ME 4182 Section A

Final Progress Report for the Console Caddy

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Executive Summary

This project was designed to eliminate the need for drivers to hand items back to passengers in a vehicle. The concept generates a method of delivery that the driver can safely, while keeping his/her attention on the road, hand back everyday items normally present in a car at the touch of a button. The two major technical problems of this design are to maintain the safety ratings of the vehicle and to ensure that no prior functionality of the vehicle is eliminated with the implementation of a solution. Many engineering tools are being used to generate a workflow towards the best solution. These methods/tools consist of a House of Quality, a Function Tree, Evaluation Matrices, Risk Assessment Charts, FEA, electrical prototyping, and many others. The selected design solution consists of a moving center console that is powered through the vehicle's battery. This center console, capable of movement, would deliver the items to the rear passengers of the vehicle. The key performance specifications are an increase in safety throughout the vehicle (incorporating both movement of the device and human operation of the device), a power usage of less than 720 Watt-Hours used during operation, and stopping notifications to augment safety. The solution is plausible due to the fact that small electric motors can run off much more than a car engine is capable of producing, the technology needed to run these already exists, and sensors can be placed to stop motion to avoid safety issues. Modern equipment can be combined with design work to create a working solution. The next steps include resizing sensor and button wires for better wire management of electrical components, addition of wiring safety mechanisms across the I-beam, correcting manufacturing processes to ensure 3D prints do not fail in the future, and potentially changing the material of the console to improve the safety factor of the design.

Introduction and Background

Every year, thousands of people pass away or are injured due to distracted driving accidents, and children are a large source of those distractions. AAA states that children have the potential to create four times as many distractions for drivers as adult passengers. Statistics also show that drivers with children and infants in a vehicle can be up to twelve times more distracted than drivers who use cellphones while driving. Often times parents must hand their children different items from the front seat. Doing so causes the drivers to turn away from the road and increases the risk of an automobile accident. Many parents with children drive minivans for accomodation of greater than 5 passengers, and this is why parents who own minivans are the target user base for the project.

To be functional, the console must be able to hold any items that the parent wants to deliver to the back through a simple button to initiate movement of the console. All of this can be done by the parent without having to strain and turn around to hand items to their children. The console will also have many safety features to ensure that children or other obstacles will not disturb its path of motion. The console delivery system will not get in the way of any existing minivan components so that minivan drivers will not have to give up any functions they currently enjoy in their minivans. The motor and peripheral components will be controlled by a microcontroller and power will be supplied from the car battery. The console will also need to be structurally sound to withstand heavy usage from children and younger users. Further design specifications will be outlined in detail further along in the report. The solution will be prototyped by the end of the semester to prove it is a viable option.

In the following sections of the paper, the design process will be discussed in detail. The first component of design is research on existing products and solutions. Then, codes and standards which affect the solution are also discussed. Design requirement topics ranging from customer requirements, market research, and design concept ideation will be introduced and explored in great detail. Concept selection and justification, industrial design, analysis, and experimentation will then follow. Differing from reports #1 and #2, final design, prototyping, manufacturing details, societal, environmental, sustainability considerations, safety, and patent claims will follow. The report will then end a conclusion covering any future work that may be pursued.

Distracted driving has a wide range of causes and by focusing on a specific cause, it is possible to mitigate overall motor vehicle accidents. This "Console Caddy" will require a design that covers a wide array of mechanical and electrical engineering expertise. The solution will aim to cover all of the customer expectations and safely reduce distracted driving caused by children.

Nomenclature

The following acronyms are relevant to this console caddy project and are used throughout this report:

OBD- On board diagnostics
NHTSA- National Highway Traffic Safety Administration
AAA- American Automobile Association
RFID- Radio Frequency Identification
FEA- Finite Element Analysis
FOS- Factor of Safety

Existing Products, Prior Art and Applicable Patents

The commercial applications of this technology arise from creating a distraction free driving environment and convenience for passengers. The center console will shuttle food, drinks, or items to the backseat with the push of a button, allowing the driver to keep their eyes focused on the road. This idea is understandably useful, so some designs have already been implemented currently. The following patents were found that we would have to be mindful of in the design process. Figure 1 shows Patent US20080290680A1 that is currently active and does not expire until January 26, 2028. The rail system of this patent is very similar to many of the designs we came up with, some being this very concept which had to be thrown out due to patent infringement. A concern with going forward could be designing around the "sliding console for use with a rail in a vehicle". Figure 2, 3, and 4, Patent US7416235B2, Patent US6921118B2, and Patent US8215688B2 respectively, all contain various sliding methods of the storage compartments that were kept in mind when designing the storage features of this team's center console.

Codes and Standards

On board diagnostics is a mandatory feature of all new cars. On-board diagnostic systems (OBD) give the vehicle owner or a repair technician access to the status of the various vehicle subsystems. The National Highway Traffic Safety Administration regulates parts that are added to vehicles based on safety needs. The NHTSA can regulate any component on a new vehicle based on a safety concern according to sema.org so this will need to be considered. Although nothing could be found specifically pertaining to automated center consoles, the main issue seen through standards are violations of safety in the form of inhibiting airbag deployment; the design team has reached out to NHTSA to inquired about what is specifically needed to keep in mind in this context. The Institute of Electrical and Electronics Engineers Standards Association must also be considered. IEEE 2030.2.1-2019 regulates the design, operation and maintenance of stationary or mobile battery energy storage system.

Customer Requirements and Engineering Design Specifications

The "2x2" stakeholder analysis is shown in Figure 5. The stakeholder analysis shows the least to most important role players in this process. It can be seen that the researchers and developers have the most power and interest as this is the team who is building the product. The mentors on the other hand have the least amount of power and interest as they are only provided to the team as a guiding resource with no real stake in this design process. The final customer has a very high interest with a lower power because once the customer needs are met the rest of this portion is left to the researchers and designers. The manufacturing and car policy creators have higher power but lower interest in a single product that will go into a certain type of vehicle. However, manufacturing will affect varying aspects of the product and the policy's will decide if this is a safe and viable product for roadways.

Design constraints on this specific model were based on the Honda Odyssey minivan. This is the most popular model van currently on the market with around 100,000 vans being sold in the United States in 2018. The center console must attach to the same anchor points, be able to be powered via the battery of the vehicle, and must not require extra work to be done to the vehicle besides the wiring. This is to keep the initial purchase point at a lower value. The electronics will have to work with direct current voltage sources, as most automobile components operate on this. A large design constraint comes from The National Highway Traffic Safety Administration because the NHTSA regulates parts that are added to vehicles based on safety needs. Generally speaking the NHTSA can regulate any component on a new vehicle based on a safety concern according to sema.org.

The House of Quality, seen in Figure 6, shows a list of customer and engineering requirements. The House of Quality is extremely important because this is a method of quantitatively showing what is important. This is critical because it is a method of finding concerns that would otherwise be overlooked. The House of Quality was used in the iterative design process to ensure the focus from the engineering requirements are met. From the customer requirements on the left region of the "House", safety is a large concern due to potential hazards from designing a moving object to be placed in an accelerating vehicle with an importance rating of 10. The stakeholders have expressed extreme concern for the safety of adding a device to a moving vehicle. This was followed by a reach for children to be less than 26 inches. This changed from 21 inches due to the new model of minivans having railing for a middle seat in the 2nd row of the vehicle. This was chosen because there is a 1:1 ratio from height to wingspan. The average height for a 7 year old was divided in two to come up with this number with an importance rating of 8 such that the solution will work. This was followed by durability because children will be using this, potentially climbing over the machine, etc.. Some other notable customer requirements changes are changing the production cost from $700 to $250 to beat the competitors according to market research. Installs with no extra alteration has changed to mounting in previous center console mounting points. This is because the railing had to be changed from suspended in air to being on the ground. This change was due to the fact that in the case of a car crash, the device would turn into a projectile that could potentially harm passengers. Since the rails are on the ground they would not need to be installed aside from the center console.

The engineering requirements are shown under the "roof" of the HOQ. The speed of 0.5 m/s was chosen based off making it slower than the average walking speed of an adult. The power usage must be less than 360 Watt-Hours which was changed from 720 Watt-Hours. This is important because the motors should never draw as much power as the car battery can provide. An extension/retract time of less than 1.5 minutes was changed to less than 30 seconds due to potential customers concerns of this taking too long to reach potentially young and impatient passengers. The weight that the center console can support was changed to 100lbs from the railing that would have been suspended being able to support this. This decreases the forces on the center console, specifically, the bending moment that would have been seen if the prior design was kept.

From entering in the correlations in the "roof", determining the relationships in the "body", and choosing a direction of improvement, the relative weight is produced for each engineering requirement. The stopping notifications was surprisingly found to be the highest relative weight of 13% which stayed the same throughout the large changes in the House of Quality. This was due to the impact on safety, ease of use, and cost. The center console being able to support 100 lbs was raised to a relative weight of 13% also. This was due to the correlation to reliability, storage room, cost, and more. The stopping notifications (audio/visual) was increased to a 12% relative weight after the changes due to safety, cost, time of extension, and maintenance.

Market Research

The demographic for this designed device is American adults with families and children that use minivans regularly to transport their families to different activities. This includes regular long-term road trips as well as weekly activities. The target price of our automated center console was between $400 and $700 based on similar high-tech consoles on the current market, but in order to be competitive, we will price our console at about $250 maximum.

The optimal market strategy is to have an option for consumers to upgrade a current console in a minivan to our updated, automated version. Conversations with different OEMs (original equipment manufacturers) such as Toyota, Honda, etc. will follow for the sale of the successful design so that it can be implemented in their design process and used as an add-on feature when a family goes to purchase a new minivan on the market.

The 2020 Honda Odyssey model is the newest version of the Honda Odyssey and no longer has a storage compartment behind the two front seats. Because of this we are able to properly mount our console to the floor of the minivan to allow it to be more secure and safe in case of a collision. Also, in the newest version of the minivan, the second row of seats has a large rail that allows the owner to shift the second row seats to allow for more flexibility. Based on this finding, our group decided to cantilever the front of the motorized console in order to not run into this thick rail.

Design Concept Ideation

In order to make a decision on a specific design that would enter the market, certain design constraints and functions must be decided first. In order to do so, a function tree depicted in Figure 7 was created to highlight some of the most important functions the center console needs to perform. These functions include: the ability to move the center console, the ability to store items similar to current models of center consoles, human-machine interaction device(s), alerting of obstacles and motion, driver arm support, and ability to power the protracted portion of the center console itself.

These primary tasks are further broken up into subfunctions, and, for each sub-function, a morphological chart was developed to examine possible solutions shown in Table 1. The purpose of the morphological chart is to show different possible solutions to the design criteria and sub-functions that are listed in the function tree. Some of the most important functions outlined in the morphological chart are as follows: Movement, types of storage, obstacle detection, initiating movement, acquiring power, and auxiliary powered sub-functions. These were chosen as the most important functions because these either directly impact safety or functionality of the center console. To enhance the safety aspect of the console (stopping the console, detecting obstacles, and initiating movement), features such as motion detection sensors and I-beam rails were identified as possible solutions to help in stopping the console at its desired position as well as sound and light indicators to alert passengers of movement. The console needs to perform its main function first and foremost, but not at this risk of injury to anyone in the vehicle.

Some of the secondary sub functions are features like ambient lighting and storage amount. The ambient lighting is a feature that would help with both aesthetics and extra visual aid in the vehicle. All of the peripheral features have to be supplied power and the main solution to this is from the main car battery. With regards to storage space, surveys show that most minivan owners would prefer to be able to serve the max amount of people in rear of the vehicle. However, the layout of the newest minivan models would not allow for the console to reach the entire back row due to the removable middle seat attachment system. For this reason, there were some design changes made that reduced the moving portion of the console (see Figure 11 compared to Figure 9). This, in turn, changed the options of electrical components for items such as the motors and motion sensors.

Further exploration into the inclined terrain on which a minivan would potentially travel showed a heightened necessity for more powerful motors that could hold the console in place against the forces of gravity or the forces of a human being. For this reason, window and car seat motors were added to the morphological chart, shown in Table 1, as “initiation of movement” options. Additionally, in regards to motion detection systems, issues with ambient light and directionality of emitted signals have resulted in time-of-flight and ultrasound sensors to be considered in addition to infrared detection devices on the morphological chart. Furthermore, motor controller options were also discussed and added to the morphological chart, with proper shielding components. In terms of location detection, an additional option of microswitches allow for the software team to detect the location (front or back) the console was last at and the direction in which it was moving before being stopped by an obstacle; knowing this information will allow it to continue in the direction it was moving once the obstacle is detected to be safely removed. Finally, audio and visual options for notifying humans of console movement were added to the morphological chart.

Preliminary Concept Selection and Justification

The aforementioned function chart and morphological chart were created from six separate console design concepts. After discussion of all features, two concepts too closely resembled designs already covered by current patents Patent US20080290680A1 , displayed in

Figure 1 and Patent US7416235B2, shown in Figure 2. A third design concept possessed features accommodated by the three remaining concepts.

Concept 1 was deemed the "Segmented Ground Rail" design, see Figure 8, where a console moves on pre-installed ground rails that are segmented to accomodate for the floor storage compartment often found in minivans. Concept 2, shown in Figure 9, was deemed the "Suspended Rails with Wheels" design is a mechanically bolted console with wheels on the ground that moves on a telescoping rail system towards the back of the vehicle from the armrest region of the driver and front passenger seats. In Figure 10, Concept 3 was deemed the "Partial Console Movement" design because only the back portion of the entire console disconnects from the front of the console and moves backwards on stacked ground rails to a fixed position in the aisle of the middle row of passenger seats.

These three concepts were thoroughly explained and discussed, and the team created an evaluation matrix based on the most contentious design criteria. An unweighted matrix and weighted matrix can be seen in Tables 2 and 3. Weights were on a scale of 1 to 7, with 7 being the most important, and were chosen based on safety, weight constraints, and ease of use and implementation. In terms of safety, Concept 3 had a stopping function of torque overload of the motors that would be used to push the rails out of the home portion of the center console; if something were to get in front of the path of motion and the motor would resist for a moment until the circuit would detect this due to the torque achieved and stop the movement altogether. Concepts 1 and 2 had a combination of mechanical hard stops, overtravels, motion detection sensors, and RFID readers. Motion detectors would be used for stopping the console if children get in the way of its movement, whereas RFID scanning would occur to stop the console at the correct position in the aisle of the center row of seats and at the back row of seats. Concepts 1 and 3 used electric motors to drive the console on ground rails and stacked rails, respectively; Concept 2, on the other hand, uses purely mechanical movement of the suspended rails with electrically assisted movement of the console on wheels. Power usage for each of these methods requires further inspection based on console weight and existing auxiliary power sources. In terms of ease of use, only Concepts 1 and 2 designed for the ability to keep the floor storage capability that most vans currently have, and both of these concepts also designed for five passengers in terms of cup holders and available storage. Concept 1 was the only design that allowed for children to have push button access to the movement functions of the console (with the ability of the driver to lock out these controls for younger children). Concept 3 was the most weight efficient due to only part of the console being moved, so it was a feature to be kept in mind. Overall, both matrices resulted in the decision of the “Suspended Rails with Wheels” system as the design concept of choice. Some features of the other two concepts will be added to this main design, including the idea of only part of the console moving backwards instead of the whole console moving backwards (in order to preserve storage space for the front seat drivers and minimize console weight), a customizable interior for the console, and lighting and sound alerts for the safety of passengers.

The model of the car console chosen above had to be completely changed after having to go back through the design process. Complications from the new model of mini van arose, resulting in all of the engineering tools would need to be remade to ensure that the proper solution was found which was shown previously. The newer models of Honda Odyssey are trending towards an extra seat in the middle row, and no longer contain floor storage space. While most models do not have this seat installed, they do have railing systems that block the movement of the console to the rear of the vehicle. The new car model creates implications that were not accounted for in the chosen design solution that the team agreed upon, rendering this design unusable. This was a large shift in the model and merely one change of many that needed to be executed. Iterations of designs based on changing customer needs is an important process in design thinking and was a good step due to the implications that would arise after having begun a prototype of an unusable design. Engineering design and analysis of the newest design can be found in the “Engineering Analysis and Experiments” section of this document.

Several electrical component decisions were made in the second round of console design. Firstly, the team is using the standard 12V car battery voltage to power all moving components of the console for easier transition into OEM manufacturability. Thus, all electrical components chosen had to meet this 12V power supply requirement. With regards to motor selection, the team has chosen window motors over DC motors, servos, and car seat motors. This is because DC motors and servos would not withstand the forces of children or gravity and would cause the console to move undesirably. Car seat motors are not often equipped with overcurrent features, which is why it was less suitable than window motors: when power is cut off to a window motor, it takes an extreme amount of torque to move the device that the motor is powering. This is a perfect feature that would allow a console to stay in place if it were to ever stop while the car is on an incline or when a person is applying a force to it. The window motors chosen (see Figure 24) have a locked stall torque of almost 4x its rated torque. Additionally, window motors are equipped with overcurrent protection that cuts power to the motor when too much force is applied against the direction of movement. While this feature's intended utility was originally to stop a window from crushing fingers or a head, it will now serve as protection against limbs and obstacles preventing console motion. The chosen window motors also come with wheels, which we may or may not use for our console as well.

There were several factors that contributed to the choice of time-of-flight sensors as the designated motion detection system. Ultrasound sensors have a wide "cone" of detection, which means that an ultrasound sensor used in the context of the automated console might mistake a mere shuffling of feet from a passenger in the backseat far away from the console as an obstacle; this would lead to a false alarm sent to the motor controller to stop the console unnecessarily. Infrared detection sensors are more sensitive to ambient light and would therefore be less accurate in obstacle detection when the car is outside in the sunlight (which is often). Furthermore, low cost infrared detection sensors have a linearity issue at close ranges that significantly lower voltage output at close-range distances. For these reasons, the team has chosen time-of-flight sensors, shown in Figure 25, because of their superior directionality and accuracy. Specifically, the team has chosen the VL53L0X time-of-flight sensors, which have a sensing range of 30mm-1000mm, which is plenty sufficient to detect motion fast enough to prevent human harm.

Motor controller selection of the Arduino Uno R3 was based on its 12V power supply (which is compatible with the 12V car battery), price, accessibility, and greater availability of libraries for better functionality accessibility. After preliminary prototyping of the electrical components, however, there was not sufficient memory for the Arduino Uno R3 to operate; four sensors collecting data constantly as well as more than eight I/O operations proved to be too difficult for the Arduino Uno to handle. As a result, the electrical design team had to transition to the Arduino MEGA, which was still compatible with the selected motor shields. Auxiliary accessories such as the LED light for notification of console movement and user interface pushbuttons were chosen to have 5V operating voltage because that is the output voltage of the Arduino Uno R3 motor controller. Furthermore, due to space constraints within the hollowed portion of the moving console and the reachability of the wires in the box holding the electronics in the prototype used for Capstone Design Expo, pinout diagrams had to be readjusted to enable easy access and correct digital pinouts for all four sensors, all six pushbuttons, both LED's, and all the power and ground wiring necessary for the proper function of all these components. This entailed reallocating analog pins to implement digital communication. Wiring diagrams and power and communication flow can be seen in Figures 32-34 of the Appendix.

There are ways to prevent children's usage of the buttons on the console until they are old enough to be responsible with its movement; much like many vehicles today have driver capabilities of locking the air conditioning control from their instrument panel in the front of the car, this design concept also has a locking ability from the instrument panel that prevents any movement of the console that is not conducted by the driver. The main concerns for this design as of now are safety when it comes to a child's proximity to the wires that are necessary for console automation. In terms of power draw for console movement, wire management in the form of a retractable wire reel, in combination with housing for the wires themselves over the I-beam, will sufficiently protect the passengers from wires. Prototype testing was done on the motors and motion sensors to ensure the console stops fast enough when detecting a human being as an obstacle. In terms of incline driving and sudden vehicle movements, the chosen window motors were tested for their locking feature effectiveness, but further incline testing at different inclines and speeds could be in future design methodology. The design of the console must have robust enough control of the motor to deliver the console at a stable rate no matter the speed, acceleration, or direction of car movement. A secondary concern is providing general additions of safety measures such as overtravel switches and sound effects to notify passengers of console movement, which the Arduino MEGA has enough storage for and can be implemented relatively easily in future iterations of design.

Industrial Design

The industrial design component of the chosen solution is important because this is how the end customer will integrate and use the device. Several industrial design considerations were focused on to meet customer requirements and increased ease of use of the console for customers. Several factors affect industrial design. Functional design choices are very important as they govern the usability of the system. Industrial design also covers aesthetic choices for the system. Even though aesthetics of a functional device is less important than the functionality, it is still a factor to consider and does affect some of the ease of use for the customer.

As previously discussed in the House of Quality, certain customer requirements such as distance from middle seats to the console and speed of the console are especially important for our design. The constraints of reach are very important because if kids are unable to reach the items on the console from a comfortable position, the console is difficult to use and not helpful. The speed of the console is very important as well because if the console is too slow the user's will be less willing to use the system. Another aspect of industrial design is the ease of human interaction. The console requires a method of interaction to begin movement and it is important that the method of interaction is clear. The design will have 4 push buttons in the front instrumentation panel for access to the drivers: Forward, Backward, Stop, and Child Lock. The first three buttons are clear in their function and the child lock will prevent the 2 buttons on the moving segment of the console from being able to control movement. The 2 buttons on the moving segment of the console will be a simple red stop and green go button to make it simple for younger children to understand.

The chosen design has been chosen such that it will not be a drastic change to the minivan look. The aim of this is to seamlessly integrate into the current models of Honda Odyssey such that it is not extremely noticeable when it is docked and potentially be unnoticed until it is used to send items to the rear. The chosen end colors of the center console will be matched to the color of the chosen interior design of the dashboard to keep the style of Honda

Odyssey due to the market demographic not wanting an item that is flashy and stands out compared to the rest of the interior. This center console will not have a branding on the outside of the center console because no items in vehicles are branded usually. Again, this center console will have a higher chance of gaining more users if this design assimilates to the design of the rest of the vehicle. The texture will be closely matched to the most common dashboard themes of the Honda Odyssey. An important aspect to note is that the target market is not to become an aftermarket product but to be an option to the car buyer when first purchasing the car. This means to match the industrial design of the Honda Odyssey on the interior having a sleek and modern layout.

Detailed Technical Analyses, Experimentation, and Design Performance Prediction

The engineering analysis and experiments are extremely important to execute following the design process. In the next paragraphs the design shift from elevated railing, to extending tracks on the floor, to the current model are discussed. An important step after making the correct changes in the design process was to speak with the stakeholders.

After meeting with Dr. Leamy (a main stakeholder), the team concluded that a redesign should take place to meet safety requirements. In the previous design, shown in Figure 9, the console would become a projectile in the event of a collision or crash. In order to secure the center console, the new design, Figure 11, integrates the previous design with a floor mounted rail as well as only allowing a small portion of the center console to move. Finite element analysis (FEA) was done on the entire center console to determine failure points and a safety factor. A force representing the weight of a 10 year old male child, 3217 flbs, was applied to both the top and side of the center console in the event that a child sat or pushed on the console with their full body weight , shown in Figure 12. The Minimum factor of safety for the automotive industry is 2 and the new design has a minimum FOS of 2, as seen in Figure 13. The Maximum Von Mises, after the test, on the console is 675 MPA. Therefore, the system failed due to exceeding the maximum stress allowed of 46 MPA, displayed in Figure 14. The system failure was due to only having two wheels.

Due to the failure of the last model, the team made a third design, depicted in Figure 15, that utilizes four wheels for stability and power. The related part drawings for this new design can be seen in Figure 22 and Figure 23. FEA was then done on the new model under the same conditions as seen in Figure 16. With the new quantity of wheels, the system tested with a minimum FOS of 8, shown in Figure 17. The maximum Von Mises on the system tested to be 3.508 MPA, as seen in Figure 18. Since the system passed the first rounds of FAE, the console was then tested under new conditions in the situation of a crash where the car flips over as seen in Figure 19 . The only forces acting on the console is the total weight and gravity. At the end of the crash analysis, the maximum Von Mises acting on the stem is 0.2769 MPA located on the ABS plastic side which would be the buckling location depicted in Figure 20 and 21.

Experimentation of electrical components was done concurrently with mechanical simulations. All automation code can be found in Appendix B of this document. Sensors were the first electrical components tested because they were the first components to be delivered to the team from their relative OEM's. One sensor was used originally to learn functionality of the sensor. It was discovered that the sensor occasionally detects a much closer value than the actual distance to an object, which triggered a false alarm stoppage of the console. To mitigate the problem of these misreadings, a counter was implemented. The counter would count consecutive readings of a small value, and once the consecutive counter reached an experimentally determined number (5 readings), the motor would stop. Implementing multiple sensors required shutting down all of the sensors at first and then changing the I2C channel addresses for each sensor while resetting each sensor individually. Implementing multiple sensors required more system memory than the Arduino UNO is able to provide. Due to these limitations, the Arduino MEGA replaced the UNO in the system. To protect the MEGA from the current draw required by the motors, motor drivers were used. Two motor drivers were stacked atop the MEGA to drive the two motors that were used to allow for communication from the MEGA to the motors in order to enable the console to move. The motor drivers also allowed for easy control of the motors. To modify the motor strength and direction, only two lines of code had to be written.

Final Design, Mockup and Prototype

Due to the need for wire management, the last design iteration has the moving piece shelled in order to allow space for the electronic components as seen in Figure 26. The walls of the base are also increased in order to allow easier access and more storage for the users. The part drawing for this final iteration can be seen in Figure 27. FEA was also done on the new model with the same conditions as the previous design iterations. Due to the increased height, a greater torque was applied on the connecting bolts that connect the base to the I-beam which in turn caused the FOS to be much lower than it was before, as shown in Figure 28. The von Mises was also higher but still within material limits. Lastly, there was a noticeable displacement in this new design due to the inside being shelled as well as the greater torque causing the console so slightly shift in the event of a 100lb child pushing against the moving component, also shown in Figure 28. This design was chosen for the prototype due to it's wire management ability and user functionality.

The final wiring management and diagrams included the following: four time of flight sensors, each with clock, data, shutdown, power and ground pins added to 20 wires that needed to be wired on a breadboard because there were not enough PWR, GND, SCL, SDA, and SHDN pins on the arduino and/or motor shields themselves to accomodate for all 20 wires. There was a separate breadboard for the pushbuttons (six buttons, each with Input and GND pins for a total of 12 wires) and LED wires (two LED's, each with Input and GND poles for a total of 4 wires), again because there were too many ground wires to allot one ground pin on the Arduino/motor shield to accommodate for all pins. The two breadboards, Arduino MEGA, portable/rechargeable battery power source for the Arduino MEGA, and two motor shields were all housed in the box underneath the moving portion of the console. The wiring for the four console sensors were wired through the hollowed out portion of the moving console in order to emulate the sensor placement on each of the four sides of the console.

The final version of code consisted of snippets taken from the programs used in testing of components. Some changes from the test programs occurred because of the merging with the mechanical components of the system. The power that was delivered to the motors was changed to better match the speed that was desired for the console. The sensor's minimum distance for incrementing the counter was also increased slightly as stopping too closely to endpoints was determined to cause uneasiness. An outline of the code flow is available in the appendix as Figure 31.

Manufacturing

The design considerations that contributed to the fabrication of our console were that the base and the front compartment needed to be constructed out of pine wood due to time restrictions. Our original design was to use a plastic filament called polylactic acid (PLA) and a 3D printer to build the entire console body. However, after finishing the back half, or the moving half of the console on the 3D printer, our team decided there would not be enough time before the Capstone Expo to complete the full prototype. Also, one cupholder took about 36 hours to print and used up an entire spool of material. The design considerations that contributed to the assembly of the prototype were to make sure that the electrical components could be stored inside the console before fully assembling the console on the i-beam support. The cup holders on the mobile half of the console could not be constructed together until the wires from the Arduino were securely placed inside the compartment below the cup holders.

First, the wooden base of the console was constructed with the front storage compartment attached with metal screws. Then, the i-beam was mounted to the base and the wheels were assembled and attached to the i-beam. Then, the 3D printed parts were combined, mounted to the i-beam, and the electrical system was mounted to the inside of the moving half of the console. Lastly, all of the components were sanded and painted to provide a cohesive appearance. The plan to produce the prototype in a mass production setting is to customize the console for varying sizes and types of minivans. Also, the entire console will be made from injection molding to create a seamless look. The consoles will be installed on new minivans and will be available for individuals to purchase as an add-on feature to their desired car. The impact on the design and material selection of the manufacturing process will largely come from the durability of the material and the cost of the material that is used. The final design will have reasonable tolerance levels, packaging and storage requirements considering that the console can be adjusted to a desired size. It will require a specific method for packaging in order to protect the console from becoming damaged and can be stored in a variety of conditions such as hot or cold temperatures.

Societal, environmental and sustainability considerations

The societal, environmental, and sustainable implications are extremely important when moving forward with any design process. These are the parameters that will affect not only future generations but also people living in society today. According to the NHTSA, “In 2017 alone, 3,166 people were killed in motor vehicle crashes involving distracted drivers.” This is important to note because the societal implications of the shuttle caddy would be aimed to reduce this number drastically by decreasing distracted driving while using this device. This would be done because the operator of the vehicle would be able to press a button that would shuttle the items to the rear of the vehicle. This is instead of having to hand each individual item back to the rear and having to take your eyes off the road.

The environmental and sustainability considerations are based off of the materials used. The materials used were Polylactic Acid Filament(PLA) used in the 3d printer, aluminum for the railing/bolts, wood for the base of the center console, and spray-paint aerosol. The PLA is made from fermented plant starch which is degradable but has added components that are not found in the environment to make this not specifically biodegradable. The wood is of course biodegradable, but the aluminum is non-renewable which would be used in small amounts. The spray paint is an aerosol which is not environmentally friendly because it changes the sun’s reflectivity in the atmosphere that can be harmful. On the mass production side, the 3d printed components(PLA) would be fabricated using injection molding. The injection molded parts would be made out of biopolymer renewable resins that is more sustainable than regular injection molded parts but are slightly more costly. The injection molded parts would be colored using dyes in the plastic instead of the aerosol spray paint used in the rapid prototyping that was done.

Risk Assessment, Safety and Liability

A risk assessment was conducted between design iterations and after the final design to identify and analyze potential events that may negatively impact individuals or assets, and making a judgement call on the tolerability of the risk. In order to do so we created a table that outlines the potential risk and ranks them based on tolerability of risk and likelihood of the risk as seen in Table 4. Outlined in this table are five major risks: Pinch Points between wheels and I-beam, Cart Collision, Electrical safety Malfunctions, Projectile upon collision, and Tripping hazard I-beam. Most of the risks associated with the Console Caddy are mechanical related and require securing the device and covering any moving parts. These risks were also categorized and put on a graph to demonstrate severity before and after countermeasures were put in place as seen in Figure 29 and 30. The bottom left of the graph is least severe and less likely, where as the top right is most severe and most likely

A risk observed before the final design was the possibility of the console becoming a projectile upon the entire vehicle flipping. To fix the potential hazard, an I-beam is mounted to the floor of the Minivan and the console is then secured to the I-beam. Risks that resulted from the I-beam change are pinch points of the wheels and tripping hazards. These risks require covers to prohibit items from getting inside the moving parts. The solution to these issues is to install a ramped, rubber cover that is hard on the outside and flexible in the center to allow the I-beam wheels to travel through. This not only eliminates the potential for pinch points but also provides a gradual incline over the I-beam, as opposed to the immediate elevation change before the cover, to eliminate the risk of tripping over the I-beam. Another risk observed before the final design was the possibility of the console becoming a projectile upon the entire vehicle flipping. To fix the potential hazard, an I-beam is mounted to the floor of the Minivan and the console is then secured to the I-beam.

Lastly, risks that are related to electrical components are cart collisions, and electrical and safety equipment malfunctions. To improve these risks, sensors and redundancies were installed and implemented around the entire cart. Sensors installed around the cart cause the cart motors to completely shut off if something passed close enough to interfere with the motion. This is a countermeasure implemented to prevent harming a person in the way of the cart. A redundancy that was also implemented to assist in this risk is a limit on the current drawn from the wheels.

When the current rises above a value of 15 Amps, it will also shut off the motors to prevent damaging the cart or injuring someone.

Patent Claims and Commercialization

The design team will not be pursuing any type of patent for this design at this time for financial capacity reasons.

Three members of the team, however, have worked at car manufacturing companies and have several contacts within these major companies (namely, General Motors, Toyota, and Chrysler- Fiat) who could help implement this design idea in some way in the future. One member has actually taken a full time job offer with Toyota, and rumors of automated console designs made by several companies are underway. Given this information, there is a possibility for commercialization in the future. The design team's idea was well-received by a breadth of van owners during the Georgia Tech Capstone Design Expo, so there is confidence within the team that this design has a market for purchase.

Summary & Future Work / Project Deliverables

The design team has accomplished the detailed design process in order to narrow down a rough design concept that encompasses all of the design parameters and engineering models used to find the best design. The team has also finished focusing more on the specific details of the design, and producing a scaled model in CAD Software. The team prototyped and tested the device to ensure that it meets all of our original design criteria. A picture of the final prototype shown at the Capstone Design Expo can be seen in Figure 35 of the Appendix. The design process is never truly done, however; in the event that this design was to move forward, the low safety factor would have to be addressed. A few ways to address this are considering a different material option or providing support material where the safety factor was low. There should also be an implementation of a speaker for sound notification of detection, an overtravel switch on both ends of the I-beam as a tertiary stopping mechanism for an even safer design, and better wiring measurements in order to minimize the “rat’s nest” effect of the several wires going to and from the motor drivers and Arduino MEGA.

This design team acknowledges Dr. Wang as a significant contributor to the success of this mechatronic design. This team also acknowledges Dr. Leamy as a significant ideator of this design.

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“PCB Mount Speaker”
https://www.adafruit.com/product/1898?gclid=CjwKCAjw9L_tBRBXEiwAOWVVCZRVt8U0fqLBvv2MpUznzWVC0r17GqvCBC1ThApZKbN7pWEeIKi5CRoCWAwQAvD_BwE

Appendix A

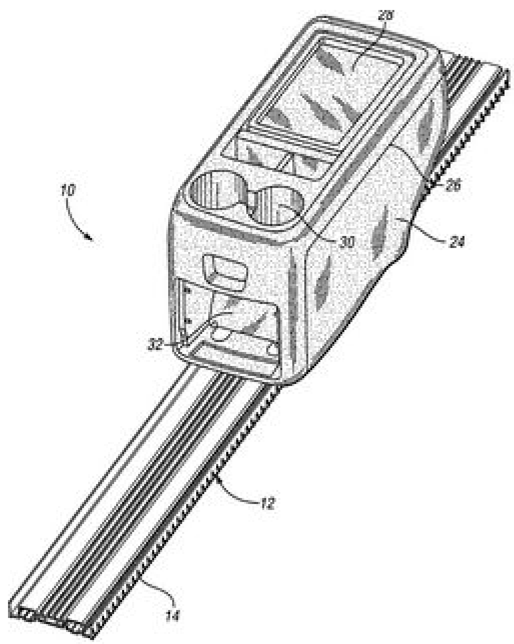


Figure 1. Patent US20080290680A1

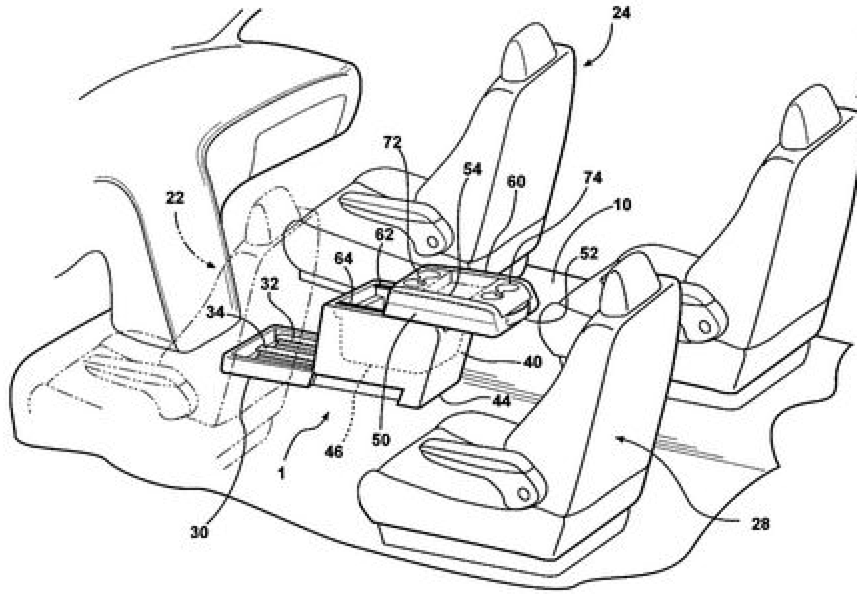


Figure 2. Patent US7416235B2

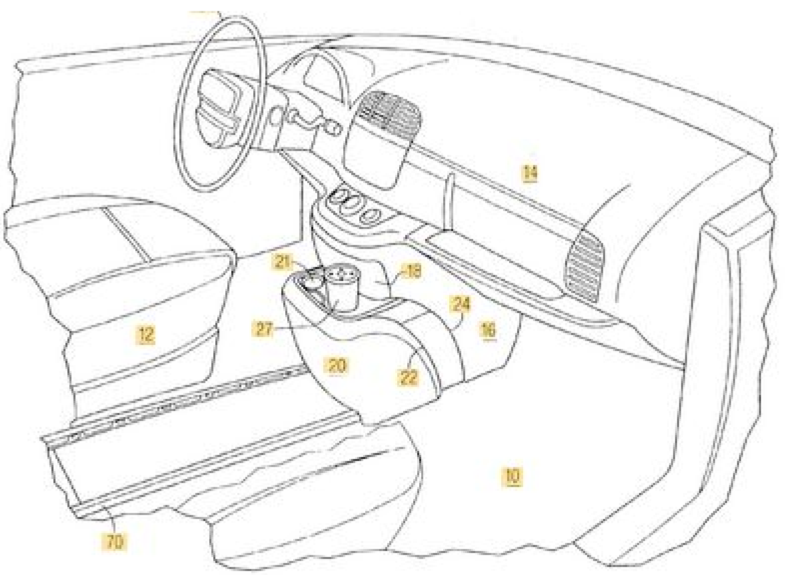


Figure 3. Patent US6921118B2

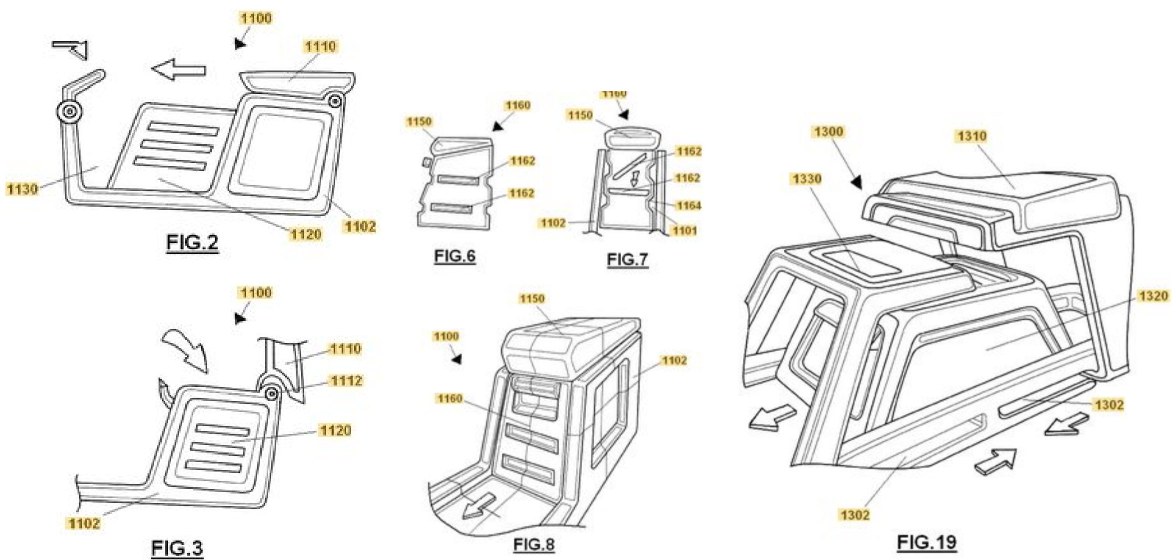


Figure 4. Patent US8215688B2

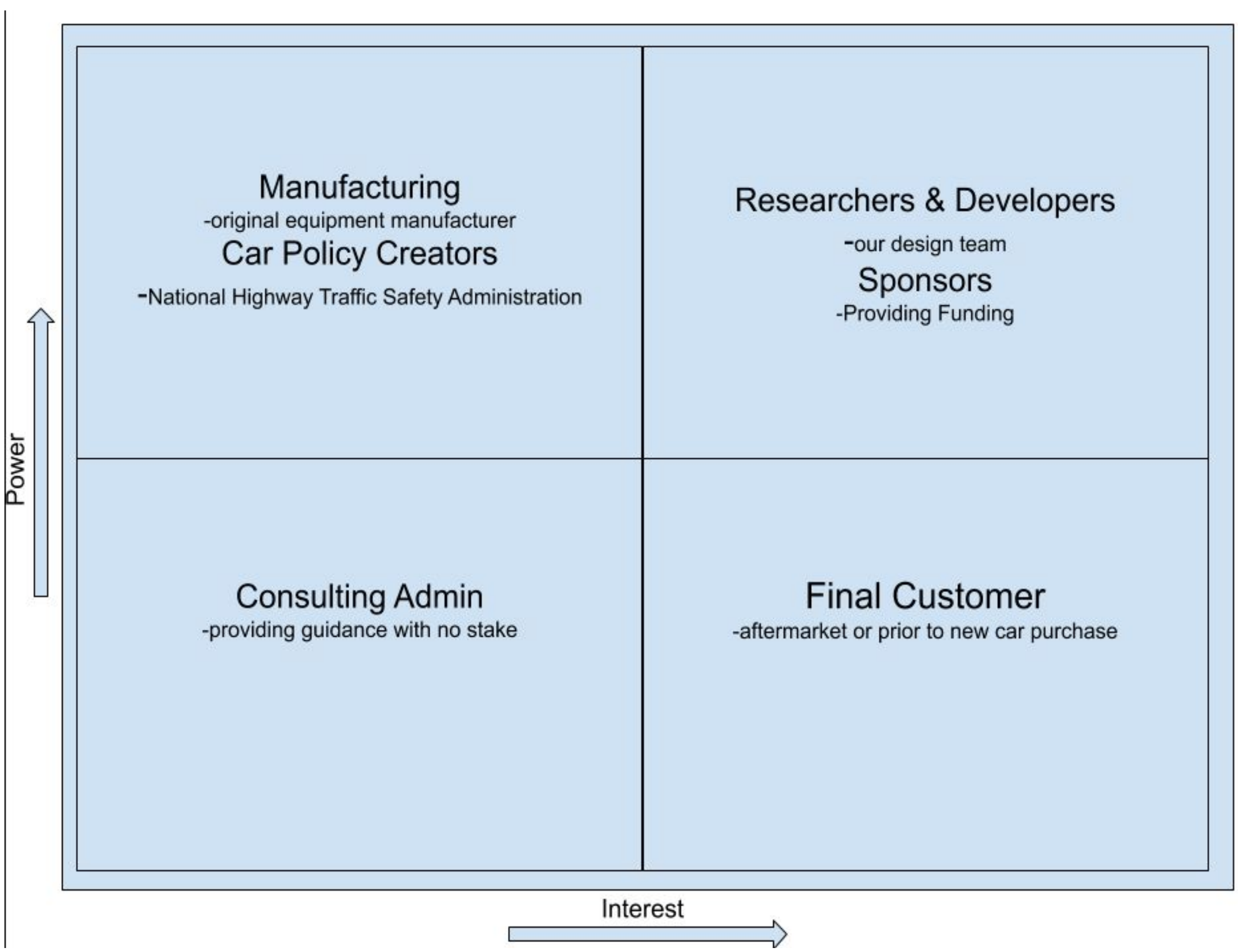


Figure 5. Stakeholder matrix

Project:	e.g. Road Warriors Capstone Design Team
Date:	

-
\+ - -
\- - - + -
\+ - + - - - -
\- - - - - - - - +

Relative Weight	Customer Importance	Customer Requirements	Speed of 0.5 m/s	Power Usage<<720 Watt-Hours	Material Strength(Rails Hold 60kg)	Mechanism/Location(Motors needs location)	Weight of Console(less than 15kg)	More than One Control Panel	Time To Extend/Retract(<1.5 minutes)	Amount Storage Space/Charging Stations	Compatibility (Electrical/Mechanical)	Stopping Notifications(Audio/Visual)	Customer Competitive Assessment
			Functional Requirements										
		Direction of Improvement	▼	□	▲	▲	□	▲	▲	▲	□	▲	
15%	8	Less Than 21 In. Reach Required	○	▽	▽	○	▽	•	•	•	•	•	
7%	4	Accessibility Of Movement Controls	○	•	▽	○	▽	•	•	▽	▽	•	
9%	5	Reliability(100,000 miles w/o failure)	•	•	•	•	•	•	•	▽	•	•	
11%	6	Cost is less than $700 final product	○	•	•	•	•	•	▽	•	•	•	
7%	4	Storage capacity of 0.0165m^3	•	•	•	•	•	▽	•	▽	○	•	
13%	7	Durability-use with no damage	•	○	•	•	•	▽	•	▽	○	•	
9%	5	Maintenance every 4-5 years	▽	•	•	○	•	▽	•	▽	•	○	
18%	10	No injuries possible from track mov.	•	▽	•	•	•	•	•	▽	•	•	
7%	4	Ease of Use(no training-intuitive)	○	▽	•	▽	•	•	•	•	•	•	
4%	2	Installs w/ No Extra Alteration	▽	○	•	•	•	▽	▽	•	•	○	
		Importance Rating Sum (Importance x Relationship)	558,181	481,81	725,4	656,3	725,4	638,1	783,6	390,9	721,8	823,6	
		Relative Weight	9%	7%	11%	10%	11%	10%	12%	6%	11%	13%	
		Our Product	5	3	1	2	1	5	3	4	2	2	
		Technical Competitive Assessment											

Figure 6. House of Quality

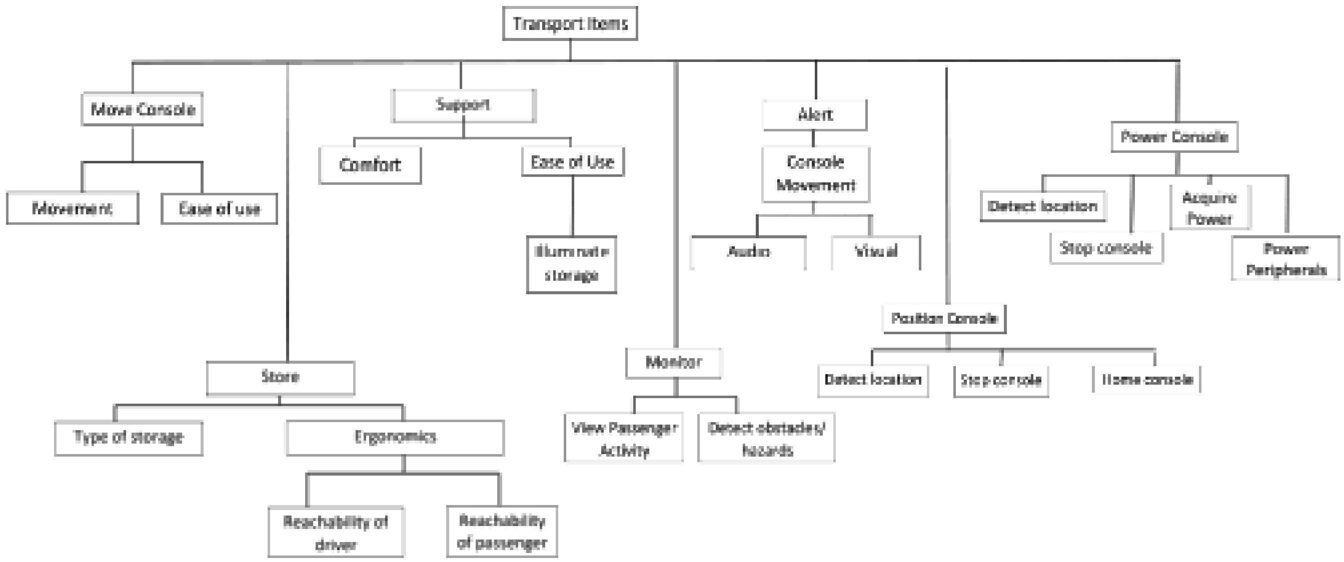


Figure 7. Function Tree

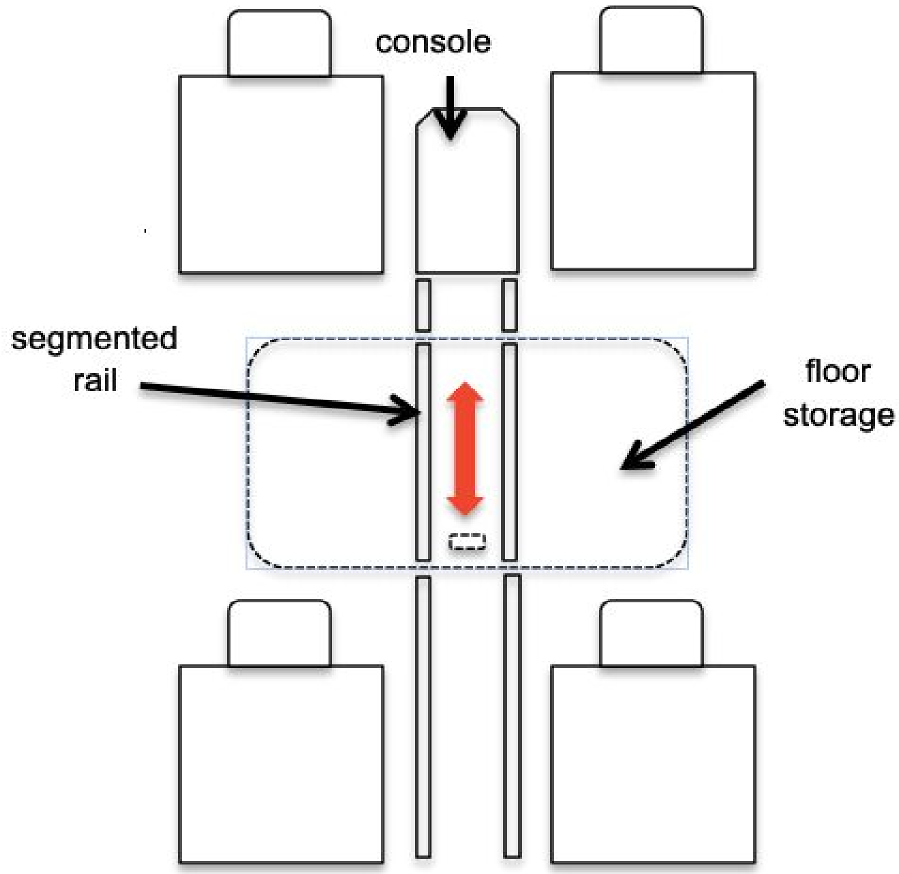


Figure 8. Segmented Ground Rail Concept

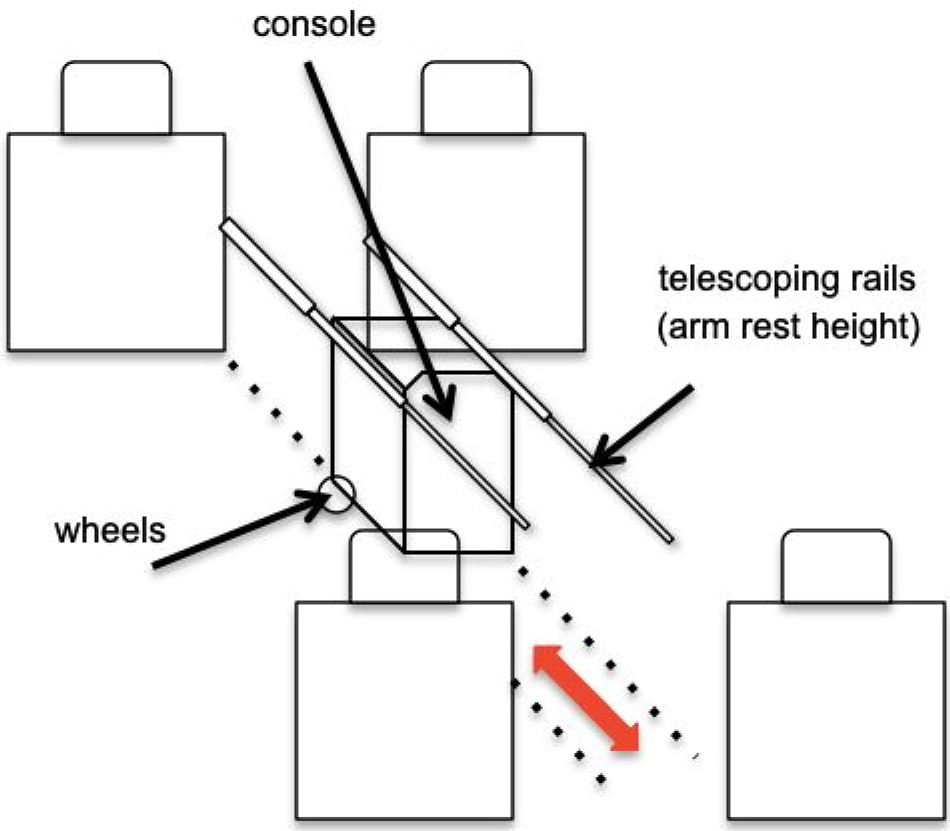


Figure 9. Suspended Side Rails with Wheels Concept

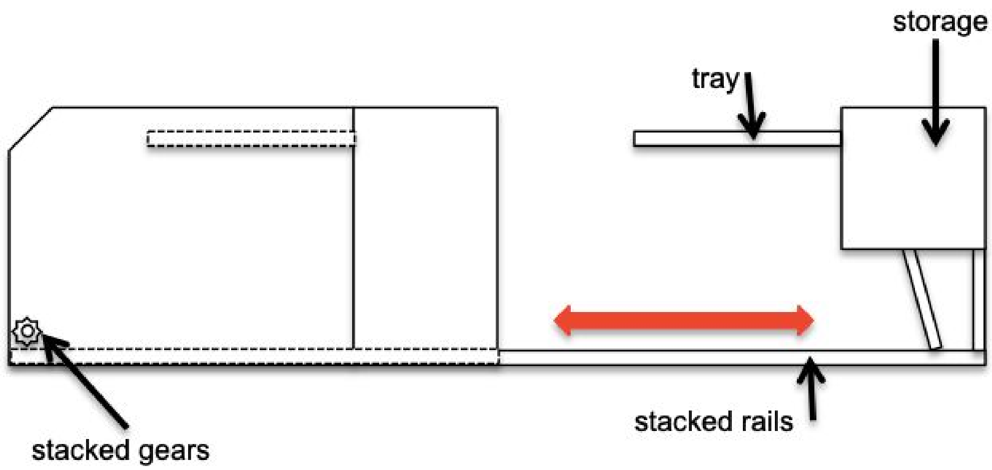


Figure 10. Partial Console Movement Concept

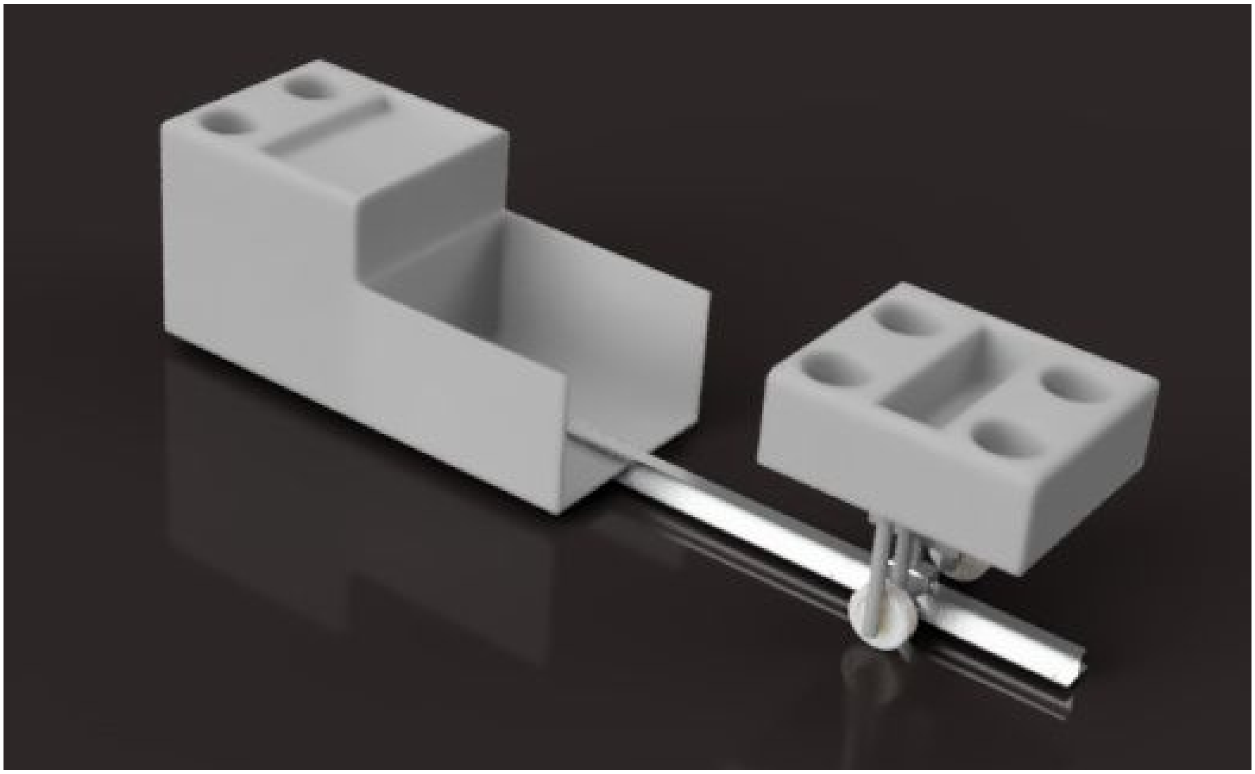


Figure 11. Ground Rail Two Wheeled Design

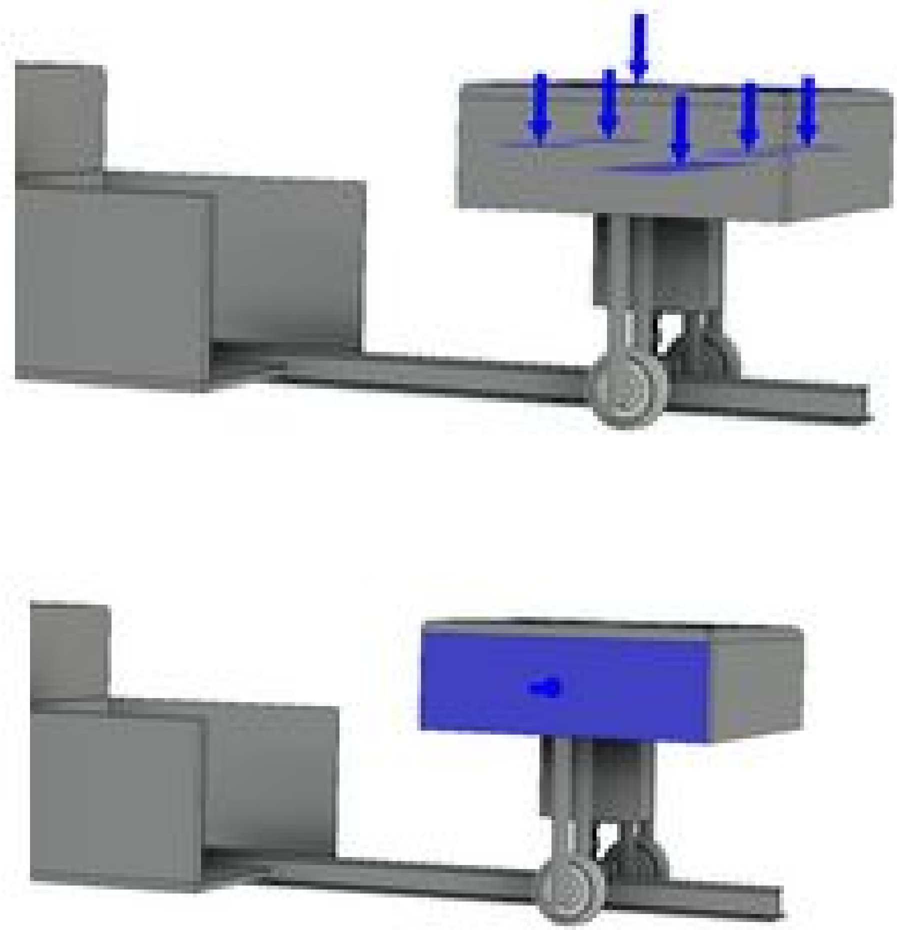


Figure 12. FEA Applied Forces for Ground Rail Two Wheeled Design

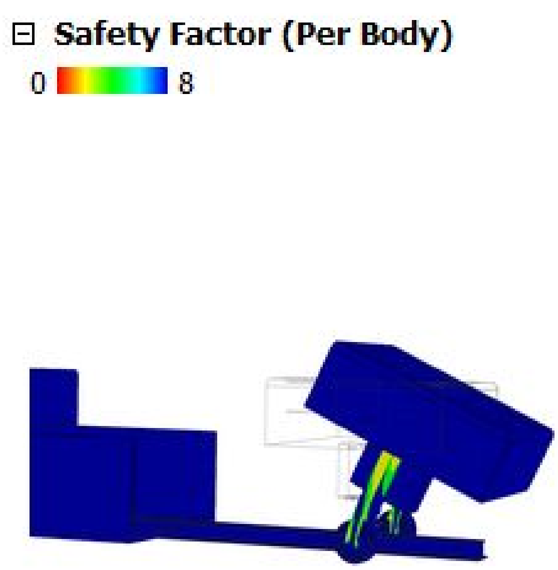


Figure 13. Safety Factor for Ground Rail Two Wheeled Design

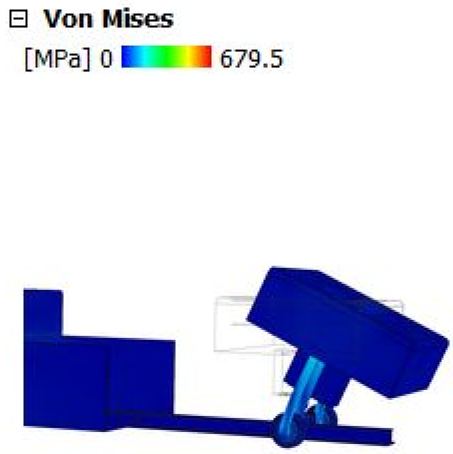


Figure 14. Von Mises for Ground Rail Two Wheeled Design

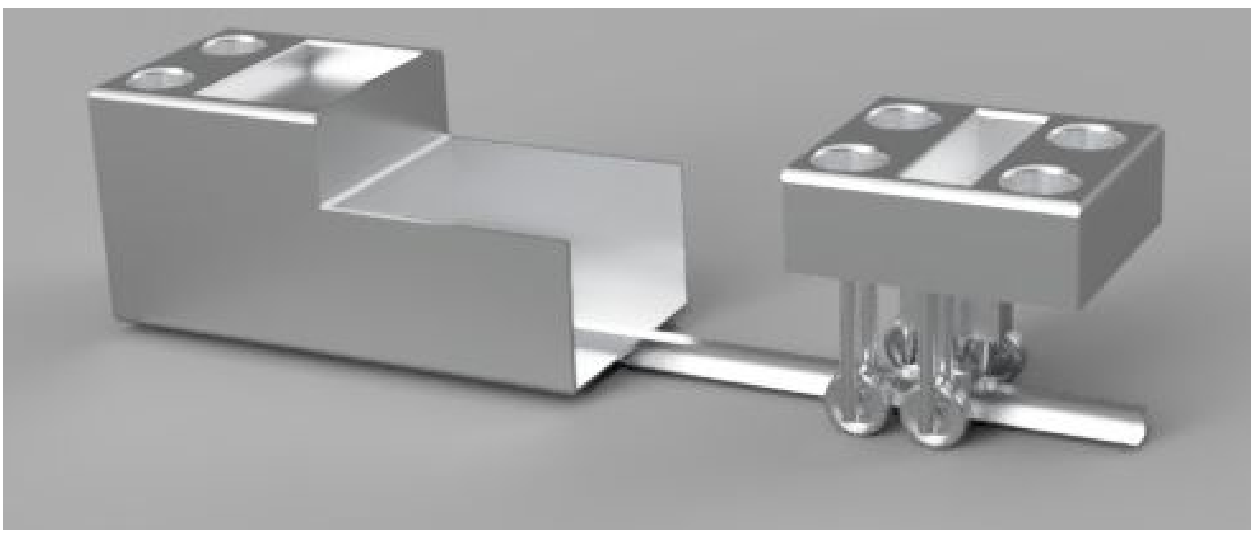


Figure 15. Ground Rail with Four Wheels Design

Figure 16. FEA Applied Forces for Ground Rail with Four Wheels Design

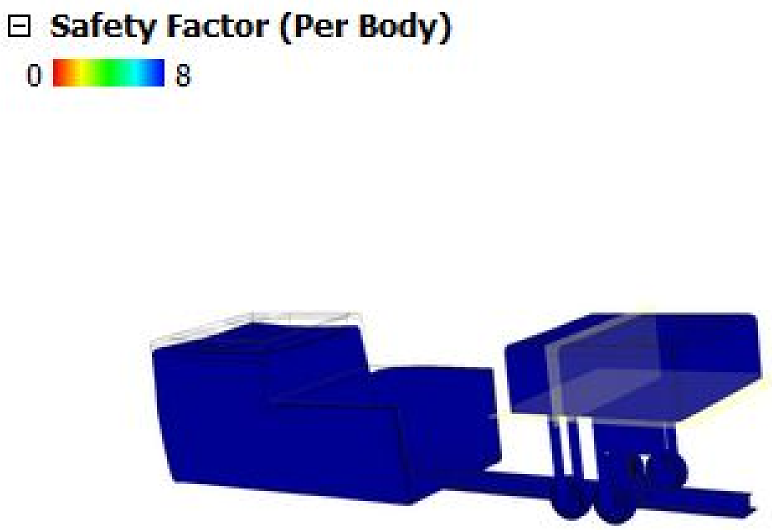


Figure 17. Safety Factor for Ground Rail with Four Wheels Design

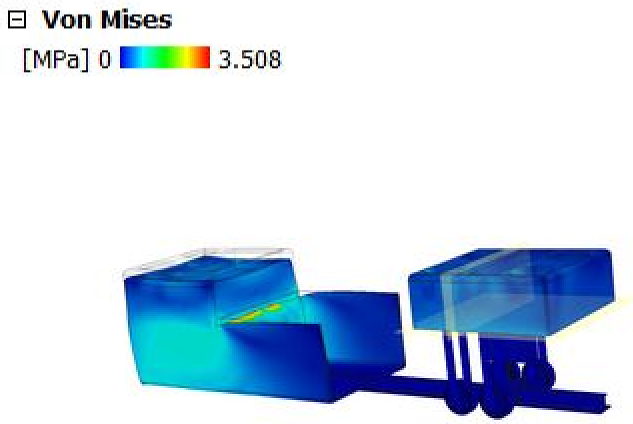


Figure 18. Von Mises for Ground Rail Four Wheeled Design

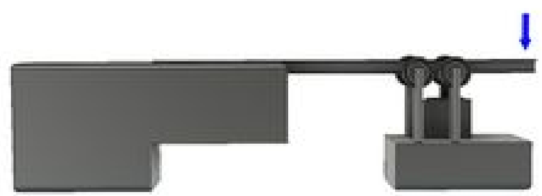


Figure 19. Force if a Car Flips Over

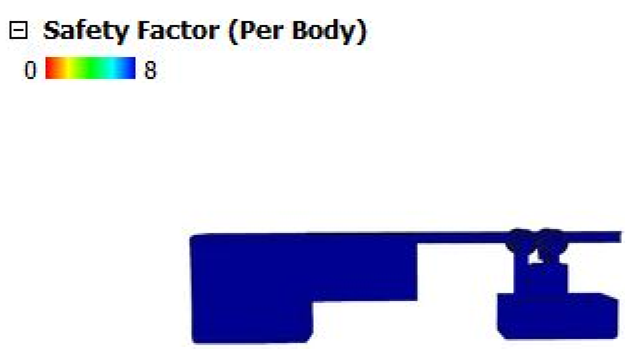


Figure 20. Safety Factor in the Event the Car Flips

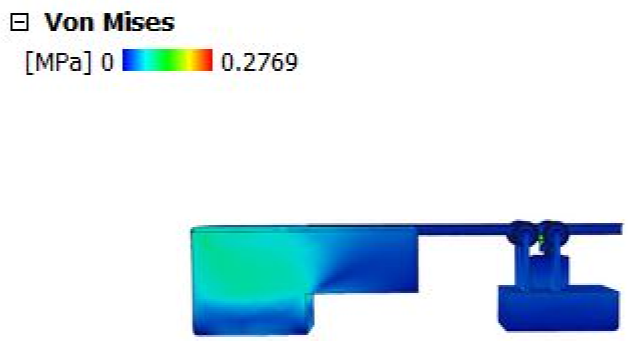
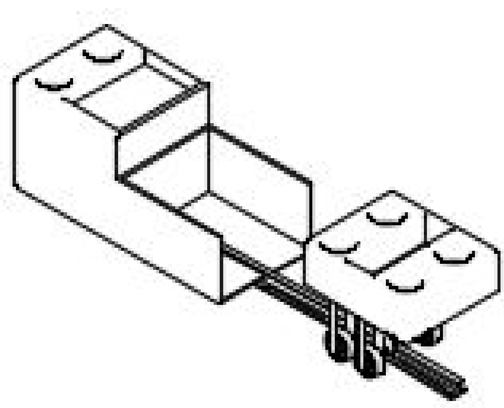


Figure 21. Von Mises for Ground Rail Four Wheeled Design if the Car Flips



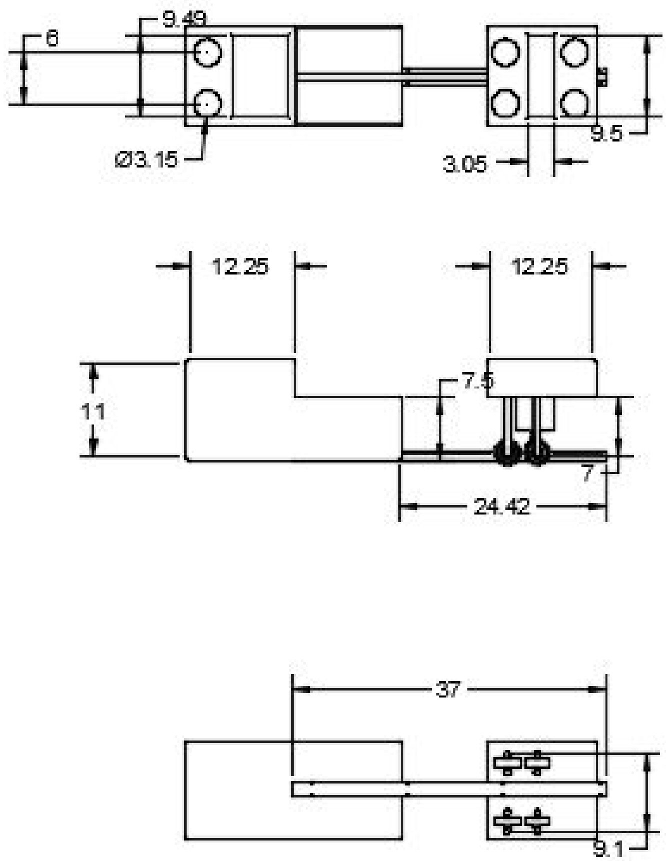


Figure 22. Part Drawing for Ground Rail with Four Wheels Design

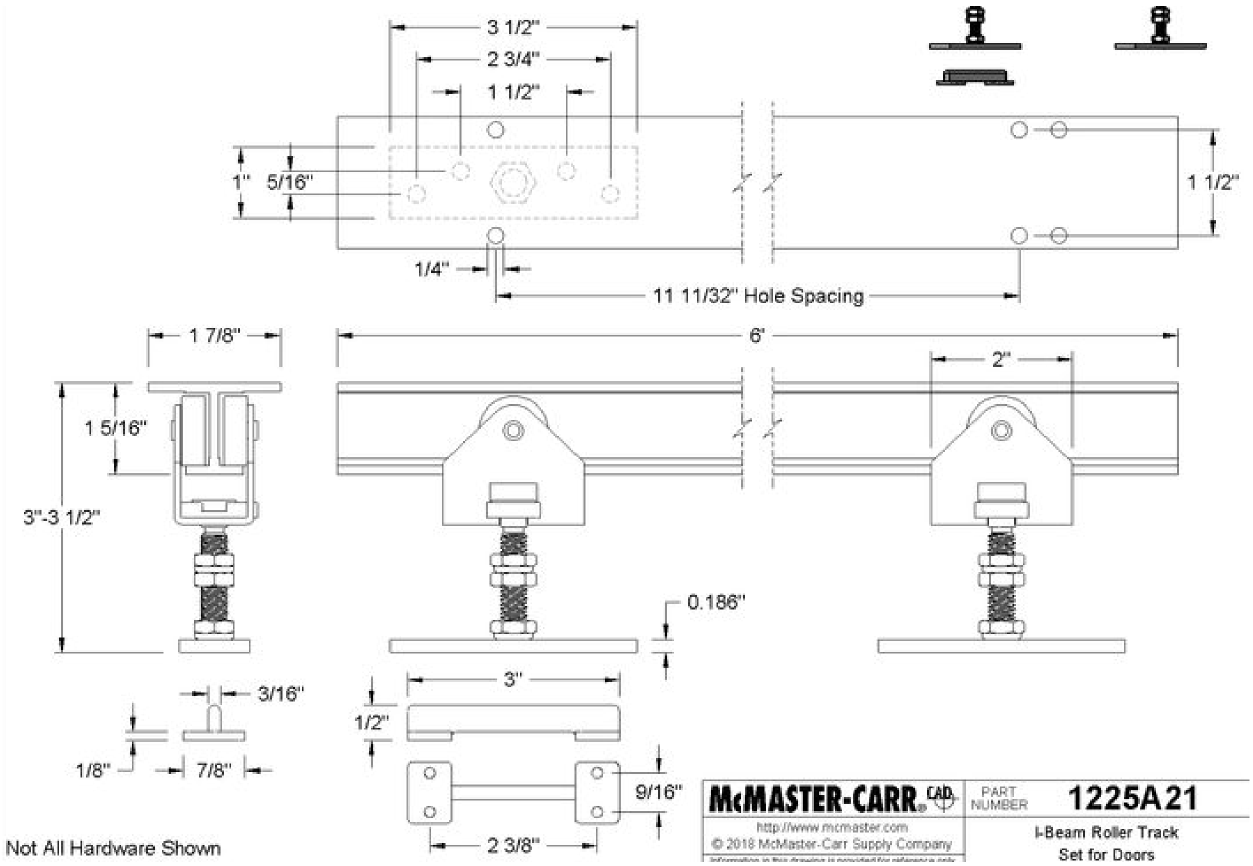


Figure 23. I-Beam Support Drawing Courtesy of McMaster-Carr

Figure 24. Power Window Motor with Coupling

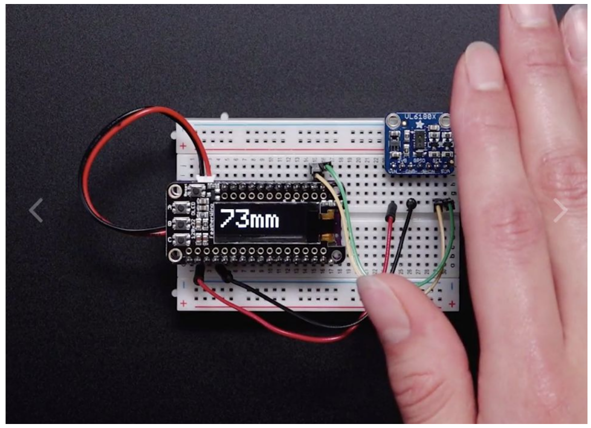


Figure 25. VL53L0X Time-of-Flight Sensor

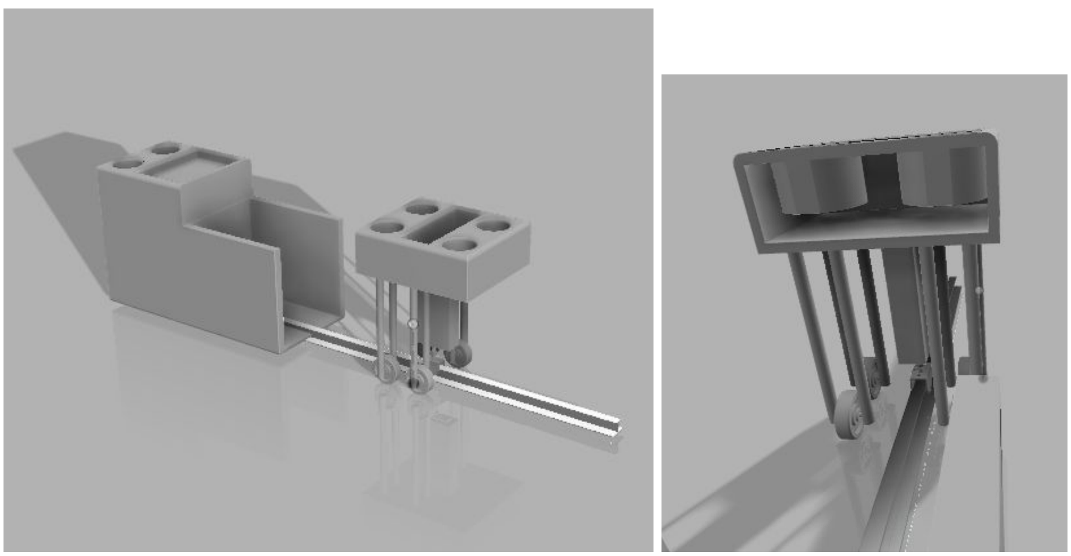


Figure 26 Shelled and Taller Console Design

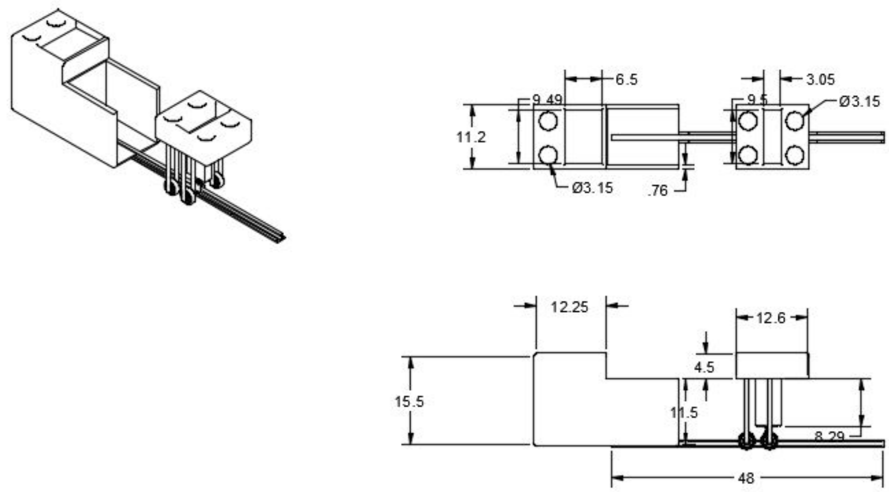


Figure 27 Part Drawing for Shelled and Taller Console Design

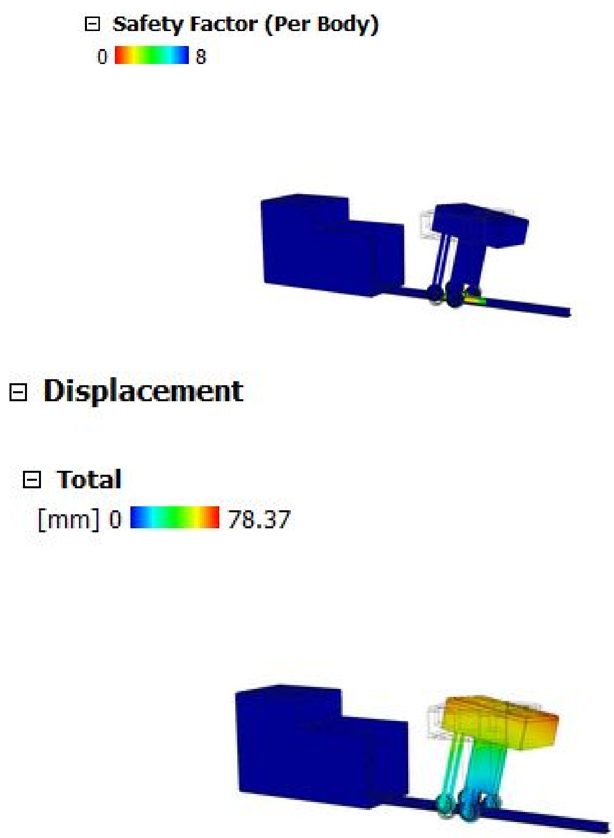


Figure 28 FEA for Shelled and Taller Console Design

Figure 29: Risk outline before mitigation

Figure 30: Risk outline after mitigation

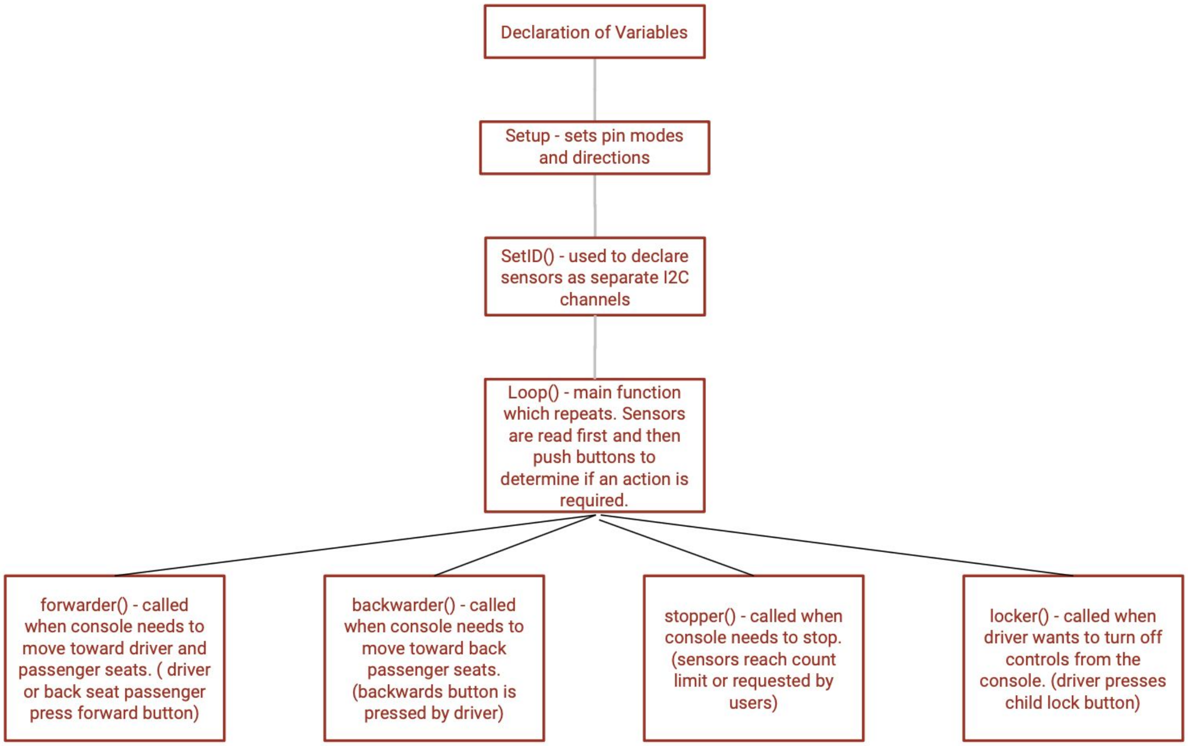


Figure 31. Code Flow

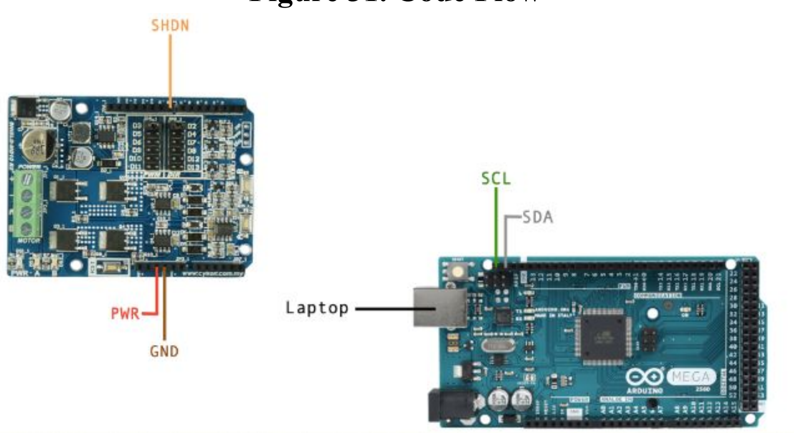


Figure 32. Wiring Diagrams for all four Time of Flight Sensors

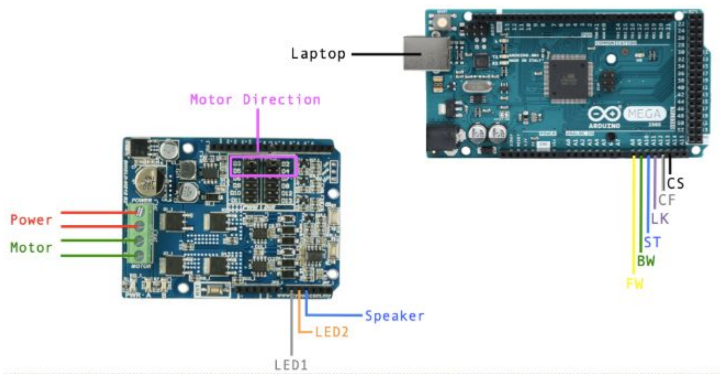


Figure 33. Wiring diagrams for Pushbuttons (FW = IP forwards, BW = IP backwards, ST = IP stop, LK = Child Lock, CF = console forwards, CS = console stop) and LED's (one for child lock, one for console movement notification)

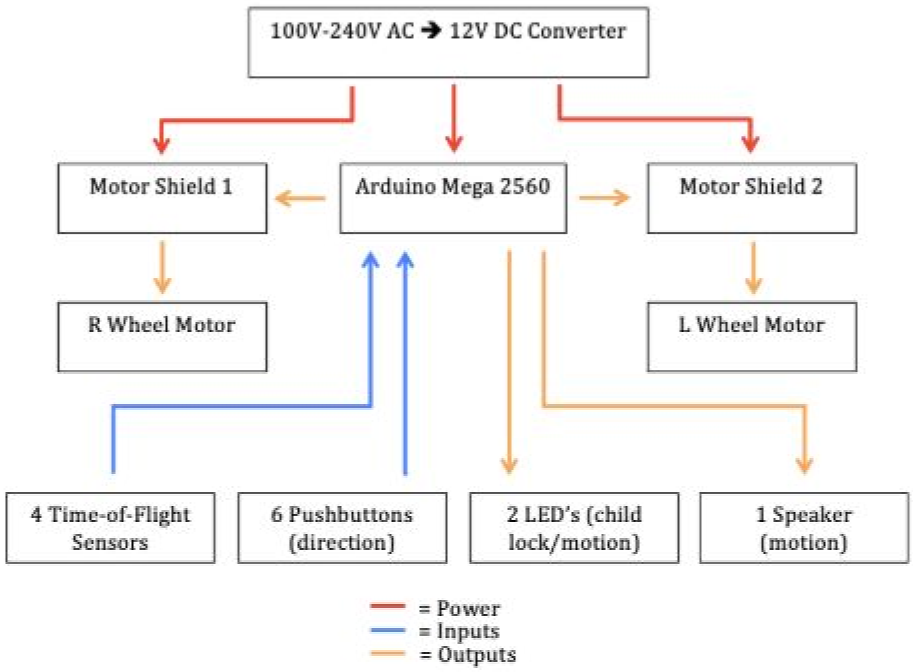
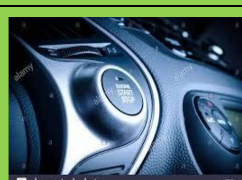
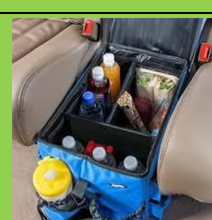
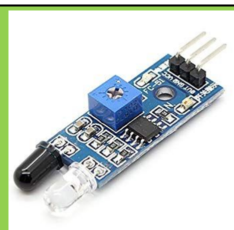
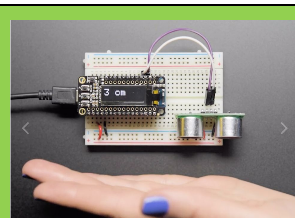
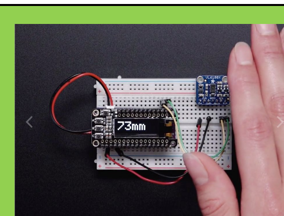


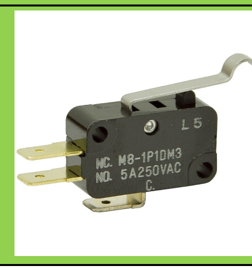
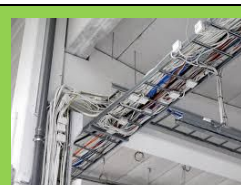
Figure 34. Power and communication block diagram of final prototype.

Figure 35. Final prototype of the Console Caddy, as seen at the Capstone Design Expo.

Tables

Functions	Solutions		
Movement			
Ease of use			
Types of storage			

Ergonomics			
Illuminate storage			
Comfort			
Motor Control			
Detect Obstacles/Hazards			
Audio Movement			

Visual Movement			
Stop Console			
Detect Location			
Home console			
Acquire power			
Initiate movement			

Power Peripherals			

Table 1: Morphological Chart

Evaluation Matrix

Concept	1	2	3
Criteria	**Segmented Ground Rails**	**Suspended Side Rails w/ Wheels**	**Partial Console Movement**
Weight	4	3	5
# of Electrical Controls for Movement	5	4	3
# of Backseat Passengers Accommodated	4	5	2
Manufacturing Cost	3	3	3
# Stopping Mechanisms	5	5	3
Compatibility w/ Existing Features	4	5	3
Safety of Movement Mechanism	3	4	3
Total	28	29	22
Relative Total	0.800	0.829	0.629

Table 2: Evaluation Matrix

Concept	**Weight**	1	2	3
Criteria		**Segmented Ground Rail**	**Suspended Rail w/ Wheels**	**Partial Console Movement**
Weight	5	4	3	5
# of Electrical Controls for Movement	1	5	4	3
# of Backseat Passengers Accommodated	4	4	5	2
Manufacturing Cost	3	3	3	3
# Stopping Mechanisms	6	5	5	3
Compatibility with Existing Features	2	4	5	3
Safety of Movement Mechanism	7	3	4	3
Total		109	116	90
Relative Total		0.778	0.829	0.643

Table 3: Weighted Evaluation Matrix

RISK MANAGEMENT MATRIX

NAME					OBJECTIVE					
REF/ID	PRE-MITIGATION				DEPARTMENT / LOCATION	MITIGATIONS / WARNINGS / REMEDIES	POST-MITIGATION			
	RISK	RISK SEVERITY	RISK LIKELIHOOD	RISK LEVEL			RISK SEVERITY	RISK LIKELIHOOD	RISK LEVEL	ACCEPTABLE TO PROCEED?
Risk 1	Pinch Points between wheels and I-beam	INTOLERABLE	PROBABLE	EXTREME	Mechanical	Installed rubber guard to prevent objects from entering possible locations	ACCEPTABLE	IMPROBABLE	LOW	YES
Risk 2	Cart Collision into objects	UNDESIRABLE	PROBABLE	EXTREME	Mechanical/ Electrical	Installed sensors and safety mechanisms to stop cart when obstacles intrude line of sight	ACCEPTABLE	POSSIBLE	LOW	YES
Risk 3	Electrical safety Malfunctions	UNDESIRABLE	POSSIBLE	MEDIUM	Electrical	Implemintted redundancies into the program and installed mechanical hard-stops	ACCEPTABLE	POSSIBLE	LOW	YES
Risk 4	Projectile upon collision	INTOLERABLE	PROBABLE	EXTREME	Mechanical	Secured I-beam to floor and then secured Cart to I-beam	ACCEPTABLE	POSSIBLE	MEDIUM	YES
Risk 5	Triping hazard I-beam	UNDESIRABLE	POSSIBLE	MEDIUM	Mechanical	Covered the rail and sloped the floor for low change in elevation	TOLERABLE	POSSIBLE	MEDIUM	YES

Table 4: Risk assessment matrix before and after mitigations

TASK NAME	START DATE	DAY OF MONTH*	END DATE	DURATION* (WORK DAYS)	DAYS COMPLETE*	DAYS REMAINING*	TEAM MEMBER	PERCENT COMPLETE
Progress Report 1- 9/20								
Determine Codes and Standards	9/1	1	9/8	8	8	0	Nikolaj	100%
Research Patents and other products	9/8	8	9/12	5	4	1	Nicole	80%
Start Market Research	9/10	10	9/16	7	4.2	3	Kathryn	60%
Produce Function Tree	9/17	17	9/18	2	0.8	1	Kenny	40%
Sketch Designs and Produce Decision Matrix	9/16	16	9/19	4	0.8	3	Shahana	20%
Progress Report 2- 10/25								
Determine specific design	9/19	19	9/30	12	12	0	Nikolaj	100%
Build Model in CAD	9/30	30	10/7	8	6.4	2	Kathryn	80%
3D Print Scaled Model	11/11	11	11/29	19	11.4	8	Sangwon	60%
Final Prototype- 12/2								
Start Prototyping	10/28	28	11/29	33	33	0	All	100%
Research more sustainable materials	11/18	18	11/22	5	4	1	Shahana	80%
Adjust and Redesign Model	10/20	20	11/11	23	13.8	9	Kenny	60%
Test machine	11/29	29	11/30	2	0.8	1	Nikolaj	40%
Finalize Prototype	11/30	30	12/1	2	0.4	2	All	20%
Final Report- 12/4								
Rehearse Pitch for Expo	12/1	1	12/2	2	2	0	All	100%
Submit Final Report	12/2	2	12/3	2	1.6	0	Kenny	80%

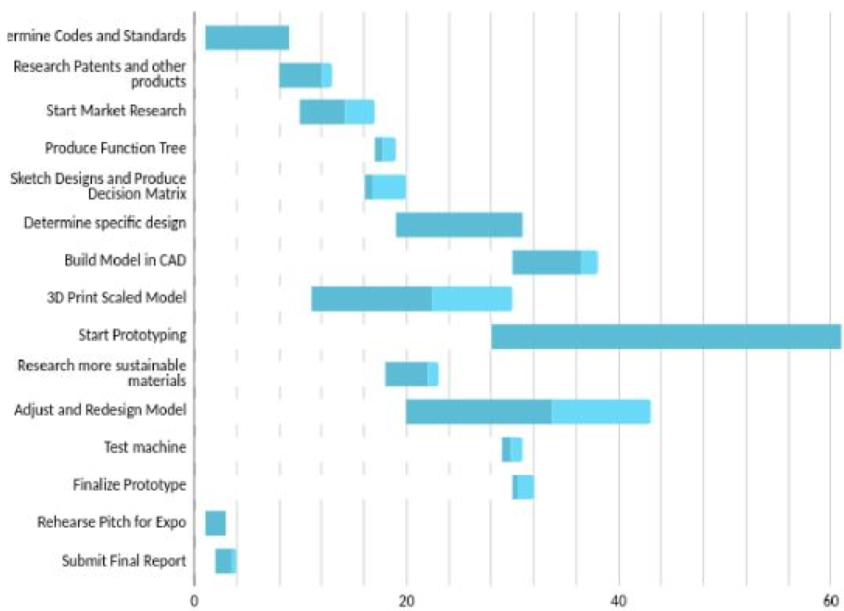


Table 5: Gantt Chart

Appendix B

```
int consoleForwards = 27;
int consoleStop = 29;
int ipForwards = 31;
int ipBackwards = 33;
int ipStop = 35;
int ipLock = 37;
int lockedLED = 39;
int movLED = 41;
int start = 1;

bool locked = 0;  // 0 = console buttons unlocked, 1 = console buttons locked
bool moving = 0;  // 0 = stopped, 1 = moving
bool dir = 0;     // 0 = bakwards, 1 = forwards

// PWM is connected to pin 3 and 5.
int pinPwm = 3;
int pinPwm2 = 5;

// DIR is connected to pin 2 and 4.
int pinDir = 2;
int pinDir2 = 4;

#include "Adafruit_VL53L0X.h"
#define LOX1_ADDRESS 0x30
#define LOX2_ADDRESS 0x31


#define SHT_LOX1 23
#define SHT_LOX2 25



Adafruit_VL53L0X lox1 = Adafruit_VL53L0X();
Adafruit_VL53L0X lox2 = Adafruit_VL53L0X();


VL53L0X_RangingMeasurementData_t measure1;
VL53L0X_RangingMeasurementData_t measure2;


int count1 = 0;
int count2 = 0;


void setID() {
  // all reset
  digitalWrite(SHT_LOX1, LOW);
  digitalWrite(SHT_LOX2, LOW);
  delay(10);

  // all unreset
```

```
  digitalWrite(SHT_LOX1, HIGH);
  digitalWrite(SHT_LOX2, HIGH);
  delay(10);

  // activating LOX1 and reseting rest
  digitalWrite(SHT_LOX1, HIGH);
  digitalWrite(SHT_LOX2, LOW);

  // initing LOX1
  if(!lox1.begin(LOX1_ADDRESS)) {
    Serial.println(F("Failed to boot first VL53L0X"));
    while(1);
  }
  delay(10);

  // activating LOX2
  digitalWrite(SHT_LOX2, HIGH);
  delay(10);

  //initing LOX2
  if(!lox2.begin(LOX2_ADDRESS)) {
    Serial.println(F("Failed to boot second VL53L0X"));
    while(1);
  }
  delay(10);

}

void setup() {
  Serial.begin(115200);

  // wait until serial port opens for native USB devices
  while (! Serial) { delay(1); }

  // put your setup code here, to run once:
  pinMode(ipForwards, INPUT);    // declare pushbutton as input
  pinMode(ipBackwards, INPUT);    // declare pushbutton as input
  pinMode(ipStop, INPUT);    // declare pushbutton as input
  pinMode(ipLock, INPUT);    // declare pushbutton as input
  pinMode(consoleForwards, INPUT);    // declare pushbutton as input
  pinMode(consoleStop, INPUT);    // declare pushbutton as input
  digitalWrite(ipForwards, HIGH);
  digitalWrite(ipBackwards, HIGH);
  digitalWrite(ipStop, HIGH);
  digitalWrite(ipLock, HIGH);
  digitalWrite(consoleForwards, HIGH);
  digitalWrite(consoleStop, HIGH);

  pinMode(pinPwm, OUTPUT);
  pinMode(pinDir, OUTPUT);
  pinMode(pinPwm2, OUTPUT);
  pinMode(pinDir2, OUTPUT);

  pinMode(SHT_LOX1, OUTPUT);
```

```
  pinMode(SHT_LOX2, OUTPUT);

  Serial.println("Shutdown pins inited...");

  digitalWrite(SHT_LOX1, LOW);
  digitalWrite(SHT_LOX2, LOW);

  Serial.println("all in reset mode...(pins are low)");


  Serial.println("Starting...");
  setID();


  pinMode(lockedLED, OUTPUT);
  pinMode(movLED, OUTPUT);

}



void loop() {

  lox1.rangingTest(&measure1, false); // pass in 'true' to get debug data printout!
  lox2.rangingTest(&measure2, false); // pass in 'true' to get debug data printout!



  if (measure1.RangeMilliMeter < 150) {
    count1++;
  }
  else {
    count1 = 0;
  }

  if (measure2.RangeMilliMeter < 150) {
    count2++;
  }
  else {
    count2 = 0;
  }

  if (count1 > 5 || count2 > 5){
    moving = stopper(moving);
  }
  else{
    moving = 1;
  }


  // put your main code here, to run repeatedly:
  if (digitalRead(ipForwards) == 0){
      Serial.println(("Moving Forwards"));
      dir = forwarder(dir);
```

```
    moving = 1;
    digitalWrite(movLED, HIGH);
    delay(500);
    digitalWrite(movLED, LOW);

  }
  else if (digitalRead(ipBackwards) == 0){
    Serial.println(("Moving Backwards"));
    dir = backwarder(dir);
    moving = 1;
    digitalWrite(movLED, HIGH);
    delay(500);
    digitalWrite(movLED, LOW);

  }
  else if (digitalRead(ipStop) == 0){
    Serial.println(("Stopped"));
    Serial.println(moving);
    moving = stopper(moving);
  }
  else if (digitalRead(ipLock) == 0){
    Serial.println(("Console Buttons Locked"));
    Serial.println(locked);
    locked = locker(locked);
  }
  else if (locked == 0 && digitalRead(consoleForwards) == 0){
    Serial.println(("Moving Forwards"));
    dir = forwarder(dir);
    moving = 1;
    digitalWrite(movLED, HIGH);
    delay(500);
    digitalWrite(movLED, LOW);

  }
  else if (locked == 0 && digitalRead(consoleStop) == 0){
    Serial.println(("Stopped"));
    Serial.println(moving);
    moving = stopper(moving);


  }


  // print sensor one reading
  Serial.print("1: ");
  if(measure1.RangeStatus != 4) {     // if not out of range
   Serial.print(measure1.RangeMilliMeter);
  } else {
   Serial.print("Out of range");
  }

  Serial.print(" ");

  // print sensor two reading
```

```
  Serial.print("2: ");
  if(measure2.RangeStatus != 4) {
    Serial.print(measure2.RangeMilliMeter);
  } else {
    Serial.print("Out of range");
  }
  Serial.println(" ");

}


bool forwarder (bool dr){
  if (dr == 1){
    // motor stuff
    Serial.println(dr);
    analogWrite(pinPwm2, 50);
    digitalWrite(pinDir2, LOW);
    analogWrite(pinPwm, 50);
    digitalWrite(pinDir, LOW);
    return dr;
  }
  else{
    // motor stop for .25 secs and then start going forwards
    dr = 1;
    Serial.println(dr);
    analogWrite(pinPwm2, 0);
    digitalWrite(pinDir2, LOW);
    analogWrite(pinPwm, 0);
    digitalWrite(pinDir, LOW);
    delay(250);
    analogWrite(pinPwm2, 50);
    digitalWrite(pinDir2, LOW);
    analogWrite(pinPwm, 50);
    digitalWrite(pinDir, LOW);
    return dr;
  }
}

bool backwarder (bool dr){
  if (dr == 0){
    // motor stuff
    Serial.println(dr);
    analogWrite(pinPwm2, 50);
    digitalWrite(pinDir2, HIGH);
    analogWrite(pinPwm, 50);
    digitalWrite(pinDir, HIGH);
    return dr;
  }
  else{
    // motor stop for .25 secs and then start reversing
    dr = 0;
    Serial.println(dr);
    analogWrite(pinPwm2, 0);
    digitalWrite(pinDir2, HIGH);
```

```
    analogWrite(pinPwm, 0);
    digitalWrite(pinDir, HIGH);
    delay(250);
    analogWrite(pinPwm2, 50);
    digitalWrite(pinDir2, HIGH);
    analogWrite(pinPwm, 50);
    digitalWrite(pinDir, HIGH);
    return dr;
  }
}

bool stopper (bool mov){
  mov = 0;
  Serial.println(mov);
  analogWrite(pinPwm2, 0);
  digitalWrite(pinDir2, HIGH);
  analogWrite(pinPwm, 0);
  digitalWrite(pinDir, HIGH);
  return mov;
}


bool locker (bool consoleLock){
  if (consoleLock == 0) {
    consoleLock = 1;
    digitalWrite(lockedLED,HIGH);
  }
  else{
    consoleLock = 0;
    digitalWrite(lockedLED,LOW);
  }
  Serial.println(consoleLock);
  delay(500);
  return consoleLock;
}
```