TECHNOLOGICAL ADVANCEMENT FOR VEHICLES OPERABLE BY THE VISUALLY IMPAIRED

by

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A Senior Project submitted

in partial fulfillment

of the requirements for the degree of

Bachelor of Science in Industrial Engineering

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San Luis Obispo

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Graded by: ______________________________ Date of Submission: ________________

Checked by: _____________________________ Approved by: ______________________

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ABSTRACT

This senior project aims to provide blind persons with the ability to effectively experience driving. This report includes the project background, literature review, designs, methodologies, results, and conclusions with project management, human factors engineering, and electronic manufacturing focuses. Other universities and professionals have accepted the Blind Driver Challenge presented by the National Federation of the Blind (NFB) or studied systems to improve vehicle feedback. The Virginia Tech vehicle, named "Odin", includes tactile and audio interfaces in order to relay information to a blind driver about vehicle heading and speed. The QFD results reveal that the amount of available information from the feedback systems ranks the most important aspect of this project's designs. The QFD also shows the importance of both speed and acceleration. The final feedback designs of the vibrating vest, steering wheel, and audio provide commands, statuses, and speed updates. The programs packaged with the SICK LIDAR sensor as well as LabVIEW will serve to accomplish the necessary programming. This project contains two expensive items that push its total cost fairly high, the dune buggy and the laser scanner. Considering the over 1000 feet of electrical wire, electrical safety signifies a very large safety concern. Innovative sensor and tactile feedback technology provide the backbone for this advancement for the visually impaired.

INTRODUCTION AND BACKGROUND

This senior project aims to provide blind persons with the ability to effectively experience driving. The Quality of Life Plus (QL+) organization allows the unique opportunity to research and produce such a product and experience within a team. Since this is a multidisciplinary senior project, the department senior project timelines differ. The project officially ends in December 2011 with an event. This industrial engineering senior project report only covers the progress up to June 2011. Therefore, the report will focus mostly on the final feedback design of the tactile vest, rather than the impending event. This report includes the project background, literature review, designs, methodologies, results, and conclusions with project management, human factors engineering, and electronic manufacturing focuses.

Problem Statement

Blind persons aspire to drive independently without the assistance of another individual. Currently, their lack of sight prevents them from safely and effectively maneuvering a vehicle. The introduction of innovative vehicle technology that adequately captures and transmits real-time data about road conditions to the blind could solve this problem.

The Team

- Project Title: Blind Driver Challenge – Cal Poly
- Slogan: Eliminating the Blind Spots
- Team Name: On Course
- Team Members: Heather Brown (Lead)
  Malcolm Lapera
  Scotty Mores
  Eric Sandoval
- Team Logo: ON COURSE

- Technical Advisor: Professor Karen Bangs
- QL+ Club Advisor: Dr. Tom Mase

Mission Statement

Our mission is to empower visually impaired veterans by providing a fun, driving experience where the public may view blind persons as individuals with capacity, ambition, and a desire for greater independence.

Expected Deliverables

This project will provide blind veterans with the experience of driving on a non-simulated course, as well as provide the public with knowledge of the new possibilities and opportunities for visually impaired persons.

Goals and Objectives

The goals and objectives of the project follow:

Goal 1) Design and fabricate an innovative, safe vehicle in which feedback systems enable a blind operator to drive independently.

- Outfit vehicle with appropriate safety features, including seat belts, bumpers, roll bar, and brakes.
- Suit the vehicle to the chosen terrain regarding tires, suspension, and frame.
- Make equipment adjustable for adult users in the 95th percentile range.
- Outfit vehicle with proper equipment to sense the environment of the vehicle setting in real-time.

- Develop feedback interfaces to communicate the environment to the user in a manner the user can understand.
- Include speed reference feedback, so that the vehicle may maintain a safe speed.
- Include a kill switch.
- Make improvements from the Virginia Tech model by including command updates, as well as status updates.

Status updates differ from command updates in that they do not simply tell the driver what to do, instead they show the driver real-time information about the course. Real-time information versus a command will allow a driver more decision making freedom about where to drive next, which more closely mimics sighted driving decision making.

Goal 2) Develop a course and create an opportunity for the public to view blind individuals driving the developed vehicle. This will illustrate to the public that blind people are individuals with capacity, ambition, and a desire for greater independence.

- Design a non-simulated, closed course for a blind driver to navigate obstacles, relying solely on the feedback systems for navigation.
- Train drivers on proper use of vehicle and navigation of course.
- The course must be safe for both drivers and spectators. Appropriate safety precautions must be made.
- Host an event to demonstrate blind drivers successfully navigating the course to the public. This includes planning, advertising, and attempting to gain positive publicity.

Scope

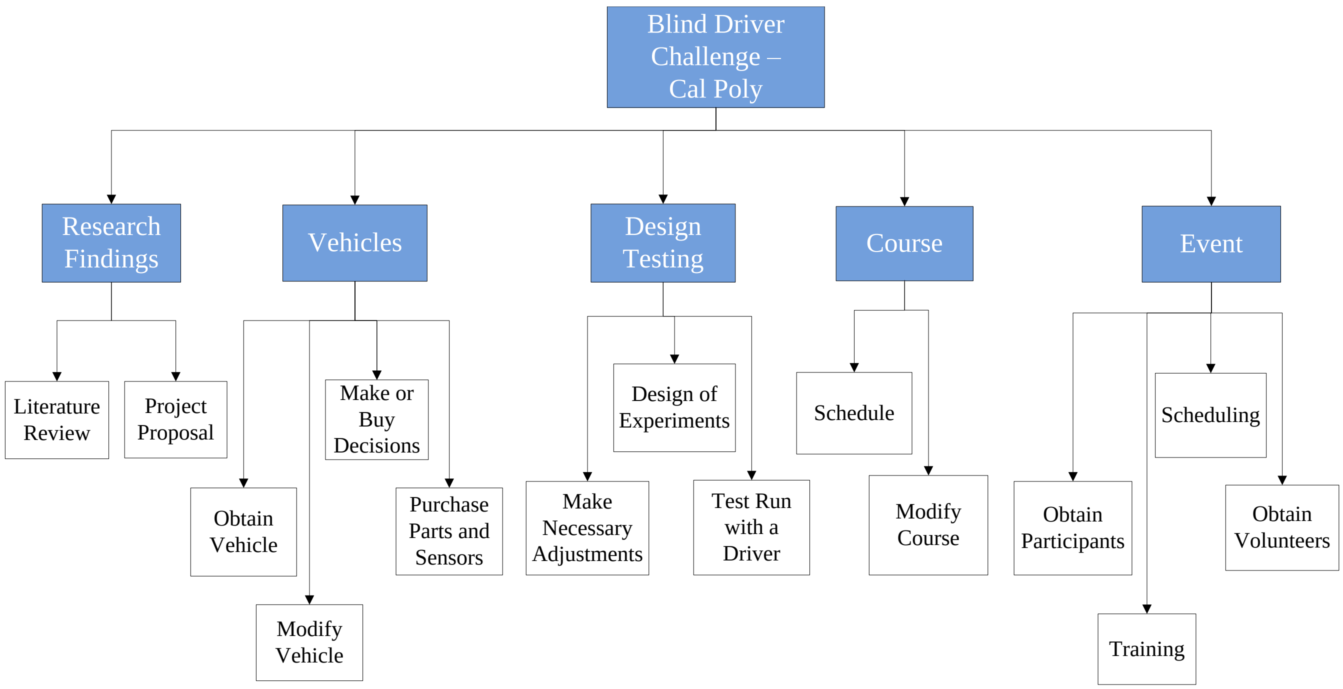
This project will create technical specifications and requirements through an investigative literature and market study with feasibility and design concepts addressed for a vehicle operated by the blind. This project does not intend to design a vehicle for mass production. The vehicle's intended use will include recreational operation on a closed course. In other words, the vehicle will not qualify as street legal. This project plans to design an event for visually impaired veterans to safely drive in a location limited to the San Luis Obispo County.

Stakeholders

- QL+, Quality of Life Plus Sponsors
    - Jon Monett, Founder and Chairman of the board
    - Scott Monett, Executive Director and President
- California Polytechnic University San Luis Obispo- College of Engineering
    - Karen Bangs, Technical Advisor
    - Dr. Tom Mase, QL+ Faculty Advisor
    - QL+ members
- Event Participants

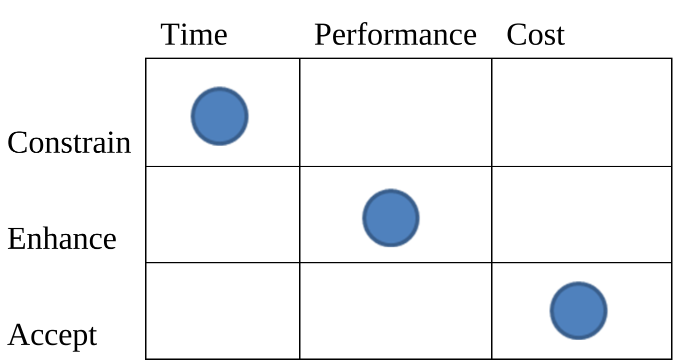
- Event Volunteers
- On Course team members
    - Heather Brown
    - Eric Sandoval
    - Scotty Mores
    - Malcolm Lapera

Work Breakdown Structure



Please see Appendix B: Gantt Chart for the total project schedule.

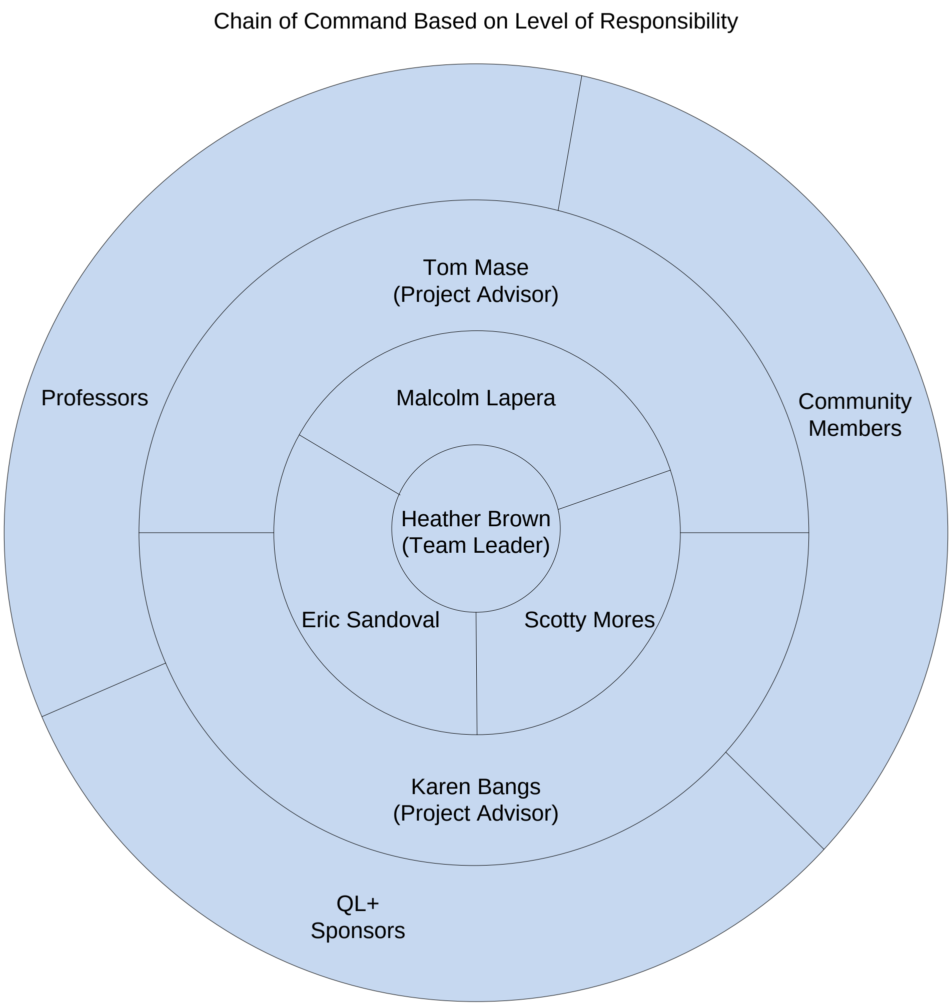
Priority Matrix



The priority matrix shows the importance of time, performance, and cost relative to the project, since a trade-off exists between the three criteria. Developing the project's priorities helps the project management to focus on the goals and responsibilities of the project throughout its duration.

The event must occur within the amount of time delegated to California Polytechnic State University senior projects, two to three school quarters, meaning that the project is constrained by time. We hope to enhance the performance of the project by providing an optimal driving experience to blind veterans. Also, there is an approximate budget for the event, but with the sponsors and resources available, we recommend that reasonable, over-budget expenses be accepted.

Chain of Command



Communication Plan

What Information	Target Audience	When	Method of Communication	Provider

Team Status Report (Assignments)	Team Members	Weekly	In Person/Email	Rotating
Team Meeting Agendas	Team Members	As Needed	In Person/Printed	Heather
Potential Issues/Problems	Team Members	As Needed	In Person/Email	Malcolm
Miscellaneous Information	Team Members	As Needed	In Person/Email	Team
Dr. Mase Status Report	Dr. Mase	Tuesdays	In person	Team
Limitations and Skills of the Blind	DRC Contact	As Needed	In Person/Email	Eric
Sponsor Related Questions	QL+ Contact	As Needed	Email	Heather
Specific Subject Knowledge	Cal Poly Professors	As Needed	In Person/Email	Scotty

The following Literature Review explains the origin of the Blind Driver Challenge and examines past design solutions.

LITERATURE REVIEW

This senior project has its roots elsewhere than California Polytechnic State University, San Luis Obispo (Cal Poly). Other universities and professionals have accepted the Blind Driver Challenge presented by the National Federation of the Blind (NFB) or studied systems to improve vehicle feedback. They have researched potential solutions, created prototypes, and revealed potential improvements. Although, they have designed and created some very advanced technology, their design, like all innovative systems, could benefit from improvement and additions. This literature review examines project significance, existing products, codes and standards, and research in the disciplines of project management, statistics and process improvement fundamentals, and human factors engineering regarding vehicle technology and project system methodologies.

Project Significance

Until just recently, within the past few years, a blind person operating a vehicle seemed impossible (Carrico, p. 517). The National Federation of the Blind (NFB) did not want the Blind Driver Challenge (BDC) to simply transport a blind person; they wanted the blind to be able to control and maneuver the vehicle with the help of real-time vehicle data and feedback (“Access”). Virginia Tech accepted this challenge and has made an enormous contribution to the empowerment of the blind through driving. Ms. Joyce Carrico had first-hand experience testing some of the Virginia Tech vehicle’s technology. She describes a computer-simulated race-track, fingerless gloves with small motors to indicate turn angle, and a compressor that forced air through platform holes to take the shape of objects that a sensor perceived. She had the most difficulty with accurately determining the shape formed by the forced air (Carrico, p. 517). This reveals a potential area of design improvement. If one university can make such a huge difference in terms of feasibility, imagine the improvements that still have yet to be made and how a multidisciplinary team of Cal Poly seniors could contribute to the advancement and recognition of a vehicle operable by the blind.

Not only does this project aim to design and fabricate a vehicle operable by the blind, it also strives to create an organized event for blind military veterans, members of the law enforcement and intelligence communities, and other public servants ("About QL+"). The Quality of Life Plus organization goals and the NFB Blind Driver Challenge may fuse together for this amazing senior project opportunity. Other stakeholders may include the National Association of Blind Veterans, a division of the NFB, and the Blinded Veterans Association (BVA). The BVA estimates that there are 165,000 blind or visually impaired veterans in the United States. Furthermore, about 13 percent of the evacuated wounded service members in Iraq and Afghanistan have suffered a serious eye injury ("Blinded Veterans Association | BVA Can Help"). This project idea aims to empower blind veterans like these, but has the potential for much more growth to benefit blind people nationwide.

Existing Products

In 2005, the National Federation for the Blind (NFB) created the Blind Driver Challenge. It challenged everyone from technology developers to college students to think outside of the box and develop tools to allow blind people to drive independently. The goal of the Blind Driver Challenge, according to the NFB Blind Driver Challenge website, is to "develop a non-visual interface for a car that can convey real-time information about driving conditions to the blind so that we can use our own capacity to think and react to interpret these data and maneuver a car safely." The Blind Driver Challenge wants to increase awareness among persons in the scientific community as well as to demonstrate that vision is not a requirement for success. It also strives to change the public's perception of blind persons by giving the public a chance to view blind people as "individuals with capacity, ambition, and a drive for greater independence." Currently the only school that has formed a team to take on this challenge is Virginia Tech. ("Blind Driver Challenge - About the Blind Driver Challenge")

Virginia Tech first began working on a vehicle that could safely be operated by a blind driver back in 2006. They currently have a team of 12 senior engineering students working to design, build, test, and implement the non-visual interfaces needed to achieve the goal.

They use a variety of different feedback systems that all work simultaneously to provide the blind driver with the information needed to navigate a course of obstacles. They claim that the “accurate and timely perception of the driving environment is critical to the success of the blind driver challenge system.” To get a view of the driving environment ahead they employ a laser range finder on the front of their vehicle. ("BDC History")

The laser range finder relays information to the driver through a combination of tactile and audio interfaces. One is called the “click wheel.” The click wheel is a steering wheel that is combined with audio cues that identifies how far to turn and in what direction by employing a standard turning unit of a “click.” The driver hears a series of clicks as well as a direction and from that can figure out how far to turn the vehicle. Another interface is the tactile vest. The vest conveys information about the drivers speed and when to brake. The vest is comprised of vibrating motors on both sides of the driver’s chest. If the driver is moving too fast, the right side vibrates, if the driver needs to make an emergency stop, both sides vibrate. (Mackay, 2009)

In Virginia Tech’s more recent years, they made a few improvements to their original designs. One included replacing the click wheel with the “Drive Grip.” The drive grip is a glove that vibrates on different hands and fingers on those hands to indicate what direction to turn and how far to turn. Another improvement was moving the velocity feedback from the tactile vest to a tactile shoe. The tactile shoe, similarly to the vest, used vibrations to tell the driver how to regulate their speed or when to brake. However, this time the vibrations ranged from the toes to the heel which correctly alerted the driver on what action needed to be taken.

This year’s team is trying another new speed regulating interface they call the “Speed Strip.” It is similar to the tactile shoe and tactile vest however it uses vibrations on the bottom and lower back to inform the driver exactly how hard to accelerate and decelerate. The goal is to give the driver more decision making ability. They have also begun using a new vehicle and their first production car, a Ford Escape Hybrid. The Escape is a specially modified version of the vehicle created by TORC called the ByWire XGVTM. It was designed to be completely controlled by a computer and Virginia Tech is modifying that platform for the blind driver challenge. (“BDC History”)

The Virginia Tech car uses a LIDAR sensor. LIDAR stands for Light Detection and Ranging. It is a way to sense objects by measuring the scattered light to find range and shape of targeted item. LIDAR is similar to RADAR, but RADAR uses radio waves. LIDAR has the distinct advantage of being able to see extremely small objects such as particles and see larger objects with greater resolution. That is because a sensor can only “see” objects down to the wavelength that it uses and light has a much shorter wavelength than radio waves. Another advantage is that RADAR requires the object to reflect the wave in order for the sensor to be able to detect it. Non-metallic objects tend to reflect almost no radio waves and are hard to detect at some frequencies. Conversely with LIDAR, the wavelength of light can be greatly varied allowing it to be tailored to detect the desired type of object.

A LIDAR, Figure 1, system usually contains a laser rangefinder that is reflected by a mirror mounted with it. There is also a scanner and optics that control the speed at which you can take pictures and affects the resolution in which they can be picked up at. The last component is a photo detector with receiver that receives all the data. (LIDAR, 2011)

Figure 1 – LIDAR sensor by SICK
<http://www.pages.drexel.edu/~kws23/tutorials/sick/sickLMS291.jpg>

Note that all of the existing products provide commands with no status updates. This project focuses on this discrepancy between autonomy and driving freedom.

Codes and Standards

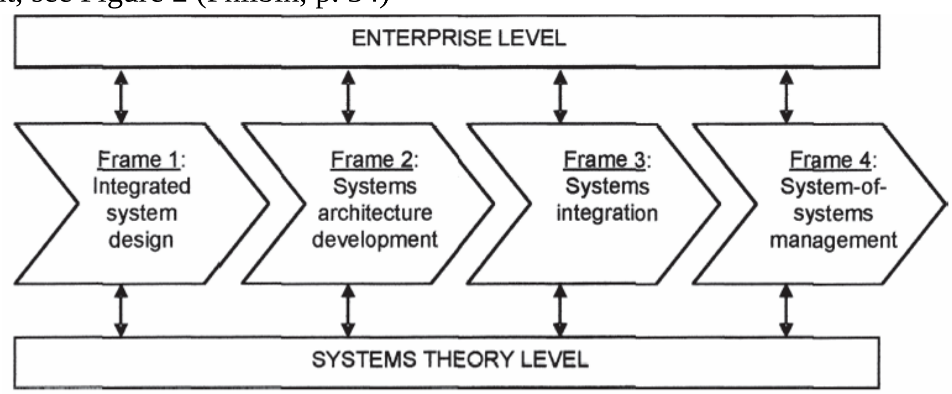
In order to better understand existing laws regarding blind or disabled people, the following codes were addressed before further research.

- Blind Pedestrians Have the Right-Of-Way (Vehicle Code Section 21963, 2009)
  - A totally or partially blind pedestrian who is carrying a predominantly white cane (with or without a red tip), or using a guide dog, shall have the right-of-way, and the driver of any vehicle approaching this pedestrian, who fails to yield the right-of-way, or to take all reasonably necessary precautions to avoid injury to this blind pedestrian, is guilty of a misdemeanor, punishable by imprisonment in the county jail not exceeding six months, or by a fine of not less than $500 nor more than $1,000, or both. This section shall not preclude prosecution under any other applicable provision of the law. (2009 California Civil Code, 2009)
- Civil Code – Section 54
  - (a) Individuals with disabilities or medical conditions have the same right as the general public to the full and free use of the streets, highways, sidewalks, walkways, public buildings, medical facilities, including hospitals, clinics, and physicians' offices, public facilities, and other public places.

- (b) For purposes of this section:
  - "Disability" means any mental or physical disability as defined in Section 12926 of the Government Code.
  - "Medical condition" has the same meaning as defined in subdivision (h) of Section 12926 of the Government Code.
- (c) A violation of the right of an individual under the Americans with Disabilities Act of 1990 (Public Law 101-336) also constitutes a violation of this section. (State of California Penal)

Project Management

As companies deal with the increase of technology and engineering based projects, more disagreement emerges regarding proper project management techniques. Although a great amount of technical and organizational complexity is often effectively managed by systems engineering and project management, the four-frames systems view can be employed as a tool to reduce technical and management risks. It accomplishes this by providing a framework that facilitates a more effective combination of traditional business management with technology management, see Figure 2 (Philbin, p. 34)



The four-frames systems framework consists of four descriptive frames that accommodate increasing levels of complexity. All four frames are supported by the systems theory level and linked to the enterprise level, thus emphasizing the need to consider a project's business as well as technical aspects.

Figure 2 – Four-Frames Systems Framework Diagram

This four-frames systems concept is purely a tool for now. It was applied to the emerging development of unmanned aerial vehicles in initial identification of system requirements, development of the systems architecture, integration of subsystems and related systems, and management of the system with non-federated or loosely-federated systems. However, the author of this research study agrees that a quantitative element still needs to be added in order to provide the connection between algorithmic-based solutions and more descriptive engineering frameworks. (Philbin, p. 39)

How does the customer fit into project management though? Other researchers propose that making progress and adding customer value during product development equates with producing useful information and reducing risk (Browning, p. 443). These, coincidentally, are some of the main goals of project management. That customer appreciates core competencies, which refer to the rareness, inimitability, and non-substitutability of the product or service (Bonjour, p. 324). Also, revealing customer values in combination with focused project objectives, collaboration with suppliers, and reuse of existing technologies can contribute toward rapid development with limited resources (Pohl, p. 372).

Statistics and Process Improvement Fundamentals

Optical flow is a well-known method used for motion-based segmentation, but in the context of vehicle passing, Kalman Filtering is the better solution for static overtaking (Alonso, p. 2739). The Kalman filter provides a well-established procedure to compute the likelihood of a time series, which is the outcome of a stationary autoregressive moving average (Gomez, p. 611). In other words, a vehicle's position can be tracked. Figure 3 shows the two main advantages, improved position estimation and prediction capability, of the Kalman filter in tracking vehicle position.

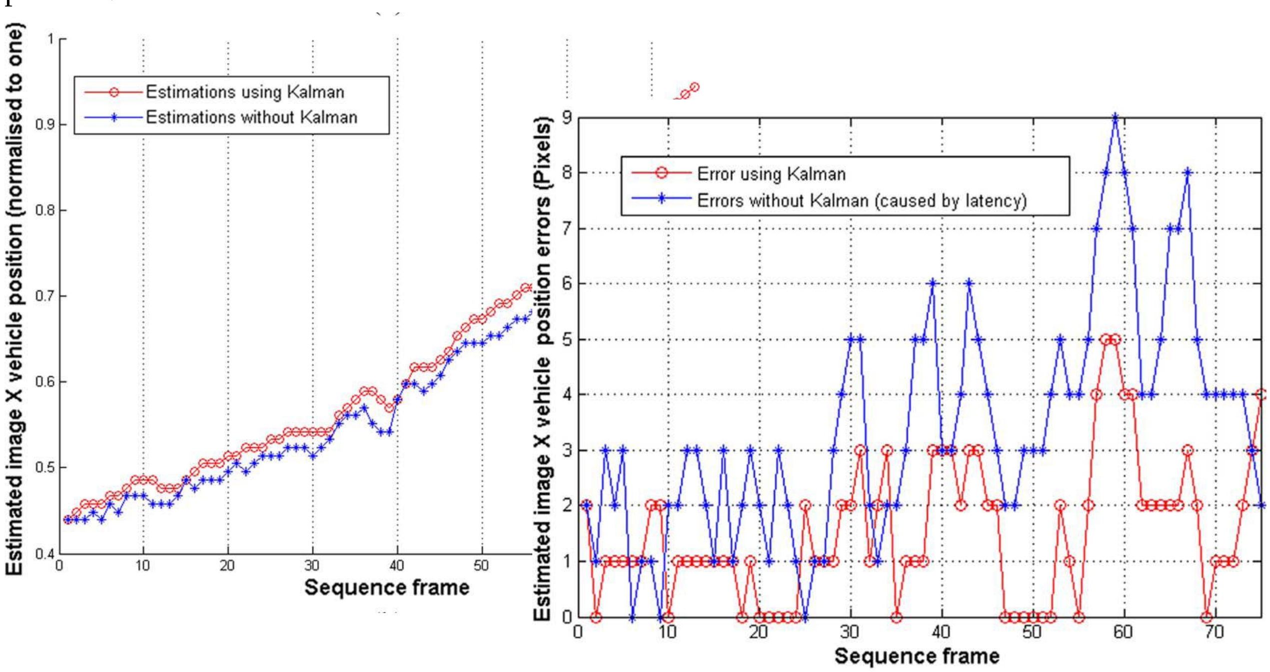


Figure 3 – Advantages of the Kalman Filter in Tracking Vehicle Position

Better position estimation was evaluated by calculating the standard deviation of the position estimation derivative. Standard deviation for non-Kalman tracking was 1.06 pixels/frame, while the standard deviation for Kalman-based tracking was only 0.78 pixels/frame (Alonso, p. 2740). Prediction capability of vehicle position was also lacking without Kalman filtering due to three frames of latency, which is a measure of time delay experienced in a system. Therefore, the

Kalman filter was used to predict the position three frames ahead to correct this latency. This is accomplished by the Kalman Filter's inherent use of the derivatives of position, being velocity, acceleration, and jerk. Using these parameters one could estimate the position in the future while still filtering out noise associated with the sensors recording the data. Due to these concluded advantages of the Kalman filter in tracking vehicle position, a system was developed to warn a driver in three dangerous circumstances: blind spots, approaching vehicles, and lane changes (Alonso, p. 2742).

Human Factors Engineering

The Virginia Polytechnic Institute and State University, College of Engineering (Virginia Tech) vehicle, named "Odin", includes tactile and audio interfaces in order to relay information to a blind driver about vehicle heading and speed, but how can a person understand and react to this information? Purdue University is conducting research on a haptic back display using a chair outfitted with tactors, a mechanism to artificially recreate forces and/or textures. The research has revealed connections between visual information and tactile cues, two of the body's five senses. The University of Genova has introduced research on another of the five senses, sound. They have investigated the use of 3D sound to relay information to the driver, allowing sound to be generated at any spatial coordinate. (Hong, p. 539)

A Yale mechanical engineering professor, John Morrell, has practical experience with the advantages of tactile cues while driving. Similar to Virginia Tech's modified massage chair, he used a modified driver's seat to alert a driver of an obstacle in their blind spot. He insists that our visual sense is already being fully employed while driving. Furthermore, a warning that appears in front of you about something that is behind you, results in a slower response time because the brain has to convert the information. (Corley, p. 13)

In a Monterrey Institute of Technology and Higher Education (ITESM) study, inattention was emphasized as the most important human factor in vehicle collision (Sosa, 2007). However, is it all the fault of the inattentive driver, or is there a lack of human factors engineering in automotive development? Current automotive development can be characterized as technology-centered solutions rather than user-centered solutions (Noy, p. 1016). For instance, the DARPA Urban Challenge even strives to eliminate the need for an operator with the slogan, "Robot Cars Drive Themselves!" (Voelcker, p. 16). Unlike DARPA, the ITESM does seem to accept the reasoning because they developed a safety system that could prevent an accident from occurring even with an inattentive driver. The system alerts the driver at a distance in order to avoid a collision, and if the driver still neglects the warnings, the system begins braking in order to decrease or avoid damage severity. It appears that human factors engineering may be the key to increase vehicle safety for all of the customers that rank safety from "extremely" to "very important" when buying a new car. (Sosa, 2007)

DESIGN

The engineering design process meshed with the Cal Poly mechanical engineering senior project design requirements served as the method of approach and assisted in the creation of an innovative vehicle system. The engineering process includes research, encompassed in the background and literature review, as well as the following steps (Ertas, 1996):

- Conceptualization
- Feasibility Assessment
- Establishing the Design Requirements
- Preliminary Design
- Detailed Design
- ~~Production Planning and Tool Design~~
- ~~Production~~

Since the project does not intend for mass production, production planning and tool design and production were not included. Instead, concept justification, programming description, and construction were added.

Conceptualization

The conceptual designs were developed through group brainstorming in the form of spider diagrams, first created on a white board and then compiled in the design notebook, as shown in Figure 4. Captain Iván Castro, a blind active military contact, and Jennifer Allen-Barker of the Cal Poly Disability Resource Center provided additional concept ideas.

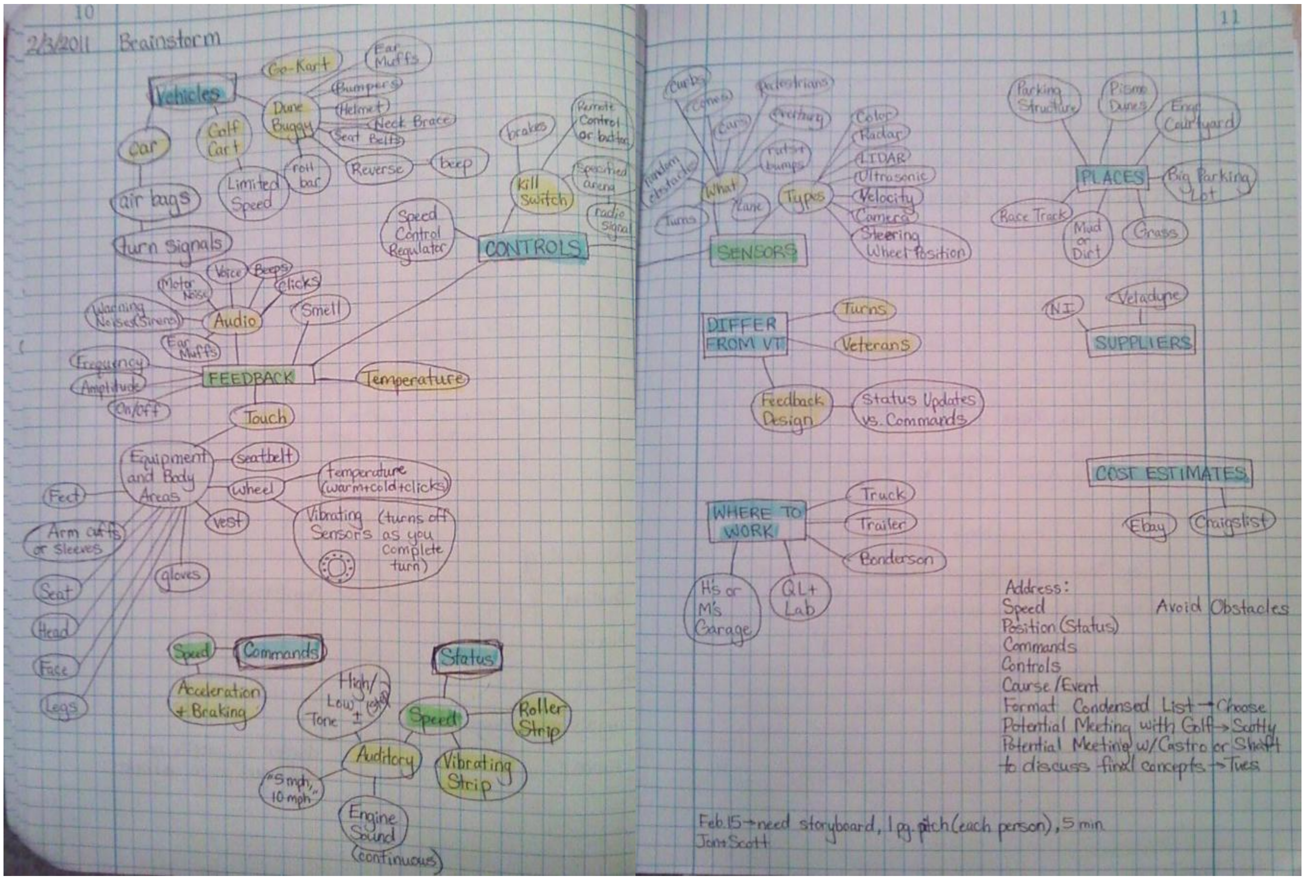


Figure 4 – Concept Spider Diagrams

Feasibility Assessment

In order to determine whether the project could proceed into the design phase, professors from the mechanical engineering (ME) and computer engineering (CPE) departments offered consultation in their areas of expertise:

- Dr. Birdsong: ME, Vehicle Collision Avoidance
- Dr. Schuster: ME, Vehicle Collision Avoidance
- Dr. Self: ME, Tactical Feedback
- Dr. Clark: CPE, Autonomous Robotics
- Dr. Lupo: CPE, Programming and Hardware

The professors agreed on the feasibility of some of the concepts. They suggested that LIDAR would work best for the project’s application, and so they recommended getting an electrical engineer or computer engineer to program. After further consulting with the CPE Autonomous Golf Cart team about their LIDAR laser and programming language, electrical engineering master’s student, Alvin Hilario, was asked to join the team as the hardware and programming authority.

Establishing Design Requirements

A Quality Function Deployment (QFD) diagram, Appendix A: QFD, illustrates the weighting of customer wants against quality characteristics. The results reveal that the amount of available information from the feedback systems ranks the most important aspect of the project's designs. The QFD also shows the importance of both speed and acceleration. To further clarify, the participants in our event should enjoy themselves and feel exhilarated while driving. These higher speeds and acceleration will provide participants with that adrenaline rush. The learning curve associated with the technologies must also be considered when determining the effectiveness of the feedback systems. With the understood quality characteristics, technical specifications can guide the final decision.

The first goal seeks to effectively modify a vehicle. To accomplish this goal, we must make sure the vehicle is structurally safe and has the correct base requirements for the task. Table 1 lists the necessary vehicle specifications.

L= Low, M= Medium, H= High

A= analysis, I= Inspection, T= Test, S= Similarity to existing designs

Table 1. Vehicle Specifications

Spec #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1	Max Speed	30 mph	+/- 5 mph	M	A, S, T
2	Acceleration	15 hp	Max	M	S, T
3	Braking	100 ft breaking distance	Max	L	S, T
4	Power Steering	Installed		L	S, I
5	Collision speed tolerance	20 mph	Max	M	A, T
6	Seatbelts	Installed		L	S
7	Kill Switch	Installed		M	A, T
8	Other modifications (Roll bars, etc.)	Installed		L	T, S, I

A kill switch will prevent an operator from dangerously veering off course. The other safety features are necessary because of the experimental nature of this event. While maintaining appropriate safety, the vehicle should obtain and maintain reasonable speeds, acceleration, and breaking. Power steering will aid in the operation of the vehicle.

The feedback specifications, Table 2, will assist in accomplishing the goal of designing a feedback system that communicates information about the environment to the user.

Table 2. Feedback Specifications

Spec #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
9	Number of Sensors	3 sensors	+/- 2 sensors	M	I
10	Processing Speed of Sensors	60 Hz	Min	M	T, I
11	Processing Speed of Computer	3.0 GHz	Min	M	T, S
12	Max force of feedback devices	15 psi	Max	L	A, T, I

A single laser scanner sensor needs enough processing speed to handle the stream of data required for real-time feedback. The feedback devices must not bruise the user, so a maximum psi limits the force deliverable by the feedback systems.

After developing a functional vehicle, an organized event will demonstrate the technology to the public and enable blind participants to enjoy the chance to drive. Along with the goals on non-autonomy, press attention, and a comfortable, safe, and enjoyable experience, the following specifications provide design guidance, Table 3.

Table 3. Course Specifications

Spec #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
13	Complimentary	$0		M	
14	Barrier distance	100 ft	Min	L	I
15	length of course	0.25 miles	Min	L	I
16	complexity of course	5 turns	+/- 2 turns	L	I
17	size of event	100 people		M	I
18	size of obstacles	2 ft	Min	L	I
19	Learning Curve	5 laps	+/- 3 laps	H	T, A

Preliminary Design

The following sketches of the initial conceptual designs illustrate the all of the concepts before choosing a final detailed design.

Vibrating Wristbands

The vibrating wristbands, Figure 5, work by giving the driver information on how they need to turn the steering wheel.

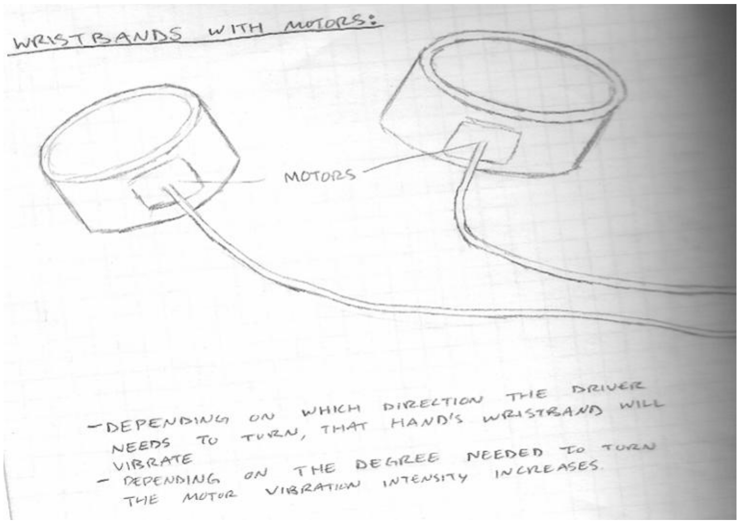


Figure 5 – Vibrating Wristbands Sketch

If there is an obstacle ahead on the road the wristbands will tell the driver whether they need to turn right or left. If the driver needs to turn left, the left wristband will begin to vibrate. Alternatively, the right wristband will vibrate if the driver needs to turn right. Depending on the degree the driver needs to turn the intensity of the vibration will increase or decrease. This concept represents a command update.

Temperature Steering Wheel

The temperature steering wheel, Figure 6, provides steering instructions by changing the temperature of different sections of the steering wheel.

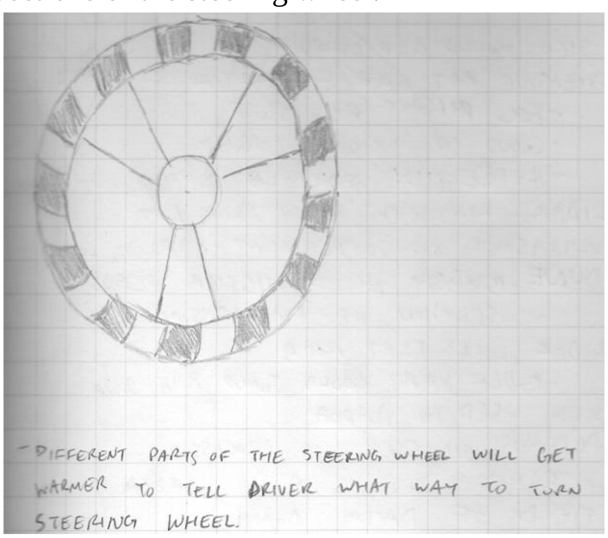


Figure 6 – Temperature Steering Wheel Sketch

The temperature steering wheel works by giving the driver information on how they need to turn the steering wheel, another command update concept. It has a heat transfer system inside the steering wheel that can heat up segments of the steering wheel giving tactile feedback.

Depending on the direction the driver needs to turn, the heat transfer system will heat the part of the steering wheel correlating to the direction and degree the driver needs to turn.

Air Chair

The air chair, Figure 7, works by relaying a map of the road, as sensed by the laser scanner, on to the chair with compressed air.

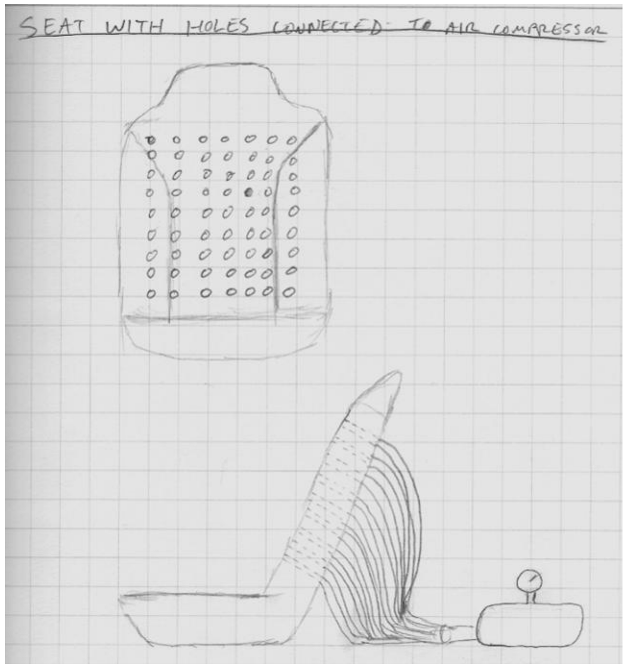


Figure 7 – Air Chair Sketch

The driver feels the map of the road on their back. This represents a status update that will reveal the course to the driver, as opposed to instructions. The chair shows the driver where they are relative to where an obstacle may be. The vehicle is depicted towards the bottom of chair and as obstacles are seen on the road by the sensor they will be shown at the top of the chair moving downward as they become closer.

Water Chair

The water chair, Figure 8, works by relaying a map of the road, as seen by the laser scanner, through a water pack equipped with water jets that is secured to the chair.

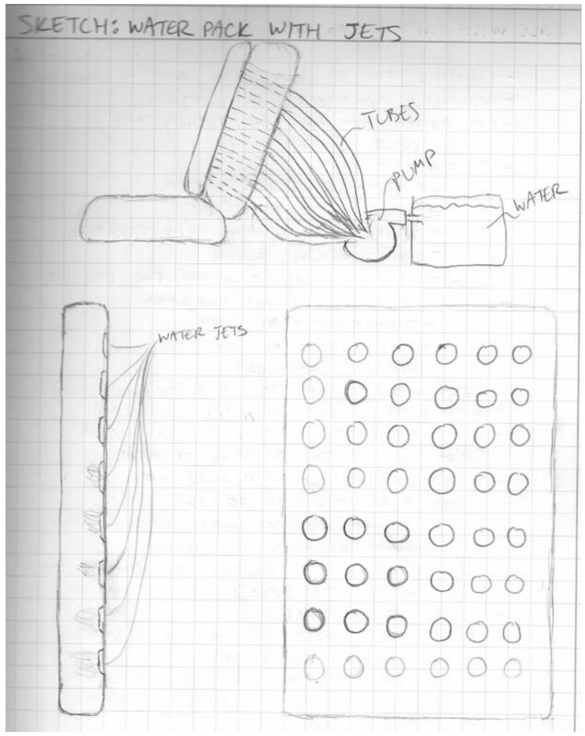


Figure 8 – Water Chair Sketch

The chair shows the driver where they are relative to the location of an obstacle. The water chair, another status feedback update, works similar to the air chair. The vehicle is depicted towards the bottom of chair and as obstacles are seen on the road by the sensor they will be shown at the top of the chair moving downward as they become closer.

Vibrating Steering Wheel

The steering wheel, Figure 9, will be divided into approximately 12 sections that can vibrate independently to indicate the direction to turn the steering wheel in, no matter how much rotation the wheel experiences. This describes yet another command update.

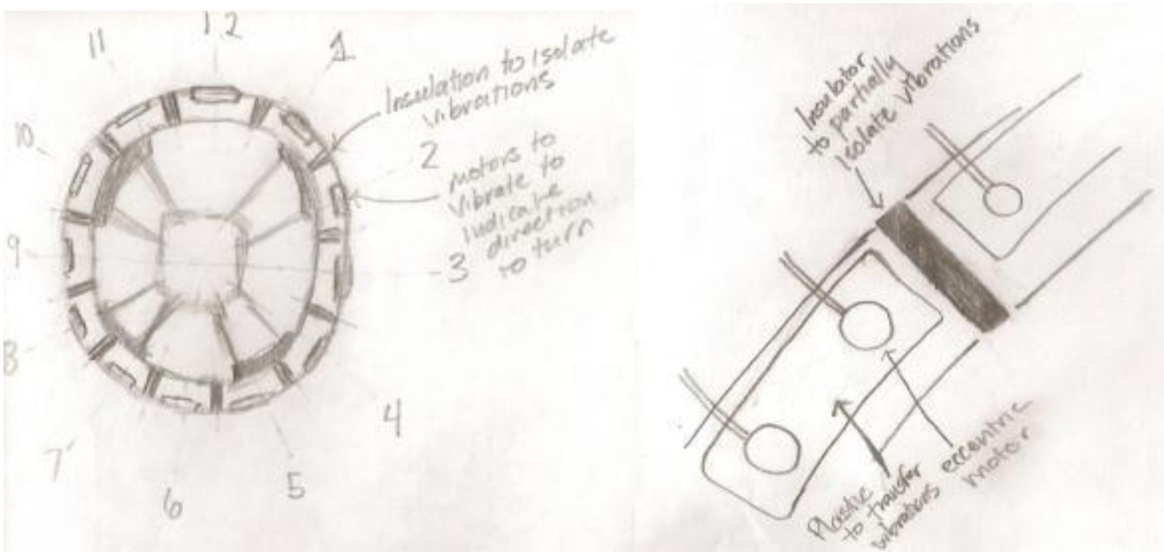


Figure 9 – Vibrating Steering Wheel Sketch

Electric eccentric motors will be used to stimulate the user, translating their vibrations through a hard plastic housing. Insulation will be used to isolate each section, but not entirely isolate vibrations to their respective sections.

The orientation of the vibrating sections will be distributed to gain a higher sensitivity for small changes in direction. This will be done by centering more sections in the "10 and 2" areas, where user's hands should be, as shown in Figure 10.

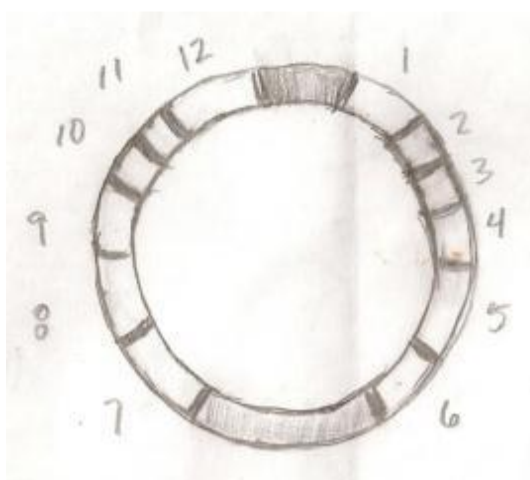


Figure 10 – Wheel Motor Distribution

For an example of turning, the steering wheel will vibrate with direction and intensity to tell the user how much to turn and in what direction, Figure 11. The dark portions are the vibrating sections.

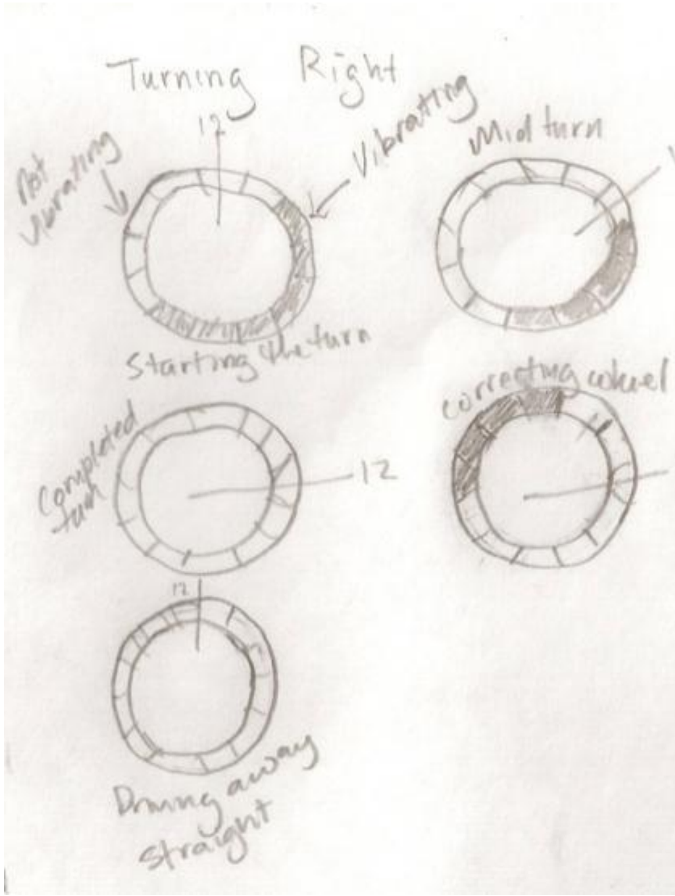


Figure 11 – Turning Sketch

Vibrating Chair

Figure 12 reveals a modified driver's seat developed by Yale mechanical engineering professor, John Morrell.

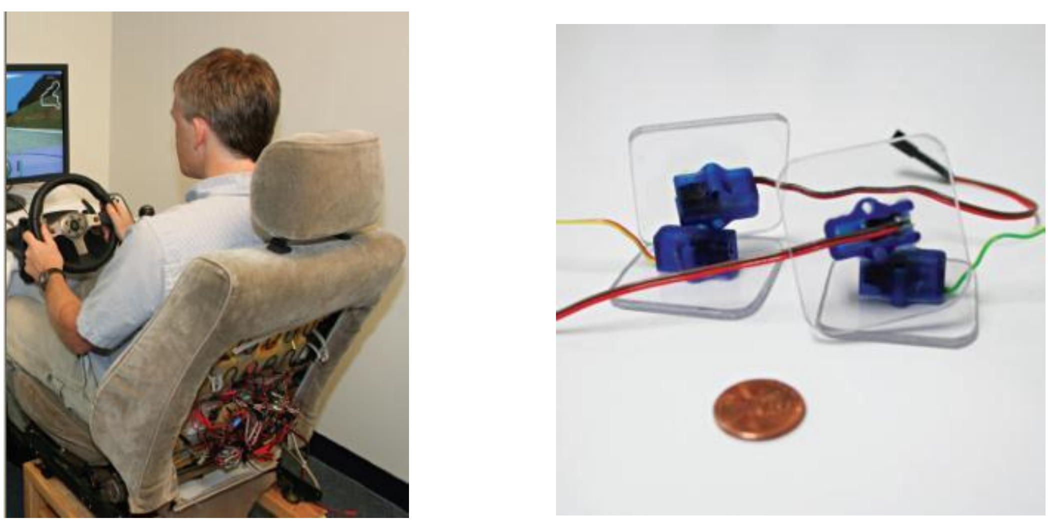


Figure 12 – Vibrating Chair
<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5490998>

It alerts a driver of an obstacle in their blind spot by activating vibrating motors and servos in the seat. This type of seat increases response time when dealing with approaching vehicles, or acts as a status update. A warning that appears in front of you about something that is behind you, results in a slower response time because the brain has to convert the information. Although the study reveals some important considerations for human factors engineering, it may not be practical for this project needs because we are dealing almost exclusively with forward obstacles.

Tactile Vest

The tactile vest, Figure 13, worn by the driver would provide real time feedback of speed and the location of obstacles.

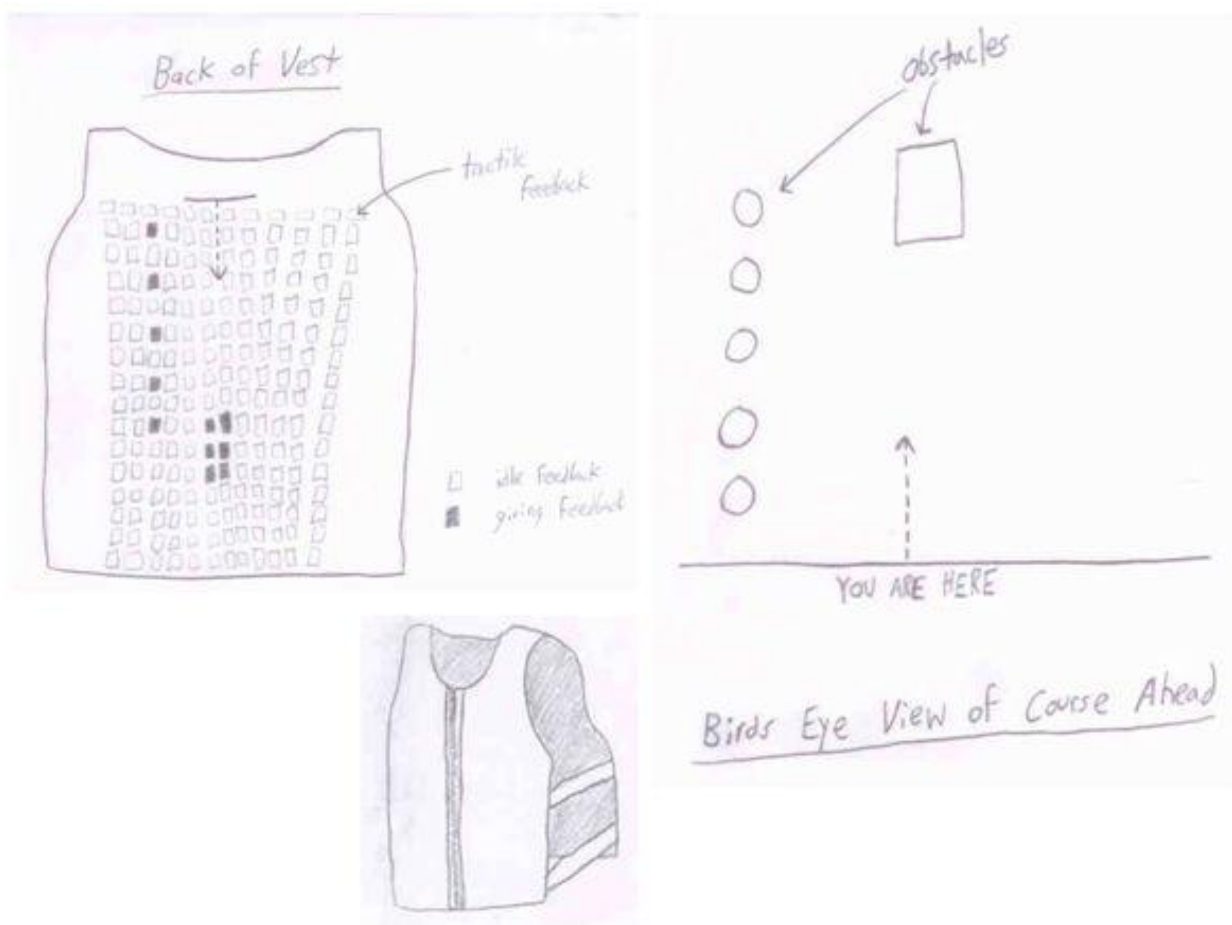


Figure 13 – Tactile Vest Sketch

The vest would project the obstacles onto the body of the driver and have them move in real-time, as if you were looking down from a bird's eye-view. That will allow the driver to "see" any obstacles in front of the vehicle. The real-time feedback, status update, will reveal the speed and location of approaching obstacles relative to the driver's orientation and projected path. The provided information will allow the driver to make decisions about whether to speed up or slow down and when and how hard to turn. The vest is outfitted with eccentric motors laid out in a grid on the back of the vest to provide the tactile information. The motors are either on or off, and active motors signal the location of an obstacle. As an obstacle moves toward the vehicle, the eccentric motors turn on and off moving the vibration from the lower back toward the shoulders of the driver. The shoulders represent the front plane of the vehicle while the lower back represents the farthest distance from the vehicle. The driver's spine represents the centerline of the vehicle as seen from the bird's eye-view. If the column of eccentric motors in the middle of the back shows an obstacle, the driver will know that he/she is on a collision course with that obstacle. If the two columns on the sides of the spine vibrate, the driver will sense an obstacle ahead to the left or right.

Tilt Chair

The tilt chair, Figure 14, would attach to the driver's seat and employ steering commands.

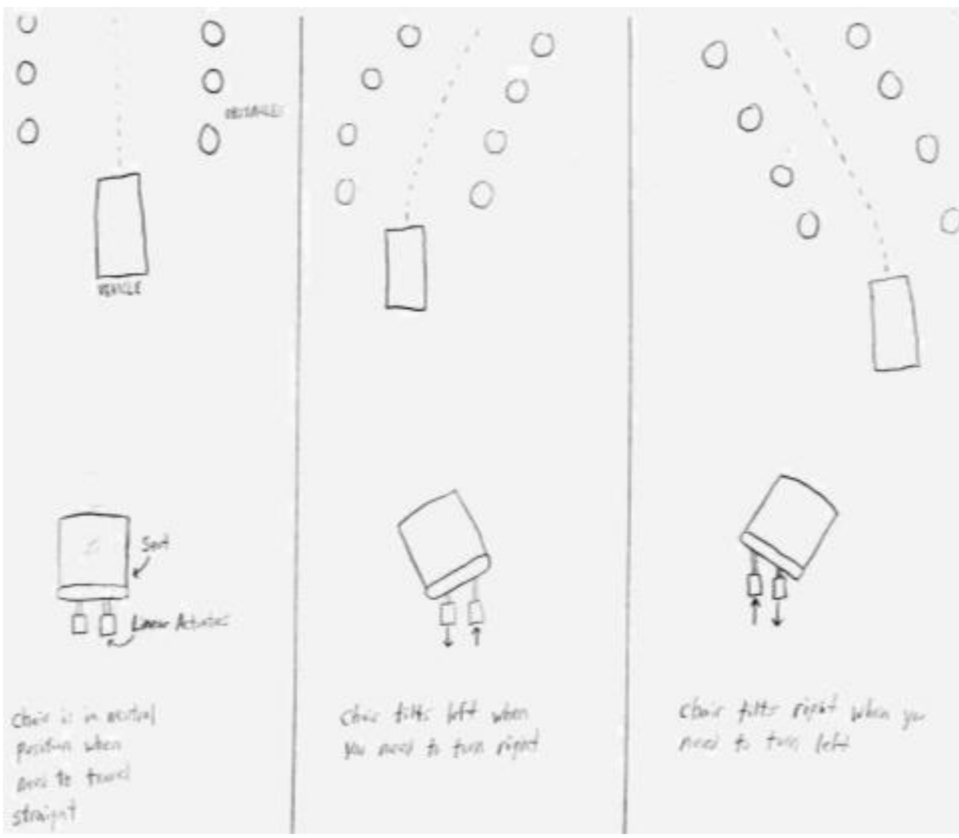


Figure 14 – Tilt Chair Sketch

The tilt chair uses linear actuators to tilt the seat to the left and right depending on what way the driver needs to turn. It also varies how far it tilts to each side to tell the diver how far they need to steer. It works on the premise that the driver wants to remain sitting upright. When no obstacles are ahead and traveling straight is appropriate, the seat will remain upright. However when a left turn is needed the seat will tilt right, and the driver will turn the steering wheel left to move their body back to upright position and turn the car correctly. As the car approaches the correct orientation and the steering wheel needs to be straightened out, the chair will tilt back in real time towards upright position. When the driver is sitting upright no action needs to be taken, but to continue traveling straight. The same logic applies, but opposite tilting occurs, for a right hand turn. It can also work where the chair tilts in the direction that you need to turn and returns to upright when traveling straight is appropriate.

Click Wheel/Pedal

The click mechanism would attach to the steering wheel or foot pedal, Figure 15.

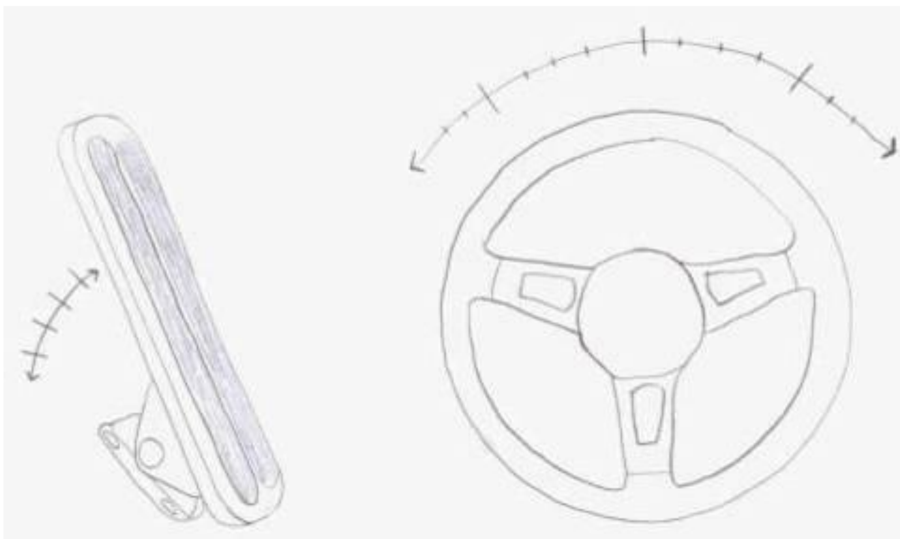


Figure 15 – Click Pedal and Wheel Sketch

It would provide relative orientation of the steering wheel or foot pedal by "clicking" as they move past certain preset increments. In this way the driver will know when the steering wheel has been pressed 25, 50, 75 and then 100% of the way, which can provide a rough feeling speed reference. Apply the same theory to the steering wheel, with it "clicking" every 30 degrees so that the driver knows how far they have turned it. The steering wheel clicking combined with audible commands would allow the driver to hear the number of clicks to turn and the direction to know how far to turn.

Course and Event

Permission to use an area posed as one of the main problems to course development. An ideal course and alternate course created options regardless of permission. The ideal course, Figure 16, is located in front of the QL+ Lab. Options include a grand entrance, closed loop, a figure 8 formation, and barbecue. Planning would be difficult for this kind of event though.

Figure 16 – Ideal Course

The alternate course, Figure 17, is located in a large, vacant Cal Poly parking lot.

Figure 17 – Alternate Course

Easy customization on a large, flat, controlled area represents the main advantage to the alternate course. With a flat, barren space, customizable obstacles increase safety as well. The disadvantage entails lower campus involvement.

Concept Justification

After generating concepts, the decision-matrix method, also known as the Pugh method, ranked and chose between the different designs. Using this method makes subjective alternative decisions more objective. The decision matrix construction steps follow:

- Choose or develop the criteria for comparison.
  The Quality Function Deployment (QFD) examined customer requirements.
- Generate a set of engineering requirements and targets.
- Select the design alternatives to be compared. Brainstorming and research developed these alternatives.
- Generate scores.
- Compute total score.

The following color-coded decision matrices identify the top scoring designs, green, the next highest scoring, yellow, and the low scoring, red (negative).

Table 4 reveals the feedback equipment decision matrix.

Table 4. Feedback Equipment Decision Matrix

	Weight Factor	Vibrating Vest	Tilt Chair	Vibrating Steering Wheel	Click Positioners	Air Chair	Water Chair	Temperature Wheel	Vibrating Wristbands	Vibrating Chair
Cost	0.12	0	-0.5	0	1	-1	-1	-1	0.5	0
Safety	0.18	0	-0.5	0	0	-0.5	-0.5	-0.5	0	0
Feasibility	0.18	0	-0.5	0	1	-1	-1	-1	0.5	0
Function	0.18	1	0.5	0.5	-1	1	1	0.5	0.5	1
Fun Factor	0.14	0	0.5	0.5	-0.5	0	0	0.5	0	0
User Interface	0.2	0	1	1	0	-0.5	-0.5	0.5	0.5	-0.5
TOTAL	1.00	0.18	0.12	0.36	0.05	-0.31	-0.31	-0.13	0.34	0.08

Safety, feasibility, and function rendered the top criteria. Safety should always rank highest. The team's knowledge and experience limited flexibility in design feasibility. Finally, without clear communication of information from the sensors the blind driver will have a difficult time successfully driving the vehicle. Although they did not have as much weight, we also took into account cost, user interface, fun factor. Both of the highest scores, highlighted in green, represent a command feedback. In order to make an improvement on the Virginia Tech model, the final feedback design combined both the vibrating steering wheel for commands and the vibrating vest for status.

Table 5 reaveals the sensor decision matrix.

Table 5. Sensor Decision Matrix

	Weight Factor	Ultrasonic	RADAR	LIDAR
Cost	0.25	1	0	-1
Feasibility	0.2	-1	0.5	1
Range	0.25	-0.5	0.5	1
Size	0.05	1	0	0
Accuracy	0.25	-0.5	0	1
TOTAL	1.00	-0.15	0.23	0.45

The decision matrix confirms the consulted professors' suggestions that the LIDAR sensor would succeed the best for the project's application. The following points summarize the LIDAR's advantages:

- Longest range
- Designed for outdoor use
- Reasonable price with 25% off university discount
- Free software available
- On-campus and company technical support
- Can be used again on future QL+ projects

The LIDAR manufacturer SICK offers three outdoor laser scanners. The project team presented these three scanners, shown in Table 6, to the QL+ sponsor, Jon Monett.

Table 6. Comparison of SICK LMS Laser Scanners

	111	151	511
Price	$4,775	$6,360	$7,018
Environment	Outdoor	Outdoor	Outdoor
Scanning Range	20 m	50 m	65 m
Object Remission	18 m @ 10%... up to 13%	18 m @ 10%... up to 75%	40 m @ 10%
Time Before Impact of Furthest Object at 10mph	4.5 sec	11.2 sec	14.5 sec
Time Before Impact of Furthest Object at 25mph	1.8 sec	4.5 sec	5.8 sec

This expensive decision represents the most difficult one in the project. The goal of allowing a blind driver to travel at speeds up to and around 25mph requires a sensor that can see far enough ahead to give the driver ample time to react to obstacles. Doing a few unit conversions and some velocity=distance/time calculations deduced that at low speeds (10mph) all of the laser scanners have sufficient range to allow at least 4.5 seconds for the driver to react. However, once at 25mph the LMS 111 only has 1.8 seconds. That means that as soon as the laser scanner detects an obstacle, the driver has 1.8 seconds to do something before he/she slams into it. When you add multiple obstacles and unfamiliar touch based feedback, the blind drivers will need much more time to react than that. Also, the more range the laser scanner has, the more versatility it offers for future teams who might further push the boundaries.

Taking these considerations into account, the team recommended the LMS 151. However, it is 10 years older than the new LMS 511 and only $700 more. Comparing the relatively small $700 difference to the $7000 price, QL+ decided to make the LMS 511 the final choice.

The laser scanner needs to attach to the dune buggy. To give it a clear view of the obstacles in front of the car, it will mount directly to the hood-area of the vehicle. The team mechanical engineers designed a mount on solid works, Figure 18, and analyzed it to ensure the security of the sensor.

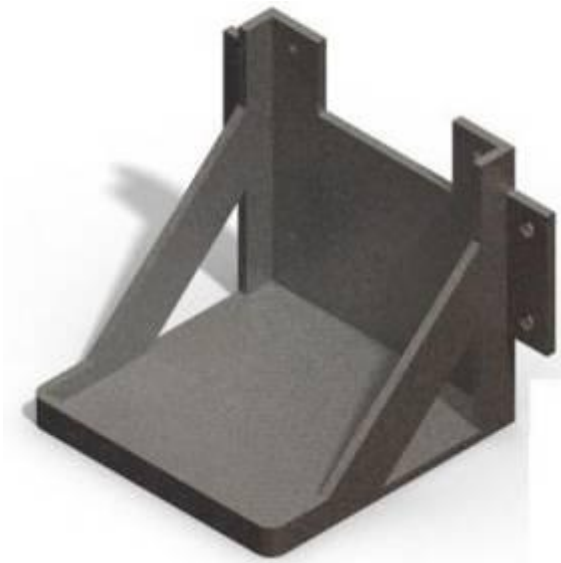


Figure 18 – SICK Laser Scanner Mount

Since the LIDAR unit already represented the biggest weight in the budget, smaller vehicles with a lower price were considered. Table 7 reveals the vehicle decision matrix.

Table 7. Vehicle Decision Matrix

	Weight Factor	**Golf Cart**	**Dune Buggy**	**Electric Vehicle**
Cost	0.25	-1	1	-1
Speed	0.15	1	0	-1
Safety	0.2	0	1	1
Braking	0.15	1	0	0
Fun Factor	0.2	0	1	0
Noise Level	0.05	-1	0	1
TOTAL	1.00	0.00	0.65	-0.15

All of the criteria had relatively equal weight except for noise level, a less important characteristic. A louder vehicle may even be preferred as the noise of the engine gives you information about speed. The dune buggy clearly offered the greatest option. A dune buggy decision matrix, Table 8, along with recommendations, Table 9, then decided the type of specifications.

Table 8. Dune Buggy Decision Matrix

	Weight Factor	A	B	C	D	E	F
Price	0.5	-1	0	1	0	1	0
Speed	0.25	1	1	0	1	-1	0
Luggage Component	0.25	1	1	1	1	-1	-1
TOTAL	1.00	0.00	0.50	0.75	0.50	0.00	-0.25

Table 9. Dune Buggy Recommendations

	Rank	Preferred Vehicle Specifications	Engine Size ~ 110cc	# of Seats 2	Price	Max Speed Min 35 mph	Luggage Component yes
A		http://gokartsusa.com/bmspowerbuggy250.aspx	17.5 hp	2	$3,499	47 mph	yes
B	**2**	**http://gokartsusa.com/BMS-King-Cobra-150-Buggy-Gokart.aspx**	**12.5 hp**	**2**	**$2,388**	**47 mph**	**yes**
C	**1**	**http://gokartsusa.com/kinroadrunmasterexplorerbuggy.aspx**	**150 cc**	**2**	**$1,763**	**42 mph**	**yes**
D	**3**	**http://gokartsusa.com/roketagk-01ktr-150adunebuggy.aspx**	**150 cc**	**2**	**$1,829**	**46 mph**	**yes**
E		http://gokartsusa.com/TrailMaster-XRX-Buggy-Gokart.aspx	6.5 hp	2	$1,399	30 mph	no
F		http://gokartsusa.com/Baron-Gokart-American-Sportworks.aspx	150 cc	2	$1,999	39 mph	no

These new dune buggies represented the baseline for used shopping. The final purchase, a used 150 cc dune buggy with a top speed of 35 mph, two seats, a luggage component, and an asking price of $1000, perfectly met the specifications. See Appendix D: Pertinent Product Literature for more information.

Detailed Design

The detailed designs expand on the preliminary designs regarding materials, hardware, construction, and interconnectivity. The two feedback final designs, the vibrating vest, Figure 19, and steering wheel, Figure 20, provide commands and status, but they do not give a quantitative speed. For further detailed vest and wheel solid model drawings see Appendix C: Assembly Drawings.

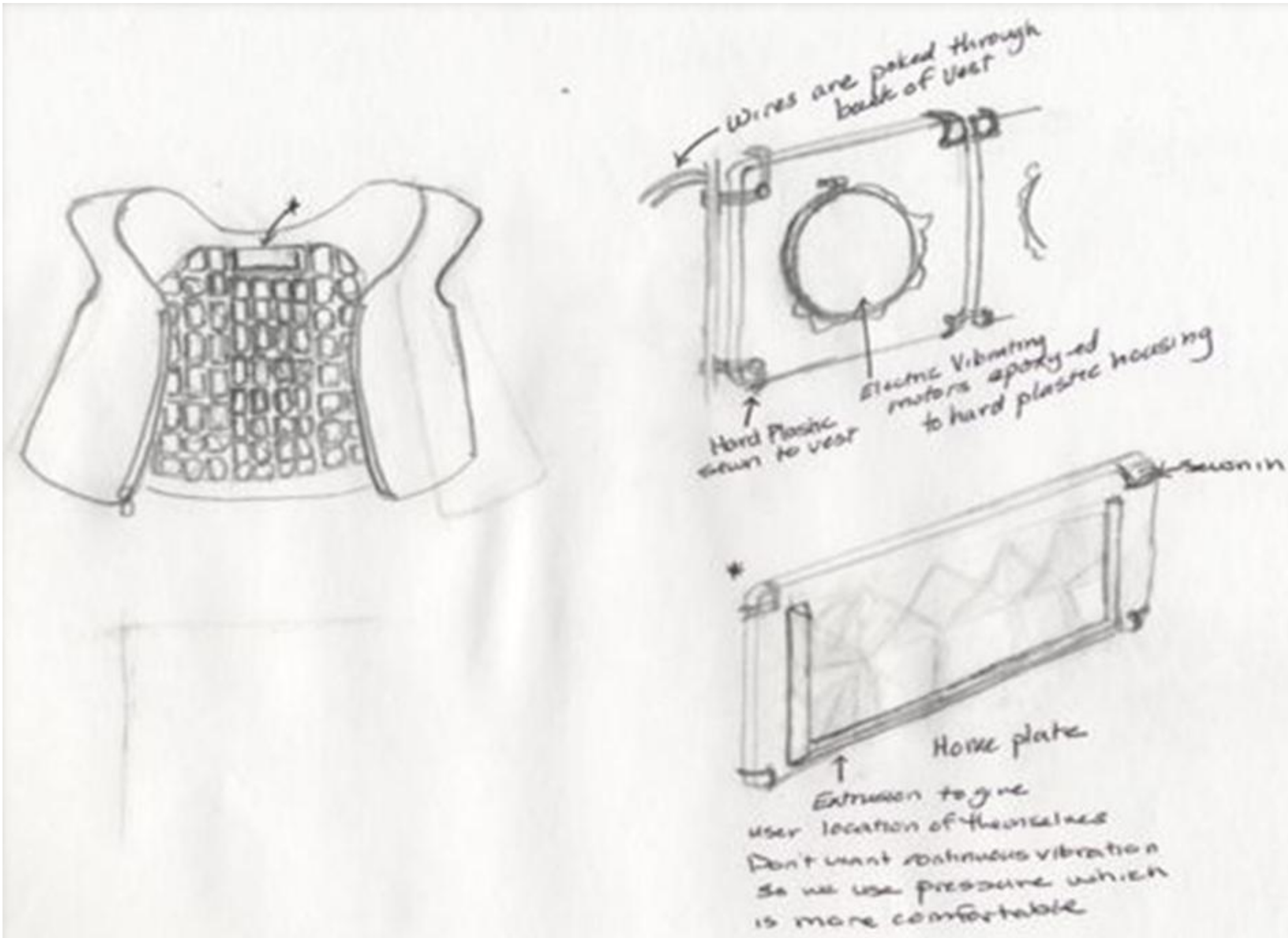


Figure 19 – Tactile Vest Detailed Design

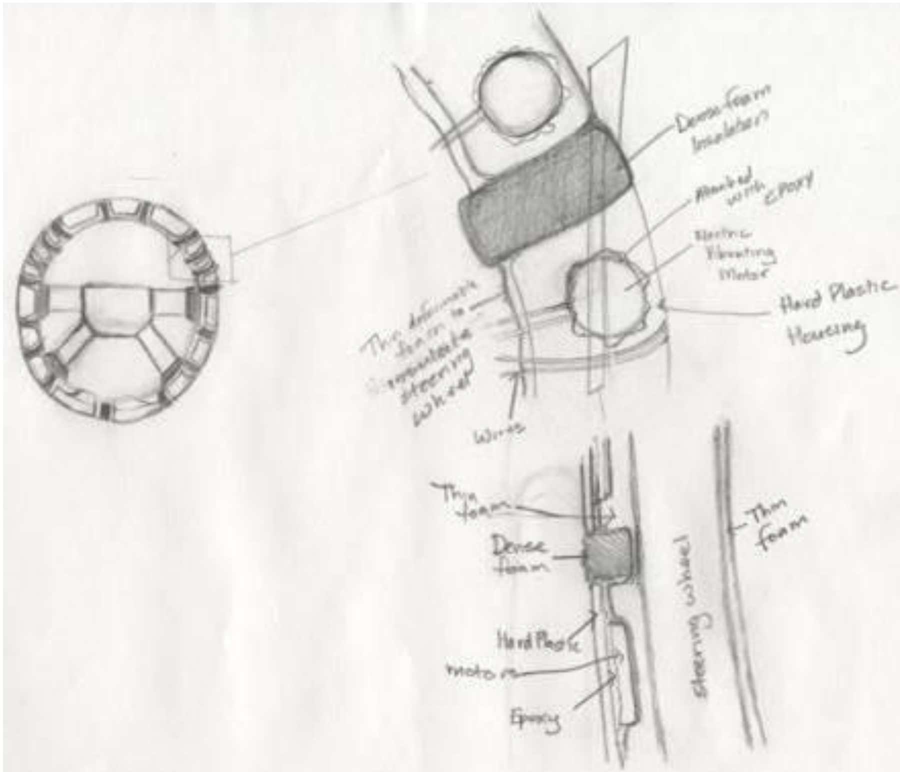


Figure 20 – Vibrating Steering Wheel Detailed Design

Although the decision matrix does not include auditory feedback, a few surveyed blind individuals stressed that auditory information was a common and comfortable way to relay information. Therefore, auditory feedback will present a speed reference. As an added safety feature the auditory feedback could also have built in alarms for when dangerous situations arise and the driver needs to take immediate action, such as sudden braking. The feedback designs combined with the dune buggy and SICK sensor complete the system integration, Figure 21. By integrating these designs, information may be delivered as clearly and effectively as possible without overloading just one of the driver's senses.

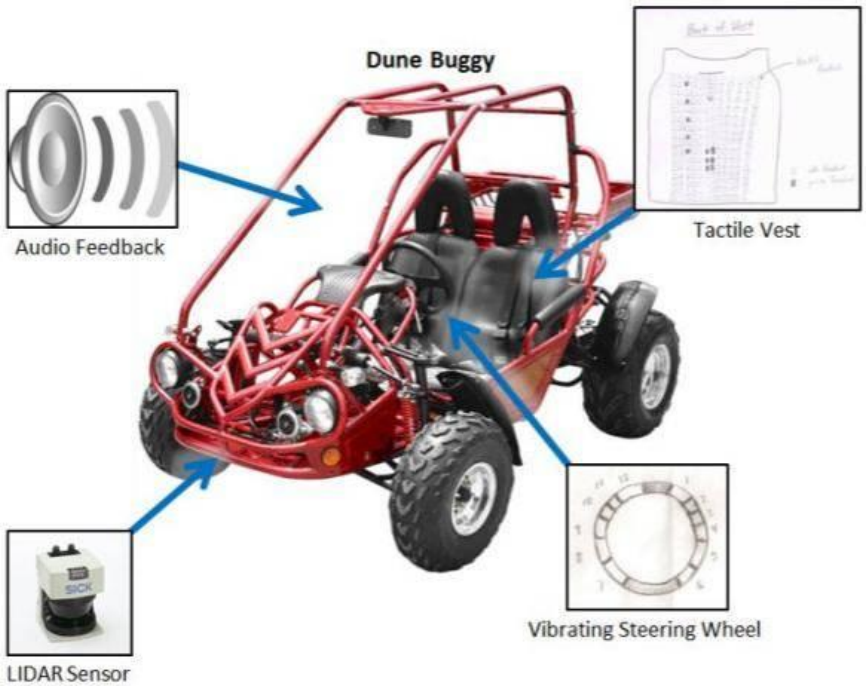


Figure 21 – System Integration

Programming Description

The programs packaged with the SICK LIDAR sensor as well as LabVIEW will serve to accomplish the necessary programming. The SICK programs will allow data gathering from the sensor into a format readable by LabVIEW. This data will take the form of distances at a corresponding angle. It will display in graphical form, but will not provide very much information until the data processing. LabView can then implement filters and image processing techniques in order to make sense of the raw data collected. Such techniques will allow object identification in the field and will associate other necessary parameters, such as distances and velocity. With these developed parameters, appropriate logic statements will produce an output, which passes to the array of motors via an RS232 cable connected to a microcontroller. LabVIEW outputs a string of hexadecimal values that correspond to a specific general purpose I/O (GPIO) port to specify exactly which MOSFETs to activate. The MSP430 microcontroller then parses this string and assigns the hexadecimal value to the appropriate port. Each port contains eight outputs. These outputs are binary, either on or off. Each output connected to a MOSFET transistor activates/deactivates an eccentric motor. The diode prevents voltage transience to protect the motors during on/off switching. In application, multiple outputs can activate simultaneously. The eccentric motors also require a 3V DC source. To power the eccentric motors and microcontrollers, the 12V car battery steps down to 3V using a DC-DC converter. All the motors connect in parallel to receive the same 3V source, as shown in Figure 22 and Figure 23.

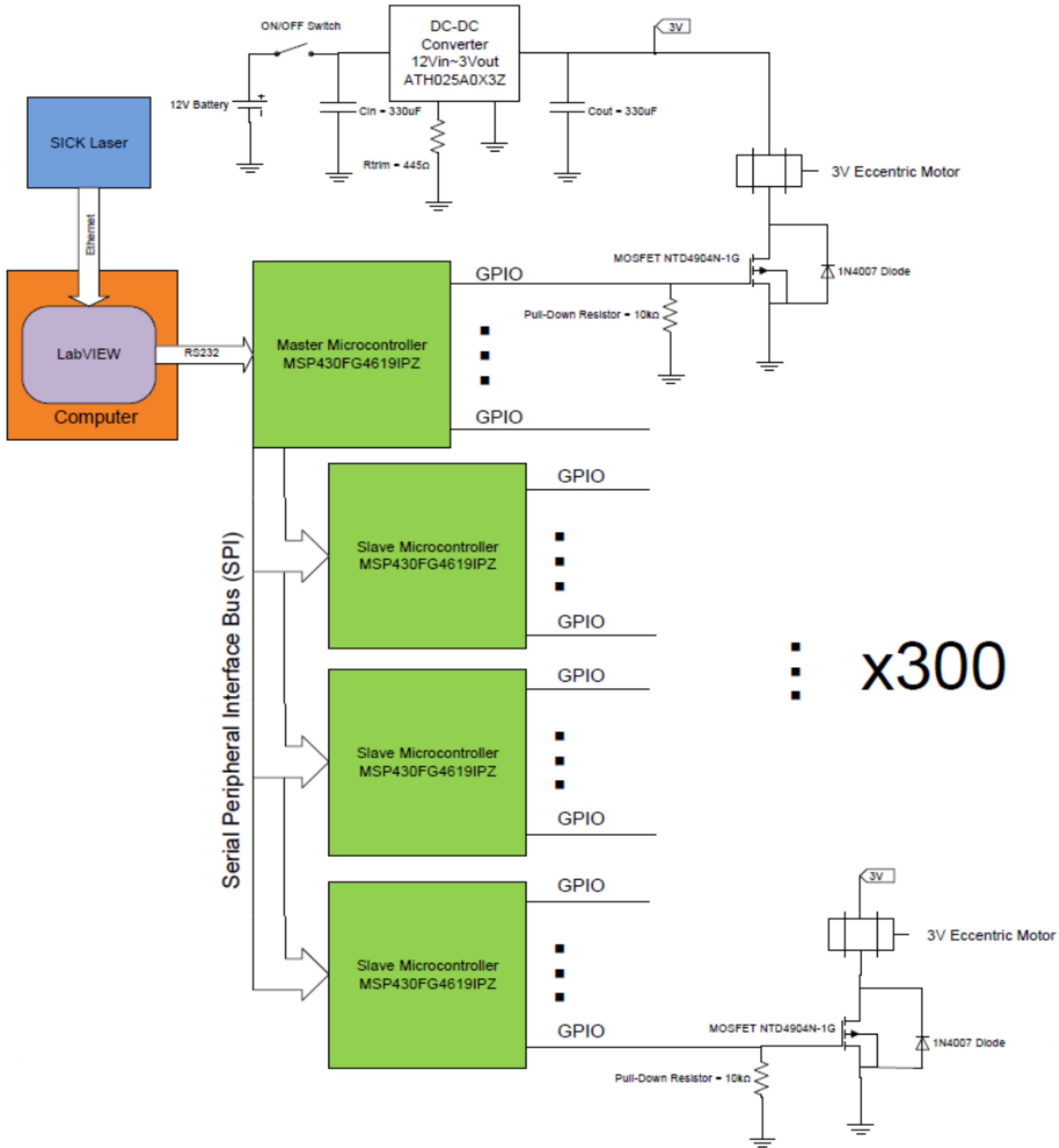


Figure 22 – Electrical Hardware Diagram

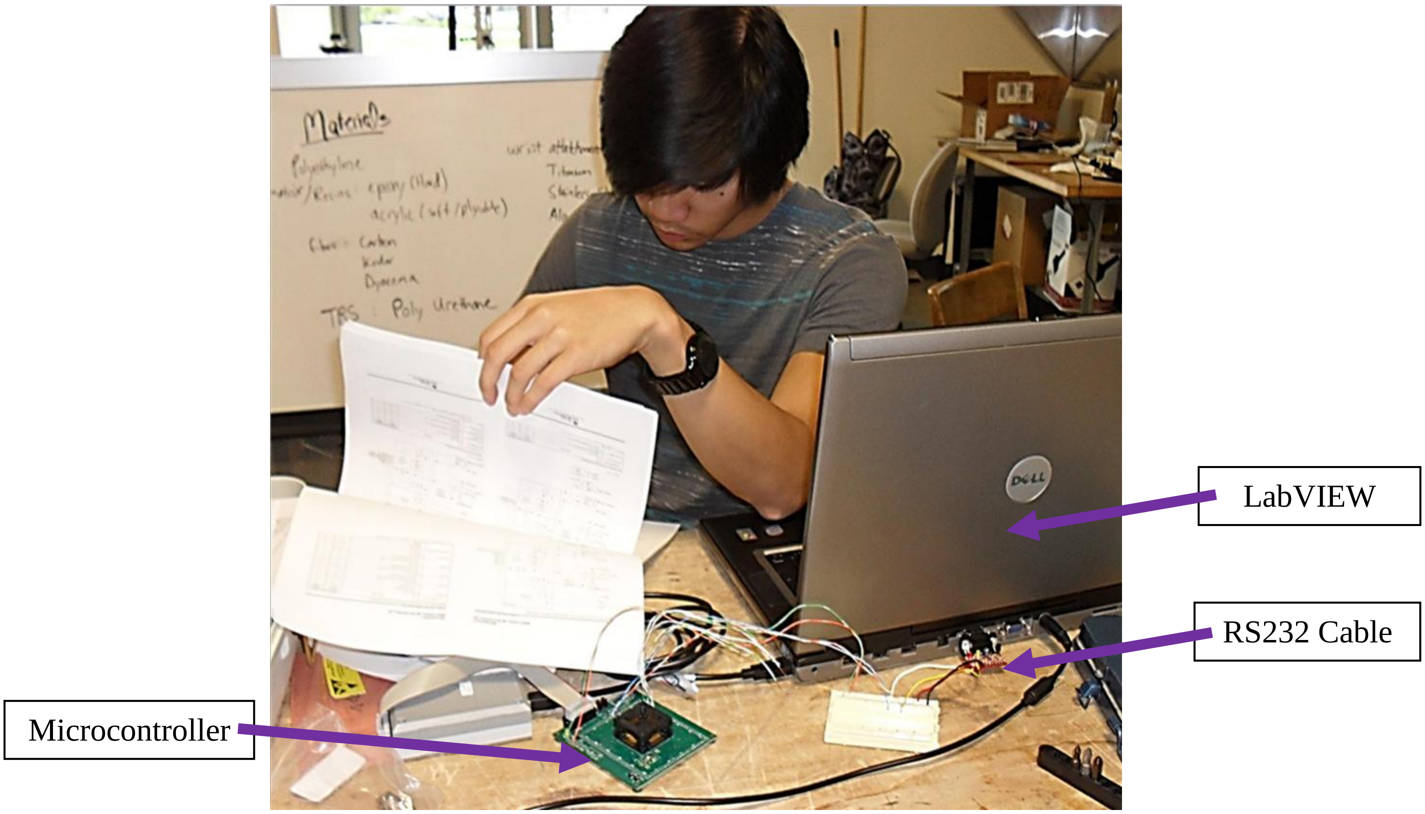


Figure 23 – Hardware Configuration

Construction

The vest has Velcro strips in the front to allow for easy dressing and removal. It also has adjustment straps, Figure 24, to ensure a snug fit snug to each driver and to keep all of the eccentric motors in contact with the body.

Figure 24 – Adjustable Vest

To mount the eccentric motors on the vest, first epoxy connects the eccentric motors to flat squares of hard plastic. Six columns with twelve rows of solder and wire connected motors that then make up the three main areas of vibration on the back. The middle two columns represent the collision course. The laser-cut plastic squares contain four holes in each corner to allow for stitching to foam, see Figure 25 for the before stitching picture.

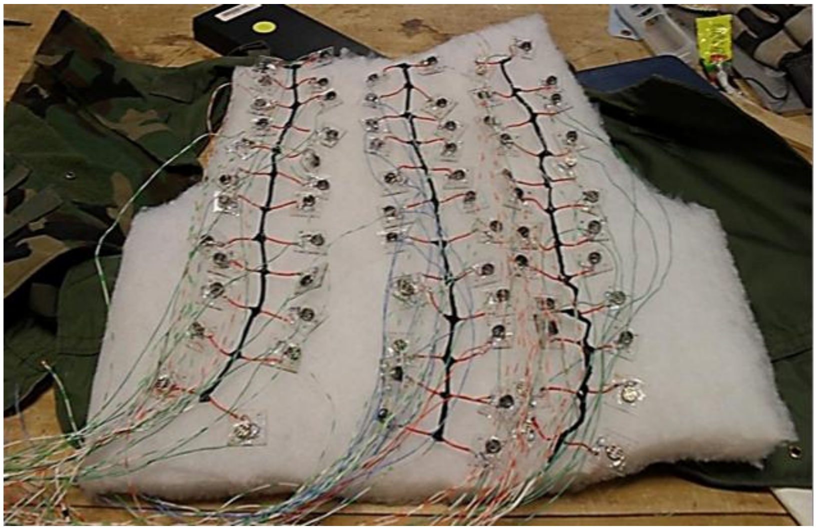


Figure 25 – Motors and Wire Before Stitching

The wires then poke through the foam and run down the back between the vest and foam. The foam stitches to the vest, completing construction of the tactile vest.

Each of the 72 motors, require an individual MOSFET, diode, and resistor to enable independent on/off switching between motors. See Figure 26 for a sample of the soldered PC board.

Figure 26 – MOSFETS, Diodes, and Resistors Board

Each motor connects to the corresponding MOSFET and to the power supply. This requires a large amount of wire, as demonstrated in Figure 27.

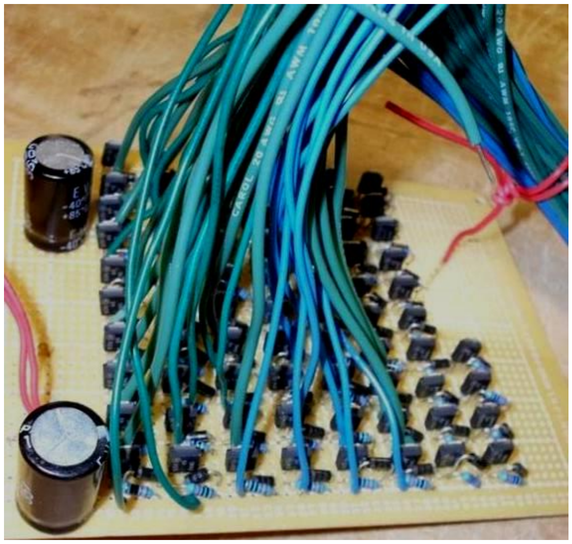


Figure 27 – Wire to Each MOSFET

These PC boards mount via screws and spacers to a thick plastic sheet that attaches in whole to the dune buggy cargo area. This provides more connection stability and hardware protection.

The laser scanner mounts to the lower front of the vehicle to allow for forward obstacle detection. It has a clear view of the road ahead across its whole 190° range. The sensor mounts to the vehicle using the SICK mounting bracket purchased from the manufacturer.

The vibrating steering wheel construction will begin over the existing steering wheel. Thin foam laid around the entire steering wheel will somewhat dampen and isolate the vibration. Then the wheel segments into appropriate sections. A hard plastic housing will be cut for each vibrating motor portion. The vibrating motors will attach to the plastic housings using epoxy. The thin foam will also help keep the motors from being damaged from applied pressure. The wires will run between the foam and the hard plastic and feed out in an appropriate location. The insulated sections will have denser foam and fasten to the steering wheel as well. Another layer may be added to give the whole wheel a smoother feel, but the segmented feel may be desired by the operators. Also, an encoder (position sensor) will mount to the steering wheel in order to communicate the position to the computer.

Maintenance and Repair Considerations

The vehicle requires routine scheduled maintenance in order to keep it running and in good condition. This involves changing the oil and filters, checking brakes, etc. Our most likely source of mechanical failure lies within the soldered electrical connections located near the motors and at the crimps. The fatigue and shear stresses subjected to these connections require preventative actions. These actions include adding electrical tape insulation, epoxy, and foam to the small wire connections, as show in Figure 28.

Figure 28 – Eccentric Motors to Plastic Squares

METHODOLOGY

To test the vest initially, the team members wore it to determine if it provides the expected feedback. The successful focused feedback provided the necessary information. However, several of the crimp connections needed repair before all of the motors could vibrate. The connections needed more secure housing to keep the vibration uninterrupted. This included housing the wires in a cable management tube and mechanically hooking the wire connections before applying solder. The cable management system also consolidates the wires for manageability coming off of the vest. The team members sat in the dune buggy driver seat with the vest on, and their movement was unrestricted even with the wires because of the measured out wire length prior to construction. Testing with an Agilent DC power supply then confirmed the vibration of each motor.

Once the vest works to the satisfaction of the sighted, blind volunteers will test their understanding and navigation with the vest. The vest doesn't differentiate whether the SICK is in a car or on foot, so the initial blind testers can safely test if the vest allows them to "see" and avoid obstacles while walking. With complete system integration, Figure 29, blind volunteers will drive our vehicle at low speed and work up to full speed once they feel confident about the feedback systems.

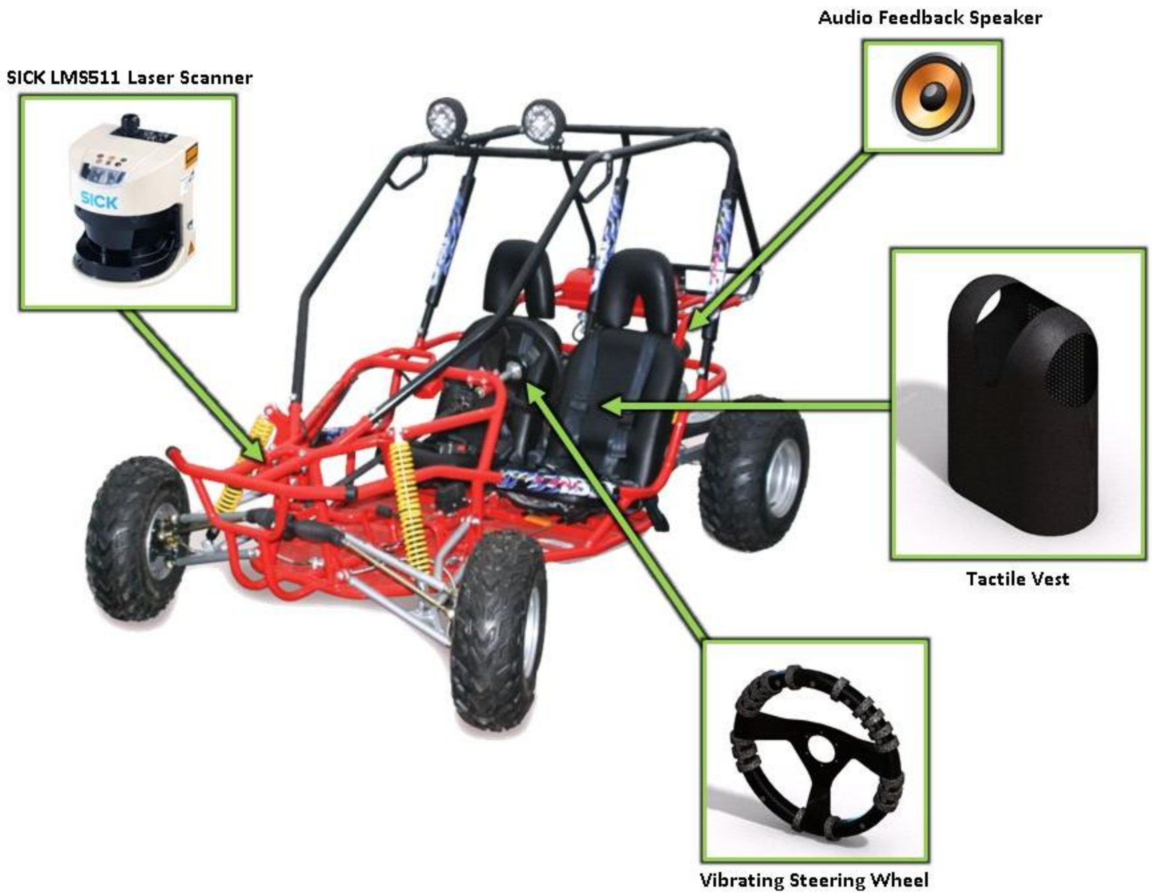


Figure 29 – System Overview

The vest prototype comprised of 72 motors can expand to 200 motors without purchasing anymore parts. The 72 motors accurately depict an obstacle on the back, such as a square. However, more testing needs to happen before determining whether or not the back is receptive enough for more motors. This testing includes a human factors engineering design of experiment. The experiment will test the factors of response time and obstacle shape accuracy.

RESULTS

This project contains two expensive items that push its total cost fairly high, the dune buggy and the laser scanner, Table 10. Together they make up over 85% of the total cost. The largest expense, the laser scanner, singlehandedly makes up 75% of the expenses at just over $7000. As the vital piece in the system, the SICK scanner acts as the "eyes" of the blind driver. The team reduced the dune buggy expense by purchasing it used.

Table 10. Cost Breakdown

Quantity	Description		Location Purchased	Subtotal	Tax and/or Shipping
1	D-Sub Male Connector	for RS232 connection	Radioshack	2.19	0.54
1	PC Board		Radioshack	3.99	
1	PC Board		Radioshack	3.99	0.35
1	Switch		Radioshack	2.99	
1	Wire		Radioshack	7.39	
1	25A Rocker		Radioshack	3.19	
4	PCB Standoffs		Radioshack	1.99	0.679875
1	Wire Ties		Radioshack	2.59	
1	Thread and Foam	for vest	Beverly's Fabrics	6.66	0.58
1	Epoxy	for motors to plastic	Home Depot	15.67	1.37
1	Vest		SLO Camp 'N Pack	35.00	3.06
3	32 kHz Crystals	for microcontroller external clock	Mouser (online)	4.50	
3	Resistors 442ohm	for 3V DC-DC Convertor	Mouser (online)	0.15	
2	Resistors 4.7kohm		Mouser (online)	0.08	
1000ft	24awg wire		Mouser (online)	90.29	27.58
10	male connector, 24 pin		Mouser (online)	2.50	
10	female connector, 24 pin		Mouser (online)	3.00	
1	DC-DC converter, 24V	for LIDAR power supply	Mouser (online)	73.50	
100	MOSFETS		Mouser (online)	36.70	
100	Resistors		Mouser (online)	3.60	8.95
100	Diodes		Mouser (online)	2.00	
1	Resistors 442ohm		Mouser (online)	0.05	
500	Male crimps		Mouser (online)	11.00	
500	Female crimps		Mouser (online)	11.00	
5	Male Pin & Socket Connectors		Mouser (online)	0.90	
5	Female Pin & Socket Connectors		Mouser (online)	1.15	14.75
150	Resistors		Mouser (online)	5.40	
150	Diodes		Mouser (online)	3.00	
150	MOFETS		Mouser (online)	55.05	
1	DC-DC converter, 3V	for microcontroller and motor power supply	Digi-Key (online)	28.30	4.53
1	DC-DC converter, 3V	for microcontroller and motor power supply	Digi-Key (online)	27.34	7.88
1	microcontroller development board and programmer, 100 pin		TI (online)	149.00	
1	microcontroller development board, 100 pin			75.00	
100	vibrating coin motors		Kysan (online)	195.00	29.84
140	vibrating coin motors		Kysan (online)	273.00	41.79
1	LMS 511	LIDAR Laser Scanner	LMS 511	7018.00	
1	Baja Motorsports	Dune Buggy	2006 Baja Dune 150cc Go Kart	1000.00	
			Grand Project Total	**9297.06**	

Considering the over 1000 feet of electrical wire, electrical safety signifies a very large safety concern. In order to protect against potential shock hazards, electrical tape secured by masking tape insulates all electrical connections. The tape and epoxy together protect against fatigue.

All electrical hardware and equipment must also remain dry and clean. The precautions of a mount and housing for the boards and insulation for the vest will maintain operating order and prevent most potential issues. If a motor connection does break loose, a hand-sized pocket will remain unstitched in the vest foam for repair access. Also, any spilt fluids greatly increase danger. Therefore, no fluids will be allowed in the vehicle.

CONCLUSIONS

Beginning with a background search and literature review, we researched the blind driver challenge and how to define the problem statement. After understanding the goals for the project, the brainstorming phase began. Then the engineering design process narrowed down and helped select the final design. Ordering took an unexpected amount of time with getting the SICK laser purchase order through Cal Poly. With ordering complete, construction finished on the vest and PC boards. The team needs to complete system integration with the steering wheel and SICK laser in the fall as well as plan an event. The available materials and prior coordination and communication with campus authorities will enable timely completion with minimal “red tape.”

Referring to the goals and objectives section, the project successfully satisfied goal 1, with the exception of command update and quantitative speed reference integration. For instance, the purchased dune buggy already had the appropriate safety features including seat belts, bumpers, roll bar, brakes, and kill switch. The dune buggy more than suits the chosen terrain of paved parking lot, since it would even safely navigate on unpaved road or grass. The vibrating vest has adjustable straps, and the dune buggy chair adjusts accordingly. This makes the equipment suitable for adults within the 95th percentile range. And finally, the SICK sensor outfits the vehicle with equipment able to sense the environment of approaching obstacles while communicating that relative location and speed to the vibrating vest.

Although the vest and the sound of the dune buggy communicate the relative speed, the quantitative speed audio feedback would provide yet another reference. This feedback’s scheduled integration will take place in fall 2011 after the vest has more exposure to volunteers. Along with the quantitative speed reference, the team plans to integrate a command feedback in the fall.

Goal 2, the course and event, remains partially complete. The event will happen the beginning of December 2011, which aligns with the team mechanical engineers senior projects’ finish. The University Police Department has agreed to the borrowing of cones (obstacles) and course. A few volunteers from the Disability Resource Center have indicated strong interest in participating in the event.

From a seemingly impossible idea, the NFB Blind Driver Challenge has changed blind driving into a very real possibility. Innovative sensor and tactile feedback technology provide the backbone for this advancement for the visually impaired. However, the LIDAR sensor only sees 190° ahead. For short-range viewing necessary for reverse parking, a future QL+ team may consider adding a much cheaper, but shorter range, ultrasonic sensor to the rear of the dune buggy. In conclusion, this project may continue to evolve for years to come, thereby eventually "eliminating the blind spots."

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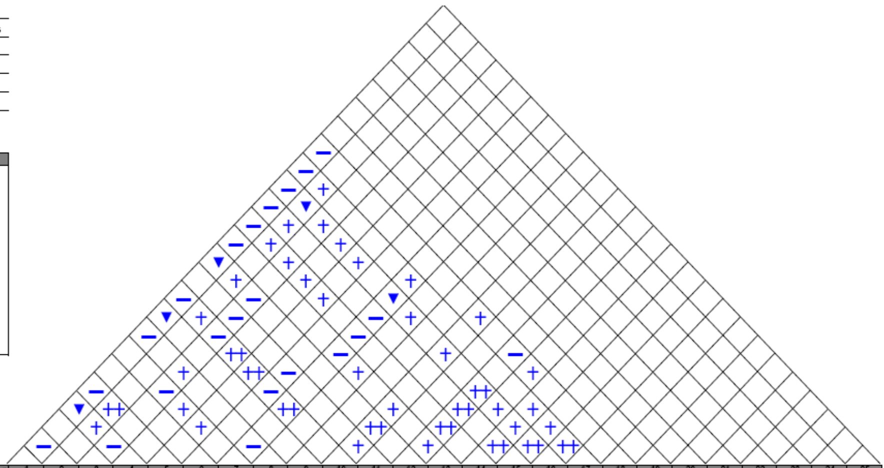
APPENDICES

Appendix A: QFD

Title: Blind Driver Challenge - Cal Poly
Author: Heather Brown, Eric Sandoval, Malcolm Lapera, Scotty Mores
Date: 1/27/2011
Notes:

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1 cost	2 max speed	3 kill switch	4 number of sensors	5 frames per second of sensors	6 seat adjustability	7 learning curve	8 length of course	9 temperature of interior of car	10 feedback mechanisms (how much info they provide)	11 force of feedback systems	12 processing speed of computer	13 size of event	14 acceleration	15 braking	16 complexity of course	17 power steering	18 size of obstacles	19	20	21	22	23	24	25
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	X	▲	▲	▲	▼	▲	X	▲	X	▲	▲	▲	▲	X	X	X							
1	9	13.5	5.0	complimentary	Θ												O												
2	9	13.5	5.0	safe vehicle/driving experience		Θ	Θ	O			O			O				Θ	Θ	O	O	Θ							
3	9	10.8	4.0	fun driving experience		Θ					Θ	O		Θ				Θ		Θ									
4	9	5.4	2.0	feedback on how well they did										Θ	O							Θ							
5	9	10.8	4.0	non-autonomous										Θ															
6	9	8.1	3.0	feels comfortable						Θ			Θ		Θ														
7	9	5.4	2.0	event for public to view								▲					Θ												
8	9	10.8	4.0	course to navigate through								Θ								Θ									
9	9	13.5	5.0	easy to understand feedback systems					Θ						Θ	Θ													
10	9	8.1	3.0	realisitc driving experience		Θ				▲				Θ			▲	Θ	O		Θ								
11																													
12																													
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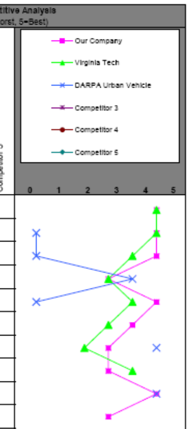
25																													
				Target or Limit Value	$5,000	30 mph	yes	3	60 Hz	6"	5 times	0.25 mile		as much as possible	15 psi	3.0 GHz	100 people	15 hp	100 ft max braking distance	5 turns, 15ft wide course	yes	2 ft tall							
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	5	3	1	5	2	2	10	1		10	4	3	9	2	2	1	3	1							
				Max Relationship Value in Column	9	9	9	3	9	9	9	9	9	9	9	9	9	9	9	9	9	9							
				Weight / Importance	121.6	291.9	121.6	40.5	121.6	81.1	137.8	135.1	73.0	356.8	210.8	121.6	97.3	291.9	145.9	235.1	113.5	170.3							
				Relative Weight	4.2	10.2	4.2	1.4	4.2	2.8	4.8	4.7	2.5	12.4	7.4	4.2	3.4	10.2	5.1	8.2	4.0	5.9							

Competitive Analysis (0=Worst, 5=Best)

Row #	Our Company	Virginia Tech	DARPA Urban Vehicle	Competitor 3	Competitor 4	Competitor 5
1	5	5				
2	5	5	0			
3	5	4	0			
4	3	3	4			
5	5	4	0			
6	4	3				
7	3	2	5			
8	3	4				
9	5		5			
10	3					

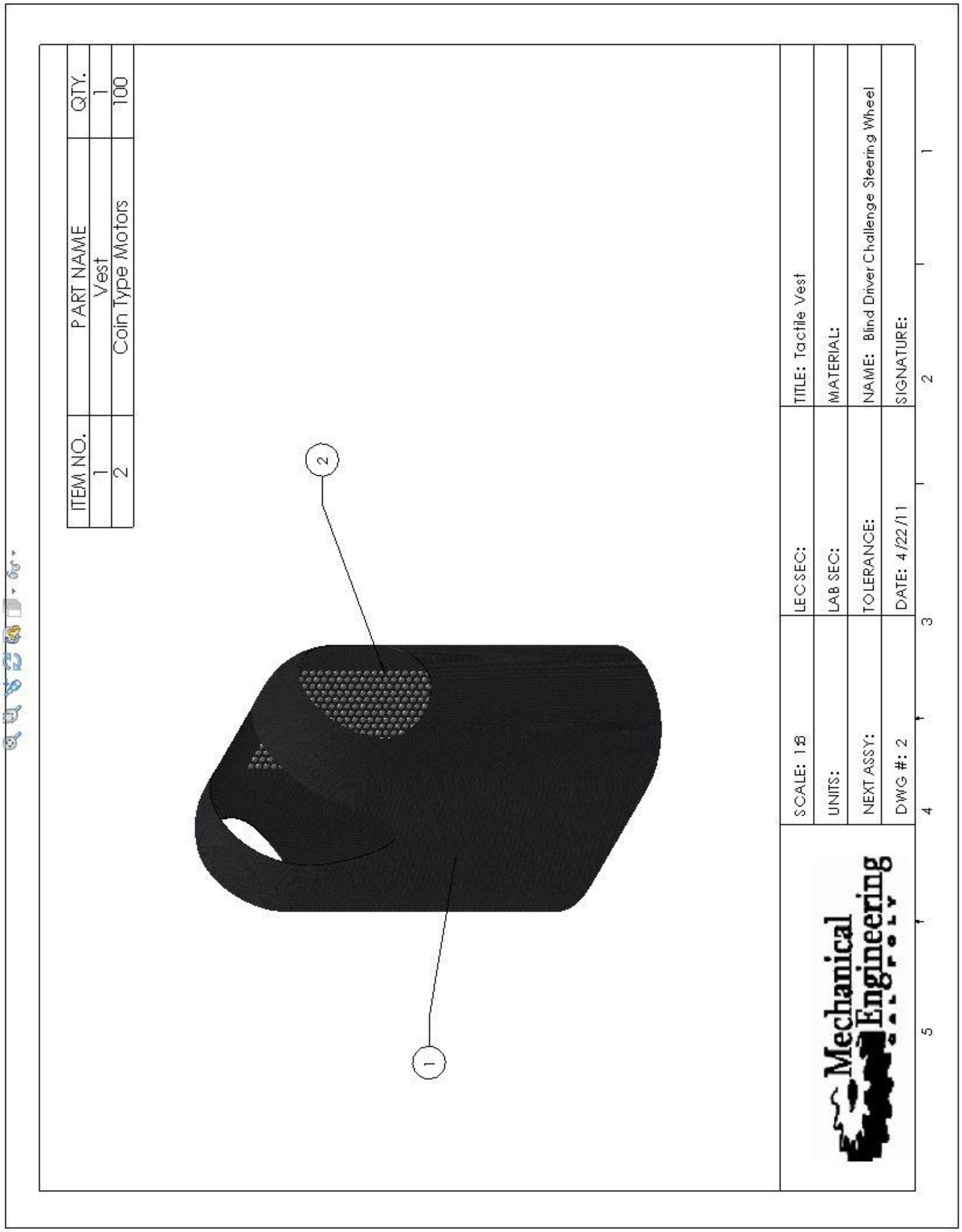


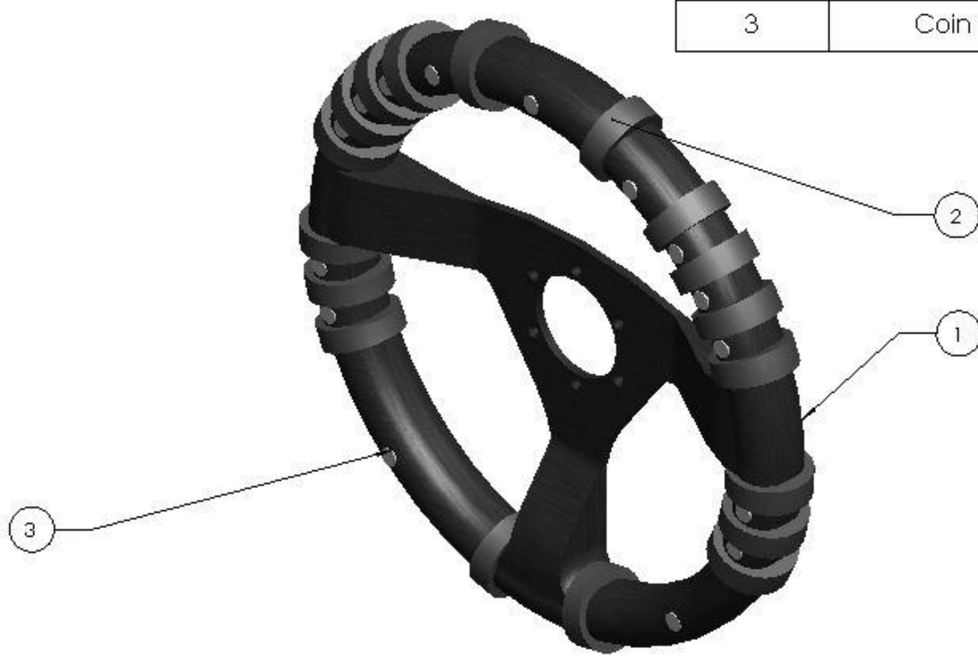
Powered by QFD Online (http://www.QFDOnline.com)

Appendix B: Gantt Chart

	Task Name	Duration	Start	Finish	Predec
1	− **Blind Driver Challenge Project Summary**	**305 days**	**Tue 10/12/10**	**Fri 12/9/11**	
2	+ **IME 481 Deliverables**	**40 days**	**Tue 10/12/10**	**Mon 12/6/10**	
9	+ **Write 2 page (min.) of findings**	**12 days**	**Thu 10/14/10**	**Fri 10/29/10**	
12	Project Presentation Night	0 days	Wed 11/10/10	Wed 11/10/10	9
13	− **Meet with Team (1st Meeting)**	**5 days**	**Mon 1/3/11**	**Fri 1/7/11**	
14	Create Team Charter	1 wk	Mon 1/3/11	Fri 1/7/11	
15	Review Ideas	1 wk	Mon 1/3/11	Fri 1/7/11	
16	− **Meet with Team (2nd Meeting)**	**10 days**	**Mon 1/10/11**	**Fri 1/21/11**	
17	Create Responsibility Matrix	2 wks	Mon 1/10/11	Fri 1/21/11	13
18	Create Chain of Command	2 wks	Mon 1/10/11	Fri 1/21/11	13
19	Create Communication Plan	2 wks	Mon 1/10/11	Fri 1/21/11	13
20	Estimate Cost	1 wk	Mon 1/17/11	Fri 1/21/11	
21	Finalize Budget	1 wk	Mon 1/24/11	Fri 1/28/11	20
22	Review Press from the Blind Driver Challenge Public Demonstration at Daytona	1 wk	Mon 1/31/11	Fri 2/4/11	21
23	Choose 3 Top Vehicle and Event Designs	3 wks	Mon 2/7/11	Fri 2/25/11	22
24	Create Decision Matrix	1 wk	Mon 2/28/11	Fri 3/4/11	23
25	Analyze Finances	2 wks	Mon 3/7/11	Fri 3/18/11	24
26	Test Design(s)	2 wks	Mon 3/28/11	Fri 4/8/11	
27	Choose Final Design and Final Location	0 days	Fri 4/8/11	Fri 4/8/11	
28	Modify Vehicle(s)	6.5 mons	Mon 4/11/11	Fri 10/7/11	27
29	Test Run Vehicle(s)	1 wk	Mon 10/17/11	Fri 10/21/11	28
30	Assess Risk	1 wk	Mon 10/24/11	Fri 10/28/11	27
31	Obtain and Schedule Volunteers	3 wks	Mon 10/31/11	Fri 11/18/11	
32	Obtain Participants	4 wks	Mon 10/17/11	Fri 11/11/11	
33	Obtain Supplies	1 wk	Mon 11/21/11	Fri 11/25/11	
34	Train Volunteers	2 days	Thu 11/24/11	Fri 11/25/11	
35	Host Event	0 wks	Sat 12/3/11	Sat 12/3/11	34,33
36	Create Participant and Volunteer Survey	2 days	Sat 12/3/11	Mon 12/5/11	35
37	Survey Participants and Volunteers	2 days	Tue 12/6/11	Wed 12/7/11	36
38	Post Audit Analysis	2 days	Thu 12/8/11	Fri 12/9/11	37
39	− **IME 482 Deliverables**	**51 days**	**Thu 3/24/11**	**Thu 6/2/11**	
40	Formulate 482 Project Update	3 days	Thu 3/24/11	Mon 3/28/11	
41	Write 482 Project Status Report	1 wk	Tue 3/29/11	Mon 4/4/11	40
42	Create 482 Status Report PowerPoint Presentation	1 wk	Tue 4/12/11	Mon 4/18/11	
43	Present 482 Status Report Presentation	0 days	Mon 4/25/11	Mon 4/25/11	42
44	Create Industrial Advisor Board (IAB) Presentation	1 wk	Tue 5/3/11	Mon 5/9/11	
45	Practice IAB Presentation	0 days	Tue 5/17/11	Tue 5/17/11	44
46	Present IAB Presentation	0 days	Fri 5/20/11	Fri 5/20/11	45
47	+ **Write Report Draft**	**20 days**	**Mon 5/2/11**	**Fri 5/27/11**	
63	Update Report with Corrections	4 days	Mon 5/30/11	Thu 6/2/11	47
64	Turn in Final Report	0 days	Thu 6/2/11	Thu 6/2/11	47,63

Appendix C: Assembly Drawings





ITEM NO.	PART NAME	QTY.
1	Steering Wheel	1
2	Foam Pieces	18
3	Coin Type Motors	15

SCALE: 1:3	LEC SEC:	TITLE: Vibrating Steering Wheel
UNITS:	LAB SEC:	MATERIAL:
NEXT ASSY:	TOLERANCE:	NAME: Blind Driver Challenge Steering Wheel
DWG #: 1	DATE: 4/22/11	SIGNATURE:

Mechanical Engineering CAL POLY

Appendix D: Pertinent Product Literature

**Full data sheets available upon request

Baja Motorsports®

BR150-D, BR150-1 Go-Kart

Read this manual carefully. It contains important safety information.
No one under the age of 16 should operate this Go-Kart

OWNER'S MANUAL

Minimum Age Requirement 16

REV. C
030209

Always wear a helmet; It could save your Life!

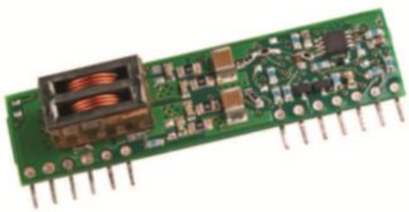
Please obtain, review, and follow provincial / municipal government acts and regulations pertaining to owning and operating an off-road vehicle.

Data Sheet
October 2, 2009

LINEAGE POWER

Austin MegaLynx™: Non-Isolated DC-DC Power Modules:
4.5 – 5.5Vdc input; 0.8 to 3.63Vdc output; 30A Output Current
6.0 – 14Vdc input; 0.8dc to 5.5Vdc output; 25A Output Current

RoHS Compliant



Applications

- Distributed power architectures
- Intermediate bus voltage applications
- Telecommunications equipment
- Servers and storage applications
- Networking equipment

Features

- Compliant to RoHS EU Directive 2002/95/EC (-Z versions)
- Compliant to ROHS EU Directive 2002/95/EC with lead solder exemption (non-Z versions)
- Delivers up to 30A of output current
- High efficiency – 93% 3.3V full load (V_{IN}=12Vdc)
- Available in two input voltage ranges
  - ATH: 4.5 to 5.5Vdc
  - ATS: 6.0 to 14Vdc
- Output voltage programmable from
  - ATH: 0.8 to 3.63Vdc
  - ATS: 0.8 to 5.5Vdc
- Small size and low profile:
  - 50.8 mm x 12.7 mm x 14.0 mm
  - 2.00 in. x 0.50 in. x 0.55 in.
- Monotonic start-up into pre-biased output
- Output voltage sequencing (EZ-SEQUENCE ™)
- Remote On/Off
- Remote Sense
- Over current and Over temperature protection
- Parallel operation with active current sharing
- Wide operating temperature range (-40°C to 85°C)
- *UL** 60950 Recognized, *CSA*† C22.2 No. 60950-00 Certified, and *VDE*‡ 0805 (EN60950-1 3rd edition) Licensed
- ISO** 9001 and ISO 14001 certified manufacturing facilities

Description

The Austin MegaLynx series SIP power modules are non-isolated DC-DC converters in an industry standard package that can deliver up to 30A of output current with a full load efficiency of 92% at 3.3Vdc output voltage (V_{IN} = 12Vdc). The ATH series of modules operate off an input voltage from 4.5 to 5.5Vdc and provide an output voltage that is programmable from 0.8 to 3.63Vdc, while the ATS series of modules have an input voltage range from 6 to 14V and provide a programmable output voltage ranging from 0.8 to 5.5Vdc. Both series have a sequencing feature that enables designers to implement various types of output voltage sequencing when powering multiple modules on the board. Additional features include remote On/Off, adjustable output voltage, remote sense, over current, over temperature protection and active current sharing between modules.

* *UL* is a registered trademark of Underwriters Laboratories, Inc.
† *CSA* is a registered trademark of Canadian Standards Association.
‡ *VDE* is a trademark of Verband Deutscher Elektrotechniker e.V.
** ISO is a registered trademark of the International Organization of Standards

Document No: DS05-012 ver. 1.05
PDF Name: austin_megalynx_sip.pdf

RECTRON
SEMICONDUCTOR
TECHNICAL SPECIFICATION

1N4001 THRU 1N4007

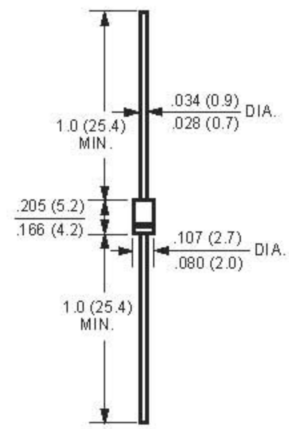
SILICON RECTIFIER

VOLTAGE RANGE 50 to 1000 Volts CURRENT 1.0 Ampere

FEATURES

* Low cost
* Low leakage
* Low forward voltage drop
* High current capability

DO-41



Dimensions in inches and (millimeters)

MECHANICAL DATA

* Case: Molded plastic
* Epoxy: Device has UL flammability classification 94V-O
* Lead: MIL-STD-202E method 208C guaranteed
* Mounting position: Any
* Weight: 0.33 gram

MAXIMUM RATINGS AND ELECTRICAL CHARACTERISTICS

Ratings at 25 °C ambient temperature unless otherwise specified.
Single phase, half wave, 60 Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

MAXIMUM RATINGS (At T_A = 25℃ unless otherwise noted)

RATINGS	SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNITS
Maximum Recurrent Peak Reverse Voltage	V_{RRM}	50	100	200	400	600	800	1000	Volts
Maximum RMS Voltage	V_{RMS}	35	70	140	280	420	560	700	Volts
Maximum DC Blocking Voltage	V_{DC}	50	100	200	400	600	800	1000	Volts
Maximum Average Forward Rectified Current at T_A = 75℃	I_o	1.0							Amps
Peak Forward Surge Current 8.3 ms single half sine-wave superimposed on rated load (JEDEC method)	I_{FSM}	30							Amps
Typical Junction Capacitance (Note)	C_J	15							pF
Typical Thermal Resistance	$R_{\theta JA}$	50							℃/W
Operating and Storage Temperature Range	T_J, T_{STG}	-55 to + 150							℃

ELECTRICAL CHARACTERISTICS (At T_A = 25℃ unless otherwise noted)

CHARACTERISTICS		SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNITS
Maximum Instantaneous Forward Voltage at 1.0A DC		V_F	1.1							Volts
Maximum DC Reverse Current at Rated DC Blocking Voltage	@T_A = 25℃	I_R	5.0							uAmps
	@T_A = 100℃		50							
Maximum Full Load Reverse Current Average, Full Cycle .375" (9.5mm) lead length at T_L = 75℃			30							uAmps

NOTES : Measured at 1 MHz and applied reverse voltage of 4.0 volts

2002-11

NTD4904N

Power MOSFET

30 V, 79 A, Single N–Channel, DPAK/IPAK

ON Semiconductor®

http://onsemi.com

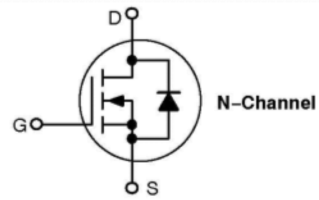
Features

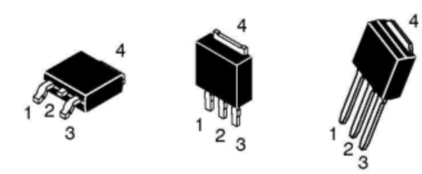
- Low $R_{DS(on)}$ to Minimize Conduction Losses
- Low Capacitance to Minimize Driver Losses
- Optimized Gate Charge to Minimize Switching Losses
- These are Pb–Free Devices

Applications

- CPU Power Delivery
- DC–DC Converters

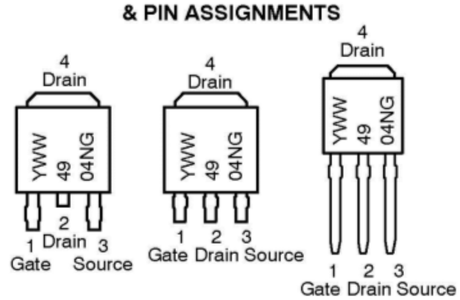
$V_{(BR)DSS}$	$R_{DS(on)}$ MAX	I_D MAX
30 V	3.7 mΩ @ 10 V	79 A
	5.5 mΩ @ 4.5 V	





CASE 369AA	CASE 369AD	CASE 369D
DPAK (Bent Lead) STYLE 2	IPAK (Straight Lead)	IPAK (Straight Lead DPAK)

MARKING DIAGRAMS & PIN ASSIGNMENTS



Y = Year
WW = Work Week
4904N = Device Code
G = Pb–Free Package

MAXIMUM RATINGS (T_J = 25°C unless otherwise noted)

Parameter			Symbol	Value	Unit
Drain–to–Source Voltage			V_{DSS}	30	V
Gate–to–Source Voltage			V_{GS}	±20	V
Continuous Drain Current ($R_{\theta JA}$) (Note 1)	Steady State	T_A = 25°C	I_D	17.8	A
		T_A = 100°C		12.6	
Power Dissipation ($R_{\theta JA}$) (Note 1)		T_A = 25°C	P_D	2.6	W
Continuous Drain Current ($R_{\theta JA}$) (Note 2)		T_A = 25°C	I_D	13	A
		T_A = 100°C		9.2	
Power Dissipation ($R_{\theta JA}$) (Note 2)		T_A = 25°C	P_D	1.4	W
Continuous Drain Current ($R_{\theta JC}$) (Note 1)		T_C = 25°C	I_D	79	A
		T_C = 100°C		56	
Power Dissipation ($R_{\theta JC}$) (Note 1)		T_C = 25°C	P_D	52	W
Pulsed Drain Current	t_p=10μs	T_A = 25°C	I_{DM}	316	A
Current Limited by Package		T_A = 25°C	$I_{DmaxPkg}$	90	A
Operating Junction and Storage Temperature			T_J, T_{stg}	–55 to 175	°C
Source Current (Body Diode)			I_S	47	A
Drain to Source dV/dt			dV/dt	6.0	V/ns
Single Pulse Drain–to–Source Avalanche Energy (T_J = 25°C, V_{DD} = 50 V, V_{GS} = 10 V, L = 0.1 mH, $I_{L(pk)}$ = 37 A, R_G = 25 Ω)			E_{AS}	68.4	mJ
Lead Temperature for Soldering Purposes (1/8″ from case for 10 s)			T_L	260	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 6 of this data sheet.

MF, MFS, RK

general purpose metal film leaded resistor

KOA SPEER ELECTRONICS, INC.

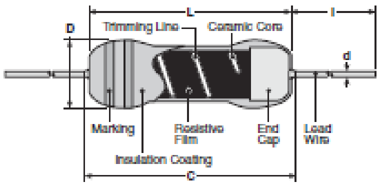
EU RoHS COMPLIANT

resistors

features

- Semi-precision metal film resistors
- The discharge path resistor is recognized by UL 1676 and c-UL (CAS-C22.2 No.1-M94). (File No. E159326) (RK only)
- Meets requirements of MIL-R-22684
- Suitable for automatic machine insertion
- MFS two times the power rating of the standard body type
- Marking: Blue-gray body color with color-coded bands
- Products with lead-free terminations meet EU RoHS and China RoHS requirements

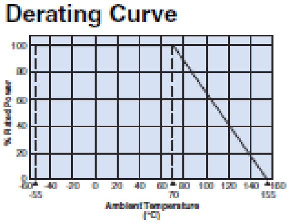
dimensions and construction



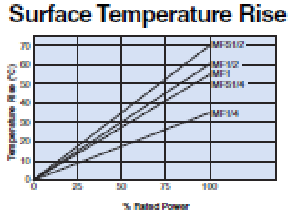
Type	Dimensions inches (mm) L (ref.)	C (max.)	D	d (nom.)	l*
MFS1/4	.126±.008 (3.2±0.2)	.133 (3.4)	.066 +.007/-.004 (1.7 +0.2/-0.1)	.018 (0.45)	1.18±.118 (30.0±3.0)
MF1/4	.248±.02 (6.3±0.5)	.280 (7.1)	.091±.012 (2.3±0.3)	.024 (0.6)	
MFS1/2	.248±.02 (6.3±0.5)	.280 (7.1)	.091±.012 (2.3±0.3)	.024 (0.6)	
MF1/2	.354±.04 (9.0±1.0)	.437 (11.1)	.138±.016 (3.5±0.4)	.024 (0.6)	
MF1	.610±.02 (15.5±0.5)	.721 (18.3)	.217±.02 (5.5±0.5)	.031 (0.8)	1.50±.118 (38.0±3.0)
RK1/4	.248±.02 (6.3±0.5)	.280 (7.1)	.091±.012 (2.3±0.3)	.024 (0.6)	0.94 min. (24.0 min.)
RK1/2	.374±.04 (9.5±1.0)	.437 (11.1)	.138±.016 (3.5±0.4)	.024 (0.6)	
RK1	.610±.04 (15.5±1.0)	.720 (18.3)	.217±.02 (5.5±0.5)	.031 (0.8)	1.50±.118 (38.0±3.0)

* Lead length changes depending on taping and forming.

Derating Curve



Surface Temperature Rise



ordering information

New Part #

MF	1/4	L	C	T52	R	R20	J
Type	**Power Rating**	**T.C.R.**	**Termination Material**	**Taping and Forming**	**Packaging**	**Nominal Resistance**	**Tolerance**
MF MFS RK	1/4: 0.25W 1/2: 0.50W 1: 1W	E: ±25 C: ±50 D: ±100 L: ±200 G: ±250 B: ±350	C: SnCu	1/4: T26, T52, VT, VTP, VTE, MT, M, U, M10, M12.5 1/2: T26, T52, VTP, VTE, M12.5, M15 1: T521	A: Ammo R: Reel	±2%: 2 significant figures + 1 multiplier ±0.5%,±1%: 3 significant figures + 1 multiplier "R" indicates decimal on value <100Ω	B: ±0.1% C: ±0.25% D: ±0.5% F: ±1% G: ±2% J: ±5%

For further information on packaging, please refer to Appendix C.

applications and ratings

Part Designation	Power Rating @ 70°C	Minimum Dielectric Withstanding Voltage	T.C.R. (ppm/°C)	Resistance Range (Ω) (B±0.1%) E-96	(C±0.25%) E-96	(D±0.5%) E-24 E-192	(F±1.0%) E-24 E-96	(G±2.0%) E-24	(J±5.0%) E-24	Absolute Maximum Working Voltage	Absolute Maximum Overload Voltage	Operating Temperature Range
MFS1/4C	0.25W	300V	C: ±50	—	—	49.9 - 562k	10 - 1M	—	—	250V	300V	-55°C to +155°C
MFS1/4D			D: ±100									

Specifications given herein may be changed at any time without prior notice. Please confirm technical specifications before you order and/or use. 2/01/11