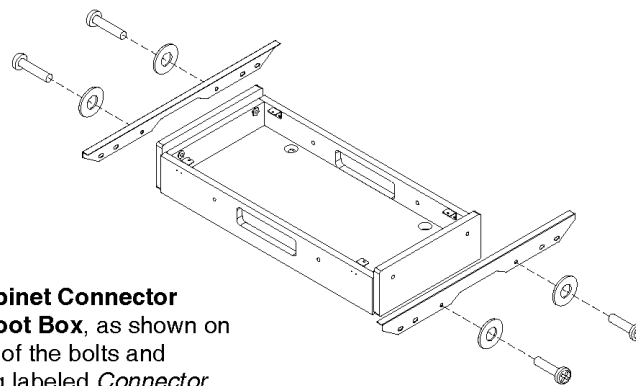
3.3.1 Step 1: Assemble Cabinet

3.3.1.1 Attach the Cabinet Connectors to the Foot Rest Box:

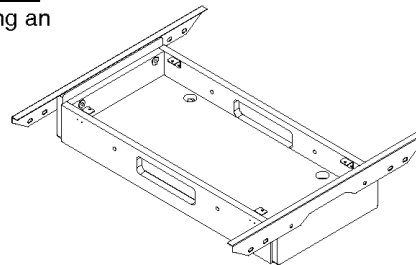
3.1 Connecting the Cabinets



Start by removing the lid of the **Foot Box**. Remove the four Phillips head screws to free the lid, and it will pull straight up. Do not close the **Foot Box** until you have finished setting up and connected all of the cables.



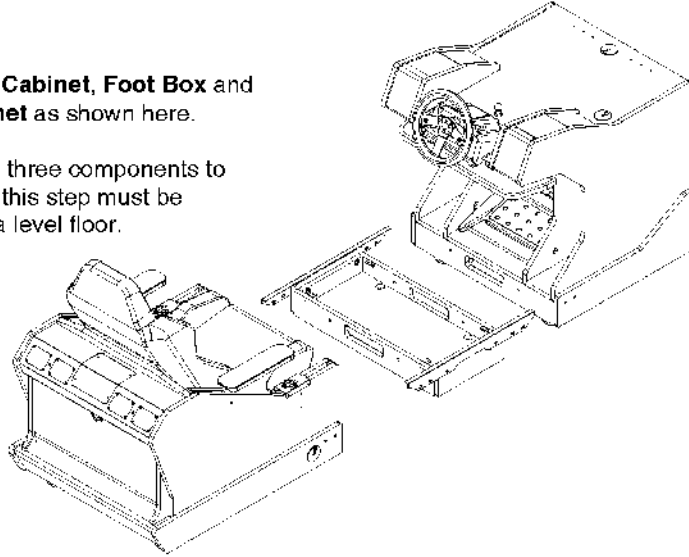
Attach the two **Cabinet Connector Brackets** to the **Foot Box**, as shown on the right. Use four of the bolts and washers in the bag labeled Connector Bracket Hardware and tighten using an Allen wrench.



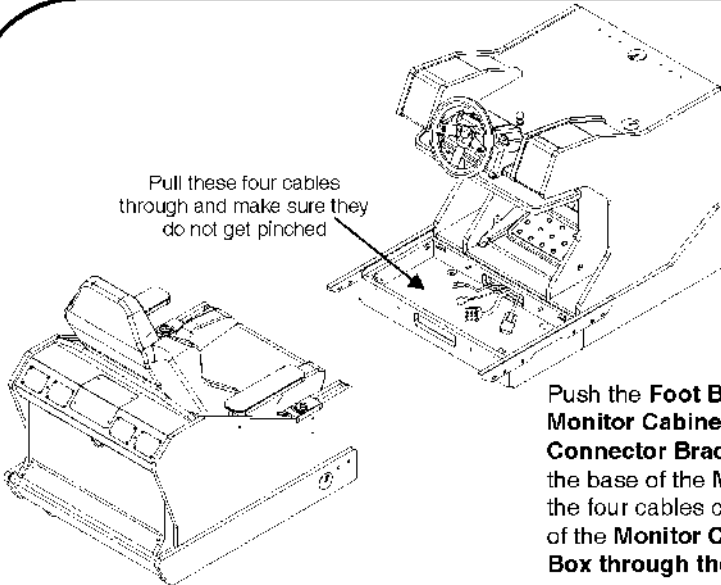
3.3.1.2 Connect Cabinets Together:

Align the **Seat Cabinet**, **Foot Box** and **Monitor Cabinet** as shown here.

NOTE: For the three components to align properly, this step must be performed on a level floor.



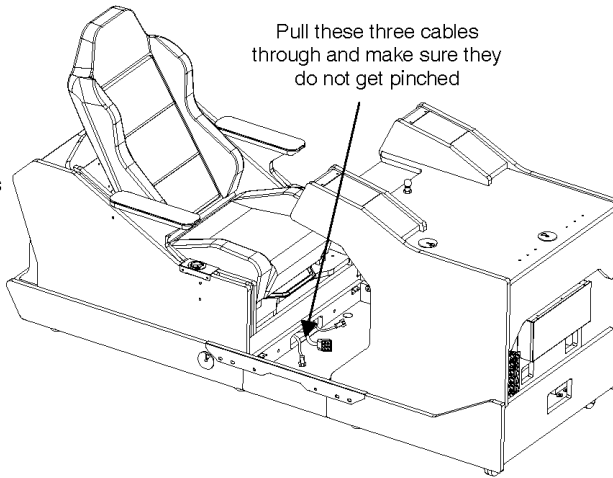
Pull these four cables through and make sure they do not get pinched



Push the **Foot Box** up against the **Monitor Cabinet** so the **Cabinet Connector Brackets** are resting on the base of the **Monitor Cabinet**. Pull the four cables coming from the bottom of the **Monitor Cabinet** into the **Foot Box** through the rectangular hole.

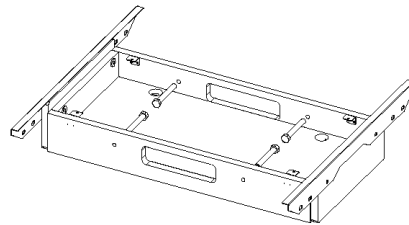
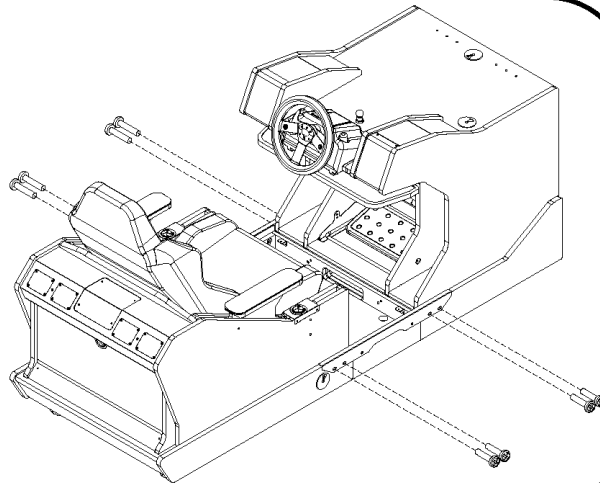
3.3.1.3 Bolt Cabinets Together:

Push the **Seat Cabinet** up to the **Foot Box** as shown, so that the **Connector Brackets** are resting on the bases of the **Monitor Cabinet** and **Seat Cabinet**. Pull the three cables coming from the bottom of the **Seat Cabinet** into the **Foot Box** through the rectangular hole.



Use the eight remaining bolts and washers in the bag labeled **Connector Bracket Hardware** to connect the **Foot Box** to the other two cabinets through the **Connector Brackets**.

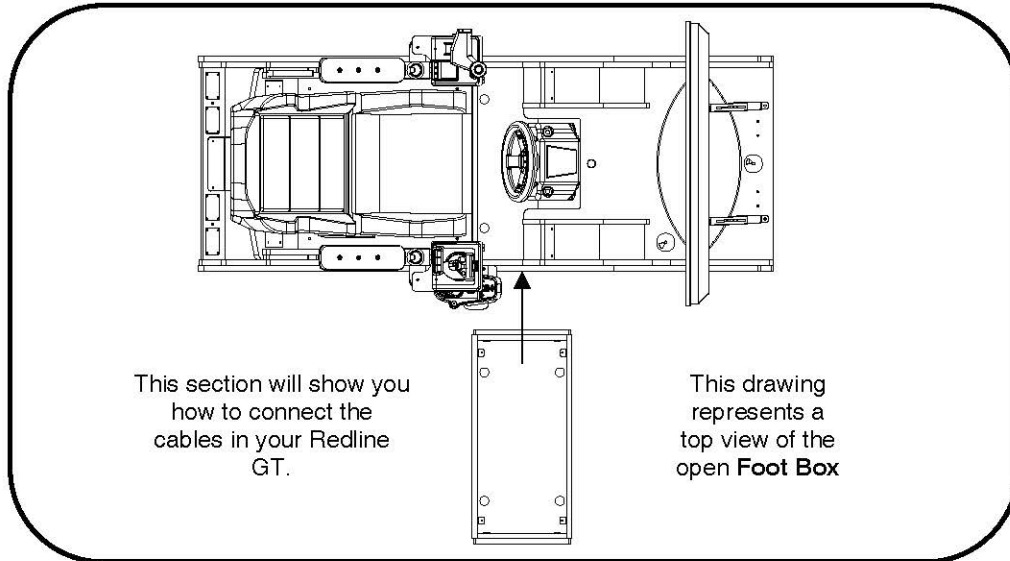
Only tighten the bolts with your hands. Do not tighten with an Allen wrench until after the next step.



Use the four bolts and washers in the bag labeled **Foot Box Connect Hardware** to connect the **Foot Box** to the **Monitor Cabinet** and **Seat Cabinet** as shown to the left. Tighten the bolts with a 7/16" wrench. Note that this image does not show the **Monitor Cabinet** or **Seat Cabinet** so that you can easily see where the bolts attach. After these bolts are tightened, tighten the outside bolts with an Allen wrench.

3.3.1.4 Connect Wires A-D in Foot Rest:

3.6 Connecting Foot Box Cables



Connect the four sets of cables that you pulled into the **Foot Box** when you connected the cabinets. First, connect the cables with the 9-pin connectors, marked A. This cable powers the taillights and speakers in the **Seat Cabinet**.

Next, connect cables B, C and D to the matching cables, which are coming up through the holes in the bottom of the **Foot Box**. These cables power the strip lighting that runs underneath Redline GT.

Connect the **Shifter** cable that you pulled through earlier to the shifter extender cable marked E.

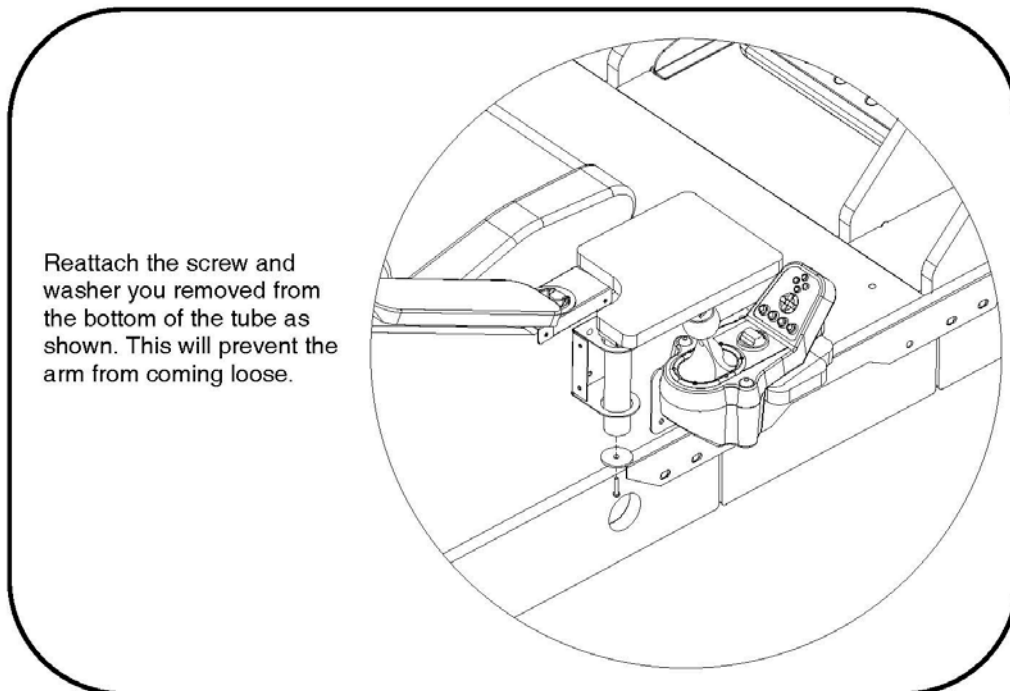
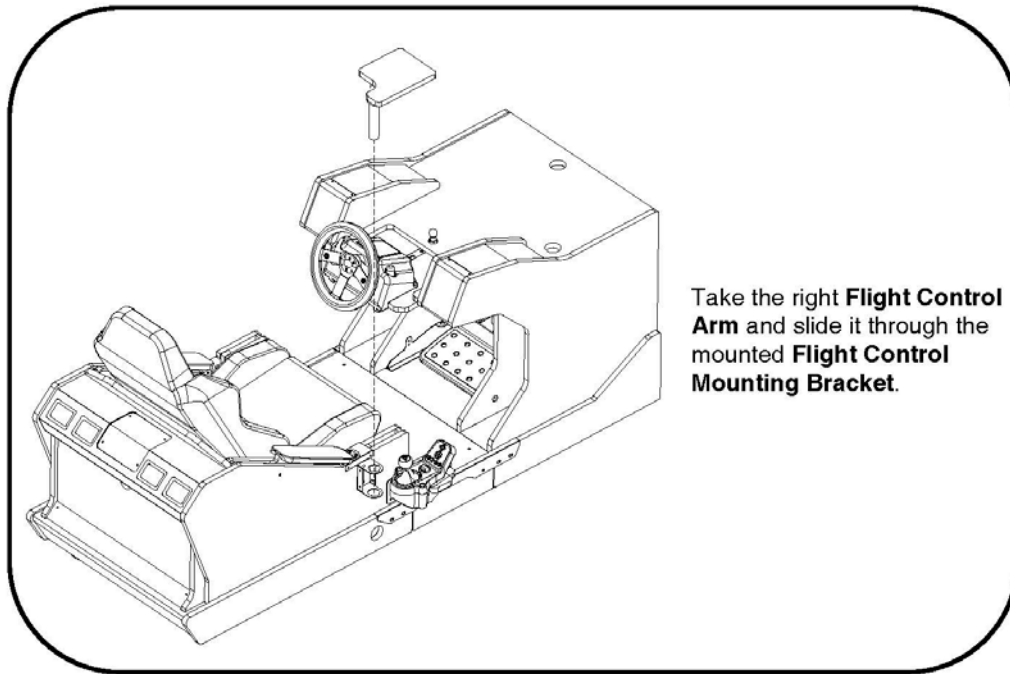
Warning: Make sure to check the labels on the cables before connecting them.

If you are using USB flight sticks, connect the USB cable from the flight sticks to cable F. For information on how to connect flight sticks, see page 14.

If you are not using USB flight sticks, cable F is unused.

When you have finished connecting the cables, replace the Foot Box Lid and secure it with the screws you removed.

3.3.1.5 Attach Right Flight Control Arm (Optional):

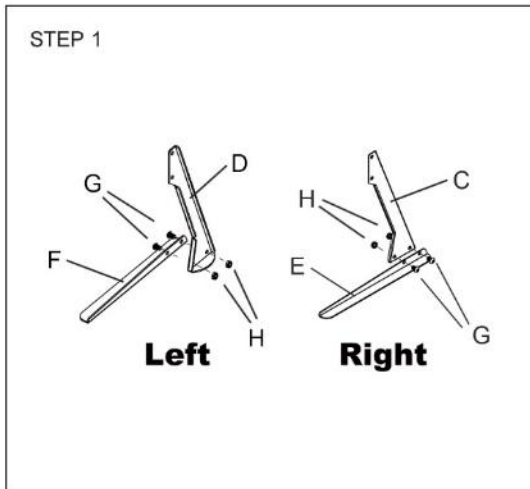


3.3.2 Step 2: Mount TV

3.3.2.1 Attach TV Stand:

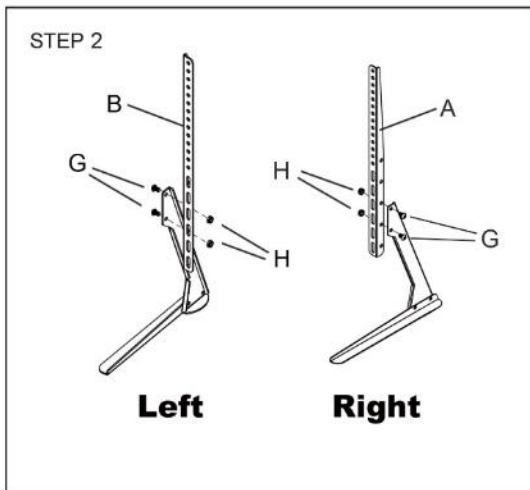
ShopJimmy.com® Stand-3770 TV Stand Instructions

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Step 1:

Attach part (F) with part (D) using screws (G) and nuts (H) for the left stand leg. Attach part (E) with part (C) using screws (G) and nuts (H) for the right stand leg.



Step 2:

Attach the completed left stand leg with the bracket (B) using screws (G) and nuts (H). Attach the completed right stand leg with the bracket (A) using screws (G) and nuts (H).

.....

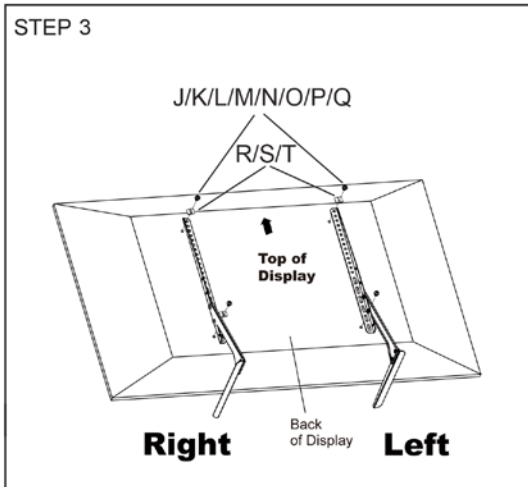
Safety Disclaimer

This TV stand is designed for most flat-screen TVs between 37" and 70" (measure screen diagonally to verify your TV size). Your TV must weigh less than 110 pounds (50 kg). Placing a TV that is too large or heavy on this TV stand is hazardous and severe injury or death can occur if the TV and furniture combination is unstable. Never allow children to climb on or play with the TV set-up. The manufacturer is not liable for damage or injury caused by incorrect mounting, assembly or use.

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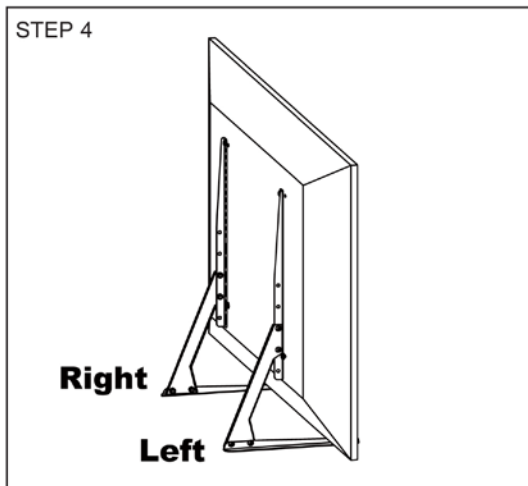
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Step 3:

Carefully lay the TV face down on a flat, non-abrasive surface using padding underneath the TV to protect the screen.

Attach the TV stand to the back of the TV using the appropriate screw size (J/K/L/M/N/O/P/Q) and spacer (if needed, R/S/T) for the TV. Make sure to fully tighten each screw with your wrench!



Step 4:

You're all set! Enjoy your new TV stand!

.....

Safety Disclaimer

This TV stand is designed for most flat-screen TVs between 37" and 70" (measure screen diagonally to verify your TV size). Your TV must weigh less than 110 pounds (50 kg). Placing a TV that is too large or heavy on this TV stand is hazardous and severe injury or death can occur if the TV and furniture combination is unstable. Never allow children to climb on or play with the TV set-up. The manufacturer is not liable for damage or injury caused by incorrect mounting, assembly or use.

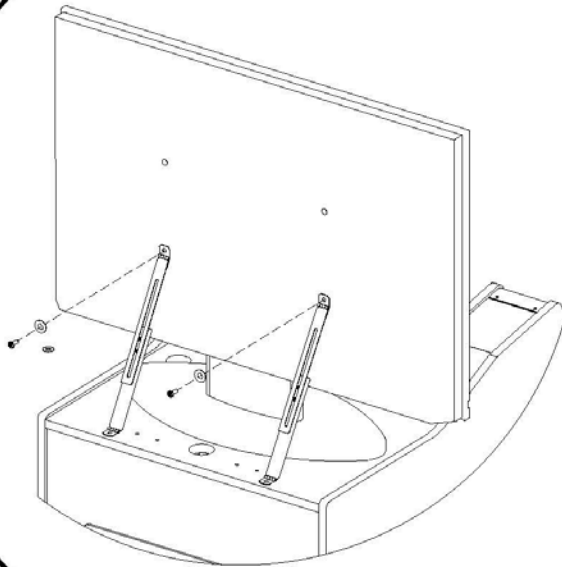
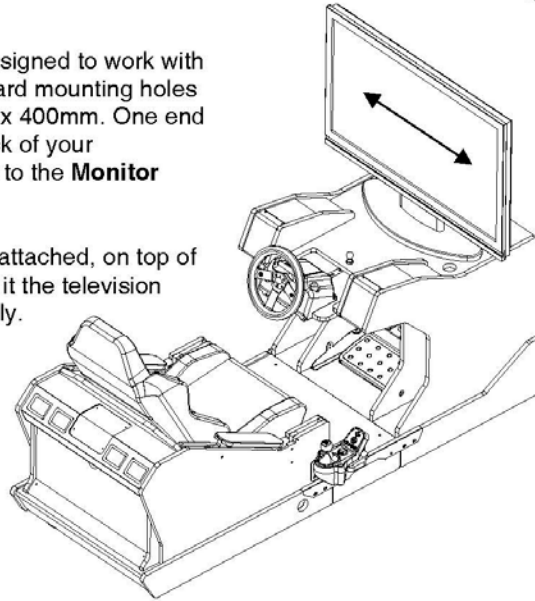
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3.3.2.2 Secure TV Support Brackets to Cabinet (Over top of Stand):

3.5 Television Support Brackets

The **TV Support Brackets** are designed to work with televisions that have VESA standard mounting holes from 200mm x 200mm to 400mm x 400mm. One end of the bracket connects to the back of your television, and the other connects to the **Monitor Cabinet**.

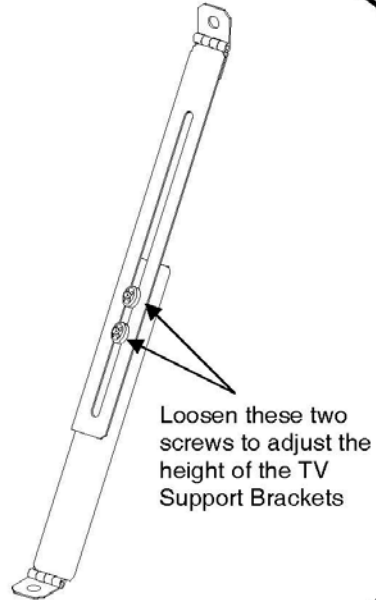
Set your television, with the base attached, on top of the **Monitor Cabinet**. Try to keep it the television approximately centered horizontally.



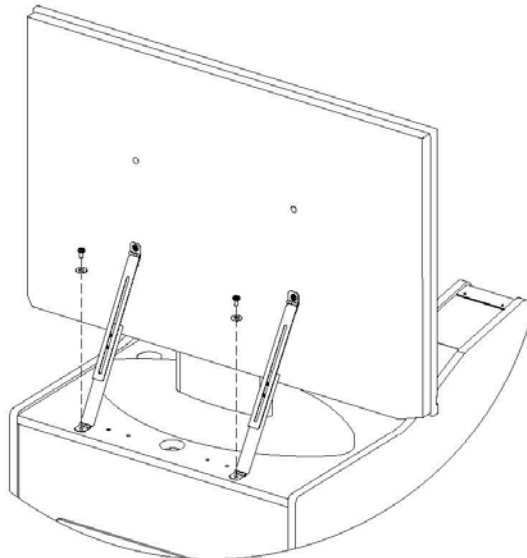
Find the bag labeled TV Bracket Hardware, which contains four different types of screws and some washers. The three sets that look similar are different sizes used to connect wall-mounting brackets to different televisions. Usually, the larger the television, the larger the screw used. Find the set of screws that fit the mounting holes on the back of your television.

Attach the **TV Support Brackets** to the lower set of mounting holes on your television with the slotted piece at the top. For the smaller screws, you will need to use the washers to keep the screw from sliding through the bracket.

You will now need to adjust the length of the **TV Support Brackets** so that the bottom mounting hole lines up with the pilot holes behind the television. Loosen, but do not remove, the two screws in the center of the bracket.



Loosen these two screws to adjust the height of the TV Support Brackets



When you have adjusted the bracket to the correct length and aligned it with the pilot hole in the cabinet, use the two longest screws and two washers in the TV Bracket Hardware bag to connect the bracket to the cabinet. Tighten the screws that were loosened to adjust the length of the bracket.

3.3.2.3 Completed:



3.3.3 Step 3: Mount Touchscreen Monitor

3.3.3.1 Slide Monitor Assembly into Holder:



3.3.3.2 Secure Monitor:



3.3.4 Step 4: Setup PC

Connect display cables from the PC to the TV and monitor. Subsequently connect all other needed accessories to the PC (Steering wheel, mouse, keyboard, etc.). Connect required power to the TV, Monitor, PC, and cabinet power supply. When ready to use power on the PC using the power button on the front of the case. Use the switch on the front of the cabinet to turn on the speakers and lights. The simulator should now be completely assembled and working.

3.4 Disassembly Instructions

The instructions outlined in section 2.3 should be followed in reverse order to break the simulator down for easy transport or for general disassembly. Start with Step 4 and work backwards until finishing Step 1 in order to completely disassemble the simulator.

4 Troubleshooting

4.1 The Steering Wheel Does Not Turn On or Car Not Moving Steering Wheel

The most common cause of this problem is a timeout in the steering wheel. Restart the simulator application. If this does not solve the problem, restart the computer. During a system reboot, the steering wheel should spin several times to calibrate its range of motion. If this does not occur, check the USB cable between the steering wheel and PC to make sure it is connected and ensure the steering wheel's power cable is plugged into the rear power strip.

4.2 The Vehicle Icon Does Not Appear On Center Console Display

In some cases, the simulator will stop providing data to the navigation screen. Restart both applications.

4.3 The Simulator Is Running Slowly

Over long running times, the performance of any application is prone to degradation. If you find the simulator is running slowly, restart both the simulator application and the center console. Also, consider restarting the PC.

4.4 The Car Has Experienced A Traffic Accident and Cannot Be Moved

Restart the current scene by accessing the pause menu (ESC) and choosing "Restart Scenario".

5 Appendix 1: Simulator Hardware

Below is a List of the hardware used in the FDOT-DCVS

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| Samsung UN55JU6700 Curved 55-Inch 4K Ultra HD Smart LED TV: | 55" Curved Flat-screen TV used as the primary display for the simulator |
| Custom-Built PC: | A custom PC featuring an Intel I7 Quad-core 4GHz processor, an NVIDIA GTX970 graphics card with 4 gigabytes on-board memory, 16 gigabytes of DDR3 1600 RAM, and a Samsung 850 EVO 500 GB SSD hard-drive |
| Microsoft Wireless All-In-One Media Keyboard: | Wireless media keyboard for experimental control and convenient stowage during experimentation |
| Various Cables: | 1 HDMI cable, 2 USB Male-to-female extension cables, 3 standard 3-conductor PC power cables |

Appendix E Task 3 Report

Task 3: Summary of AV Simulation Modifications and Documentation

University of Central Florida - Institute for Simulation and Training

1. Background

The purpose for this task was to modify the AV Simulation to support new requirements identified as a result of Task 2, and to add support for additional data recording and analysis needed for human-in-the-loop experimentation. Additionally, training materials were further developed for operation of the AV Simulation.

2. Method

In order to produce a useful testbed for human-in-the-loop experiments, the University of Central Florida's Institute for Simulation and Training created the Florida Department of Transportation Connected and Driverless Vehicle Simulator (FDOT-DCVS). Researchers exhibited the simulator at the 2015 Florida Autonomous Vehicles Summit (FAVS). Experts and stakeholders were encouraged to experience the simulations devised by researchers at UCF and to provide criticisms and suggestions.

Researchers chose the FAVS as a feedback site because of the concentration of industry professionals and stakeholder personnel present. The simulator was demonstrated to transportation engineers, Florida Department of Transportation personnel, sensor technology manufacturers, university researchers, automotive industry representatives, and members of the general public. The feedback generated by the various attendees provided the backbone of the modifications needed for the next stage of research for the project. The summary presented here highlights key improvements made to the simulation as a result of key areas for improvement identified as part of Task 2 of the effort.

3. Summary of Simulation Improvement

The following section describes overall changes made to the simulation to address areas for improvement developed under Task 2. A list of key changes matched to feedback is located in Appendix 2. Additional modifications were also made to improve overall simulator robustness and to support human-in-the-loop data collection as described below.

1. Vehicle Performance Improvement

For this phase of the project, the research team adjusted the driving profile of the vehicle to be more consistent with user expectations of a four-door sedan. In particular, when in drive, the vehicle will now idle forward without the user intervening. Moreover, a gearing system was added for manual driving in Park, Neutral, Reverse, and Drive mode. Researchers also adjusted the steering curvature profile of the vehicle at speeds above 40 miles per hour to reduce oversteering.

Researchers also constructed a connected-vehicle training course for familiarizing participants in human-in-the-loop experiments with the steering profile of the car at various speeds and iconography.

Researchers adjusted the autonomous vehicle's lane following algorithms at high speeds as well to facilitate more comfortable lane-switching and banked-turn experiences on the highways of the simulated city. A re-factoring of the underlying state logic for driving also improved the vehicle's ability to take greater advantage of opportunities presented by changes in traffic, such as clearance in adjacent lanes, and left/right turns into traffic. Traffic light controllers were also modified such that the autonomous navigation algorithm will behave more consistent with expectations of passing and red-light stopping behaviors.

2. Other Simulation Additions

In addition to changes to address feedback from the FAVS, other changes were made to better support future use cases such as human-in-the-loop data collection and demonstrations. Specific changes include:

- Logging simulation events and data
 - All interactive object states are recorded (e.g. traffic, pedestrians)
 - Simulation events (e.g. movie playing, icons added to map)
 - Player car state (position, velocities, steering/break inputs)
 - Sound effects and other alert/tone events
 - Center console screen capture at different rates
- Options Menu
 - From "Pause/Resume" menu screen ability to turn on "Looping," which causes scenario to continuously repeat for demonstrations
 - Ability to turn on/off steering wheel for autonomous demos. Feature added to prevent possible "burn-out" of steering wheel hardware when simulation left looping for extended periods of time
- Scene Fading
 - Scenarios fade-in and out at start end to indicate when scenario starts/end to user
- Code-Refactoring
 - Improvements autonomous navigation algorithms for player and other traffic vehicles
 - Better sub-state logic (e.g. lane changes, turning, following)
 - Improved steering logic at different speeds and driving sub-states
 - Collision prediction
 - Each car caches location and future state information and shared across other vehicles internally
 - Better prediction based on intended goals/behaviors to be executed
 - Results in less traffic back-ups or other edge cases where vehicle may get stuck

4. Conclusion

In summary, researchers reviewed feedback from experts in the field attending the FAVS to identify key improvements needed to the underlying simulation system. Additional notes regarding the overall simulation performance were also made resulting in several improvements and additions the final system. The overall simulation should now better reflect user expectations for autonomous driving and support more robust manual driving use-cases for CV studies. Finally,

additional data logging was added to the system to track as much information regarding the simulation and users' interaction with it for analysis of human performance in future experiments.

5. Appendix 1: Summary of FAVS Simulator Comments

| Comment | Context |
|---|--|
| I would have run that yellow light. The car stops too conservatively at lights. | In regards to the driverless car's strict rule to stop for yellow lights, even in cases where the car may have safely crossed the light. |
| The vehicle is very hard to control at this speed. | In regards to the simulated car's tight steering at high velocities. |
| The vehicle appears to be having trouble staying in the middle of its lane. | In regards to the driverless car's tendency to correct frequently on the highway |
| The graphics of this simulator are very impressive | A user remarking on the visual quality of the downtown area of the simulated city. |
| So, I can play with my phone while the car drives itself? that is really neat. | Comments on the advantages of such an autonomous vehicle |
| I'm not sure I trust this car to make good decisions | A user commenting on transparency of the driverless car on the highway |
| I am really eager to see how different demographic groups respond to this simulation | In regards to the potential of this form of human-in-the-loop testing |
| I would be interested to see how this simulator integrates with existing sensors and automation technology. | In regards to the potential of integrating real sensor data into the simulated vehicle. |
| My kids would love this! | In regards to the general excitement value of piloting the connected car. (This was the most common comment). |
| The console display feels very realistic. | A user remarking on the level of detail of the center console. |
| The vehicle drives like a truck in some respects. Even though I am in drive, I must hit the gas to go. | In regards to the driverless car's low idle power. |
| I am unsure why the car is beeping at me. | In regards to the vehicle's warning tones |
| The center console and navigation display feels like a real car. The experience feels authentic. | |
| The traffic patterns feel believable in the simulator. | |

6. Appendix 2: Resolutions To Simulator Comments

| Comment | Context | Resolution |
|--|--|--|
| I would have run that yellow light. The car stops too conservatively at lights. | In regards to the driverless car's strict rule to stop for yellow lights, even in cases where the car may have safely crossed the light. | Reduced the stopping threshold which controls whether the car stops at a yellow light to more closely match passenger expectations. |
| The vehicle is very hard to control at this speed. | In regards to the simulated car's tight steering at higher velocities found on major roadways. | Improved the steering curve profile of the car at different speed ranges to better facilitate tighter control, in particular for high speeds found on highways. |
| The vehicle appears to be having trouble staying in the middle of its lane. | In regards to the driverless car's tendency to correct too frequently on the highway | <ol style="list-style-type: none"> 1) Corrected the offending lanes on the highway simulation. Lanes did not properly match realistic highways and were too extreme. 2) Reduced the car's tendency to overcorrect such that it more naturally follows the curvature of the road. |
| The vehicle drives like a truck in some respects. Even though I am in drive, I must hit the gas to go. | In regards to the driverless car's low idle power. | <ol style="list-style-type: none"> 3) Created a more realistic gearing system for manual driving use-cases. The car now has P, R, N, and D gear positions. 4) In drive, the car will idle forward like a typical vehicle. 5) Tightened the throttle response to make the car accelerate more realistically. |

Appendix F User Guide

Driverless and Connected Vehicle Simulation Manual

University of Central Florida - Institute for Simulation and Training

1 Background

The simulator is designed from a commercial arcade cabinet using a ruggedized desktop PC and 55” curved flat-panel display. The user drives using a force-feedback enabled steering wheel and weighted pedals. A second, touch-enabled monitor provides the center console of the vehicle. The center console features a complete interactive console display including simulated climate controls, a functional web-browser, a navigation interface, and a media player. Figure 1 provides an overview of the simulator system.



Figure 19: The FDOT DCVS is an advanced simulator used for measuring human experiences with connected vehicles. Top Left: A side view of the complete simulator system. Right: The complete interactive dashboard console display showing the routing and media player panes. Bottom-left: A view from the main screen of the simulator as the car approaches a parking garage. The dashboard iconography replicates (with permission) that of the Tesla Model S.

The simulation experience contains two distinct driving scenarios to demonstrate driverless vehicle research concepts. In each case, the user navigates a simulated city with other vehicles, pedestrians, and typical traffic patterns. In each case, the simulator presents users combinations of driving hazards including jaywalking, sudden slowdowns, traffic jams, and vehicles running red lights (see Figure 2).



Figure 20: Hazardous Road Conditions. Top Left: The driverless car stops as a pedestrian walks across the street. Top Right: The driverless car navigates heavy traffic in the busy downtown. Bottom Left: Traffic on the highway abruptly slows to a crawl as the police car activates its sirens. Bottom Right: The driverless car brakes abruptly as another car runs a red light.

In Scenario 1, the vehicle begins parked in a parking lot in connected vehicle mode (i.e. manual driving). The user drives the car around the parking lot to familiarize themselves with the driving profile of the car and the iconography of the virtual dashboard and center console. Once the user is ready, they exit the parking lot and the vehicle switches to autonomous mode. The car proceeds through a simulated downtown where the autonomous vehicle must avoid hazards such as vehicles running red-lights and pedestrians jaywalking across the busy city streets (see Figure 2). The car then turns onto the highway.

Once on the highway, the vehicle plays a video on the in-dash media player (Figure 1) which distracts the user. During the video, the car must make a sudden stop as traffic slows for an emergency vehicle. Warning tones play as the brakes of the vehicle screech the car to a safe speed. Once traffic clears, the car exits the scenario. In the future, responses to surprises such as a sudden stop will measure situation awareness in the pilot of the vehicle.

The second scenario is a practical mirror of the first. The vehicle begins on a long segment of highway and makes several lane changes at high speed as it approaches the downtown exit. During the maneuvers, a video plays through the in-dash media player, and a sudden stop occurs as in Scenario 1. Once the vehicle exits the highway, it encounters similar hazards in the downtown area. As the vehicle exits downtown (towards the parking lot from Scenario 1), the scenario ends. Scenario two serves to highlight the simulator's highway driving capabilities and messaging capability, as well as the ability to use the simulated city to test a number of routes, destinations, and hazards.

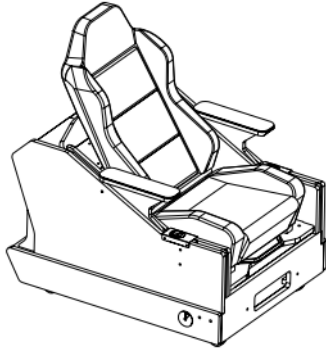
2 Simulator Assembly

The following section describes the individual components making up the physical hardware associated with the simulator and how to assemble and disassemble for transportation.

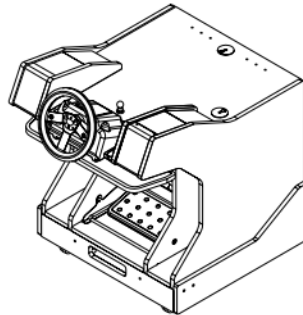
2.1 Parts

Below is a list of all major parts/components needed in the simulator's assembly.

Seat Cabinet



Monitor Cabinet



TV



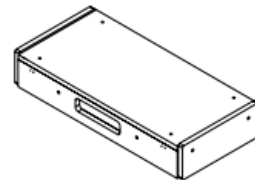
Monitor



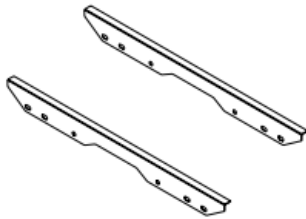
PC



Foot Box



Cabinet Connector Brackets



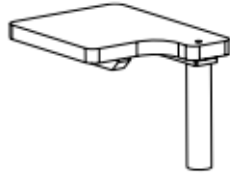
TV Stand



TV Support Brackets



Flight Control Arm



Cables



The mounting hardware required for assembly.

- 4x M6x30 Screws (PH #1)
- 4x M8x30 Screws (PH #1)
- 2x Square Spacers
- 8x Cap Screws (3/16" hex)
- 8x Nuts (7/16" Wrench)
- 12x 1/4-20 x 1-3/4" Socket Cap Screws

2.2 Tools

A list of the tools required for assembly is listed below.

- Philips #1 Screwdriver
- Philips #2 Screwdriver
- 5mm Allen Key/Hex Wrench
- 3/16" Allen Key/Hex Wrench
- 1/2" (Socket)Wrench
- 7/16" (Socket)Wrench

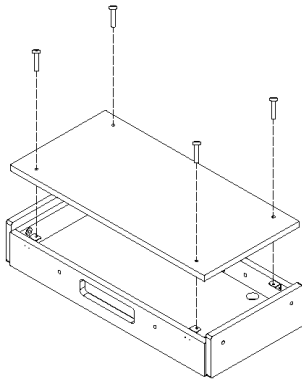
2.3 Assembly Instructions

In the subsequent sections you will find step-by-step instructions on how to assemble all the major components of the simulator into a working unit. Ensure you have all of the appropriate mounting hardware and tools before beginning the process. Follow the four steps outlined in order to guarantee proper assembly.

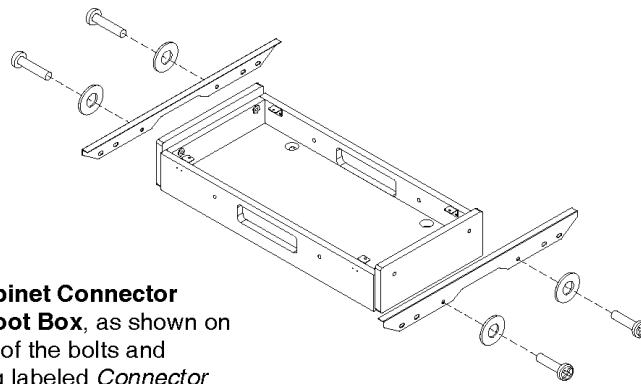
2.3.1 Step 1: Assemble Cabinet

2.3.1.1 Attach the Cabinet Connectors to the Foot Rest Box:

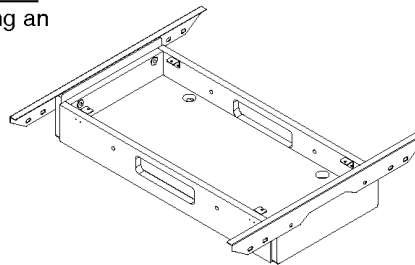
3.1 Connecting the Cabinets



Start by removing the lid of the **Foot Box**. Remove the four Phillips head screws to free the lid, and it will pull straight up. Do not close the **Foot Box** until you have finished setting up and connected all of the cables.



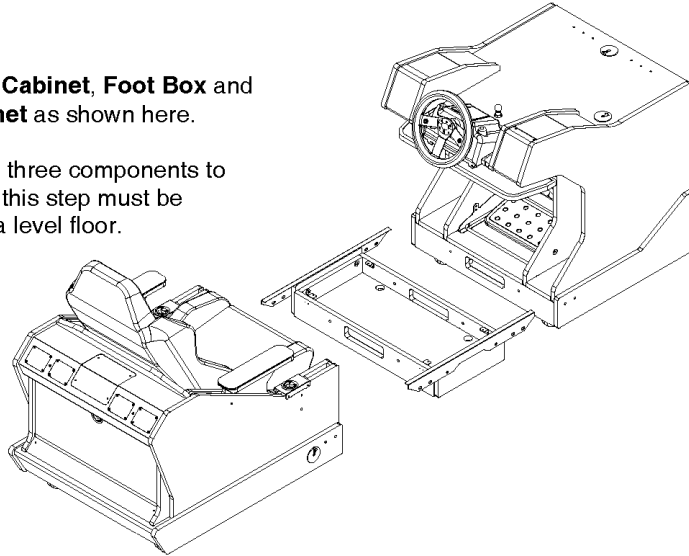
Attach the two **Cabinet Connector Brackets** to the **Foot Box**, as shown on the right. Use four of the bolts and washers in the bag labeled Connector Bracket Hardware and tighten using an Allen wrench.



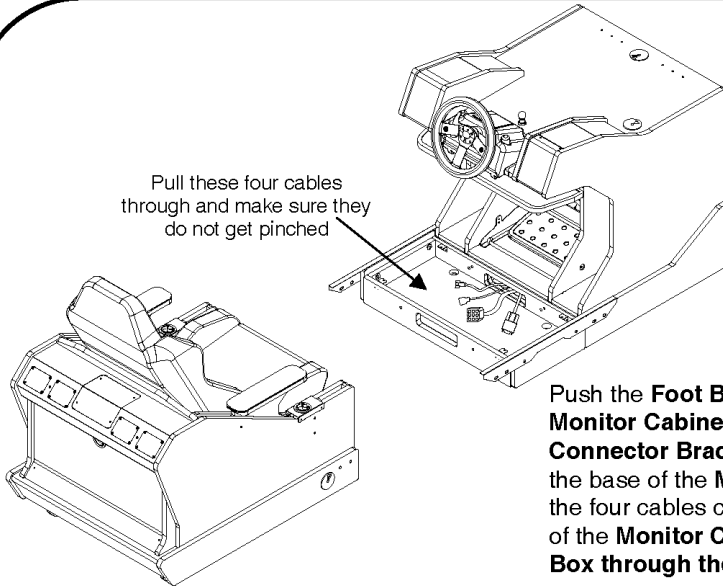
2.3.1.2 Connect Cabinets Together:

Align the **Seat Cabinet**, **Foot Box** and **Monitor Cabinet** as shown here.

NOTE: For the three components to align properly, this step must be performed on a level floor.



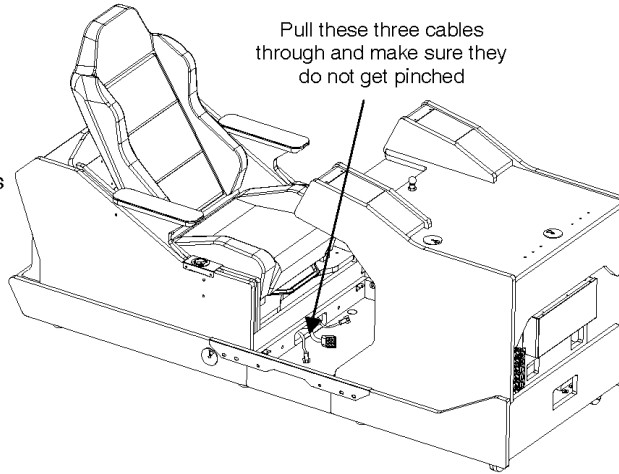
Pull these four cables through and make sure they do not get pinched



Push the **Foot Box** up against the **Monitor Cabinet** so the **Cabinet Connector Brackets** are resting on the base of the **Monitor Cabinet**. Pull the four cables coming from the bottom of the **Monitor Cabinet** into the **Foot Box** through the rectangular hole.

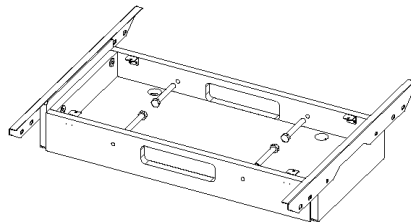
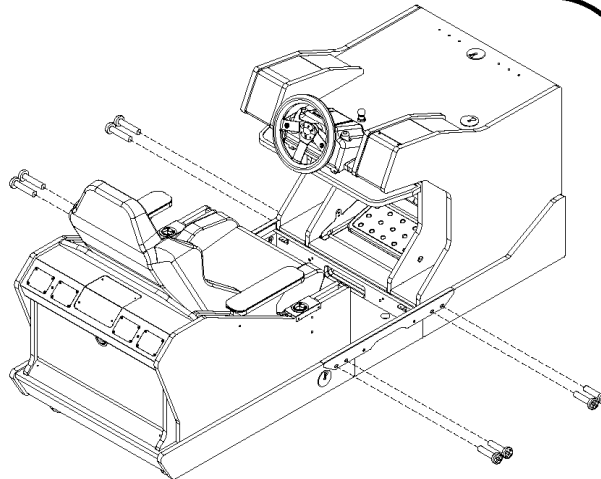
2.3.1.3 Bolt Cabinets Together:

Push the **Seat Cabinet** up to the **Foot Box** as shown, so that the **Connector Brackets** are resting on the bases of the **Monitor Cabinet** and **Seat Cabinet**. Pull the three cables coming from the bottom of the **Seat Cabinet** into the **Foot Box** through the rectangular hole.



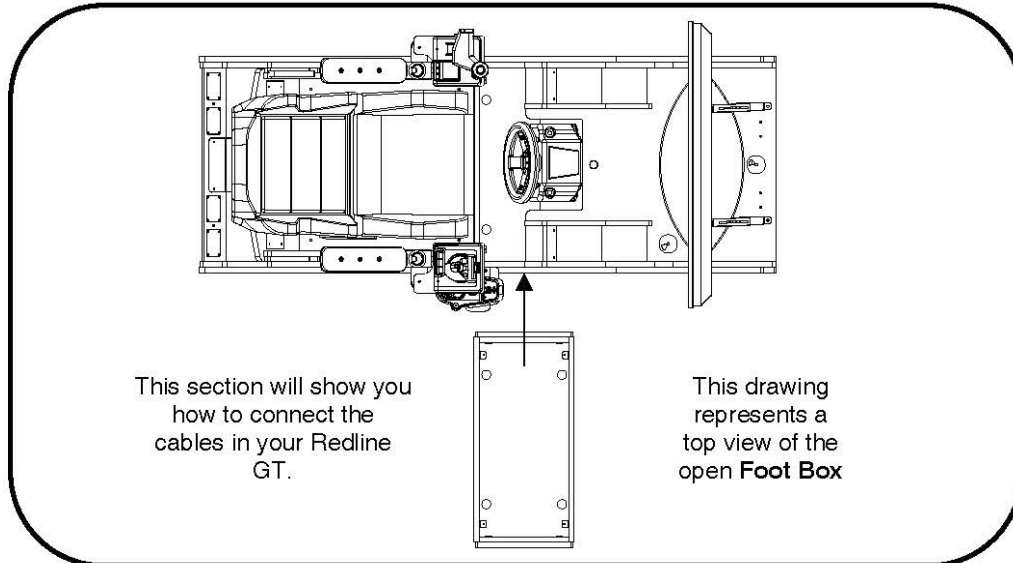
Use the eight remaining bolts and washers in the bag labeled **Connector Bracket Hardware** to connect the **Foot Box** to the other two cabinets through the **Connector Brackets**.

Only tighten the bolts with your hands. Do not tighten with an Allen wrench until after the next step.



Use the four bolts and washers in the bag labeled **Foot Box Connect Hardware** to connect the **Foot Box** to the **Monitor Cabinet** and **Seat Cabinet** as shown to the left. Tighten the bolts with a 7/16" wrench. Note that this image does not show the **Monitor Cabinet** or **Seat Cabinet** so that you can easily see where the bolts attach. After these bolts are tightened, tighten the outside bolts with an Allen wrench.

3.6 Connecting Foot Box Cables



Connect the four sets of cables that you pulled into the **Foot Box** when you connected the cabinets. First, connect the cables with the 9-pin connectors, marked A. This cable powers the taillights and speakers in the **Seat Cabinet**.

Next, connect cables B, C and D to the matching cables, which are coming up through the holes in the bottom of the **Foot Box**. These cables power the strip lighting that runs underneath Redline GT.

Connect the **Shifter** cable that you pulled through earlier to the shifter extender cable marked E.

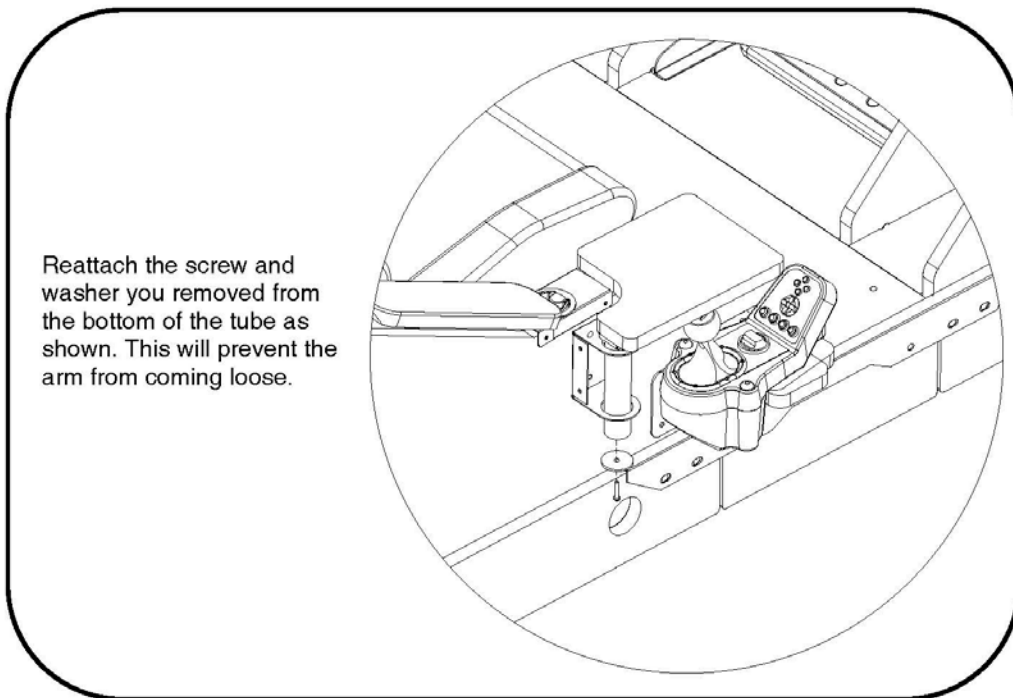
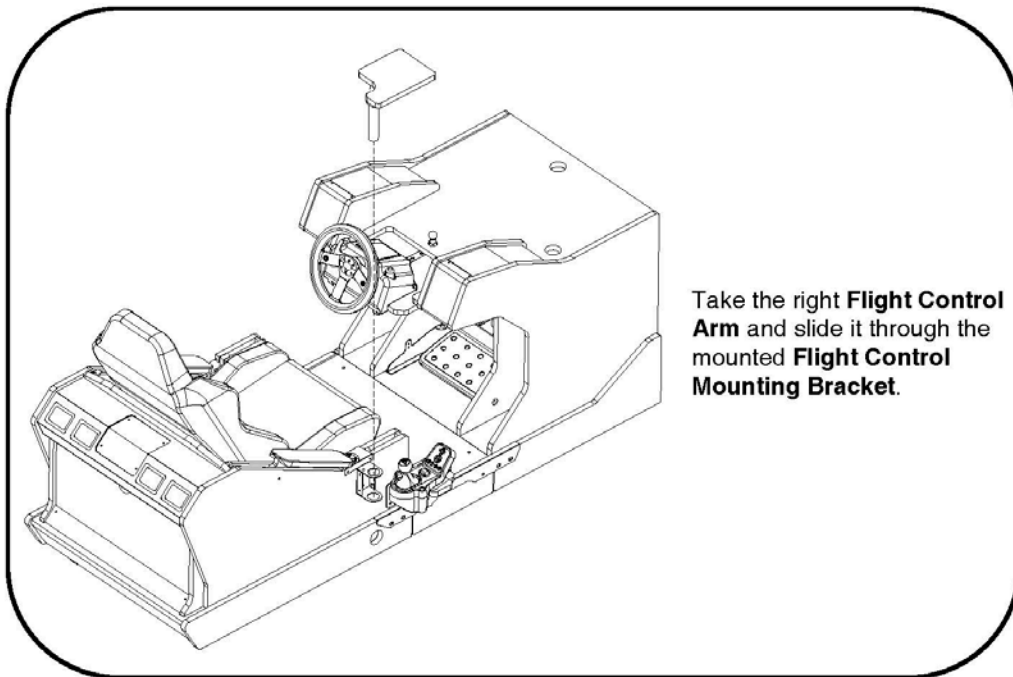
Warning: Make sure to check the labels on the cables before connecting them.

If you are using USB flight sticks, connect the USB cable from the flight sticks to cable F. For information on how to connect flight sticks, see page 14.

If you are not using USB flight sticks, cable F is unused.

When you have finished connecting the cables, replace the Foot Box Lid and secure it with the screws you removed.

2.3.1.5 Attach Right Flight Control Arm (Optional):

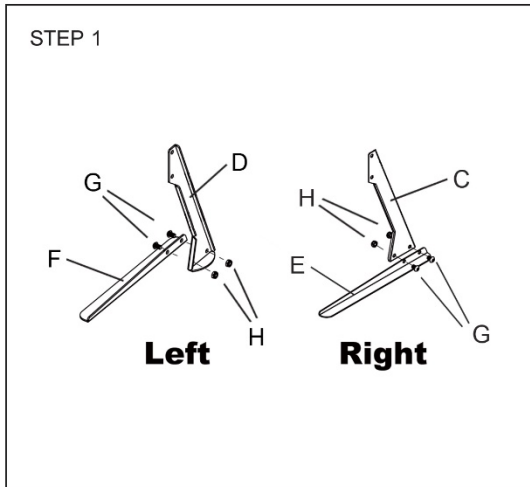


2.3.2 Step 2: Mount TV

2.3.2.1 Attach TV Stand:

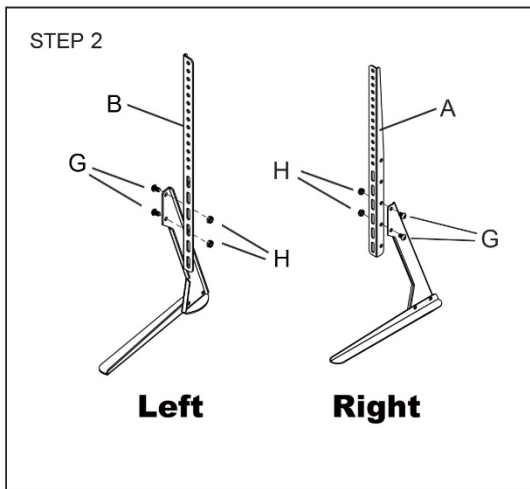
ShopJimmy.com® Stand-3770 TV Stand Instructions

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Step 1:

Attach part (F) with part (D) using screws (G) and nuts (H) for the left stand leg. Attach part (E) with part (C) using screws (G) and nuts (H) for the right stand leg.



Step 2:

Attach the completed left stand leg with the bracket (B) using screws (G) and nuts (H). Attach the completed right stand leg with the bracket (A) using screws (G) and nuts (H).

.....

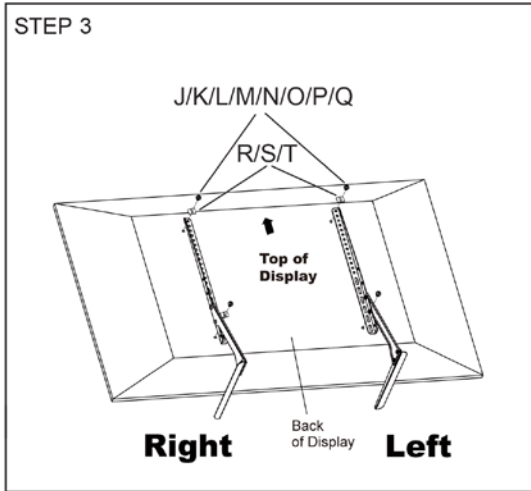
Safety Disclaimer

This TV stand is designed for most flat-screen TVs between 37" and 70" (measure screen diagonally to verify your TV size). Your TV must weigh less than 110 pounds (50 kg). Placing a TV that is too large or heavy on this TV stand is hazardous and severe injury or death can occur if the TV and furniture combination is unstable. Never allow children to climb on or play with the TV set-up. The manufacturer is not liable for damage or injury caused by incorrect mounting, assembly or use.

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ShopJimmy.com Stand-3770 TV Stand Instructions

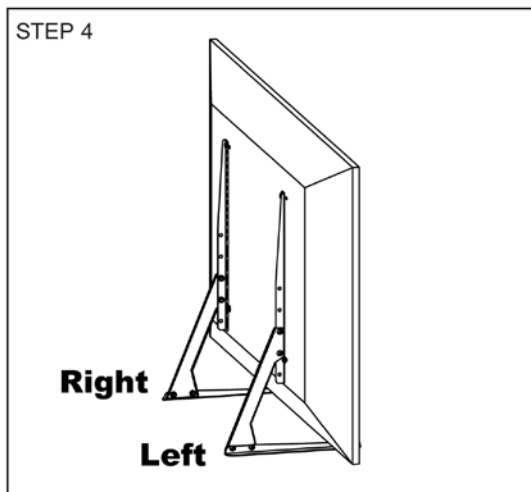
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Step 3:

Carefully lay the TV face down on a flat, non-abrasive surface using padding underneath the TV to protect the screen.

Attach the TV stand to the back of the TV using the appropriate screw size (J/K/L/M/N/O/P/Q) and spacer (if needed, R/S/T) for the TV. Make sure to fully tighten each screw with your wrench!



Step 4:

You're all set! Enjoy your new TV stand!

.....

Safety Disclaimer

This TV stand is designed for most flat-screen TVs between 37" and 70" (measure screen diagonally to verify your TV size). Your TV must weigh less than 110 pounds (50 kg). Placing a TV that is too large or heavy on this TV stand is hazardous and severe injury or death can occur if the TV and furniture combination is unstable. Never allow children to climb on or play with the TV set-up. The manufacturer is not liable for damage or injury caused by incorrect mounting, assembly or use.

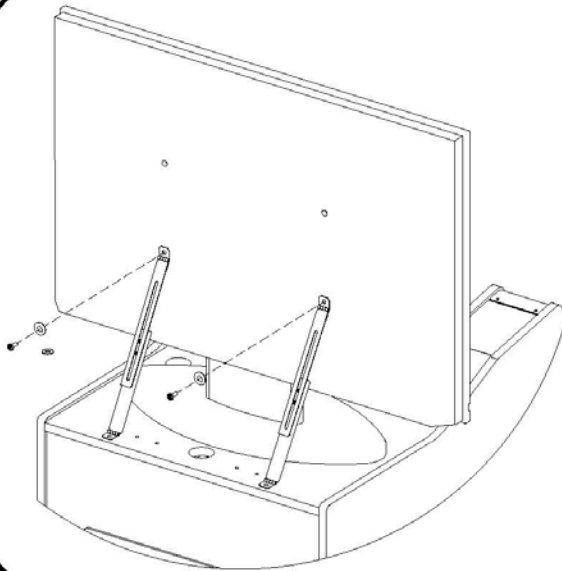
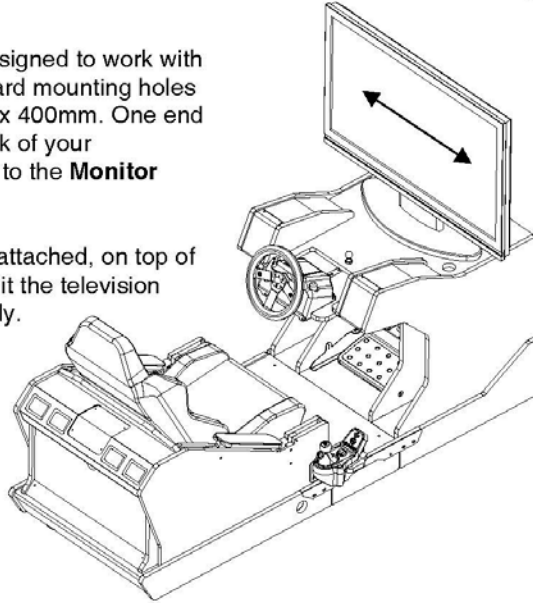
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2.3.2.2 Secure TV Support Brackets to Cabinet (Over top of Stand):

3.5 Television Support Brackets

The **TV Support Brackets** are designed to work with televisions that have VESA standard mounting holes from 200mm x 200mm to 400mm x 400mm. One end of the bracket connects to the back of your television, and the other connects to the **Monitor Cabinet**.

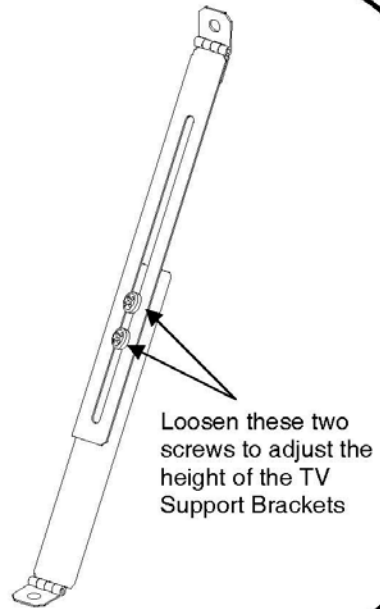
Set your television, with the base attached, on top of the **Monitor Cabinet**. Try to keep it the television approximately centered horizontally.



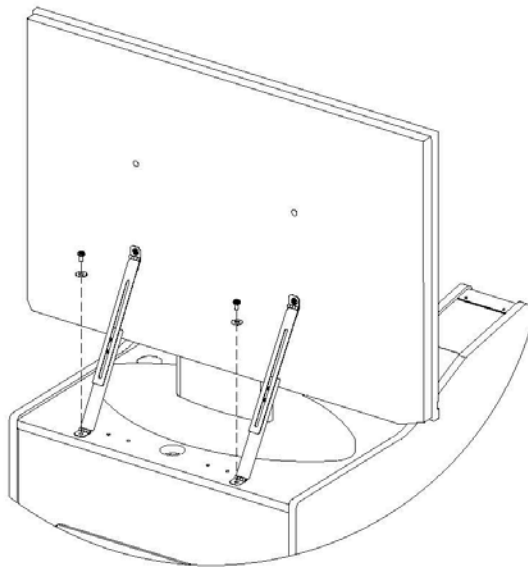
Find the bag labeled TV Bracket Hardware, which contains four different types of screws and some washers. The three sets that look similar are different sizes used to connect wall-mounting brackets to different televisions. Usually, the larger the television, the larger the screw used. Find the set of screws that fit the mounting holes on the back of your television.

Attach the **TV Support Brackets** to the lower set of mounting holes on your television with the slotted piece at the top. For the smaller screws, you will need to use the washers to keep the screw from sliding through the bracket.

You will now need to adjust the length of the **TV Support Brackets** so that the bottom mounting hole lines up with the pilot holes behind the television. Loosen, but do not remove, the two screws in the center of the bracket.



Loosen these two screws to adjust the height of the TV Support Brackets



When you have adjusted the bracket to the correct length and aligned it with the pilot hole in the cabinet, use the two longest screws and two washers in the TV Bracket Hardware bag to connect the bracket to the cabinet. Tighten the screws that were loosened to adjust the length of the bracket.

2.3.2.3 Completed TV Mount:

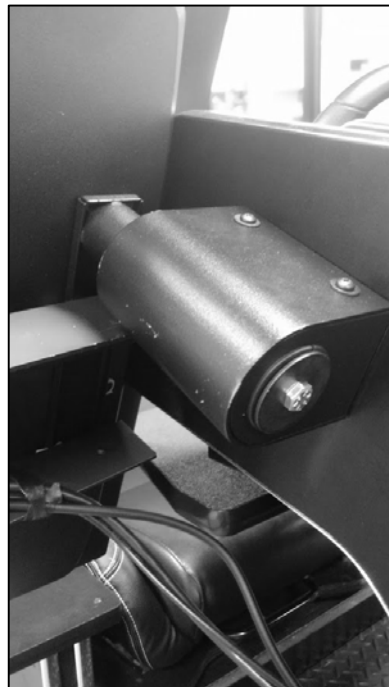


2.3.3 Step 3: Mount Touchscreen Monitor

2.3.3.1 Slide Monitor Assembly into Holder:



2.3.3.2 Secure Monitor With Screw and Socket Wrench:



2.3.4 Step 4: Setup PC

Connect display cables from the PC to the TV and monitor. Subsequently connect all other needed accessories to the PC (Steering wheel, mouse, keyboard, etc.). Connect required power to the TV, Monitor, PC, and cabinet power supply. When ready to use power on the PC using the power button on the front of the case. Use the switch on the front of the cabinet to turn on the speakers and lights. The simulator should now be completely assembled and working.

2.4 Disassembly Instructions

The instructions outlined in section 2.3 should be followed in reverse order to break the simulator down for easy transport or for general disassembly. Start with Step 4 and work backwards until finishing Step 1 in order to completely disassemble the simulator.

3 Simulator Execution

3.1 Powering on the Simulator

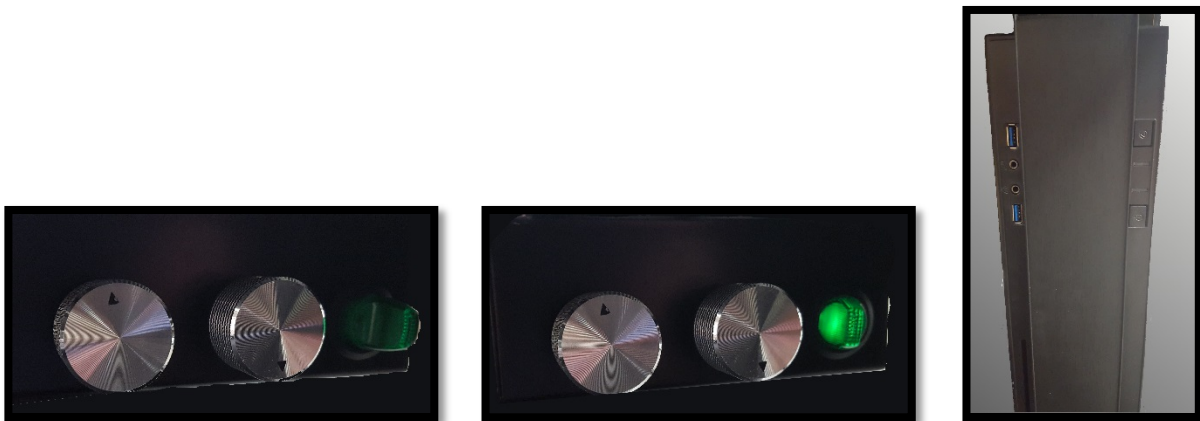


Figure 21: The power switch and pc are located under the right front speaker, near the bottom of the center console. *Left:* The power switch in the "Off" position. *Center:* The power switch in the "On" position. *Right:* The PC which powers the simulation. The power button on the PC is the bottom right button.

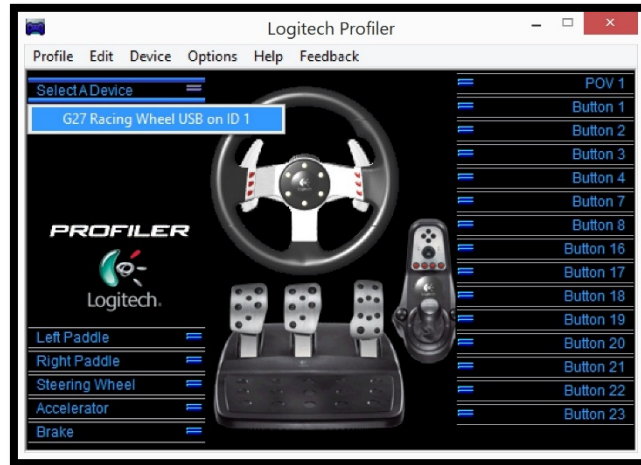
To power on the simulator, first make sure the power strip in the rear is plugged in. The total power usage of the simulator is low enough to occupy a standard outlet. Next, ensure the green toggle switch under the right speaker is in the "On" position. Press the power button on the PC to power it up (Figure 3).

3.1.1 PC Login

Once the computer has booted, login to windows using your chosen login information. The default simulator is accessed with the user FDOT and password FDOTfdot99.

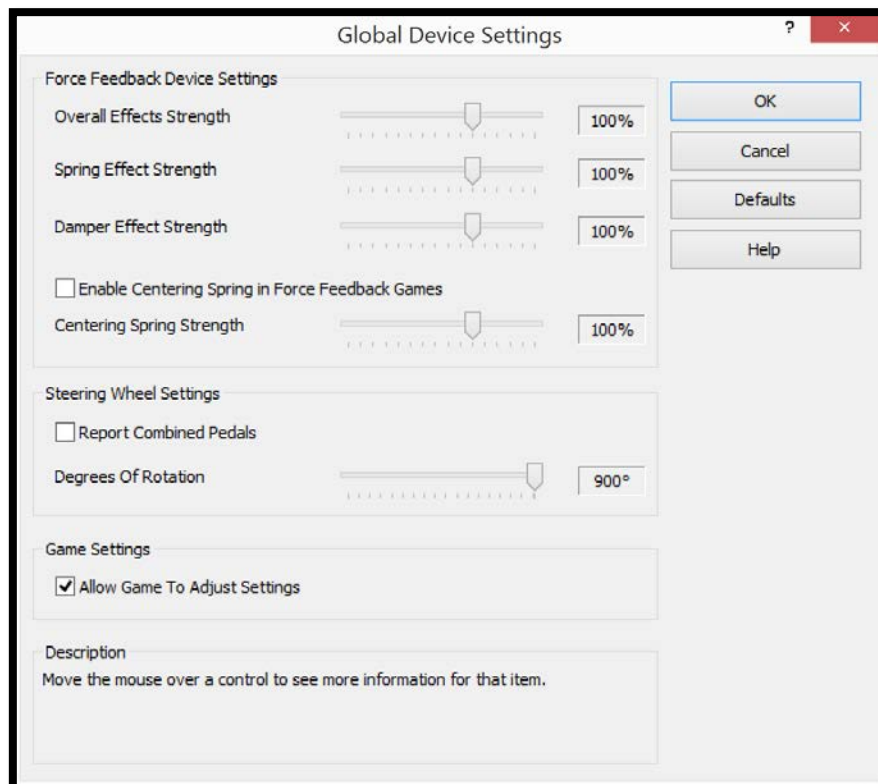
3.2 Setting up the Logitech G27 Steering Wheel

The G27 Steering wheel needs to be properly configured to work correctly with the simulator. To properly configure the steering wheel, first launch the Logitech Gaming Software from the



Windows Start Menu, and then hover over 'Select A Device', and click on the option for 'G27 Racing Wheel USB'.

Then select options, and click Global Device Settings. From the new window, set the 'Degrees of Rotation' option to 900°.



3.3 Launching the Simulation



Figure 22: Launching the Application. From Left. *First:* The Center Panel icon launches the navigation and entertainment interface. *Second:* The DriverlessCar Icon launches the DCVS. *Third:* The Loading screen for the simulator. *Fourth:* The main menu of the simulator offers three options: Play Scenario 1, Play Scenario 2, or Exit the program.

Once you login, click on the FDOT console display icon on the desktop. (Figure 4). This will launch the center console application on the secondary display. Once the console application has launched. Double click the FDOT DCVS icon on the desktop. The loading screen will appear and then the main menu of the application. From here, you can click to play Scenario 1, play Scenario 2, change scenario options, or exit the program (see Figure 4).

Selecting Options will open the following window:



Figure 23: The Options Menu

Here, you can click to toggle the Looping On and Wheel On settings. Settings Looping to On will restart the selected Scenario at the of the scene, while setting it to off will return the user to the Main Menu at the end of the scene. Setting Wheel to On will enable the Steering Wheel Force Feedback, while setting it to off will not turn off input, but will turn off Force Feedback. Force feedback will cause the wheel to follow the cars movements in autonomous mode, and will center itself in manual mode.

3.4 Running a Scenario

To run a scenario, click on its title in the main menu. The screen will fade to black and fade back in once the scenario is ready. In Scenario 1, the user (pilot) will have control of the vehicle until they leave the parking lot. The vehicle will then drive through the city to the highway. Scenario 2 is an entirely automated scenario. The vehicle begins on the highway and drives towards the parking lot.

3.4.1 The Pause Menu

While a scenario is running, pressing the escape key (ESC) will open the pause menu (Figure 6). From the pause menu, one can choose to resume the current scenario, restart the current scenario or return to the main menu. The last option controls what will happen when the scenario ends. If the option reads "Looping On", the scenario will restart when the end is reached. If the option reads "Looping off" the simulator will return to the main menu once the scenario is complete.

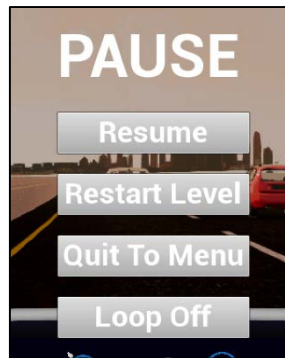


Figure 24: The Pause Menu Screen.

3.5 The Center Console Display

The center console display (Figure 7) provides several areas of interaction. The navigation screen area can be zoomed by "pinching" the screen with two fingers or clicking on either of the magnifying glass icons. The map can be locked or unlocked from the car by clicking the lock button. The web-browser is also interactive. Users may click on links to load different pages (internet connection required). Users can also interact with the climate controls, however these do not control any aspect of the surrounding climate.

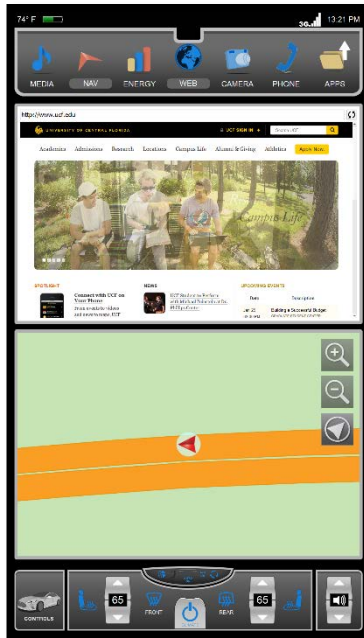


Figure 25: Center Console Display

3.5.1 Exiting the Center Console display

Clicking on the Controls icon in the bottom left corner of the center console screen will open the Configuration window. To exit the center console, click the "Exit Application" icon in this menu.

3.5.2 Data Logging & Script Execution

From the controls panel, the Participant Id and Group Id can be set. Each unique Participant Id and Group Id creates a new folder to which the center console application logs data for the entire simulation. Log data includes the location and orientation of the player and other vehicles, changes to the pedals, steering wheel, or button states, and simulation events.

To begin data logging and execution of simulation scripts click the ‘Start Task’ button from the “LOGGING” tab. This will also launch scripts to play movies and other display events during loaded scenarios. Running the task ensures that the video is played when the player reaches the appropriate locations in the scene. Starting the task can be performed prior to starting a scenario from the main PC screen of the 3D simulation.

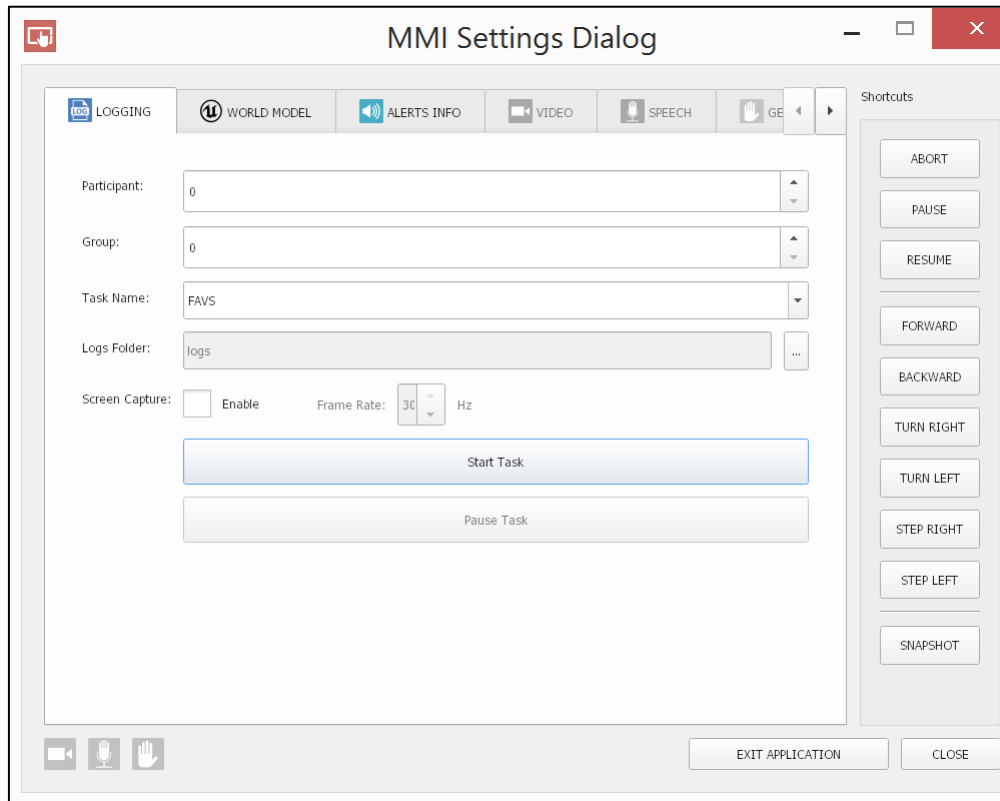


Figure 26: Center Console Configuration Dialog.

4 Troubleshooting

4.1 The steering wheel does not turn / The car does not respond to steering

The most common cause of this problem is a timeout in the steering wheel. Restart the simulator application. If this does not solve the problem, restart the computer. During a system reboot, the steering wheel should spin several times to calibrate its range of motion. If this does not occur, check the USB cable between the steering wheel and PC to make sure it is connected and ensure the steering wheel's power cable is plugged into the rear power strip.

4.2 The vehicle icon does not appear on the center console.

In some cases, the simulator will stop providing data to the navigation screen. Restart both applications.

4.3 The simulator is running slowly

Over long running times, the performance of any application is prone to degradation. If you find the simulator is running slowly, restart both the simulator application and the center console. Also, consider restarting the PC.

4.4 The car has experienced a traffic accident and cannot be moved

Restart the current scene by accessing the pause menu (ESC) and choosing "Restart Scenario".

5 Appendix 1: Simulator Hardware

Below is a List of the hardware used in the FDOT-DCVS

| | |
|---|---|
| Chicago Gaming Redline GT Gaming Cabinet: | A commercial arcade cabinet which serves as the base of the simulator. Includes steering-wheel and pedals |
| ViewSonic TD2220 Touch Monitor: | 22" touch monitor which serves as the center console screen |
| Samsung UN55JU6700 Curved 55-Inch 4K Ultra HD Smart LED TV: | 55" Curved Flat-screen TV used as the primary display for the simulator |
| Custom-Built PC: | A custom PC featuring an Intel I7 Quad-core 4GHz processor, an NVIDIA GTX970 graphics card with 4 gigabytes on-board memory, 16 gigabytes of DDR3 1600 RAM, and a Samsung 850 EVO 500 GB SSD hard-drive |
| Microsoft Wireless All-In-One Media Keyboard: | Wireless media keyboard for experimental control and convenient stowage during experimentation |
| Various Cables: | 1 HDMI cable, 2 USB Male-to-female extension cables, 3 standard 3-conductor PC power cables |

Appendix G Task 4 Report

Task 4: AV Experimentation Roadmap

University of Central Florida - Institute for Simulation and Training

1. Background

The purpose of this task was to identify key challenges associated with Automated Vehicle (AV) displays for design of empirical research using the Connected and Automated Vehicle (CAV) Simulation developed in Tasks 1 through 3 of this effort. Results from this task will pave the road to future research efforts into AV technologies. Furthermore, for the purposes here, AV technologies refers to both Connected Vehicles (CV) and vehicles with build in automation (e.g. automatic braking).

2. Method

Discussions between FDOT and UCF personnel, meetings at outreach events, and a review of the literature were performed to identify AV scenarios and capabilities to evaluate a drivers understanding of status displays, emergency messages, and trust in AV technologies. Specific measures of interest for AV technologies included a performance such as a driver's ability to accurately interpret AV messages, reduction of collisions, and subjective measures as provided through workload, usability, and trust in automation. UCF then identified a roadmap consisting of three consecutive studies to drive creation of protocols, data analysis plans, and publications for human-in-the-loop studies leveraging the CAV Simulation developed in Tasks 1-3.

The following section describes an overview of findings from the literature review of AV technologies conducted. A complete matrix of documents reviewed is located in Appendix 1 which includes details about the research studies conducted in each article. A full list of article abstracts and their corresponding citations is located in Appendix 2. The purpose of this section is to identify areas of research yet to be fully investigated, providing opportunities for new studies that will best advance our understanding of new AV messages.

3. Review of the Literature

Overall, the literature revealed a number of connected vehicle studies incorporating a variety of different messages, with in-vehicle alerts ranging from email and text to intersection violation warnings (e.g. vehicle running stop sign). The National Highway Traffic Safety Administration (NHTSA) has identified several new messages CVs could make available including Intersection Movement Assist, Left Turn Assist, Emergency Electronic Brake Light, Forward Collision Warning, Blind Spot Warning/Lane Change Warning, and Do-Not-Pass Warning (U.S. Department of Transportation, 2014). Of all identified messages, Forward Collision Warnings (FCW) were the most commonly studied. Within this topic area, researchers studied effects on driver behavior, a driver's engagement in a secondary task, and older and younger drivers' responses to FCW systems.

Koustanai (2012) believed that drivers could more effectively use and develop trust in a FCW system with proper training and exposure. To test these hypotheses, their team executed a simulation-based study consisting of 28 participants some of which received hands on training with the FCW systems, some participants only read the FCW manual, and the remaining participants had no familiarity with the system. The results showed that drivers with hands on training demonstrated more effective interactions, had no collisions, better reactions in most situations, and increased trust (Koustanai, Delhomme, & Mas, 2012).

Muhrer et al. (2012) conducted a laboratory study regarding driving and gaze behavior while using a FCW and FCW+ (FCW with autonomous braking) system while performing a secondary task. A total of 30 participants ranging in age from 30-40 years old received training on how to use the FCW+ system. The Surrogate Reference Task (SuRT), (Mattes, 2003), acted as the secondary task, and was used to examine visual attention allocation; however, drivers were told to only perform the secondary task when they felt safe to do so. In this experiment, a substantial number of accidents occurred in critical situations without FCW+, but no accidents occurred in critical situations during the use of FCW+. Researchers also discovered that driving with the FCW system did not lead to more engagement in the secondary task. Therefore, a FCW or a FCW+ system could help reduce countless vehicle accidents and not cause driver distractions.

A study conducted by Cotte et al. (2001) was one of the few studies that researched the impact of AV technologies on elderly drivers. Researchers had 62 participants ranging in age from 30-40 and 65 to 81 years old. Using a driving simulator, participants were instructed to drive 50 MPH with a focus on avoiding collisions. Participants were told that the warning system was not always accurate, and auditory warnings were delivered if they drove too fast, too slow, or were at risk of a forward collision. If drivers drove too fast or too slow a female's voice reminded them to drive at least 50 MPH. If drivers drove over 57 MPH a police siren went off. The collision warning was a male voice that said, "Brake, brake, brake, brake." The results of the study determined that overall there were no differences between age groups. Researchers did however notice a significant effect when comparing drivers who did and did not receive the warnings. Drivers that received the warning drove much slower than drivers who did not receive a warning.

In general, a common theme across all studies reviewed was to test different modalities for message delivery. Three modalities are available to alert drivers of safety issues – auditory, visual, and tactile. However, there is no specific research that shows whether one modality (or combination thereof) is more effective in preventing an accident, nor is the implementation format within a modality consistent within studies. This is clearly shown in previously described study of Cotte et al. (2001) which employed voiced auditory messages (e.g. "slow down") and cues (e.g. police siren). Furthermore, trust is a common concern reported by both researchers and drivers. For example, researchers have tried increasing the level of trust in AV technologies by either giving drivers prior training with the technology (Koustanai, Delhomme, & Mas, 2012) or allowing drivers to use technology that shares in their driving goals. An example study testing shared driving goals was Verberne et al. (2012), where different Adaptive Cruise Control (ACC) either matched the drivers goals (i.e. energy efficiency, comfort, speed, and safety) or did not, and how that description affected trust. Overall, researchers have conducted numerous studies over the last ten to fifteen years to answer many questions regarding AV technologies; however, with a

large focus in recent years on ACC and FCW, there is still a significant amount of research yet to be done to support more recently identified AV messages.

With AV research focused primarily on FCW, a significant lack of research on connected vehicles involving older adults was revealed. The majority of the studies conducted with AVs had a maximum participant age range of approximately fifty years old. There is not enough research done to determine how older drivers would perceive or react to a AV messages. Therefore, in addition to growing research on different types of messages, much of the research conducted with AV technology should be expanded to elderly drivers. This factor is particularly needed since research shows that AV research with collision warnings are more likely to benefit older drivers because it helps them compensate for age-related sensory and cognitive changes (Cotte, Meyer, & Coughlin, 2001).

Beyond age related research, an area that requires significant focus is modality. Many researchers conducted studies primarily with audio messages (either spoken messages or cues and sounds); however, audio messages may be ineffective if there is a lot of noise in the vehicle or if the driver is driving with their windows down (Singer, Lerner, Walrath, & Gill, 2015). Continued research is needed to determine which of the three modalities would be best suited to alert drivers of a variety of safety messages. For example, do drivers respond better to an audio message versus a tactile message, or both? Perhaps, depending on the urgency of the safety messages, drivers should receive all three modality alerts.

In addition to researching effects of older drivers and modalities, with research focused primarily on FCW, lateral drift, and lane change/merge crash warnings, it can be said that there are a number of safety messages lacking basic research warnings (Sayer, et al., 2011; Fitch, Bowman, & Llaneras, 2014). Research to date has not focused on alerts for impending/future events including emergency vehicles, wrong way driving, intersection movement assist, and intersection violation warning, especially across different age groups. Moreover, with inclusion of more AV warnings and messages we must be cognizant of overloading drivers. An abundance of research has shown that increased volume and complexity of information results in adverse impacts on decision making performance (Iselin, 1998; Miller, 1956; Streufert S. , 1970; Streufert S. C., 1973) and threaten the benefits of in-vehicle support systems (Carsten & Nilsson, 2001; ECMT, 1995; Rumar, 1990). Table 1 below lists AV messages most likely to benefit from additional research as described, with each safety warning having the potential to significantly impact the number of vehicle accidents and fatalities that occur every year.

Table 4. Table of AV messages for future research.

| MESSAGE | DESCRIPTION |
|--------------------------------|--|
| Curve Speed Warning | Alerts driver to slow down for upcoming turn or changes in road |
| Intersection Movement Assist | Alerts driver that it is unsafe to enter the intersection due to conflicting traffic |
| Intersection Violation Warning | Alerts driver they are about to commit a violation at an intersection |
| Pedestrian/Bicyclist Presence | Alerts driver to a pedestrian or bicyclist presence |

| | |
|-------------------|---|
| Wrong-way Driving | Alert driver that someone is driving the wrong-way down a road/coming right at them |
|-------------------|---|

4. Future Research

As technology has become more sophisticated, the car industry is becoming increasingly interested in developing connected and autonomous vehicles. Compared to traditional driving, use of AV technology will involve human factors issues, such as losing situation awareness, being overloaded or distracted by AV safety messages, and trust issues to the system. Based on the information gathered in the literature review, most previous work only focused on basic messages in traditional modalities. Also, age effects of interacting with AV technology was not considered. Therefore, future work should be done in an effort to close those research gaps. To help fill gaps identified, the following series of studies are recommended.

Study 1

This study will investigate individual differences (e.g. age, gender) in the impact of AV technology on driver performance compared to a baseline (no AV messages). Participants in at age groups, (i.e. young drivers, adult drivers, and senior drivers), will be recruited to understand the effects of age when interacting with and without AV technology. Specifically, we will apply at least two types of AV safety messages, such as intersection violation warning and emergency vehicle alert. This study will test how much those AV technology could facilitate driver in different ages in terms of improving driving performance, enhancing traffic efficiency, and preventing accidents.

Study 2

This study will focus on the modalities of how the connected vehicle's safety messages are delivered. Traditionally, on board messages are delivered either visually or with audio technology. This study will test other modalities, such as tactile messages, to determine if other modalities are more beneficial and effective over traditional ones. This study will also compare different age groups similar to Study 1, while attempting to improve upon/augment AV safety messages previously investigated.

Study 3

This study will test the impact of additional AV safety messages on driving performance. Additional types of AV safety messages may include collision warnings, lane departure, and traffic conditions in combination with AV messages investigated in Study 1 and 2. Since too much information or inappropriate messages may distract or overload the drivers, inappropriate safety messages may be detrimental to driving performance. Experimentation is needed to understand the influence of multiple AV safety messages in different scenarios, such as highway driving and local driving. Study 3 will test a variety of AV safety message in highway and local driving scenarios using at least a college study population.

5. Conclusion

In summary, while AV research has advanced significantly over the last ten years, there are still a lot of unanswered questions and gaps in the research. Moreover, additional efforts are needed to evaluate best practices for delivery of this information. During the last 15 years, a rapid expansion

in the use of robotics for military applications resulted in vendors creating different interfaces for control of each platform. This led to different training requirements for use of each robot, single-use instrumentation and control devices, and increased costs. Addressing this and other interoperability challenges lead to the creation of new standards to ease access, training, and integration of aerial and ground vehicles such as the Joint Architecture for Unmanned Systems (JAUS), (Wikipedia, 2015; Barber, Davis, Nicholson, Chen, & Finkelstein, 2008). In order to prevent similarly disparate methods of AV signaling across manufacturers and vehicle types, research is needed identify best practices and guidelines that meet safety requirements for all drivers of different generations. Our intention is to close a portion of that research gap by conducting studies on a few key questions that have not been addressed such as the effect AV technology has on older drivers and the importance of communicating safety messages to drivers and the best modality/modalities to be used for that purpose.

6. Bibliography

- Barber, D., Davis, L., Nicholson, D., Chen, J. Y., & Finkelstein, N. (2008). The Mixed-Initiative Experimental Testbed for Collaborative Human Robot Interactions. *26th Army Science Conference*, (pp. 483-489). Orlando, FL USA.
- Carsten, O., & Nilsson, L. (2001). Safety assessment of driver assistance systems. *European Journal of Transportation and Infrastructure Research*, *1*, 225-224.
- Cotte, N., Meyer, J., & Coughlin, J. F. (2001). Older and Younger Drivers' Reliance on Collision Warning Systems. *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting* (pp. 277-280). Minneapolis: HFES.
- ECMT. (1995). Statement of principles of good practice concerning the ergonomics and safety of in-vehicle information systems. *In New Information technologies in the Road Transport Sector: Policy Issues, Ergonomics and Safety* (pp. 35-42). The European Conference of Ministers of Transport.
- Fitch, G. M., Bowman, D. S., & Llaneras, E. (2014). Using Wizard of Oz Technique to Evaluate Connected Vehicles: Distracted Driver Performance to Multiple Alerts in a Multiple-Conflict Scenario. *Proceedings of the Transportation Research Board 93rd*. Washington DC: Transportation Research Board.
- Iselin, E. R. (1998). The effects of information load and information diversity on decision quality in structured decision task. *Accounting Organizations and Society*, *13*(2), 147-164.
- Koustanai, A., Delhomme, P., & Mas, A. (2012, October). Simulator Training with a Forward Collision Warning System: Effects on Driver-System Interactions and Driver Trust. *Human Factors*, *54*(5), 709-721.
- Mattes, S. (2003). The lane change task as a tool for driver distraction. *Quality of Work and Products in Enterprises of the Future*, 57-60.
- Miller, G. A. (1956). The magic number of seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, *63*, 81-97.
- Muhrer, E., Reinprecht, K., & Vollrath, M. (2012, October). Driving with a Partially Autonomous Forward Collision Warning System: How do Drivers React? *Human Factors*, *54*(5), 698-708.
- Rumar, K. (1990). The basic driver error: late detection. *Ergonomics*, 1281-1290.
- Sayer, J., LeBlanc, D., Bogard, S., Funkhouser, S., Bao, D., Buonarosa, M. L., & Blankespoor, A. (2011). *Integrated Vehicle-Based Safety Systems Field Operational Test Final Program Report*. Washington D.C.: U.S. Department of Transportation National Highway Traffic Safety Administration.
- Singer, J., Lerner, N., Walrath, J., & Gill, M. (2015). *Warning and Message Perception under Ambient Noise Conditions: On-Road Experiment Report under Crash Warning Interface Metrics 3 Program*. Washington, DC: US Department of Transportation.
- Streffert, S. (1970). Complexity and complex decision making: convergences between differentiation and integration approaches to the prediction of task performance. *Journal of Experimental Social Psychology*, *6*(4), 494-509.

- Streufert, S. C. (1973). Effects of information relevance on decision making in complex environments. *Memory & Cognition*, 1(3), 224-228.
- U.S. Department of Transportation. (2014, 10 14). *V2V Communications Fact Sheet*. Retrieved from Vehicle-to-Vehicle Communications: http://www.safercar.gov/staticfiles/safercar/v2v/V2V_Fact_Sheet_101414_v2a.pdf
- Verberne, F. M., Ham, J., & Midden, C. J. (2012, October). Trust in Smart Systems: Sharing Driving Goals and Giving Information to Increase Trustworthiness and Acceptability of Smart Systems in Cars. *Human Factors*, 54(5), 799-810.
- Wikipedia. (2015, 01 06). *JAUS*. Retrieved from Wikipedia: <https://en.wikipedia.org/wiki/JAUS>

