Department of Computer Science & Engineering
The University of Texas at Arlington

System Requirements Specification
CSE 4316: Senior Design I
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CAN on Wheels
Modular EV

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Revision History

Revision	Date	Author(s)	Description
0.1	10.17.2023	HS	document creation
0.2	10.23.2023	HS, ED, CF, DR, LI	modified all sections
0.3	10.24.2023	HS, ED, CF, DR, LI	complete draft

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1 Product Concept

The modular electric vehicle is intended to provide a platform for automotive software engineers to prototype and try out new modules on the fly. It would help facilitate the current process of development for different car model configurations and trims. Also, this platform can provide a way to bridge the gap between mechanical, embedded, and software engineers by providing layers of abstraction.

1.1 Purpose and Use

The modular electrical vehicle will have a set of modules working together to enhance the features of a given car. Engineers would have to develop a module that would be compatible with the car and test its behavior with other modules. If a car manufacturer dictates that certain modules will be in a specific vehicle, the engineers can take already existing modules and test them in that configuration to observe its behavior.

1.2 Intended Audience

The modular electric vehicle is originally intended for embedded automotive engineers to rapidly prototype different modules that are typically found in modern car systems. As the platform matures, the audience can then expand to software developers who would want to write software for a car's infotainment syste, while still having a way to access hardware data from the car. Eventually, even mechanics would have an interface to monitor the status of the car and even remove the modules that are not essential to the vehicle if desired. Another customer base can be Universities who would like to use the electric vehicle platform as a learning tool to show future engineers the different components of the car.

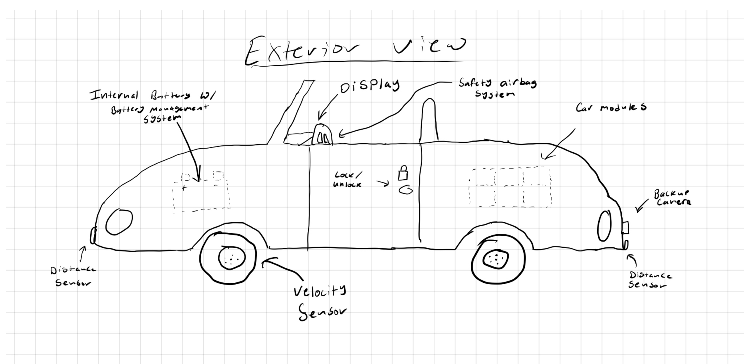

Figure 1: Modular Electrical Vehicle Conceptual Drawing

2 PRODUCT DESCRIPTION

This section provides the reader with an overview of the CAN-On-Wheels electric vehicle. The primary operational aspects of the product, from the perspective of end users, maintainers. and administrators, are defined here. The key features and functions found in the product as well as critical user interactions and user interfaces are described in detail.

2.1 FEATURES & FUNCTIONS

The electric vehicle will have many features which include: A central device running a real-time operating system, various plug-and-play modules with varying functionality, a graphical display that allows the user to interact with and view vehicle systems, a crash collision system, a simple drive assist system, a battery management system, a motor controller, a fail brake system, accelerator control system, and remote control with lock/unlock functionality. These features can be seen in Figures 2 and 3. In Figure 2, the module input/output (labeled 'A') can be seen. The purposes of these are to allow the user to plug in modules with ease which invoke various functions within the vehicle. The next major feature is labeled 'B' in the diagram, which are ultrasonic sensors used to detect objects. To support these sensors, a backup camera (labeled 'C') will be placed at the rear to display what is behind the vehicle. Additionally, collision sensors will be placed on the sides of the vehicle (labeled 'D'), to detect collisions, and trigger safety protocols.

The next major feature is labeled 'E' in Figure 2, and represents the locking system in the EV's doors, which will be locked/unlocked using the remote control shown in Figure 3. Next is the battery and battery management system, which are labeled 'F' and 'G' respectively in Figure 2. The battery management system will monitor the battery, energy conservation, and protection from possible damage. To complement all of these features and provide a way for the user to interface with the systems, a central display (labeled 'H') along with a controller (labeled 'I'), will be placed on the car console. Finally, a velocity detecting sensor will be placed on or near a wheel of the car (labeled 'J'), and a central computer will be placed in the front of the vehicle (labeled 'K'). The central computer will manage the entire system, acting as a hub for data to be stored, and transferred to the various systems throughout the vehicle. Using this central computer, the state of the vehicle will be tracked, managed, and displayed to the user.

2.2 EXTERNAL INPUTS & OUTPUTS

This electric vehicle will have many external data flows. One major one is the controller input from the user, which will lock/unlock the car, as well as control its movement. As a result, the user will be expected to move the sticks on the controller to control the car. Another external input that will be required from the user is the modules themselves. The user will be expected to add and remove modules to create different functionality within the vehicle. Some other major external data that the car will be expected to see are nearby objects to guide the vehicle and alert the user, a voltage supply, and radio frequencies from the controller. As for the outputs, the car will be expected to output data taken from the sensors and systems to then display it to the user. This data will include: vehicle speed, battery life, battery usage, device states, time of day, and any errors or dangers. Additionally, the car will deploy airbags on collision, and alert the user of any problems. All of these inputs and outputs can be seen in Table 2.

2.3 PRODUCT INTERFACES

The only interface that will be provided in this project is the central display noted previously. This display will show the status of the vehicle and its devices and also provide the time of day. The display will require the various sensors and their outputs to achieve its purpose. The concept display can be seen in Figure 4.

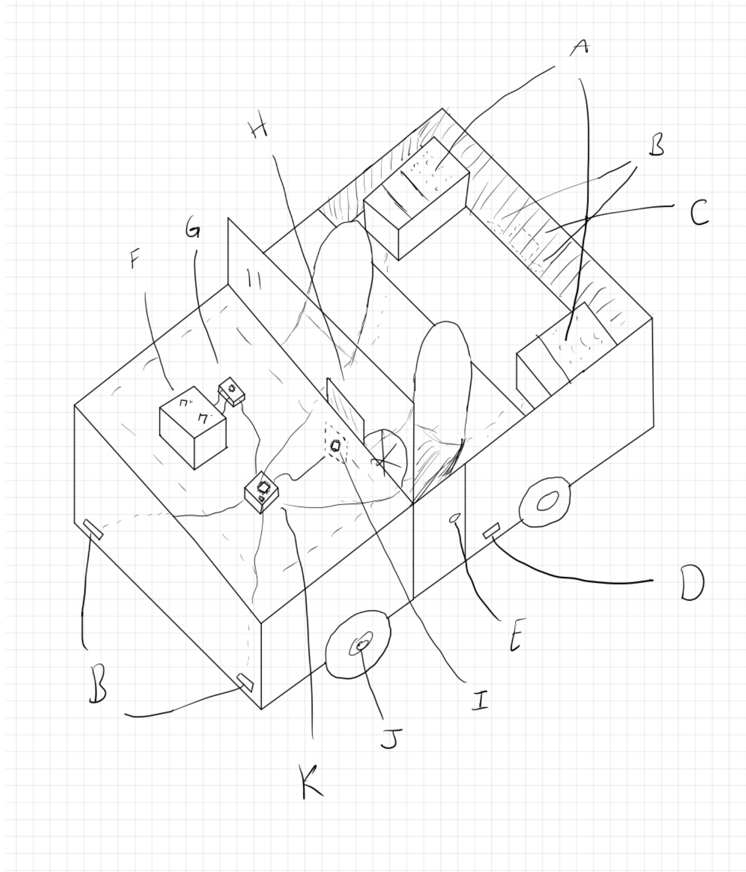

Figure 2: Modular Electric Vehicle Conceptual Diagram

Name	Description	Use
Controller	Controls vehicle by transmitting radio waves that are received by the central computer system of the car	Allows user to drive the vehicle and unlock/lock the doors
Modules	Modules that can be inserted and removed from the vehicle that provide various functionality	Allow the user to effortlessly add and remove functionality
Objects	Various objects around the vehicle	Allow the vehicle to navigate its surroundings successfully
Voltage Supply	A storage device that stores electrical charge, creating a voltage	Supplies power to all vehicle components
Radio Signal	A signal that can be used to transfer data wirelessly	Allow the controller to send commands to the vehicle
Sensors	Senses various signals and events	Show the vehicle state and drive functionality

Table 2: Features Table

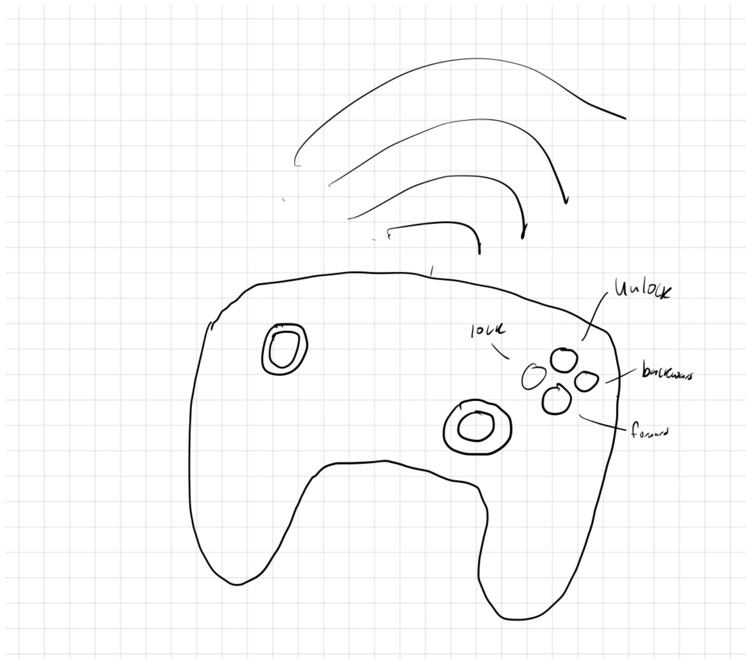

Figure 3: Vehicle Controller Conceptual Diagram

3 Customer Requirements

The modular electrical vehicle will have a battery management system, drive assist system, limp home mode, security system, motor control system, sensor display, RTOS, a remote control system, and a drive assist system. All these systems will work synchronously to provide a model of a production electric vehicle.

3.1 Battery Management System

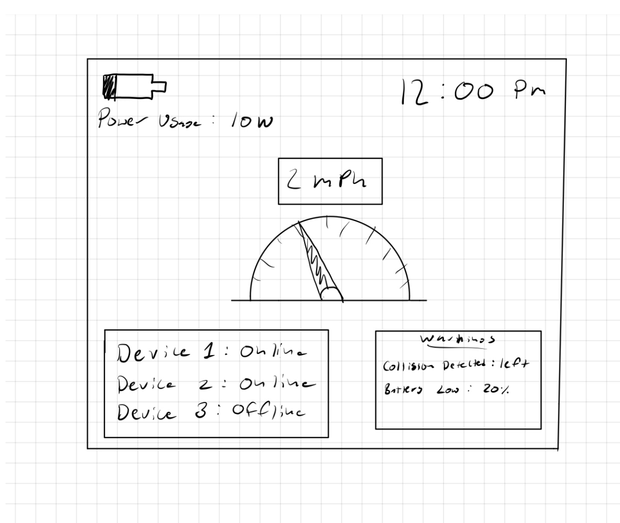

Figure 4: Central Display Conceptual Drawing

3.1.1 Description

The battery management system will maintain optimal voltage levels, maximum battery life, and proper temperature control to create the most stable system possible.

3.1.2 Source

No added sources.

3.1.3 Constraints

We cannot buy every top of the line product due to budget constraints, therefore we are exploring developing some technology to manage the batteries, voltage levels, temperature, and potentially more. That said we cannot promise to provide the best solution on the market, only the best solution we can provide due to budget constraints and the limited working capacity of the team.

3.1.4 Standards

No established and recognized standards for this process as of the time of drafting this document (October 2023).

3.1.5 Priority

High

3.2 Motor Control System

3.2.1 Description

We need to be able to dictate the motion of the product and for that we are developing a motor control system. The motor control system will include direction of product when in motion and the speed at which it moves.

3.2.2 Source

https://www.ecfr.gov/current/title-46/chapter-I/subchapter-J/part-111/subpart-111.70/section-111.70-3

3.2.3 Constraints

Range of motion will be a constraint as with any standard car. Movement directions can be potentially limited.

3.2.4 Standards

46 CRF 111.70-3 [1]

3.2.5 Priority

Critical

3.3 Remote Control

3.3.1 Description

The vehicle's movement will be controllable via some external device. The external device should be able to communicate with the motor control system.

3.3.2 Source

Destiny Rogers (CAN on Wheels).

3.3.3 Constraints

The remote control device must not interfere with any other communication protocols present in the device or the modules created by the CAN on Wheels team. The protocol of the remote control device should also be made known to consumers.

3.3.4 Standards

To be determined.

3.3.5 Priority

High

3.4 Drive Assist System

3.4.1 Description

We will be implementing a drive assist system to help with movement of the vehicle. The main efforts are going into lane assisting, emergency breaking, detecting and notifying if an object has entered our blind spots, collision sensors with feedback and Adaptive Cruise Control.

3.4.2 Source

https://www.iso.org/standard/71515.html https://www.iso.org/standard/50347.html

3.4.3 Constraints

We will fall under a list of constraints for these capabilities. The lane assist will be a limited feature because it assumes we will already be in a lane but will work to make sure we are moving in the intended direction. It may be difficult to determine the difference between the vibration signature of a collision and a someone picking up and potentially shaking the vehicle. Also providing an airbag might not me be practical or feasible due to budget constraints but we are exploring symbolic alternatives.

3.4.4 Standards

ISO 15622:2018 [2] ISO 11270:2014 [3]

3.4.5 Priority

Moderate

3.5 Limp Home Mode

3.5.1 Description

The product should enter "limp home mode" whenever there is a major fault that could compromise the safety of the vehicle and users. The vehicle should operate at a greatly reduced speed and notify the user that an error has occurred.

3.5.2 Source

Destiny Rogers (CAN on Wheels).

3.5.3 Constraints

Limp home mode should be able to operate in the event that other systems or sensors fail with the exception of the battery management system. As a result, it cannot be dependent on data from those systems other than errors and faults.

3.5.4 Standards

40 CFR 86.010-18

3.5.5 Priority

Moderate

3.6 Security System

3.6.1 Description

The electrical vehicle platform will implement a simple locking mechanism that will prevent the vehicle from being operable unless it receives a specific unlock signal from a remote control. This system will be using a transponder that will respond to the vehicle's interrogation signal. The vehicle will have a car alarm system, and locking mechanism in response to a disturbance.

3.6.2 Source

Chris Conly and Hector Sosa.

3.6.3 Constraints

In the scope of this project, the vehicle is mostly intended for development of embedded software, therefore, it will not be help the strictest of standards in terms of security. However, as the product matures, and other systems have been firmly established, then the system can be implemented appropriately. Also, the vehicle platform is a small scale version of the the real vehicle, so the mechanisms would not be subject to stress.

3.6.4 Standards

NHTSA for Cyber Security [4]

3.6.5 Priority

Moderate

3.7 RTOS

3.7.1 Description

The electric vehicle must be able to get real time data from all of it's sensors at a timely manner in order to adjust thee constantly changing road conditions of the road itself. This RTOS will be able to manage to the data that its receiving from the various sensors and give it back to other modules at a timely manner.

3.7.2 Source

Hector Sosa

3.7.3 Constraints

The RTOS will need a small footprint in order to allow space for other tasks. It must have a predefined priority level for each module that will read off data at a certain rate.

3.7.4 Standards

ISO 26262 ASIL D

3.7.5 Priority

Moderate

3.8 Autonomous Driving System

3.8.1 Description

The vehicle will be able to navigate and move on its own to a specified location as a partially autonomous vehicle. It must do so without creating hazardous situations and maintain a speed similar to what a user would travel at.

3.8.2 Source

Leonardo Ibarra (CAN on Wheels).

3.8.3 Constraints

This system must not be in use simultaneously with the remote control device. There must be a method by which to switch between autonomous mode and remote control mode. This requirement may not be implemented before the drive assist system.

3.8.4 Standards

ISO 26262 [5] ISO 21448 [6]

3.8.5 Priority

Future

4 Packaging Requirements

This section lists the packaging requirements for the electric vehicle. It describes each attribute that will be shipped with the product and how it will be packaged. Additionally, it describes how the software will be added to the vehicle.

4.1 Packaging

4.1.1 Description

The car will be packaged and shipped in a cardboard box, with styrofoam protecting the frame, and electronics.

4.1.2 Source

The boxes will be purchased in bulk from a wholesaler.

4.1.3 Constraints

The boxes will need to be large enough to hold the car, with styrofoam that are shaped to the vehicle. Additionally, the inner protection will need to be strong enough to protect all electronics.

4.1.4 Standards

The packaging will have to follow the Fair Packaging and Labeling Act, which requires that the box be labeled to disclose net contents, identity of commodity, and name and place of business of the product's manufacturer, packer, or distributor. Additionally, the product will need to be labeled with a message regarding its electronic contents, and may only be shipped by ground vehicles, due to the battery.

4.1.5 Priority

This packaging is a major priority, as it is required to ship the product, as well as protect it throughout its travel.

4.2 Modules

4.2.1 Description

The package will need to contain a subset of modules, so that the customers will be able to experience the product right out of the box. These modules will be plug and play, and will provide the basic functionality of the vehicle.

4.2.2 Source

These modules will be produced and manufactured solely by us.

4.2.3 Constraints

The size of the package will dictate how many of these can be shipped with the product. Additionally, the speed at which they can be produced, will determine the number of shipments we can make at a time.

4.2.4 Standards

Any cables will need to be packaged separately.

4.2.5 Priority

High priority because these modules drive some of the major functionalities within the vehicle.

4.3 Quick Start and Installation Guide

4.3.1 Description

The package will contain a quick start and installation guide, which will teach the consumer about the vehicle functions, steps to use the vehicle, and how to update the software.

4.3.2 Source

We will be creating and printing these pamphlets ourselves.

4.3.3 Constraints

Must contain all information the customer needs. Cannot mis-inform the user. Additionally, it will have to include safety instructions.

4.3.4 Standards

Will need to follow the ASTM F963-23 toy safety standards, as children could drive in the vehicle. The document will also have to be completely original and written by us.

4.3.5 Priority

Very high priority because it teaches the user how to use the product, how to do it safely, and allows us to comply with the various safety standards required.

4.4 Loaded Software

4.4.1 Description

The software will come pre-loaded to the vehicle. This will allow the car to work out the box.

4.4.2 Source

We will create and load the software.

4.4.3 Constraints

Must work without any error, and be easily accessible/adaptable.

4.4.4 Standards

Must comply with all safety standards, and be completely original work.

4.4.5 Priority

Lower priority because the pamphlet will contain instructions to install the software.

5 Performance Requirements

This section will define the requirements related to the efficiency of the electric vehicle and speed of operation. Requirements will apply to the operation of the vehicle itself and associated modules created by the CAN on Wheels team.

5.1 Maximum Speed

5.1.1 Description

The maximum speed of the vehicle should be higher than 3mph. Users may be allowed to increase the maximum speed by modifying the software, but the default maximum speed of the vehicle should not exceed 10mph.

5.1.2 Source

Chris Conly.

5.1.3 Constraints

Consumer expectation is that a remote control device not exceed a speed at which the device can be operated without difficulty. Additionally, exceeding a certain speed may damage the battery.

5.1.4 Standards

No applicable standards.

5.1.5 Priority

High

5.2 Battery Life

5.2.1 Description

The vehicle should be able to operate on battery power for at least 1.5 hours. This includes any modules connected to the vehicle during operation.

5.2.2 Source

Chris Conly.

5.2.3 Constraints

In order to simulate a full-sized vehicle, the electric vehicle must be capable of functioning long enough to withstand some amount of testing when new modules are installed.

5.2.4 Standards

16 CFR 1505.6

5.2.5 Priority

Critical

5.3 Charge Time

5.3.1 Description

A fully discharged battery should reach maximum charge within 18 hours. A minimally charged battery should reach maximum charge within 6 hours. The battery should be able to support the vehicle and modules for the specified battery life after charging for this time.

5.3.2 Source

Hector Sosa (CAN on Wheels).

5.3.3 Constraints

Charging the battery at a faster rate may cause damage and result in a need for replacement, and without a method of reusing the battery, would adversely effect the environment and push cost on the customer.

5.3.4 Standards

16 CFR 1505.6

5.3.5 Priority

Moderate

5.4 Maximum Cargo Weight

5.4.1 Description

The vehicle must be able to carry external objects (cargo) totaling 100lbs without adversely impacting performance or reducing battery life by more than 30 minutes.

5.4.2 Source

Chris Conly.

5.4.3 Constraints

As vehicles are designed to carry people and objects, this is a necessary requirement to simulate a full-sized vehicle.

5.4.4 Standards

No applicable standards.

5.4.5 Priority

High

5.5 Module Set Up

5.5.1 Description

Module installation should take no longer than 5 seconds. In this time, a given module should be able to connect to the vehicle and be ready for operation.

5.5.2 Source

Destiny Rogers (CAN on Wheels).

5.5.3 Constraints

Consumer expectations dictate that "plug-and-play" devices be functional in a very short time period with little to no set up.

5.5.4 Standards

No applicable standards.

5.5.5 Priority

High

6 Safety Requirements

The modular electric vehicle contains several electrical components that could potentially cause harm. To avoid the risk of harm, the modular electric vehicle must follow several safety requirements. This section will discuss the several steps that need to be taken to provide a safe working environment as well as a safe product.

6.1 Laboratory equipment lockout/tagout (LOTO) procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Critical

6.2 National Electric Code (NEC) wiring compliance

6.2.1 Description

Any electrical wiring must be completed in compliance with all requirements specified in the National Electric Code. This includes wire runs, insulation, grounding, enclosures, over-current protection, and all other specifications.

6.2.2 Source

CSE Senior Design laboratory policy

6.2.3 Constraints

High voltage power sources, as defined in NFPA 70, will be avoided as much as possible in order to minimize potential hazards.

6.2.4 Standards

NFPA 70

6.2.5 Priority

Critical

6.3 RIA robotic manipulator safety standards

6.3.1 Description

Robotic manipulators, if used, will either housed in a compliant lockout cell with all required safety interlocks, or certified as a "collaborative" unit from the manufacturer.

6.3.2 Source

CSE Senior Design laboratory policy

6.3.3 Constraints

Collaborative robotic manipulators will be preferred over non-collaborative units in order to minimize potential hazards. Sourcing and use of any required safety interlock mechanisms will be the responsibility of the engineering team.

6.3.4 Standards

ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems, RIA TR15.606-2016 Collaborative Robots

6.3.5 Priority

Critical

7 Maintenance & Support Requirements

Because the electric vehicle is designed to be user-friendly and plug-in-play, it is necessary to provide maintenance and guidance to properly use the electric vehicle. This section describes what resources will be required for the CAN on Wheels team to provide adequate maintenance support for the electric vehicle.

7.1 User Manual

7.1.1 Description

A user manual that will contain standard instructions on how to install, troubleshoot, and operate the different modules of the electric vehicle will need to be written. Some of the sections of the user manual would include a brief functional description section of how each module is installed and how it operates on the electric vehicle, a detailed overview of the electrical vehicle with all its modules, and a electrical characteristics section which would include ideal working conditions, max speeds, max voltages, etc., and a troubleshooting section where it highlights instructions on how to solve typical problems that have the possibility to occur on the product.

7.1.2 Source

IEC/IEEE 82079-1:2019

7.1.3 Constraints

The user manual will only be available in English because the electric vehicle is limited to only be used in the United States. Involving international support would be very expensive and the language barrier would cost even more resources like translators with a background in engineering

7.1.4 Standards

- User manual must comply with and acknowledge relevant safety and regulatory standards
- User manual must be organized and presentable by the IEC standards
- Revision control is implemented for every manual which includes the publication date and version of the manual

7.1.5 Priority

Critical

7.2 Source Code

7.2.1 Description

The source code and its documentation for the electric vehicle will be available through GitHub. Contributors will be allowed to view and use the code to modify certain modules or troubleshooting via debugging tools.

7.2.2 Source

CAN on Wheels Team

7.2.3 Constraints

As the maintainers of the source code, ethical practices must be followed for every contributor that is using the source code. Security measures will need to be added to avoid vulnerabilities.

7.2.4 Standards

- Documentation will be kept up to date for every update that occurs on the source code

7.2.5 Priority

Moderate

7.3 CAN on Wheels Email Address

7.3.1 Description

A designated email address for general questions will be used to answer questions regarding any issues with the electric vehicle. Emails will be thoroughly reviewed by a team member before answering.

7.3.2 Source

CAN on Wheels Team

7.3.3 Constraints

Because the team is fairly small, reviews will occur 2-3 business days after the email has been sent. However, this can be delayed depending on the complexity of the problem.

7.3.4 Standards

- All emails received will be given a sufficient answer, even if the question being asked is out of the scope
- Email etiquette standards are being followed

7.3.5 Priority

Moderate

8 Other Requirements

The modular electrical vehicle will need to have modular architecture that will allow for car manufactures or other end users to modify the electric vehicle to their needs. These modifications can range from the communication system and all the way to the controllers of the vehicle hardware itself.

8.1 Flexible Intercommunication System

8.1.1 Description

As the demand for drive assist technologies and autonomous driving are rising, the amount of information transferred is increasing as well. The vehicle, which will be implementing a CAN bus system, should be able to port its inter-module communication system to another protocol such as ethernet. This would allow for the vehicle to mature and change with the current trends in industry.

8.1.2 Source

Hector Sosa (CAN on Wheels)

8.1.3 Constraints

The code written for the intercommunication of the modules should be written in a way that it allows for the end user to port it with relative ease to another system. When designing wiring of the vehicle, it should allow enough space for all of the required wires to pass through one module to another with minimal electrical noise.

8.1.4 Standards

70 FR 48047

8.1.5 Priority

Future

8.2 Software Defined Architecture

8.2.1 Description

The modular electrical vehicle should have the capabilities to manage its own hardware operations, add functionality, primarily through software [7]. The need for hardware modules can be limited to the vehicle itself, but by allowing a platform by which software developers can design new software that can be built upon this platform will allow for the vehicle to have new features that can added and removed via software

8.2.2 Source

Hector Sosa (CAN on Wheels)

8.2.3 Constraints

The architecture of the software for the given electrical vehicle should be constructed in layered approach by which each subsequent layers provides a layer of abstraction for the end user. It should be theoretically be possible for a developer to design an app for the car itself without needing all the prerequisite knowledge of the hardware and controllers that are already in place of the vehicle itself.

8.2.4 Standards

No applicable Standards have been found at this moment.

8.2.5 Priority

Future

9 Future Items

All requirements that are listed as priority 5 (Future) are listed in this section. These requirements will not be included in the prototype version of the vehicle due to time constraints and a lack of feasibility. Future versions of the product may include these items, or modules may be created at a later date that add this functionality to the prototype.

9.1 Autonomous Driving System

9.1.1 Description

The vehicle will be able to navigate and move on its own to a specified location as a partially autonomous vehicle. It must do so without creating hazardous situations and maintain a speed similar to what a user would travel at.

9.1.2 Source

Leonardo Ibarra (CAN on Wheels).

9.1.3 Constraints

This system must not be in use simultaneously with the remote control device. There must be a method by which to switch between autonomous mode and remote control mode. This requirement may not be implemented before the drive assist system.

9.1.4 Standards

ISO 26262 [5] ISO 21448 [6]

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Future

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The modular electrical vehicle should have the capabilities to manage its own hardware operations, add functionality, primarily through software [7]. The need for hardware modules can be limited to the vehicle itself, but by allowing a platform by which software developers can design new software that can be built upon this platform will allow for the vehicle to have new features that can added and removed via software

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9.3.4 Standards

No applicable Standards have been found at this moment.

9.3.5 Priority

Future

References

[1] *46 CRF 111.70-3 Motor controllers and motor-control centers*, Code of Federal Regulations Std.

[2] *ISO 15622 Intelligent transport systems: Adaptive cruise control systems*, Code of Federal Regulations Std., Rev. 2018.

[3] *ISO 11270 Intelligent transport systems: Lane keeping assistance systems (LKAS)*, Code of Federal Regulations Std., Rev. 2014.

[4] "Nhtsa updates us cybersecurity guidelines for vehicles," Oct. 2023.

[5] *ISO 26262 Road vehicles: Functional safety*, Code of Federal Regulations Std., Rev. 2018.

[6] *ISO 21448 Road vehicles: Safety of the intended functionality*, Code of Federal Regulations Std., Rev. 2022.

[7] "Software-defined vehicles: The ultimate guide," Oct. 2023.