**Thesis Portfolio**

**An Immersive Driving Simulator with Autonomous Capabilities**
(Technical Report)

**The United States' Administrative Social Responsibility to Combat Climate Change**
(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Mosed Saroor
Spring, 2022

Department of Mechanical Engineering

**Table of Contents**

**Sociotechnical Synthesis**

With society and administrations alike growing evermore worried about the state of our planet concerning climate change and the carbon emissions that have caused it, ideas and potential solutions have arisen amidst the crisis. While there have been successful and rather unsuccessful attempts in installing policies to limit these emissions, one method that has worked on a smaller scale is the development of certain technologies that have been made attractive for reasons pertaining to how environmentally friendly they can be. One such example is the Tesla model, which has taken the vehicle industry by storm since its release in 2008. Arguably the most popular electric vehicle in the market today, consumers continue to make the switch from fuel powered vehicles to electric powered vehicles as they believe they will have to make that switch regardless and find the system to be much more efficient and viable (Voelcker 2021). For our technical project, we have developed a driving simulator that incorporates autonomous features that create an immersive experience for its users. My group has worked to create an attractive and unique product that separates itself from competitors in the market in an attempt to set a foundation or gain interest from able companies that are familiar to this market.

Although my STS research paper pertains more towards government involvement in combating climate change, a big inspiration for our technical work was to create a product that is environmentally friendly. There are many uses for the driving simulator, with the biggest plus being that certain tests of autonomous features and everyday uses of a vehicle can be done safely and efficiently through a computer simulation, which can eliminate the harmful emissions caused by mass uses of these physical vehicles. While creating this driving simulator was time consuming and expensive, we can not expect that every DMV will install them in an effort to host driving exams for learning drivers, but our main goal was to attract big corporations in moving all of their testing to simulators. Autonomy is the future and is becoming more and more evident in newer vehicles every year. A car from 2008 almost certainly lacks autonomous features such as autonomous emergency braking (AEB) and blind spot monitoring (BSM) that many cars today would have. So it was just as important to us in not only creating a working system, but to also keep up with this market so that we can attract the big players in this industry. In doing so, we will move one small step closer in reducing emissions that can be so easily done through the software that is at hand and readily available.

# ME Design II - Driving Simulator Team Final Report

Anne Forrest Butler, Johnny Grant, Chet Kleppin, Andrew Lin, Mosed Saroor, and Casey Welch

University of Virginia

Spring 2022

# 1 Introduction

## 1.1 Relevance

There is no doubt that the integration of autonomy in modern technologies is a rampant trend among most sectors of the world's industries today. Autonomous systems have been implemented in manufacturing to ease the burden of menial and potentially dangerous tasks, in the commercial world to disrupt human-to-human interactions in light of a global pandemic, and most relevantly to this topic, in the automotive industry to free our ever-busy hands and minds while commuting in cars. Surely autonomy is prevalent in a plethora of other fields, but it is in these sectors where ethical dilemmas sprout from underneath every effort at its implementation into technology. As human oversight is disconnected from the functions of these technologies, there arises concern in how they will behave in situations which commonly require the complicated nature of human intuition and decision-making. In general, the dilemma our society faces as autonomy spreads throughout the world is how it will be safely integrated into organizations and human daily life. There are many ways to navigate the process of fostering public trust in autonomous systems, but the particular one of interest in this context is simulated studies. Specifically, virtually simulating autonomous automobiles and how they interact with their environment. Simulation software such as this can allow self-driving vehicle manufacturers to gain insight on how the algorithms their autonomous systems utilize hold up in potential real-world scenarios. While manufacturers can alternatively just test their technology in the real-world, this often incurs undesirable risks and consequences, such as harm to vehicle operators, pedestrians, and other third parties. An autonomous driving simulator would give these companies a platform in which they can safely test and develop their systems. Additionally, simulators can also serve to familiarize consumers with operating autonomous vehicles. As self-driving vehicles become more prevalent throughout the world, it’s important that the common user feels comfortable riding in an autonomous car. Experiencing it first in a simulated environment would be an effective way to ease consumers into familiarity with this technology. With these concerns in mind, we aim to develop an autonomous driving simulator as a valuable resource for self-driving vehicle production and familiarization.

### 1.2 Review of Past Work

Pre-existing research into the development of autonomous driving simulators shows that similar approaches to our problem have been attempted, but none fully address the goals we seek to accomplish. Nonetheless, these serve as valuable examples by which we can guide our own research and development. Each of the referenced studies can be classified into one of two approaches: a primary focus on the user experience and immersivity or a primary focus on external factors and functions, such as simulated traffic or pedestrians. With respect to the first kind of approach, a 2015 study conducted by Baltodano, et. al. documented the development of the Real Roads Autonomous Driving Simulator (RRADS). Their research aimed to gather the overall public attitudes and expectations of how an autonomous vehicle is intended to feel. The data was then used to inform the ongoing development of their simulator, and specifically to maximize the immersivity of their design. Other studies that have sought to address immersivity and user experience include Koo et. al. (2014), which was concerned with user understanding of safety features; Bellem et. al. (2016), which sought to assess whether or not moving-base driving simulators induce a comfortable and realistic sense of motion; and Häuslschmid et. al. (2017), where it was found that indicator displays showing the autonomous algorithm actively processing external data fostered greater user trust. The findings of these studies serve to inform our own development, as we can gauge what consumers seek in a simulated autonomous experience.

Several other studies align more with the second approach we've established, where there's a greater focus on external functions in the simulated environment. In 2017, You et. al. published a paper that detailed their research into generating realistic virtual environments for autonomous driving simulators. They developed a system which took non-realistic virtual image input and processed it into realistic scene structures. Similar studies include Chao et. al. (2020), which documented research into reconstructing detailed traffic flows using real-time traffic data with traffic simulation models; and Pérez-Gil et. al. (2022), where the use of deep learning algorithms was proposed as a means to create more effective simulated autonomous algorithms.

Based on our preliminary research and the input of our customers' needs and specifications, we've established these primary objectives:

- Construct an immersive, realistic user environment. The cockpit should resemble the actual interior of a car to the greatest extent possible.
- Develop the simulator to be fully operable in a manual functioning mode. This will allow the user to swap between autonomous and manual mode, which is a vital function of actual autonomous vehicles.
- Generate a realistic virtual environment. The user should be able to drive reasonable distances and interact with other moving entities in a realistic city-like landscape.
- Create a bounded, encompassing display.

- Mitigate latency between user input and haptic/visual response to be negligibly perceptible.

These objectives are intended to guide our development toward our end goal and satisfy our customers' expectations.

In order to accomplish our objectives, we've broken down our process into three main stages:

1) Design and research
    a) Customer input
    b) Concept generation and selection
    c) Research into previous studies
    d) CAD of necessary components
    e) Gathering background on software and other tools
    f) Ordering parts and components
2) Development
    a) Installation and familiarization with necessary software
    b) Acquiring and installing components for chassis and frame
    c) Constructing bounded display
    d) Generating code for vital functions in simulation software
3) Testing
    a) Benchmark testing of software CPU/GPU usage
    b) Latency testing for input and response
    c) Long-term assessment of structural integrity

d) Assessment of user immersivity and general experience

e) Sensor data analysis

## 2 Essential Knowledge

There are three past teams from Virginia Tech who have worked on developing an autonomous driving simulator prior to our team. In 2018, Virginia Tech's capstone team was focused on developing their driver's space, an enclosure to surround the MOOG platform, and a display system. For their driver's space, the team chose to utilize a gaming seat as their driver's seat and to incorporate an actual dashboard into their design along with their steering wheel. For their enclosure, the team chose to construct a frame out of aluminum bars and then use polycarbonate boards connected with aluminum sheets to create walls around the platform. For their projection system, the group chose to utilize one curved monitor and one projector placed at the back of the enclosure. The team chose to use a similar software setup to the original 2017 team, who utilized OpenDS as their software for rendering graphics simulation, ROS as their merging platform between OpenDS and Gazebo, and Gazebo as their robust physics simulation.

In 2019, Virginia Tech's capstone team decided to focus on creating an HD mapping software for their simulator, improving the driver space, and enhancing the software algorithm's efficiency. The team chose to utilize the same interior, enclosure, and projection system as the 2018 team. The primary issues the team faced regarding the driver space were unnecessary vibrations created by the projector and a lack of ability to adjust the position of the driver seat. The team also chose to utilize the same software setup as the 2018 team, however they found that their graphics were consistently lagging and that maintaining the multi-platform communication was difficult. The 2019 team recommended for future improvements to the system, to utilize a software system called DSpace in order to reduce system lag and improve graphic rendering.

Both the 2018 and 2019 teams chose to utilize OpenDS and Gazebo due to the built in physics engine within OpenDS and the ROS compatibility included within Gazebo. However both softwares' graphics are outdated and our team experienced issues finding source code to enhance the software's environments. The projector system utilized by both teams were more immersive than the original monitor system utilized by the 2017 team. However, by attaching the projector to the outside of the enclosure, the teams experienced issues with the projector causing vibrations that could be felt within the driver space.

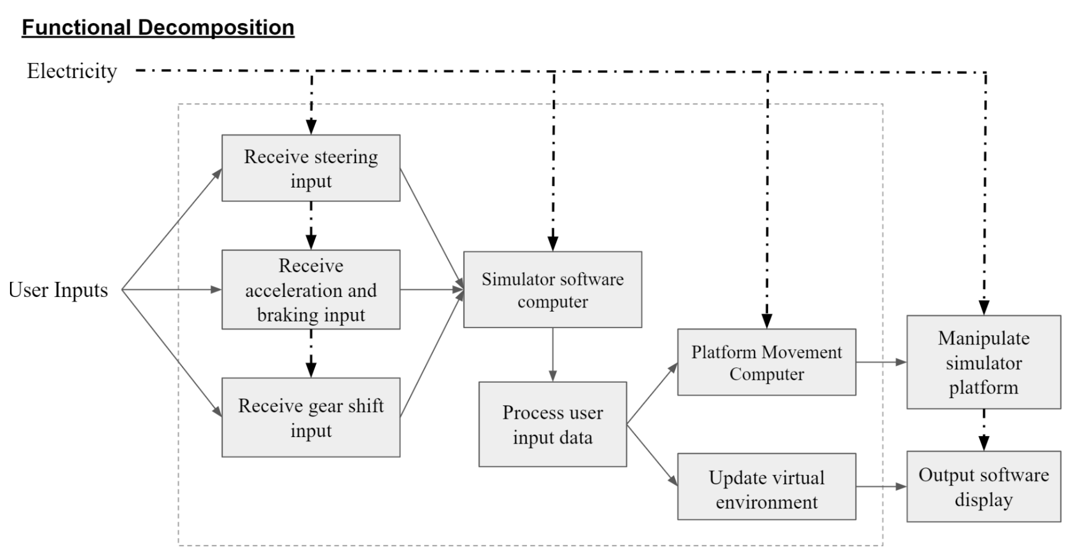
Our team's goal is to develop a fully operating autonomous driving simulator that at a minimum, matches the capabilities of commercially available simulators. We are going to focus on achieving this goal by making our simulator more immersive than the previous efforts made by past teams. Our immersiveness is going to be developed via the usage of a newer software system entitled CARLA, the utilization of a realistic vehicle interior, and the creation of a CAVE projection system.

# 3 Design Process

## 3.1 Customer Needs and Target Specifications

The customers have all expressed that they want their experience within the driving simulator to be more immersive through various enhancements. Based on the five specific needs that they outlined, we created five target specifications. First and foremost, the customers have expressed that they want less delay in the steering and pedal responses. In order to accomplish this, we developed the target specification to mitigate the latency between the steering input and the visual response to ten milliseconds. Next, the customers said they wanted to feel like they were in a real car. In order to accomplish this, we developed the target specification of creating the driver space using the interior of an actual car. The customers also said they wanted the graphics to be more steady as the simulator moved. In order to make our display system more stable, we created the target specification of fixing our projector system to the ceiling rather than the simulator's enclosure. This would ensure the projection was not affected by the simulator's movements. The customers also stated that they wanted a spacious driving environment that still included all necessary driving features. We decided that the target specification of creating a driver space using the interior of an actual car would guarantee us the necessary space and set up to accomplish this objective. Lastly the customers expressed that they wanted the driving space to revolve around autonomous designs. They want the driving space to have an aesthetic appeal and functionality that models current autonomous vehicle trends. In order to achieve this objective, our team developed the target specification of integrating a visual aid like an ipad into the interior of the car.

### 3.2 Concept generation



With these target specifications in mind, our team was able to develop three solutions using the functional decomposition illustrated above. We broke down our system into various sub-functions and identified which functions had various potential solutions. The sub-functions we identified with various potential solutions were our graphics display, our visual environment software, and our gear shift inputs. In all of the solutions we identified a wheel as our steering input, actuators for platform movement, ROS as our communication protocol, Gazebo as our software to actuate movement, a 240V outlet as our power source, and a button to initiate an emergency stop. In solution one, we would utilize automatic gear shifts, DSpace for our environment software, and monitors for our display system. In solution 2, we would utilize a manual gear shifter, virtual reality for our display system, and DSpace for our environment software. In solution three, we would utilize an automatic gear shifter, a projector for our display system, and openDS for our environment software. A chart of all three solutions and their sub-functions and their various subfunctions is illustrated below.

| Sub-Functions | Solution 1 | Solution 2 | Solution 3 |
|---|---|---|---|
| Steering Input | Wheel | Wheel | Wheel |
| **Gear shift Inputs** | Automatic Stick | Manual Stick and Clutch | Automatic Stick |
| **Output software display** | Monitors | VR | Projectors |
| Platform movement | Actuators | Actuators | Actuators |
| Communication Protocol | ROS | ROS | ROS |
| **Software to visualize environment** | OpenDS | Dspace | OpenDS |

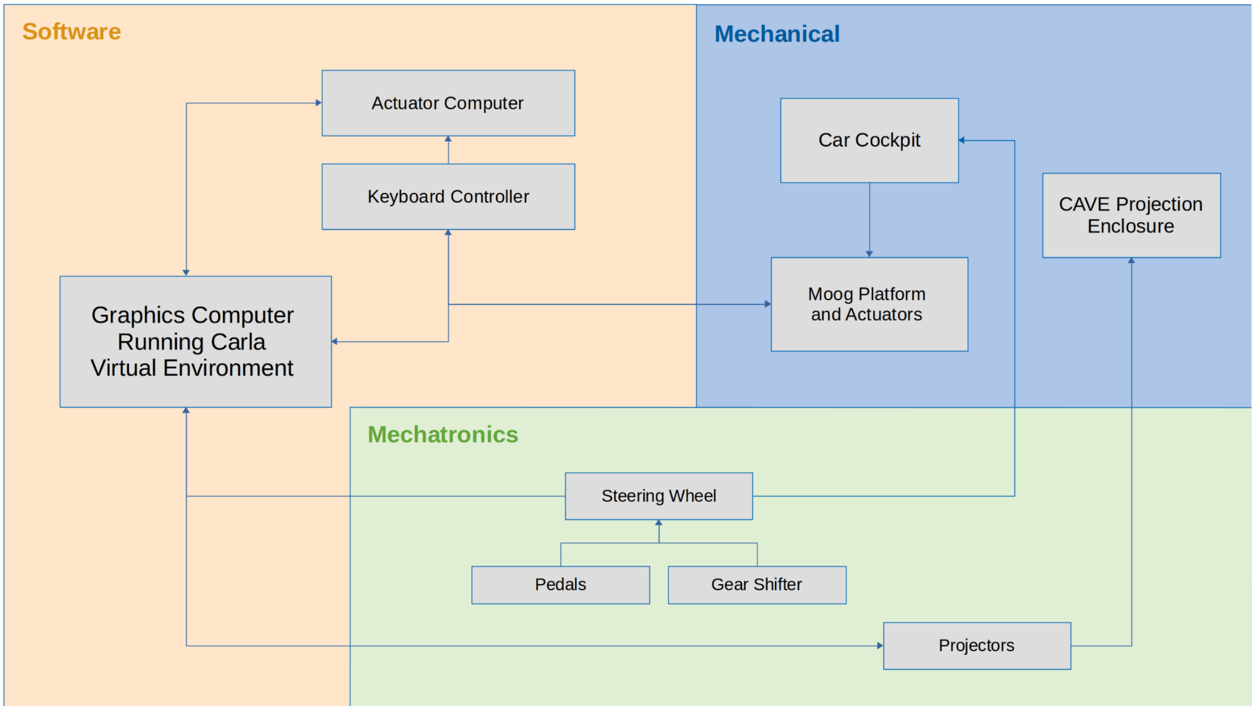
| | | | |
|---|---|---|---|
| Software to actuate motion | Gazebo | Gazebo | Gazebo |
| Power Source | 240 V Outlet | 240 V Outet | 240 V Outlet |
| Emergency Stop | Button | Button | Button |
| Programming Language | Python/ Java | Python/ Java | Python/ Java |

### 3.3 Concept selection

We ended up selecting solution three due to its score on the Screening and Scoring and its ability to meet all target specifications and customer needs. Solution three had potential as well, however we ended up deciding that the use of projectors rather than monitors would more effectively achieve the customer's desire to feel like they were in a real car. Furthermore, with the usage of projectors our team realized we could develop a CAVE projection system, which would allow for the simulator to have 270 degrees of display and really enhance the immersiveness of the experience.

However, as the project progressed, we altered from our original concept and decided to try out an updated environment software called CARLA. CARLA was more effectively able to fulfill the customer need for a low latency between steering input and visual response. Furthermore, through CARLA, the latency between user inputs and the motion platforms' response could be lowered to a maximum delay of three ms.

## 4 Final Design

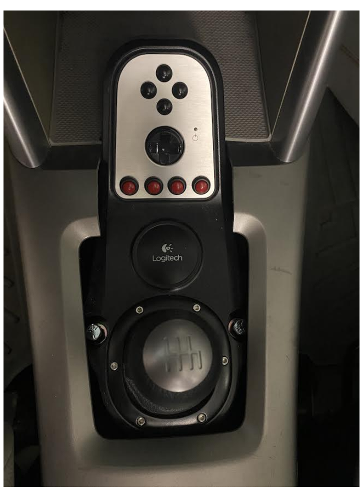



The final design of the system is categorized into three sectors: mechanical, mechatronics, and software. Each category overlaps and interfaces with each other category. The arrows in the diagram above show the simple relationships between each component and the following subsequent sections will elaborate on the interfacing systems.

Beginning with the mechanical portion of the project, the final design utilizes a cockpit enclosure of a 2009 Subaru Forester mounted to a MOOG motion base platform seen in the figure on the right. The Subaru Forester was selected due to its simple dashboard display which provided us the space necessary to install our own steering wheel,

pedals, and gear shifter while still adhering to the space constraints we were given.

The mechatronic components of our design include the user controls and display devices. This area of our design essentially involves interfacing the hardware with our simulation software. The cockpit is centered within our CAVE projection system, which incorporates three short-throw projectors to create an immersive view of the simulated environment as seen in the diagram on the right. The projectors have been arranged and installed to achieve a range of view of about 200 degrees. The user controls consist of a Logitech steering wheel, set of foot pedals, and stick shifter. These controls are installed in the positions where the original components were stripped from the vehicle and can be seen in the figures below. The steering wheel consists of several buttons which allow the operator to adjust certain parameters of the virtual environment, such as the point of view, autonomous/manual driving mode, and other essential functions. All of the user controls are connected directly to the computer running CARLA and control movement within the simulation software.

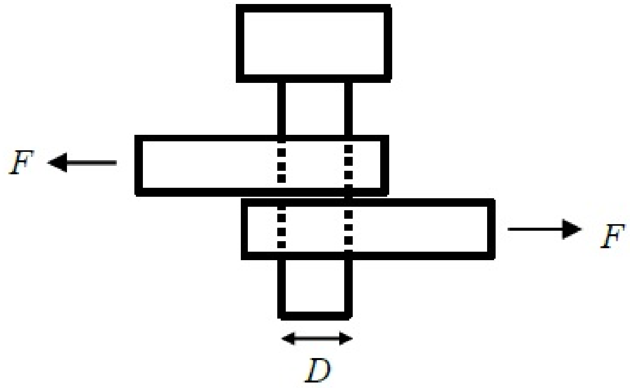



The final design of the software portion starts with the python scripts running through the CARLA software. There are various scripts including synchronous driving, multiple manual drivers, steering capabilities with the keyboard or steering wheel, generating traffic and pedestrians, etc. Each driving script incorporates various CARLA API's to function along with sending commands to the MOOG in order to send it to certain locations. There are also many different driving features ranging from large changes such as an autonomous driving feature to smaller details such as being able to use the headlights. This allows for the system to showcase an advanced system while also not forgetting the little details that make the entire experience more realistic and immersive. For the steering wheel, because Ubuntu are incompatible with Logitech wheels, many drivers were either created or found in order to make them function seamlessly in the system by providing options such as autocenter, force feedback, spring friction, gain, etc.

## 5 Mathematical/Numerical Analysis

Mechanical:

The main goal of mechanical numerical analysis was to assure the safety of the chassis. Because the frame of a car was mounted onto a moving platform, two modes of failure could potentially occur that must be mathematically predicted. Firstly, static failure could occur due to plastic deformation of any of the parts associated with bolting. The kinds of static failure that are possible are compressive failure resulting from the bolts stress concentrations on the platforms or shear failure of the bolts. To analyze the designed system two different single shear stress equations can be used. Double shear stress will not be used because no bolt passes through the MOOG, wood, and car chassis. Rather, bolts either pass through the MOOG and wood, or wood and car.




$$\boldsymbol{\tau} = \frac{F}{A} = \frac{F}{\pi r^2}$$

Half inch bolts are used as the geometric criteria of the equation. A force can be determined assuming 400 pounds for two people and 600 pounds for the chassis of the car. At a five degree tilt angle, the applied force is 87 lbs. With five bolts from the chassis to the wood, and a minimum shear strength of a ½ inch bolt being 11,000 lbs a safety factor of 632 is achieved.

Knowing that there are more bolts from the wood to the MOOG and because of Newton's Second Law, the same force is applied in this scenario. However, it is distributed across more bolts thus failure would occur between the chassis and the wood and not the MOOG and the wood. Next, static failure could occur due to stress concentrations in the wood because it is the weakest link in the scenario. Again, the applied force of 1000 lbs and a number of bolts is five, dand the documentation of the plywood's minimum compressive strength is 4500 psi. This results in a safety factor of 51. The real potential mode of failure will be fatigue failure from motion, cycles and vibrations.

Based on a solidworks static analysis using an applied force of 87 lbs at a five degree angle of tilt, the bolt was well within the minimum shear stress which was in agreement with the above analysis of the bolted system.  Using that static analysis, a fatigue study was run with the same force value using fully reversed loading.  The results of the analysis showed there was no damage to the bolt and that the stress placed on the bolt was below the applicable values on the SN-curve.  This is understandable as the system is running at a low degree of tilt so the applied force being distributed among the bolts is minimal.  This is further supported by the safety factor calculated above for the shear force.

Software:

**Hexadecimal to Decimal Conversion Chart**

| Hexadecimal | Decimal | Hexadecimal | Decimal | Hexadecimal | Decimal | Hexadecimal | Decimal |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 41 | 65 | 81 | 129 | C1 | 193 |
| 2 | 2 | 42 | 66 | 82 | 130 | C2 | 194 |
| 3 | 3 | 43 | 67 | 83 | 131 | C3 | 195 |
| 4 | 4 | 44 | 68 | 84 | 132 | C4 | 196 |
| 5 | 5 | 45 | 69 | 85 | 133 | C5 | 197 |
| 6 | 6 | 46 | 70 | 86 | 134 | C6 | 198 |
| 7 | 7 | 47 | 71 | 87 | 135 | C7 | 199 |
| 8 | 8 | 48 | 72 | 88 | 136 | C8 | 200 |
| 9 | 9 | 49 | 73 | 89 | 137 | C9 | 201 |
| A | 10 | 4A | 74 | 8A | 138 | CA | 202 |
| B | 11 | 4B | 75 | 8B | 139 | CB | 203 |
| C | 12 | 4C | 76 | 8C | 140 | CC | 204 |
| D | 13 | 4D | 77 | 8D | 141 | CD | 205 |

MOOG only takes in binary information so in order to communicate with it, we have to send in hexadecimal information from the python scripts. First, a 5 percent range of tilt is calculated based on the total range of motion the MOOG can perform. Once finding out the decimal number amount equivalent to 5 percent of tilt, we can convert it into hexadecimal numbers through an online converter. This process is repeated for each actuator in order to find the entire command to send and the commands are written as the following:

**cmd = xff/x82/x1F/x3F/xFF/x3F/xFF/x3F/xFF/x3F/xFF/x3F/xFF/x3F/xFF/x3F/xFF/x29/x00**

Determines what the MOOG does. 82 means new position, B4 engages, etc
Checksum: All hexadecimals needs to add up to this
Individual actuators. Actuator A. 1st hexadecimal  is low byte, 2nd is high byte

## 6 Experimental Validation

Parametric study and experimentation was conducted to test many different parameters. Firstly, with safety of the simulator being of utmost importance, safety experiments were run. Aggressive python scripts that move quickly and go to angles much more extreme than will be used in simulation were run. By doing this, the experiments confirmed that the chassis of the vehicle was properly mounted to the MOOG. No shifting or any signs of failure occurred at any bolt locations. The MOOG platform does move slightly, but does not shift significantly or dangerously. By testing the MOOG to its extremes with the chassis on it and people in the car, experimentation determined safety during simulation.

Other parameters that were experimentally tested include immersivity. By sitting in the car and visually testing all points of view and angles the screens are all fully enclosed and immerse the driver. This parametric experimental testing identified areas for improvement. The frame rate of the display ranged from eight frames per second to fifteen. The human eye being able to see up to 60 fps, a newer and stronger graphics card is recommended to maximize immersivity. Also, minor adjustments to display angles could remove display gaps.

Other parametric experimentation included user input testing and autonomous driving. User inputs respond appropriately during experimentation with a latency of 3ms. User inputs are interpreted and sent to the MOOG in an appropriate manner in accordance with a vehicle motion model, however the MOOG outputs in a jerky manner leaving room for algorithm improvement in that area. Also, CARLA's default autonomous vehicle algorithm was tested and situationally self-driven effectively. Being open source, another area for improvement would be in making a new self-driving algorithm or even partnering with and testing another company's proprietary software.

Additionally, the upgrade of the new simulated environment software has allowed for the addition and improvement of autonomous driving capabilities. The new software CARLA has additional sensors that were not readily available nor user friendly on softwares utilized by past groups. A button on the steering wheel was allotted to switch between the six sensors available on CARLA. The first and default sensor is RGB, which uses a range of red, green, and blue colors to display a realistic image of the environment. The next sensor is depth, in which the system acquires multi-point distances to get a better understanding of the 3D environment. Following the depth sensor, CARLA provides several other depth sensors, including a gray scale and a logarithmic gray scale. The three depth sensors can be interchanged, depending if the user wants to work with a sensor that uses relative values of dark and light that would greatly simplify the computer algorithm. After the three depth sensors, the fifth sensor is semantic segmentation. This sensor groups parts of the image together based on similarity to visualize the environment. The final sensor is Lidar. Lidar is the most key sensor as it effectively allows autonomous features to work through shooting lasers and measuring the return time. By doing so, the system is able to see the environment around it and understand the placement of objects in the environment while also being fully able to at night. We experimentally tested a suite of sensors provided with CARLA to visually verify the change of display. Limited data was collected from running these different sensor versions, so future groups could work to improve sensors to be empirical as well as visual. These sensors emphasize different components of distance and position mapping to be utilized using autonomous algorithms. This is important for future teams as the current self-driving feature on CARLA requires optimization to be effectively functional. As mentioned before, these sensors will allow companies to use the existing system we have created to test and improve their own proprietary autonomous algorithms.

## 7 Operations Manual

In order to operate the system with the MOOG motion platform, first connect the MOOG USB and keyboard from the computer located in the bottom of the MOOG system to the computer located outside of the CAVE system. Turn on the both switches on the MOOG computer located on opposing sides of the computer. One appears as a plastic toggle switch and the other appears as a small metal lever toggle switch. Plug in the green plug to the wall outlet and the MOOG computer power plug to the power strip. This starts up the MOOG system and the monitor on the right side should appear with all the actuators location and the sound of the computer should sound like a fan turning on. If both the monitor is not on and the sound of a fan is not present, not all the plugs and switches have been engaged. If you want to test with the keyboard go to part 1). If you want to test with CARLA or with other python scripts go to part 2).

Make sure all projectors are turned on for the CAVE system and also check that displays are in the correct order if you plan to showcase the CAVE design. This can be done in settings in the displays section.

*Note: Any sudo command's password is 'password'

*Note: CARLA does not need the MOOG to run and if you don't want the MOOG on, leave it off but still complete each step excluding the step 1 in part 2.

**Part 1) MOOG Keyboard controls**

If wanting to test individual actuators, click 'q' and type in '6D2MAINT' and once the screen turns back to the actuators, click 'e' and then hold the '+' or '-' to lift or drop the MOOG respectively. In order to lift the MOOG with desired actuators, click either '1', '2', '3', '4', '5', and/or ‘6’ to lock certain actuators then use the previous ‘+’ and ‘-’ buttons to move the MOOG. Other commands in the mode are listed within the MOOG manual binder.

**Part 2) CARLA Setup/MOOG**

In order to set up the MOOG

1) click ‘q’ and type in ‘170-122’ on the MOOG connected keyboard/monitor.
   a) This prepares the MOOG to take in serial commands from python scripts on the other computer.

Turn on the other computer outside the CAVE system and login to drivesim user. The password is ‘password’.

2) In the directory /home, type in these commands in order
   a) sudo su
   b) cd /
   c) cd dev
   d) chown <username> ttyUSB0
      i) <username> is ‘drivesim’ for our computer
      ii) Leave this terminal tab open and open a separate tab

Open up the terminal and type in the following command to turn on CARLA in any directory.

3) sudo docker run --privileged --gpus all --net=host -e DISPLAY=$DISPLAY carlasim/carla:0.9.13 /bin/bash ./CarlaUE4.sh
   a) If you run into this error: sh: 1: xdg-user-dir: not found
      i) Red herring error. Don't worry about this
   b) If you do not want the screen open, add the following to the end of the command ‘-RenderOffScreen’ so it should look like sudo docker run --privileged --gpus all --net=host -e DISPLAY=$DISPLAY carlasim/carla:0.9.13 /bin/bash ./CarlaUE4.sh -RenderOffScreen’
   c) If you want to load it in low quality mode, add the following to the end of the command ‘-quality-level=Low’
   d) Do not close this terminal and open new terminal tabs for other setup and scripts

**Part 3) Steering Wheel Setup**

With either steering wheel, plug in all corresponding plugs. The gear shifter, pedals, power source, and USB to the computer. Go to the section for the steering wheel you decide to use.

*Note: The connection between the Logitech G920 and the integrated gear shifter is not compatible so a new steering wheel may be needed. The gear shifter works with the old Logitech G27 wheel but the wheel has issues with clicking random buttons at random intervals. We recommend using the Logitech G920 as it still has all functionality, but it loses some of the immersiveness.

Logitech G920

Currently the driving scripts are made for the Logitech G920. In order to set up the steering wheel to work with the scripts, go into the downloads/usb_modeswitch directory and type in the following command

4) sudo usb_modeswitch -c /etc/usb_modeswitch.d/046d:c261
    a) This should say the switch was successful and you can check by typing in the following command 'jstest-gtk' to see if there is a Logitech G920 joystick.
    b) If you want to change button configuration on the steering wheel later, 'jstest-gtk' helps you keep track of the button layout.

In order to get force feedback for the Logitech G920 type in the following command which should open an application

5) oversteer
    a) More documentation can be found at https://github.com/berarma/oversteer
    b) At the top, go to the tab for the wheel and slide the autocenter force feedback slider at the bottom to desired feedback. Our group set it around 30. Check if the steering wheel is no longer slack.

Logitech G27

This was the previous steering wheel which was the Logitech G27. The modeswitch is unnecessary for this wheel. Can check and configure the steering wheel buttons with the command 'jstest-gtk' to map buttons on the gear shifter.

In order to fix the force feedback issue, refer to step 5 in the Logitech G920 section. If that does not work, there is a workaround. In the directory Documents/PythonAPI/new-lg4ff, type in the command 'sudo make load' and in the directory /sys/bus/hid/drivers/logitech/0003:046D:C29B.0005, open the autocenter file and change it to approximately 40000. More documentation can be found at

https://github.com/berarma/new-lg4ff.

*Note: Depending on the pedals you use, you may need to change the wheel.ini file in the Documents/PythonAPI/examples directory to fix the brake and accelerate buttons.

**<u>Part 4) Python Scripts</u>**

There are multiple scripts within the Documents/PythonAPI/examples directory that run with CARLA. For the main one, if you want to drive with the keyboard, type in the following command in the Documents/PythonAPI/examples directory

6) python manual_driving.py
    a) This allows you to run the system with just the keyboard. Clicking ‘h’ will drop down some settings that CARLA has including but not limited to, autonomous driving, sensor data, radar visualization, switching sensors, car views, etc.
    b) In order to see sensor and car data, you must render with the screen in step 3 in part 2 as that is where the data is shown.

In order to run the system and drive with the steering wheel, type in the following command in the Documents/PythonAPI/examples directory

7) python demo.py
    a) If the MOOG will not work with the script, try ‘python manual_driving_newsteering.py’ instead.
    b) If you want to see CAVE view, type in the command ‘python demo_cave.py’
        i) This will open a resizable window and you need to stretch the pygame window across the 3 projectors to make the CAVE immersion.
        ii) This script is very slow with the current hardware so we recommend using it only when showing off the CAVE functionality or once a better GPU is purchased.
    c) The buttons have been labeled on the wheel with different icons but functionality can also be found in the code.
    d) This has most of the functionality of the manual_driving.py script but allows driving with the wheel.

If you want to generate traffic for when you are driving, type in the following command in the Documents/PythonAPI/examples directory

8) python generate_traffic.py

a) Sometimes the traffic may be frozen so you may need to close the scripts and rerun them.
   i) Soft fix:
      (1) Restart CARLA
      (2) run ./synchronous.py
      (3) run ./generate_traffic.py
      (4) run ./manual_control.py
      (5) close synchronous and generate_traffic
      (6) rerun ./generate_traffic.py

**Part 5) Code and documentation**

The CARLA scripts utilize CARLA's driving simulator's APIs in order to function. Much of there documentation can be found at the following link

9) https://carla.readthedocs.io/en/latest/python_api/
   a) This documentation also covers various sections for troubleshooting the software and working with it.

For MOOG movement, we sent commands directly to the platform using hexadecimals. This is found in the IMUSensor section of the code and can be improved upon to smooth out the movements of the simulator. In order to understand what each byte does in the hexadecimal command, the MOOG manual binder explains it. For our commands, each one works a separate actuator but in the future, a degree of freedom mode will help it be more exact.

Also, to improve communication, a ROS bridge and ROS can be connected to the CARLA software. Documentation and steps for this can be found on the CARLA website

10) https://carla.readthedocs.io/projects/ros-bridge/en/latest/

**Part 6) Disassembling**

To turn off the system, turn off both switches and unplug all MOOG outlet connections. Turn off the computer and make sure the projectors are off before leaving. If you completely shut down the computer versus putting it to sleep, each step will need to be redone.

**Troubleshooting**

- If it says ‘# USB permission denied’ when running a script, it means the MOOG serial commands have not been connected and to fix this, redo step 2 in part 2.

- If you load up the script and it says missing joystick 0, it means the steering wheel has not been configured correctly in part 3. Redo step 4 and 5 in part 3.

- If running with the MOOG and when running the driving scripts, the MOOG platform moves up then has a communications error, try resetting the MOOG.
  - Repeat step 1 in part 1, then run the script again.
  - If it still doesn’t work after multiple attempts, try the other scripts in subsections of steps 7 of part 4.

- If the python scripts within the directory Documents/PythonAPI/examples are not working because there is no connection, check if CARLA is opened.
  - You can do this by typing in the command ‘docker container ls’ and checking if there is a CARLA application opened. If there is, restart it by removing it and reopening it using ‘docker rm -f <ContainerID>’ and then step 3 in part 2.

**<u>Miscellaneous</u>**

- If you want to see the other CARLA files within the docker container, type in ‘docker exec -t -i <ContainerID> /bin/bash’

- There is also an old version of CARLA downloaded if you chose to use that instead
  - sudo docker run -e SDL_VIDEODRIVER=x11 -e DISPLAY=$DISPLAY -v /tmp/.X11-unix:/tmp/.X11-unix -p 2000-2002:2000-2002 -it --gpus all carlasim/carla:0.9.10 ./CarlaUE4.sh -opengl

- There is a gazebo environment if you chose to use that driving simulator instead in the directory ‘desktop/environment’.

## 8 Conclusions and Future Work

Our team has made significant progress towards reaching our goal of developing an autonomous driving simulator over the course of the past two semesters. We were able to create a fully enclosed and immersive driver space, incorporate a new virtual environment software in order to decrease the latency between the graphics and our steering inputs, and develop a CAVE projection system with a 270 degree range of projection. We have had to make significant changes to our design over this year, resulting in our progress being slower than predicted.

However, we were able to expedite our progress this semester and in turn remain on schedule and accomplish our established goals.

Future work for the mechanical side of the project includes mostly aesthetic appeal and safety improvements. The projection onto the right wall could be improved by constructing a wall similar to the wall utilized for the left screen. The right wall has a number of pipes running across it and the projector for the right wall is slightly blocked by overhead ducts and in turn can not fully project onto the wall. Building a taller wall that's closer to the projector could improve this. Furthermore, the placement of the MOOG platform could also be adjusted in order to ensure it's positioned on a more stable surface. Right now, we have it positioned on top of metal grates due to the lack of space we have in our lab. These metal grates cause the Moog to shake during operation, create loud noises, and lack a proper place to be bolted. Future work to be accomplished regarding software includes enabling a ROS-bridge with ROS in order to send CARLA sensor information to the MOOG platform. Once we are able to send information to the MOOG, the platform should move in all 360 degrees corresponding to the physics of the virtual car.

Future work for the software team includes moving towards a more autonomous oriented design, in which CARLA's lidar capabilities are taken advantage of to create a product with features that are not available in today's driving simulators. While CARLA's Autopilot system works to some extent, future teams will have to troubleshoot its script as it is not totally reliable and will often drift off the road with frequent collisions. The lidar sensor can be further used to create autonomous features, such as autonomous emergency braking (AEB) and blind spot monitoring (BSM). These features will modernize the driving simulator as they are a key part and often staple of the modern vehicles that are released today

## Works Cited


Baltodano, Sonia & Sibi, Srinath & Martelaro, Nikolas & Gowda, Nikhil & Ju, Wendy. (2015). The RRADS platform: a real road autonomous driving simulator. 10.1145/2799250.2799288.

Bellem, H., Klüver, M., Schrauf, M., Schöner, H.-P., Hecht, H., & Krems, J. F. (2017). Can We Study Autonomous Driving Comfort in Moving-Base Driving Simulators? A Validation Study. Human Factors, 59(3), 442–456. https://doi.org/10.1177/0018720816682647

Chao, Q., Bi, H., Li, W., Mao, T., Wang, Z., Lin, M.C. and Deng, Z. (2020), A Survey on Visual Traffic Simulation: Models, Evaluations, and Applications in Autonomous Driving. Computer Graphics Forum, 39: 287-308. https://doi.org/10.1111/cgf.13803

Häuslschmid, Renate & Bülow, Max & Pfleging, Bastian & Butz, Andreas. (2017). Supporting Trust in Autonomous Driving. 319-329. 10.1145/3025171.3025198.

Koo, J., Kwac, J., Ju, W. et al. Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust, and performance. Int J Interact Des Manuf 9, 269–275 (2014). https://doi.org/10.1007/s12008-014-0227-2

Pérez-Gil, Ó., Barea, R., López-Guillén, E. et al. Deep reinforcement learning based control for Autonomous Vehicles in CARLA. Multimed Tools Appl 81, 3553–3576 (2022). https://doi.org/10.1007/s11042-021-11437-3

You, Y., Pan, X., Wang, Z., & Lu, C. (2017). Virtual to Real Reinforcement Learning for Autonomous Driving. ArXiv, abs/1704.03952.

**The United States' Administrative Social Responsibility to Combat Climate Change**

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Mosed Saroor

Spring, 2022

On my honor as a University Student, I have neither given nor received

unauthorized aid on this assignment as defined by the Honor Guidelines

for Thesis-Related Assignments

Signature: *Mosed Saroor* Date: 5/3/2022

Mosed Saroor

Approved __________________________________________ Date __________

Hannah Rogers, Department of Engineering and Society

**Abstract**

The United States has been a big industry player for as long as technology saw its first major developments during the Industrial Revolution. These great advancements have been met with terrible potential consequences that will see a much more different planet earth than the one humans have inhabited for over a million years. Politicians are not the same as they were a century prior and another century before that, however the climate situation remains the same. Only recently does the majority of politicians and society see that action must be taken to avoid mass relocation of coastal city inhabitants and the fatal effects of a warmer climate. Cooperation will be key but as necessary as realism. This paper will explore the small steps on how to go about potential solutions. However, many if not all solutions will come off as unideal to someone or some party. This thesis will explore successful and unsuccessful policies implemented by governments as well as businesses that have thrived in response or negligence to the climate crisis. These relationships ultimately connect the government with those that it governs: major corporations that are continuously responsible and the general public that will suffer from those actions.

**Introduction**

The advancement of technological systems over the last few centuries has seen an increase in quality of living and a much easier means of completing daily tasks that have allowed societies in nations across the globe to prosper greatly. However, this convenient way of living has certainly incurred a number of consequences and brings up the debate on who is responsible for the situation at hand and whether or not they have the tools necessary to manage any disastrous outcome should they come to fruition. World superpowers such as the United States and China have long pumped carbon emissions into the environment as far back as the end of the industrial revolution. There is no doubt that the planet earth will suffer greatly from these emissions but with ethics having a greater influence on society today, people have turned their attention to those who suffer greatest from these actions: the impoverished people of these superpower nations as well as their surrounding nations. These people and nations are ones who are less fortunate in not having the financial resources in adapting to these disastrous repercussions while contributing an incomparable amount of emissions to their neighboring countries. This does not even dive into the fact that many of these countries are already susceptible to the devastating natural disasters that are already occurring and will only get worse as climate change takes its toll in the near future. A striking example of one of these less fortunate nations would be Haiti, who are responsible for just 0.01% of global emissions (Appendix A), a stark difference from the United States' staggering 14.02% share of global emissions (Appendix B). While Haiti may emit much less than some global superpowers, being an island country will have devastating effects on its welfare and infrastructure. A warmer climate results in rising sea levels as well as extreme weather events like hurricanes. Haitians will unfortunately be familiar with awful weather events such as the 2016 occurrence of four hurricanes in the space of thirty days that ravaged the nation, taking many lives and destroying its infrastructure (Rubenstein 2019).While the United States may be the largest providers of carbon emissions into the atmosphere and thus a major nation at fault for the inevitable future, they are also one of the most financially capable and politically able nations in the world in reaching such an ambitious goal. The United States' administration should consider this along with an added responsibility for neighboring nations that will undeservedly suffer from climate change, such as Haiti. With ethics lenses like justice and common good as well as social responsibility at hand, the United States' administration should look towards methods of shaping a better future by establishing related policies, developing renewable energy efficient technologies, and encouraging society to be more environmentally friendly.

**Policies to Derive from**

The United States is not the only nation that has pumped carbon emissions into the environment and thus it is not the only nation to take action or debate on the best methods moving forward in the global battle against climate change. While Australia may be on the other side of the planet from the United States, their administration is a good model in analyzing how the positive effects of installing renewable energy technology heavily outweigh any negative effects. Many of the Australian administration's goals were ambitious and seemed too expensive for opposing political leaders to move forward with, which caused backlash against certain bills such as the National Energy Guarantee (NEG) policy. NEG sought to accommodate for the increased need for energy whilst looking to incorporate a higher percentage of renewable energy sources into its portfolio (Appendix C). However, this repeated opposition in the government led to many of Australia's goals being either reduced or postponed. The policy's rivals were successful in limiting the bill when

> On 20 August 2018 the former PM announced that the climate change target aspect of the NEG would be abandoned, in a futile attempt to ward off a leadership challenge. A political crisis and Federal leadership spill ensued anyhow on 24 August, when Mr Turnbull was replaced by Mr Morrison, with the backing of the hard right. The NEG proposal was abandoned by the new government in September 2018 (Prest, 2018, p.9)

This showcases why it is important for the administration of the United States to 'lock in' certain policies and goals and find a balance that would prevent any future administration from doing the same as what had happened in Australia, especially when the branches are controlled by leaders who would favor such policies. Of course, Australia is far different from the United States in their political culture and especially their industrial culture. However, their efforts in introducing bills and eventually having opposing parties find a middle ground in environmental and renewable energy policies should serve as an inspiration for the current administration of the United States. A large source of democratic voters in the 2020 presidential election came from Biden's support of tackling the climate change crisis as well as the indifference of the Trump administration regarding the subject. Viewing Biden's presidency through a justice ethics lens, one would feel as if a greater attempt and funding should be dedicated to providing solutions on climate change that will carry through long term and many administrations after. No one solution will fix the problem that is posed by carbon emissions. Many solutions will be required, whether they are of a lower or higher scale of effort. President Joe Biden's decision to reverse former President Donald Trump's choice of departing the Paris Climate Accords is one that will be a huge step in achieving the nation's carbon neutral deadlines by 2050, but there needs to be so much more considering the promise his administration had made in handling this issue. It is very much possible to find a balance in limiting carbon emissions and promoting renewable energy technologies considering President Trump seemed to be a major outlier in policies dealing with climate change in comparison with past presidents, both Democratic and Republican. While rejoining the Paris Climate Accords is a huge step forward, certain small steps such as policies that encourage companies and incentivize those in society to make the switch to renewable energy will take the nation and the world that much further in creating a sustainable future.

A more practical policy that the government could implement would be the carbon tax. Taxing industrial giants for however many carbon emissions a company releases into the atmosphere would not only encourage said companies to limit emissions but would also provide additional funding for the government to allow the Department of Energy (DOE) to support a more environmentally friendly approach themselves. This would be no easy feat to accomplish, however. While it may come as a more ethical approach from the United States administration, other nations such as China would be more than willing to allow some of the largest corporations to settle in their nation where their laws would benefit them. These companies would happily go about their business freely and continue releasing the vast amount of carbon they already do, which would be a huge double blow to the American economy and the mission against climate change.

**Technology Development**

Renewable energy has made headlines in the power industry as companies and nations seek a method of providing energy for when fossil fuel sources are depleted in the future as well as adorning their names to the general public. Many American gas companies have made it a clear goal of theirs to incorporate biomethane into their future in a plan to lessen their dependence on fossil fuels in favor of more readily available organic matter. While biomethane emits carbon, this carbon comes from organic matter and thus does not contribute excessive additions to the carbon cycle. One company that has caught the attention of the public is Tesla Inc., who create electric vehicles (EVs). Tesla's sudden rise in the automobile industry has been made even more evident with its soaring price in the stock market. The demand has spread to China, another industrial superpower who is also dealing with climate issues. Tesla's stock price has risen from $17 in June of 2010 to a staggering $650 in December of 2020 (Harper 2020).While also coming off as style-savvy, their electric battery dependent cars have increasingly become more frequent on American roads. Because of gas prices rising and becoming unpredictable, consumers are beginning to make the switch to EVs in large volumes as seen in Tesla's quarterly report of sales which saw an increase from as little as 20,000 units in 2013 to 936,000 units in 2021, an 87% increase from the previous year (DW 2022). Tesla is not the only company that have made EVs a large portion of their market, with Rivian and Lucid Motors also recently reaching a sizable market cap (Cain 2021).

With carbon being the main culprit behind climate change, there is a way that carbon rich sources can still be primarily used while drastically reducing carbon emissions. Carbon capture and storage technologies have been greatly considered but would have to meet enormously high levels of engineering to match the output of carbon emissions that a power plant typically produces. However, this would be no easy solution to accomplish as

> The technology is well understood and is used in other industrial applications, although some considerable scale-up would be required to deal with the $CO_2$ output from a standard (e.g 1 GW) power station, which might burn 3.5 million tonnes of coal per year (Rhodes, 2012, p.3).

While this method may seem tedious to maintain over a single plant, let alone the thousands already functioning in the United States, the much more effective and industry opposed solution of a carbon tax can be forgotten. Not only would a large market be required for this solution to be sustainable, but there is also the problem of handling the resulting solvents from post-combustion. The carbon can easily be stored to a suitable depth of one kilometer underground (LSE 20…) while solvents such as oxygen and nitrogen will be forced back into the atmosphere. This could have negative effects, with too much oxygen into the atmosphere limiting the earth's intake of sunlight and affecting the climate on its own (Zielinski 2015). Whether the government encourages these technologies or consumers turn towards companies that have made similar approaches in their products or means of production, environmentally friendly technology will be key in establishing a greener future for the world.

**Encouragement of Switching to Carbon-Neutral**

On a much smaller scale, the government can introduce policies that might not necessarily limit the public, but incentivize changing one's lifestyle towards a more earth friendly one. Those that are already in possession of EVs already benefit from not having to visit the gas station and deal with often expensive gas prices. However, working with EV companies the government can make purchasing these models much more affordable and convenient for consumers. The administration could do this by reintroducing the $7,500 tax credit that was available for the first 200,000 Tesla owners (Jones 2019). A major limitation of owning EVs is the lack of EV charging stations which could be crucial in potential cross-country or distant road trips through certain states, particularly the Midwest and South. Alabama and Montana have 8.4 and 10 charging points per 100,000 vehicles, respectively. That is a huge drop off from states that are more populated or closer to the coast, such as California and Massachusetts which have 103.6 and 66.9 charging points per 100,000 vehicles, respectively (Tucker 2021). There is no doubt that Elon Musk of Tesla Inc., is by far the richest man currently on the planet, so there would need to be some sort of balance with Tesla and other EV companies that doesn't require the government to take too much out of its budget. In fact, such policies could cost the administration little to nothing considering the massive increase in sales that would greatly benefit these companies.

There are also many ways to influence individuals to be more environmentally friendly on a smaller scale. Taxes and fees can be slightly reduced for the driver of any EV. School buses would not last forever and thus the newer models being developed should strongly be considered in making them electrically powered. There can be a break from sales taxes for any one eating at local restaurants which would have a sizable reduction in carbon emissions stemming from the food industry. Simply, the government could also advertise through entertainment that it is an important matter and remind society that the administration is working to come up with a solution in both the short term and long term future. While many more people believe in climate change, there are still many who do not realize its devastating effects. Many people believe that the government itself does not realize the harmful future if action is not taken soon with 67% of U.S adults saying in a poll that the federal government is doing too little to reduce the effects of climate change (Appendix D). All of these small actions combined would certainly not erase carbon emissions from industrial plants in the same way that policies such as a carbon tax would, but they would help in the long run by instilling an environmentally friendly attitude among society and the future generations.

## Conclusion

As seen in the stalling of major policies limiting carbon emissions that the United States and other nations have come across, limiting carbon emissions will be a difficult task yet one that needed to be done some time ago. The process of a solution will need to be facilitated by world leading administrations following previous ones that have contributed the most to the situation while providing very little help for their future. Adaptation and mitigation will certainly be effective but only keep the financially able countries stable on a short term schedule. The development of technology over the last few centuries has had tremendous benefits for much of the world, but will have even more devastating effects that many people today will see in their lifetimes. The fight against climate change will be a long and difficult battle, but it will take a great effort and cooperation from many groups: the administration with industry leaders, nations with each other, people with their neighbors. Ambitious projects such as the Tesla model and policies that encourage them and anything in reducing emissions are key in preparing a new industrial revolution: one that is carbon neutral and is steadily making the switch to renewable energy sources. If the government can take small steps in the right direction and effectively approach the climate change crisis with the support of its inhabiting people and corporations, planet earth could end up having a slightly brighter future than the horrifying one that lies ahead for its people.

## References

*Modelling of Australia's National Energy Guarantee*. BloombergNEF. (2018, June 20). Retrieved March 29, 2022, from https://about.bnef.com/blog/modelling-australias-national-energy-guarantee/

Cain, T. (n.d.). *Tesla sales figures – US market*. GCBC. Retrieved March 29, 2022, from https://www.goodcarbadcar.net/tesla-us-sales-figures/

(www.dw.com), D. W. (n.d.). *Tesla posts sales of almost 1 million cars in 2021: DW: 03.01.2022*. DW.COM. Retrieved March 28, 2022, from https://www.dw.com/en/tesla-posts-sales-of-almost-1-million-cars-in-2021/a-60313972

Simon Evans. (2021, October 27). *Analysis: Which countries are historically responsible for climate change?* Carbon Brief. Retrieved March 29, 2022, from https://www.carbonbrief.org/analysis-which-countries-are-historically-responsible-for-climate-change

Harper, J. (2020, December 29). *Tesla: Soaring share price creates Army of 'teslanaires'*. BBC News. Retrieved May 3, 2022, from https://www.bbc.com/news/business-55391571

Jones, J. (2021, August 11). *How much does a Tesla cost?* MagnifyMoney. Retrieved March 29, 2022, from https://www.magnifymoney.com/blog/auto-loan/tesla-cost/

LSE. (2021, January 14). *What is carbon capture and storage and what role can it play in tackling climate change?* Grantham Research Institute on climate change and the environment. Retrieved March 29, 2022, from https://www.lse.ac.uk/granthaminstitute/explainers/what-is-carbon-capture-and-storage-and-what-role-can-it-play-in-tackling-climate-change/#:~:text=Carbon%20capture%20and%20storage%20(CCS,processes%20such%20as%20cement%20production.

Marconi, R. (2021, November 17). *Breaking down the biggest EV-makers by market cap*. TheStreet. Retrieved March 29, 2022, from https://www.thestreet.com/lifestyle/the-biggest-ev-makers-by-market-cap

Pew Research Center. (2019, November 22). *Majorities of Americans say the federal government is not doing enough to protect the climate, environment*. Pew Research Center Science & Society. Retrieved March 29, 2022, from https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/ps_11-25-19_climate-energy-00-015/

Prest, J. (2018). Australian Renewable Energy Law: Carbon Lock-in or Clean Energy Transition? *Renewable Energy Law and Policy Review*, *9*(1), 44–67. https://www.jstor.org/stable/26638292

Rhodes, C. J. (2012). Carbon capture and storage. Science Progress (1933- ), 95(4), 473–483. http://www.jstor.org/stable/43425787

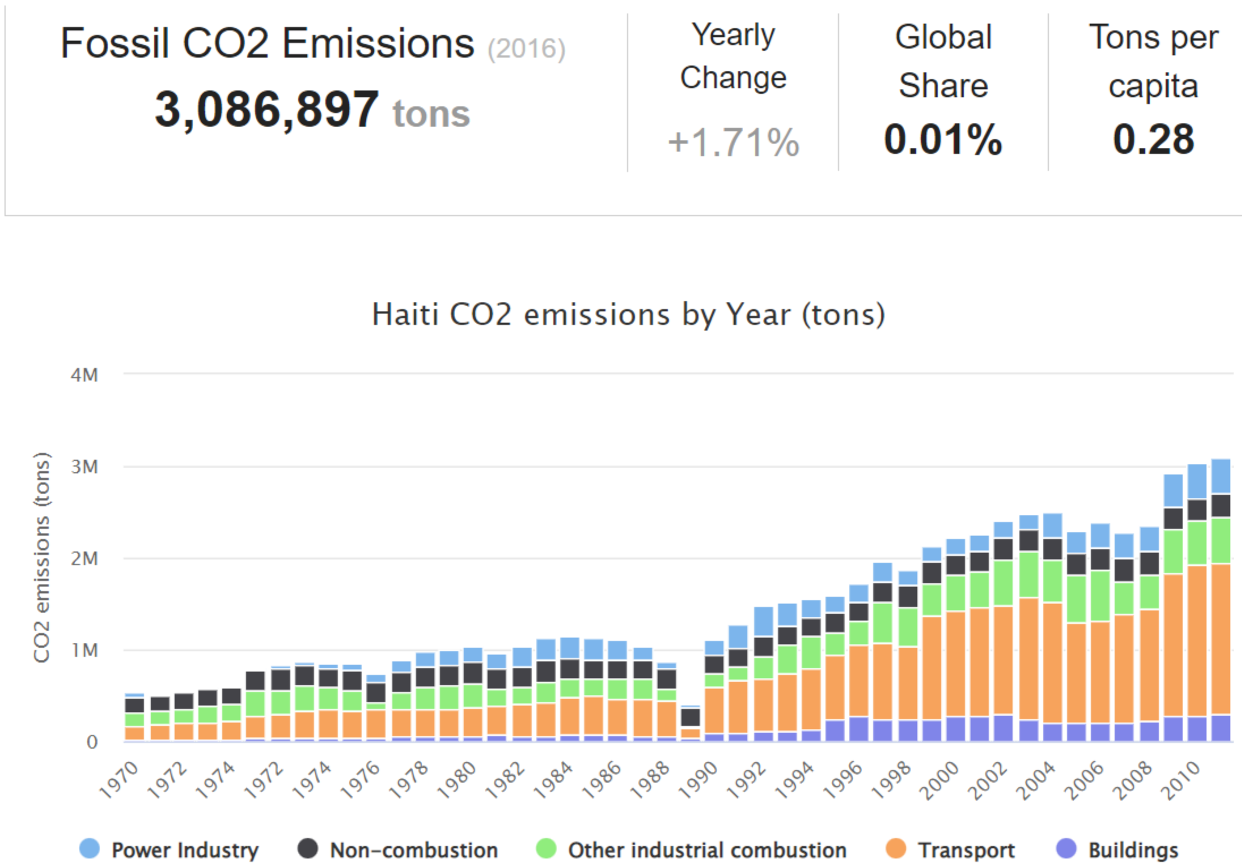
Rubenstein, M., Chris, Lambert, S., Brittany, Fecht, S., Kelly, Marcovich, A. G., Melaku, S., & Fortier, J. (2019, July 31). *Climate change in Haiti*. State of the Planet. Retrieved May 3, 2022, from https://news.climate.columbia.edu/2012/02/01/climate-change-in-haiti/

Tucker. (n.d.). *Report ranks states by EV charging outlets - kelley blue book*. Retrieved March 29, 2022, from https://www.kbb.com/car-news/report-ranks-states-by-ev-charging-outlets/

USAID. (2017, December 31). *Climate risk profile: Haiti*. Global Climate Change. Retrieved March 29, 2022, from https://www.climatelinks.org/resources/climate-risk-profile-haiti

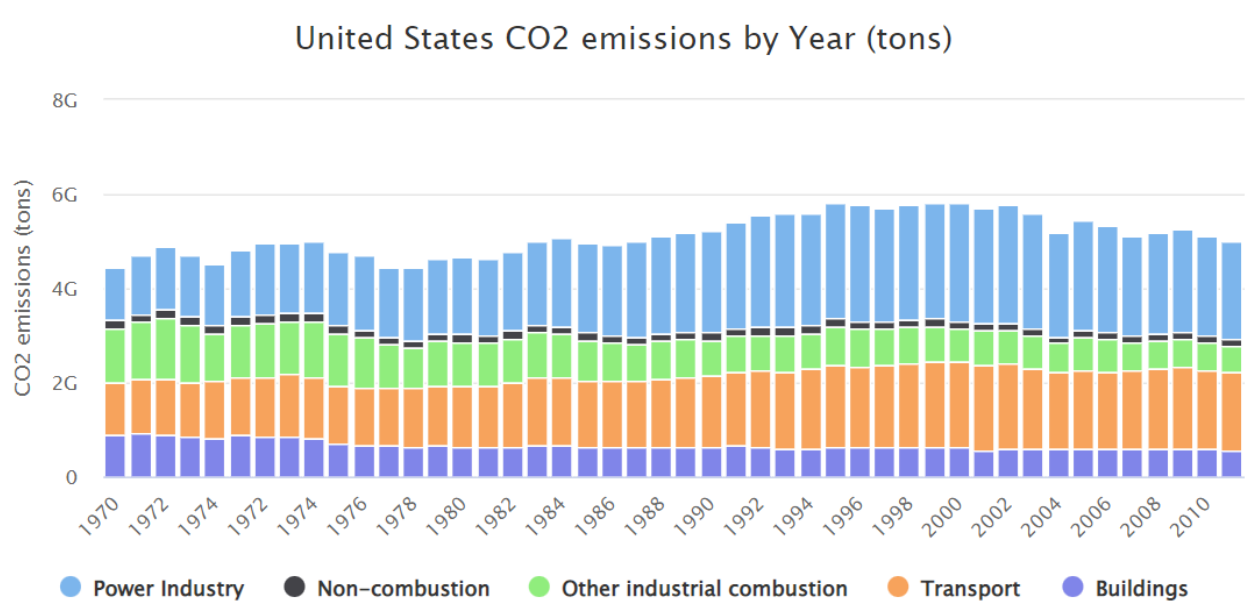
Zielinski, S. (2015, June 11). *Earth's oxygen levels can affect its climate*. Smithsonian.com. Retrieved March 29, 2022, from https://www.smithsonianmag.com/science-nature/earths-oxygen-levels-can-affect-its-climate-180955572/#:~:text=Even%20though%20oxygen%20is%20not,altered%20climate%20in%20the%20past.

## Appendix

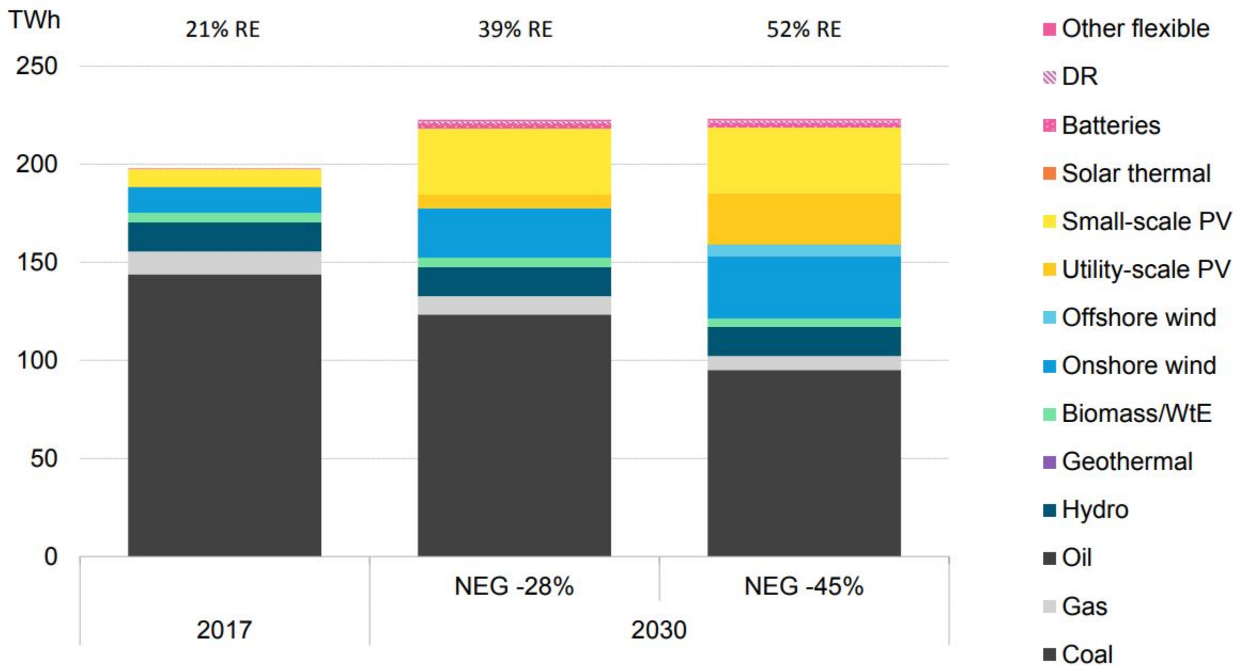



Appendix A (Worldometer 2022)

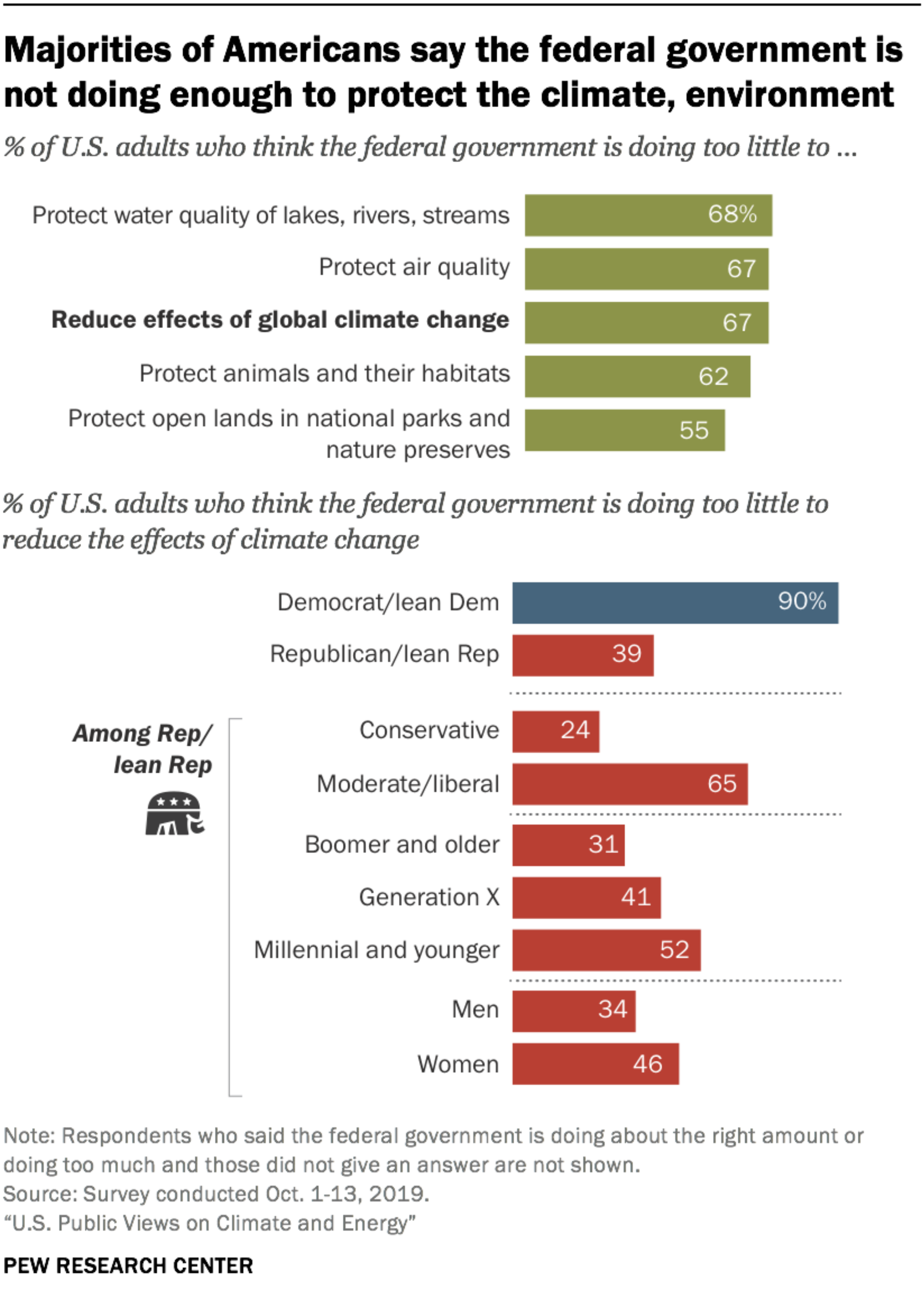
| Fossil CO2 Emissions (2016) | Yearly Change | Global Share | Tons per capita |
|---|---|---|---|
| **5,011,686,600** tons | -2.01% | **14.02%** | **15.52** |




Appendix B (Worldometer 2022)




Appendix C (BloombergNEF 2017)




Appendix D (Pew Research Center 2019)

**Driving Simulator Project**

(Technical Paper)

**The Government's Potential Involvement in Installing Renewable Energy Technologies**

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

Mosed Saroor

Fall, 2021

Technical Project Team Members

Anne Forrest Butler

Casey Welch

Andrew Lin

Chet Kleppin

Casey Welch

On my honor as a University Student, I have neither given nor received

unauthorized aid on this assignment as defined by the Honor Guidelines

for Thesis-Related Assignments

Signature: *Mosed Saroor* Date: 11/11/2021

Mosed Saroor

Approved: _________________________________________ Date: __________

Tomonari Furukawa, Department of Choose Department

Approved: _________________________________________ Date: __________

Adarsh Ramakrishnan, Department of Engineering and Society

**Introduction**

For well over a century, the human race has dramatically increased its usage of fossil fuels. From powering homes in the late 19th century to dominating many aspects of the average individual's life, fossil fuels have provided an efficient yet consequential means of supplying energy. However, growing concern coupled with advancing technology has led to scientific proof that carbon emissions from fossil fuel consumption is harmful to the planet. It is indeed a problem that could benefit from small lifestyle changes in all of society. However, this solution is small in comparison to the annual volumes of carbon emissions that enter the atmosphere from the big players in various industries. Several sources of the problem are noted because of their massive impacts: 29% and 23% of global greenhouse gas emissions stem from transportation and industry, respectively (EPA 2019). The ideal solution would be for the government to fully back carbon-limiting policies such as converting transportation methods to electric-based and policies that strongly limit companies' carbon emissions. This result would be next to impossible to achieve and leads to yet another problem in the battle against climate change: the society and its government. Compared to poll results in the 20th century, more people believe that climate change exists and should be a top priority for the government. These numbers, however, are not enough to make a significant and immediate impact. Despite being the majority, only 53% of registered voters believe that global warming should be a top priority for the government (Schwartz 2021). Of that number, 86% and 12% of Liberal Democrats and Conservative Republicans agree with that majority, respectively. Seeing as the control over the government shifts every 4-8 years typically, this division between parties on a major topic like climate change and renewable energy shows that any major policy or change is unlikely to be used to its full effects as there is simply not enough time. One aspect of technology that is mentioned in conversation with climate change and has gained more attention over the last few decades would be the topic of autonomous driving. While it is not uncommon for people in society to oppose the idea of autonomous driving due to safety concerns and the lack of user control, studies and the progress in development have shown that autonomous driving is indeed safe and improving annually. On the other side of a technological approach, the driving simulator would be met with approval in society due to its major purpose of promoting safety. As seen in Appendix A, the driving simulator utilizes both user control and trust in a computer which allows for people to practice driving without the consequence of getting into an accident or releasing harmful substances into the atmosphere. The issue is the lack of development or popularity that current driving simulators have in the market. Certain partly-autonomous driving features that were initially met with hostility are now being used and preferred by more people everyday. For example, 33% of American drivers believe that some of these features, such as parking or lane departure assistance improve the driving experience (Gerber 2021). From a human perspective, it is clear that global warming is taking its toll on society and that developments in technology are available and at disposal for solving the problem and lessening its devastating effects. Certain technologies such as the driving simulator and those related to autonomous driving can be developed to be more efficient, cost effective, and attractive to customers in society and the government to encourage safer alternatives to methods that have enhanced climate change. Society must make it clear to the government and its officials that these technologies must be developed and molded so the problem of climate change and its devastating effects can be solved as part of a longer term goal.

**Technical**

Despite the only practical use of a driving simulator being a source of practice or examination in driving exams, it can make a sizable dent out of the 29% of global greenhouse gas emissions from transportation. There are plenty of other technologies that can be considered sufficient in turning the tide of climate change. One noteworthy method is disbursement of aerosols in the atmosphere to combat climate change caused by carbon emissions. Students of a Harvard University team did this by sending a remote controlled balloon with a gondola that emitted aerosol particles and collected data in meteorologically safer areas. Although it is not based on a land-traveling vehicle, the balloon is considered an autonomous vehicle that understands its environment and can act without user control. One successful piece of technology that has been successfully utilized under autonomous driving would be the Tesla car. Tesla models have gradually increased their name in the automobile and autonomous vehicle industry and have provided a carbon-safe method of travel. Like many other autonomous vehicles and technologies that visually process its surroundings, Tesla models use cameras similar to lidar to map out the environment and help the robot make a decision (Appendix B). In the case of an autonomous vehicle versus a driving simulator, it is important to have the proper technology in creating a map that influences a robot's autonomous decision making. Depending on the map, whether simulation or an interpretation of real life, a user's position and potential on a developed map will influence the system's preparation physically for what will happen next. If a vehicle is anticipating movement down a steep hill, it must allow for safety in the platform for the user, whether that is inside a physical autonomous vehicle, or the motion platform that makes the base of the driving simulator. Because driving simulators on the market are still relatively new and very much in development, such as major brands such as DrivingMBA and Thrustmaster, there is much room for improvement. The Driving Simulator based in the University of Virginia's VICTOR lab for Machine Design I has been in development over the course of three fourth year Mechanical Engineering teams for their respective projects. Despite being a sufficient model and having the capability to compete with leading driving simulators in the market, this model is one that can also use improvement. The system revolves around the MOOG motion base platform (Appendix C), which uses electric linear actuators rather than hydraulic motion control. While the usage of actuators is preferred and is a recommended alternative to those products on the market for faster and more accurate motion, much of the software used is old and was outdated even when the first team began in 2016. There is a lot for this industry's leaders to do, whether that is to include a manual transmission option to attract new consumers or improve software to enhance graphics and response time for a more immersive experience. Adding certain changes or features that can attract more customers will be crucial in furthering the availability and development of this market for driving simulators and autonomous vehicles. In Biden's campaign surveys, it was seen that two thirds of participants were in favor of installing 300,000 electric vehicle charging stations in the United States by 2030 (Schwartz 2021). This shows the increase in demand and ownership of electric and autonomous cars that will be ongoing in the future for several decades.

**STS**

With such limitations on the small scale of these solutions, it must come down to the government to either allow the private sector to bypass certain holds or to take major action from itself. It is significant for those involved in developing technology to look at it from a socio-technical perspective. Many socio-technical concepts will be crucial in the fight for prevention from further climate change. The triangle of society, technology, and organization is a good point to consider. The technology that will be developed to utilize renewable energy effectively will have to come from the government if there is to be major progress, and it is important to consider whether the government is acting as a society or an organization. Using such new technologies will not only be seen as a nuisance for some people, but may also be uneasy for others that feel comfortable when using products that are common in society. It will be a slow transition and that is why people and companies should be encouraged and rewarded for switching to renewable energy, such as minor tax breaks for those that drive electric cars. With two parties that oppose each other on most major topics, it would be difficult two find some sort of long term goal to solve the issue that is at hand. The effects of climate change have been felt for the last many decades and solutions have been either ineffective or shut down before realizing its slow, yet true potential. Anticipatory governance is expected and ever present in today's politics, but failing to take a real effect. While the government and society will always be able to adapt to situations when called upon, the division in government does not allow for any true methods of mitigation or anticipation. Projects and agreements with other nations fall apart when a new president is elected and the planet suffers from the lack of progress. That is why it's crucial for either society to let it be known what the voting body's goals for an administration are and for a party to let the citizens know what its ambitions are regarding fighting climate change. One major solution and topic that is under heavy debate would be the government's potential implementation of a carbon tax on its major companies. While a carbon tax is effective in vastly limiting and controlling the number of carbon emissions within a nation's borders, there is still the chance that companies would leave for a more lenient country to conduct its business without a carbon tax. In a utopian society all nations would come together to agree that companies should not be selfish in this way and work with the majority of people worldwide in taking a huge part in battling climate change. Creating a challenge in the economy sector is unfavorable for both sides and can lead to controversial decisions, such as the Trump administration (Appendix D) pulling out of the Paris Climate Change Agreement. Another route the government could take would be to establish a net amount of annual carbon emissions across each industry. Dividends of this net amount would then be sold or pre-determined to each company within that industry, that way the amount of carbon emissions is controlled while also providing a chance for a company to 'out-carbon' its competitors. Emergence is a great topic to consider when thinking about the different methods the government can follow to further implement renewable energy into society. That is similar to any approach the government decides to take to combat climate change. Not only will policies such as a carbon tax have to be made against the main contributors to climate change, but renewable energy technology will have to be further developed and used across the nation. For a solution from the government to be successful, it must have pieces of different qualities that cover most problems and satisfy as many people with opposing views as possible.

**Research Question**

In order for the government to take action on establishing renewable energy efficient technologies across the nation for regular use, it must first recognize from the voters themselves that the issue should be a top priority. Many experts and top people in this industry urge the government to take a stance now as carbon emissions must be eliminated to virtually zero emissions very soon if there is to be a significant change in the future, both near and distant. Organizations and lobbyists must work together in finding data that both supports renewable energy technologies and shows that the people will vote for whichever administration has a better plan for solving this crisis. The government sways between either two parties every 4-8 years roughly but if the majority of people who believe in climate change make it clear that this is a top priority to gain their support, then the nation could settle on one party or related administrations that will fight this long battle for decades to come in order to finally initiate a major solution. The climate change crisis is one that will not be going away anytime soon and will further impact society down the road. That is why it is crucial for future office holders to consider this problem by making it a highlight of their campaign to not only gain potential voters but to actually deal with the problem at hand. Several major countries around the world have implemented laws that relaxed restrictions on usage of autonomous vehicles, such as Germany and Japan. This makes for an interesting correlation between countries with policies allowing autonomous driving versus the plateau or fall in rate of carbon emissions created by those same countries.

**Conclusion**

The driving simulator and autonomous vehicles are related in just one branch of technology that can provide a small but noticeable effect on annual carbon emissions. If related technologies are further developed and made to look attractive to customers, then people will immerse these products into society and allow for their purpose to benefit the planet. However, if society wants to see these changes, it will have to make it be known to officials running for office that it can be a deciding factor in elections in order to push the agenda on parties that already disagree on most topics. It is up to the government to somehow establish these systems, but that will only be possible if the people start at a small scale and show to government officials and bodies that fighting climate change with renewable energy technologies is a top priority for the nation and the world. These ideas, coupled with the vast resources of renewable energy technologies that innovators across the globe are developing, will be the front runners in establishing a carbon free society in the future. The topics of autonomous driving with related technologies and the effects of carbon-neutral policies are relatively new and will take a while to fully analyze, but they are exciting topics when considering how technology will impact society and other factors in the future, both near and far.

**References**

Alexander, M. (2021, July 8). 2 types of green energy projects growing in 2021: Wind and solar energy tech can help the planet. TechRepublic. Retrieved October 14, 2021, from

Caperton, R. W. (n.d.). Good government investments in renewable energy. Center for American Progress. Retrieved October 14, 2021, from https://www.americanprogress.org/issues/green/reports/2012/01/10/10956/good-governme nt-investments-in-renewable-energy/.

Environmental Protection Agency. (n.d.). EPA. Retrieved October 14, 2021, from https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#:~:text=In%202019 %2C%20greenhouse%20gas%20emissions,of%20U.S.%20greenhouse%20gas%20emissio ns.

Mary Beth Gallagher | Department of Mechanical Engineering. (n.d.). The race to develop Renewable Energy Technologies. MIT News | Massachusetts Institute of Technology. Retrieved October 14, 2021, from https://news.mit.edu/2019/race-develop-renewable-energy-technologies-1218.

Autonomous (Self Driving) vehicle statistics 2021. Gerber Injury Law. (2021, October 28). Retrieved November 11, 2021, from https://gerberinjurylaw.com/autonomous-vehicle-statistics/.

Gibbs, A. (2019, September 17). Harvard groups research planet-cooling aerosols. Harvard Gazette. Retrieved October 14, 2021, from https://news.harvard.edu/gazette/story/2019/09/harvard-groups-research-planet-cooling-aer osols/.

Robinson, Q. (2021, September 21). America's innovators will solve climate change, not regulators. TechCrunch. Retrieved October 14, 2021, from https://techcrunch.com/2021/09/21/americas-innovators-will-solve-climate-change-not-reg ulators/.

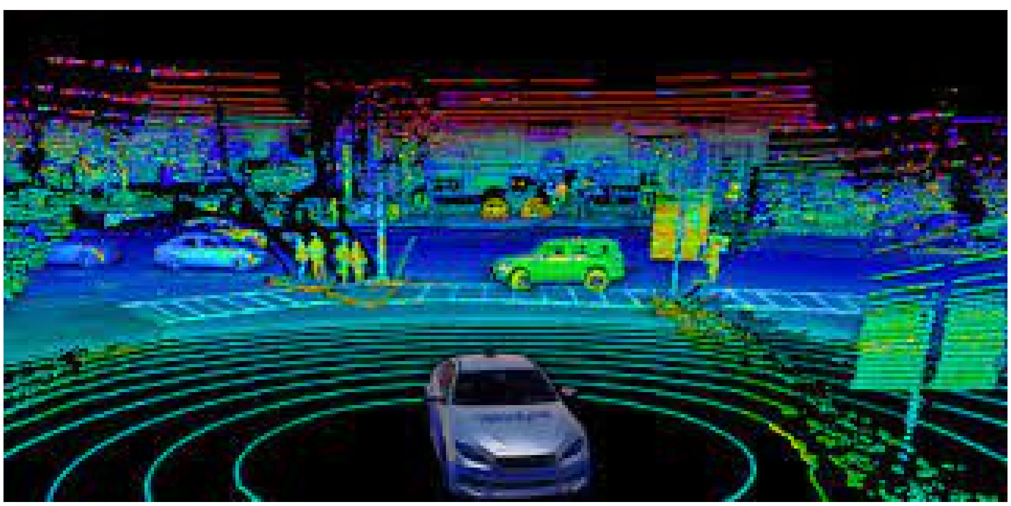
Schwartz, J. (2021, January 15). Survey finds majority of voters support initiatives to fight climate change. The New York Times. Retrieved October 14, 2021, from https://www.nytimes.com/2021/01/15/climate/climate-change-survey.html.

How volcanoes influence climate. How Volcanoes Influence Climate | UCAR Center for Science Education. (n.d.). Retrieved October 14, 2021, from https://scied.ucar.edu/learning-zone/how-climate-works/how-volcanoes-influence-climate#:~:text=The%20gases%20and%20dust%20particles,the%20characteristics%20of%20the% 20eruption.

Zogopoulos, E. (2020, November 23). Tesla's mission: Accelerating world's transition to Sustainable Energy. Energy Industry Review. Retrieved October 14, 2021, from https://energyindustryreview.com/analysis/teslas-mission-accelerating-worlds-transition-tosustainable-energy/.

**Appendix**

Appendix A



Appendix B

Appendix C


Appendix D