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

System Requirements Specification
CSE 4317: Senior Design II
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Parking Lot Rover Team
GPS-RTK Parking Lot Rover

Sean-Michael Woerner
Abiria Placide
Liliana Diaz
Bryan Bidjocka
Mariane Sanchez

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1 Product Concept

This section describes the purpose, use, and intended user audience for the Parking Lot Rover. The rover will be a system that performs autonomous actions to stripe a parking lot. Users of the rover will be able to perform complete parking lot striping and re-striping at a higher performance.

1.1 Purpose and Use

The purpose of building this autonomous rover is to reduce financial costs and increase efficiency in parking lot striping, or possibly re-striping. Though there are machines that already stripe a parking lot in an efficient manner, the majority are manually controlled and have a higher margin of error percentage than our rover that will have a less percentage. The rover will receive signals from the GPS modules in order to know where to stripe, and will do so automatically with no manual labor. Thus, it will lower labor costs and increase the amount of parking striping. This product is only to be used specifically for parking lot areas.

1.2 Intended Audience

This product will be intended for audiences who need access to parking lot striping or re-striping. The rover will appeal more to companies or organizations that have either ownership of parking lots, enforce parking lot regulations, or paint parking lots. The main intended audience of this product are companies that do parking lot striping. One example of an intended audience is the Department of Transportation. This department is in charge of making sure that parking lots follow strict regulations for transportation safety. The rover could save the department funds that would go to hiring a company to do it for them. Other potential customers are building owners, apartment complex owners, and/or parking structure owners. The rover should be available for commercial use to follow legal requirements in striping parking lots by the Department of Transportation.

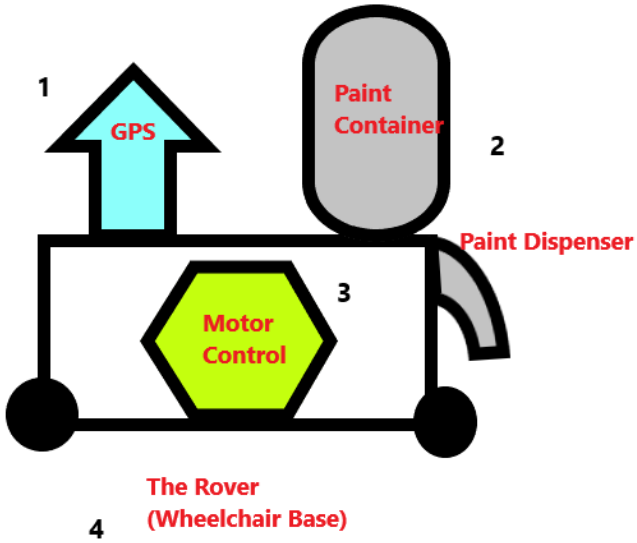

Figure 1: Conceptual drawing of the Autonomous Rover

2 PRODUCT DESCRIPTION

This section provides the reader with the overview of the Parking lot Rover. The primary operational aspects of the rover will be its functionality with using high precision RTK-GPS with GNSS correction. This section will also define the perspectives of end users, maintainers, and administrators. The key features and functions found in the rover, as well as critical user interactions and user interfaces are described in detail in this section.

2.1 FEATURES & FUNCTIONS

This rover will be an autonomous rover that will release paint in specific locations to create parking lot stripes to create a parking space, hence create a parking lot. It will use GPS modules in order to receive the data in order to know where to move and where to distribute the paint. It will not be able to remove paint, but it will be able to re-stripe a faded parking lot if given the right coordinates. The rover will be fully autonomous but can be controlled manually if any error occurs where it could become unresponsive to the automatic system.

The parking lot rover is made from an electronic wheelchair base, in order to decrease cost of building, containing the motor, power source, and be connected to 4 different wheels for balance and mobility. The wiring hardware on the roof of the base will be covered by a protective layer that will be made of Plexiglas or a type of hard plastic to prevent damage to the connections. This cover is necessary to preserve the integrity of the rover, the external hardware and all connections.Refer to Figure 1 for the conceptual drawing of the rover. Number 1 demonstrates the rover with the motor controls within the square-like base.

On the roof of the base, above the protective layer, will be the paint and GPS components. There will be a paint container that will have to be made of a sustainable in order to not cause leaks that could later malfunction the rover. This container would also be large enough to hold large quantities of paint sufficient to paint a parking lot. To distribute the paint, the container will have a solenoid valve that will be completed in the near future.

The GPS component will be our base module used to receive and send signals to an external base module. This GPS module will be used by an external signal sent through a GPS satellite that connects with the external base module. These signals will notify the rover where to go, and where to distribute the paint. There may be an external device, such as a phone or laptop, connected through Bluetooth connection to receive data of the rover. This data will be used to understand the rover's location, amount of paint, and/or if any errors ongoing. Internet usage may be needed in order to connect the GPS component to a PixHawk that will connect to the motors and control most of all the connections on the rover.

2.2 EXTERNAL INPUTS & OUTPUTS

The rover requires and expects to receive many data signals from end users to know where it's location is to determine the size of the parking lot. Using it's location and the size of the area, the rover will identify how many parking lot stripes will be needed to complete it's job. Table 2 below specifies all the data and information that flows into and out of the system of the rover.

2.3 PRODUCT INTERFACES

The operational interfaces that will be used on the rover will be an external device, such as mobile phone or laptop computer, that could display the location and amount of paint in the paint container. Mission Planner software will be used to control the rover. Since we do not have access to the main rover at this time, implementations of the mission software and sample home screen can be seen in Figure 2. This software will allow to give the rover commands on where to go, how fast, and where to complete an

action, such as paint the stripe. There will be emergency off switches on the rover, made specifically to prevent a mess of paint and/or a runaway rover. The sample rover is displayed in Figure 1 above.

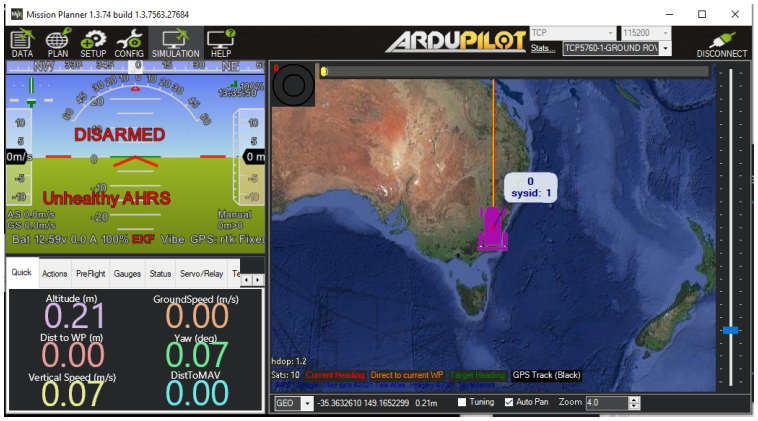

Figure 2: Mission Planner Software "Home Screen"

Name	Description	Use
GPS signals	The coordinates from the GPS satellite that sends coordinates and information of location	To know the size of the parking lot and location
Base Station signals	Input signal sent from a movable base station	to receive GPS signals if far from home base station
User Paint Signal	A signal to know when to distribute paint	To create the stripes of the parking lot
Module data	Output data signals sent to the GPS base station	Sent to alert User of location
Rover-Control signal	The signal to connect the rover to a remote control	If "auto-pilot" unavailable, the user will be able to control the rover
Completion Signal	Output signal from the rover to the base station	to alert User of job completion
Bluetooth	the connection signal that will be connected to an external device	this will display the rover's information data

Table 2: Critical Data (External Inputs and Outputs)

3 Customer Requirements

Current parking lot striping methods are costly and inefficient, but with the creation of the rover could decrease costs and increase performance efficiency. One autonomous robotic rover could potentially stripe more parking lots than a manual machine. Companies that own these manual machines require precise planning and accurate painting ability to not create any mistakes, and possibly lose revenue. To create this rover, we focus on creating a low-cost rover to automatically know where to go and where to paint using cheaper materials and lowering labor costs. The rover's user interface will need to be easy enough so that not only companies can use it, but parking lot owners who may not have any technological skills.

Figure 3: Possible Lines created by the Rover

3.1 Paint Distribution

3.1.1 Description

The paint stripes done by the rover will have to be precise and accurate in location. These stripes will require to be distanced within a certain amount in order to create a viable parking space for the functional parking lot. Distributing the paint must be as precise and accurate as possible to create smooth straight lines and not create any "messes" due to paint splatter. Figure 4 demonstrates what errors could occur when handling a manual machine compared to the autonomous rover. Figure 3 demonstrates how proper stripes should be painted. Since the rover will not move in circles, the lines that it will paint will be straight from the paint distributor, which is still in the process of being developed. The lines will be painted in certain dimensions to qualify as a viable parking space.

3.1.2 Source

The source of the requirement is from the CSE Senior Design project specifications and the department of transportation. The department of transportation has strict rules on parking lot facility designs.

3.1.3 Constraints

There will be sustainable and environmental constraints mainly on the texture of the parking lot area. Smooth lines could be an issue if the texture is not right. Lines may not appear straight or smooth if parking lot is created on uneven ground. The painted stripes must be able to last to decrease the potential cost of re-striping in the future.

Figure 4: Possible Lines created by a Manual Machine

3.1.4 STANDARDS

A parking facility has to be designed to maintain a minimum size of parking spaces. The parking lines should be easily distinguishable by the material used, in this case the paint. The parking lot stripes and lines must fit the dimensions for the three types of parking spaces, which can be seen in Figure 5.

3.1.5 PRIORITY

The priority of this requirement relative to other specified requirements is Critical.

3.2 GPS CONNECTIVITY

3.2.1 DESCRIPTION

The parking lot rover must be able to have GPS connectivity through an external base station module and the RTK GPS module. This will be easier for the customer to use, by inputting coordinates the rover will automatically know the dimensions of the future parking lot in order to stripe in specific areas for the parking spaces.

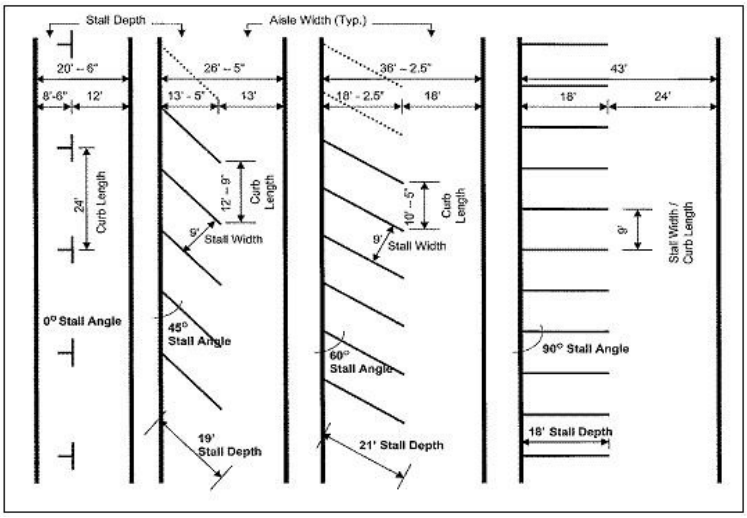

Figure 5: Different Types of Parking Spaces

3.2.2 Source

The source of the requirement is the CSE Senior Design project specifications and United States Air Force Regulations

3.2.3 Constraints

The applicable constraints for this rover are the distance that the rover can connect to the home base station that connects to the GPS satellite. There could also be environmental constraints as weather could affect the satellite signal if the GPS base module does not have a strong signal.

3.2.4 Standards

All GPS usage should be used in accordance by the government and United States Air Force. When using the GPS modules, the users should use the GPS connections without "hindering peaceful civil use of the system elsewhere," meaning it should not be used for hostile reasons.

3.2.5 Priority

The priority of this requirement relative to other specified requirements is Critical.

3.3 Bluetooth Connectivity

3.3.1 Description

Though the parking lot will be a full autonomous rover, it will be connected via Bluetooth to an external mobile device or laptop computer that will withhold status and data information. The rover will send will able to send data concerning paint status, if it is empty or full, location and status on the job completion. This Bluetooth device would prevent any errors or malfunctions from going unnoticed.

3.3.2 Source

The source of the requirement is the Parking lot Rover team members and National Institute of Standards and Technology

3.3.3 Constraints

The applicable constraints for this rover are the distance. They rover may not connected to the Bluetooth device if connectivity is not strong enough.

3.3.4 Standards

Since this is a short-ranged wireless device, the users and the team would have to follow the National Institute of Standards and Technology's guide to prevent any "high jacking" of the device, or any others, connected.

3.3.5 Priority

The priority of this requirement relative to the other specified requirements is Low.

3.4 Paint

3.4.1 Description

There are different types of paints that can be used to stripe a parking lot. This is important because it would follow the department of transportation's requirements on parking spaces being distinguishable. The type of paint that will be used by the rover should be Alkyd oil based or Latex based. Alkyd paint is used for re-stripes and new parking lot facilities while Latex paints are used for resurfaced parking lots. White paint should be used for parking lot striping, but if following the Department of Transportation's guidelines, yellow, red and blue may be used for other requirements based on regulations, such as fire lanes, handicap spaces, or blocked lanes.

3.4.2 Source

The source of the requirement is the CSE Senior design project specifications.

3.4.3 Constraints

Constraints would be access to certain paints and mileage required to fully stripe a parking lot.

3.4.4 Standards

The state's Department of Transportation must set a proper ration for disabled spaces in private and public parking lots. This would require the change of paint, from white to blue in order to create a suitable parking space mandated by the American with Disabilities Act Accessibility Guidelines.

3.4.5 Priority

The priority of this requirement relative to other specified requirements is High.

3.5 Autonomous Rover

3.5.1 Description

The parking lot rover will be an autonomous machine. It will receive GPS signals from the base station to know where to go, as well as know where to stripe the paint for the parking lot. Compared to manual machines, the autonomous rover will only require user input of location. The rover will create it's own blueprint on where it will go to stripe paint, rather than "sketch" an outline and paint the stripes afterwards. It is time consuming and costly if mistakes are made. This rover should reduce any margin of errors caused by manually driven paint striping machines.

3.5.2 Source

The source of the requirement is the CSE Senior design project specifications.

3.5.3 Constraints

Constraints would be the GPS signals being strong enough and user knowing how to operate an autonomous machine.

3.5.4 STANDARDS

Under the ISO and IEC standards, the rover must follow all safety requirements. The rover should be able to have a maximum space to maneuver and should be able to be navigated manually by a user.

3.5.5 PRIORITY

The priority of this requirement relative to other specified requirements is Critical.

4 Packaging Requirements

The rover with it's hardware for mobility will be fully assembled in the box. Separate attachments that do not affect the rover's mobility will be included for the user to install such as the container for paint which will be mounted on top of the rover and batteries for the rover's power source. The rover's software will be pre-loaded and out-of-box ready so that the user can immediately connect to it and use it as needed. When the rover has been completed, it will look like a manual paint striping machine, but be half the size and potentially be half the cost. When the rover is delivered to the customer, the rover will be disassembled for lower risk of damage. The rover's mobility software and hardware will not be affected by detaching components, if done properly. The rover base, that contains the power source and motor controls will be sent in it's own box, and the paint container and dispenser will be in it's own box. The rover software will be pre-loaded into the hardware. Once the paint container and dispenser are mounted onto the rover, the user may connect the software to the rover and use it as needed.

4.1 Rover Body

4.1.1 Description

The major body of the rover will include all hardware for mobility such as: wheels,control motors, and plastic or plexi-glass encasing.

4.1.2 Source

The source of the requirement is the CSE Senior design project specifications and the USPS mailing standards

4.1.3 Constraints

Economic and safety constraints are relevant to this requirement. If the rover base is past a certain weight limit, shipping may become pricey, and would require safety measures to be implemented so that delivery personnel not get injured when delivering. If rover base arrives damaged, compensation can be available, which could be costly.

4.1.4 Standards

Packaging will follow the Fair Packaging and Labeling Act to ensure safety and recognition of the contents inside the package.

4.1.5 Priority

The priority of this requirement relative to other specified requirements is Critical

4.2 Paint Container and Dispenser

4.2.1 Description

Plastic container that will hold the paint for dispersion by the rover. This user will attach this part on top of the rover and mount with a specific type of screw provided by the Parking Lot Rover Team.

4.2.2 Source

The source of the requirement is the CSE Senior design project specifications and the USPS mailing standards

4.2.3 Constraints

Economic and safety constraints are relevant to this requirement. If the paint container and dispenser are past a certain weight limit, shipping may become pricey, and would require safety measures to

be implemented so that delivery personnel not get injured when delivering. If components arrives damaged, compensation can be available, which could be costly.

4.2.4 Standards

Packaging will follow the Fair Packaging and Labeling Act to ensure safety and recognition of the contents inside the package.

4.2.5 Priority

The priority of this requirement relative to other specified requirements is Critical

4.3 Batteries

4.3.1 Description

Batteries used as the power source for the rover will be packaged and delivered in it's own box to prevent damage to the other components. The user will attach the batteries manually before using the rover.

4.3.2 Source

The source of the requirement is the CSE Senior design project specifications and the USPS mailing standards

4.3.3 Constraints

Economic and safety constraints are relevant to this requirement. If the batteries are past a certain weight limit, shipping may become pricey, and would require safety measures to be implemented so that delivery personnel not get injured when delivering. If components arrives damaged, compensation can be available, which could be costly. Another constraint is environmental. Some batteries can be damaging to the environment if batteries burst from poor packaging.

4.3.4 Standards

Packaging will follow the Fair Packaging and Labeling Act to ensure safety and recognition of the contents inside the package.

4.3.5 Priority

The priority of this requirement relative to other specified requirements is Critical

5 Performance Requirements

This section includes the requirements for high performance of the parking lot rover, including the layout, creation of the stripes, sufficient battery life, and paint mileage.

5.1 Layout Verification

5.1.1 Description

The software the rover will require will be Mission Planner Mission Planner will be used to get a layout of the parking lot as well and allow the user to mark any obstacles such as curbs, bollards, and wheel stops if any. This layout will give the rover directions on where to possibly stripe, and what path to follow.

5.1.2 Source

C & L Services and Mission Planner. CSE Senior Design Specifications.

5.1.3 Constraints

Internet/GPS connectivity strength. If there is no internet connectivity, GPS connectivity will be unavailable. The rover must have a strong internet connection, which could be affected by any environmental issues such as rain or strong winds.

5.1.4 Standards

To have a high functioning rover with Mission Planner, the rover user must follow all Internet Safety Protocols and all GPS usage should be used in accordance by the government and United States Air Force

5.1.5 Priority

The priority of this requirement relative to other specified requirements is Critical

5.2 Parking Stripes

5.2.1 Description

The rover must be able to paint a straight line that is 4 inches wide by 15 - 18 inches long according to the Department of Transportation regulations. Must be able to distribute a sufficient amount of paint for three types of stripes: new layout, re-stripes, and resurfaced re-stripes. These stripes will create the parking stalls, that are critical for a parking lot. For each parking spot, the rover should be able to stripe parking spaces that are at least 96 inches (2440 mm) or at least 132 inches (3350 mm) for cars and vans respectively. Figure 5 displays the parking stalls and stripes necessary to create a parking stall.

5.2.2 Source

The sources for this requirement are the Texas Department of Licensing and Regulation and the CSE Senior Design specifications

5.2.3 Constraints

Constraints relevant to this requirement are sustainability and safety. The paint stripes must be able to sustain weather and tear and must follow safety guidelines by the department of transportation. Another constraint is environment, lot layout, curb placements and wheels stops may affect how well the creation of the parking stripes is performed.

5.2.4 Standards

Texas Accessibility Standards Section 502.2 Vehicle Spaces states the dimensions needed for car and van parking spaces. Section 502.3 Access Aisles states the needed dimensions for access aisles as two parking spaces may share a common access aisle.

5.2.5 Priority

The priority of this requirement relative to other specified requirements is Critical

5.3 Sufficient Battery Life and Mileage

5.3.1 Description

Wheelchair batteries typically last for eight hours and are expected to reach a range of ten to twenty miles. This would require the rover to either have a stronger battery voltage to have sufficient battery life to complete striping one or even possibly more parking lots.

5.3.2 Source

The sources of the requirement are the Parking Lot Rover team and the Scootaround Personal Transportation Solutions

5.3.3 Constraints

Weather conditions, wheelchair power, electronic component power. The constraints relevant to this requirement are environmental, safety and sustainability. Weather conditions would affect when the parking lot rover could be out doing a service. All safety measures must be followed when using high voltage batteries and the rover batteries must be able to sustain the amount of work.

5.3.4 Standards

To follow all standards working with batteries, the users and the rover team must follow the Occupational Safety and Health Standard OSHA 1910.132.

5.3.5 Priority

The priority of this requirement relative to other specified requirements is Critical

6 Safety Requirements

When using this product make sure it is properly grounded as it is an electronic device. It is also important that the rover is kept away from chemicals and wet surfaces. These conditions would cause unexpected behavior or even shock to the user. Lastly, keep devices emitting radioactive signals away from this device. It would interfere with the RTK-GPS Module from satellites above the atmosphere.

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

The priority of this requirement relative to other specified requirements is 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

The priority of this requirement relative to other specified requirements is 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

The priority of this requirement relative to other specified requirements is Critical

7 Maintenance & Support Requirements

These are requirements needed for support and maintenance of the rover after delivery. The following requirements are necessary to correct errors and avoid hardware failures.

7.1 Firmware Update

7.1.1 Description

Update the rover firmware to explore new features. Go to the product website and search for available firmware updates. Connect the rover to a computer using a USB cable, and download the updates onto the rover.

7.1.2 Source

Parking Lot Rover Team.

7.1.3 Constraints

Firmware update can only be done when a new firmware version is made available on the website.

7.1.4 Standards

The firmware updates will follow the Platform Firmware Resiliency Guidelines (NIST SP 800-193).

7.1.5 Priority

High

7.2 Replace the paint

7.2.1 Description

The spray paint that comes with the rover needs to be replaced when it runs out.

7.2.2 Source

Parking Lot Rover Team.

7.2.3 Constraints

Not every type of paint can be used for parking lot striping. For best results, water based acrylic paint should be used. This is because it is durable, has high brightness, and also environmentally friendly.

7.2.4 Standards

ASTM D4227-05: Standard Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces.

7.2.5 Priority

Critical

7.3 Charging/Replacing the Battery

7.3.1 Description

The rover should be connected to power when the battery is low. The battery should be replaced if the operating time of the rover between charges, is shorter than normal.

7.3.2 Source

CSE Senior Design Project Specification

7.3.3 CONSTRAINTS

Only use rechargeable batteries recommended by the parking lot rover team. Product safety cannot be guaranteed with other batteries.

7.3.4 STANDARDS

IEC 62133: Safety requirements for portable sealed secondary cells and batteries containing alkaline or other non-acid electrolytes.

7.3.5 PRIORITY

Critical

8 Other Requirements

This section specifies anything else that is required for the rover to be complete. These requirements are related to the rover architecture/design.

8.1 LCD Screen

8.1.1 Description

The rover will have an LCD screen that will display the battery percentage and the amount of liquid left in the paint container.

8.1.2 Source

Parking lot rover team.

8.1.3 Constraints

The amount of information displayed will depend on the size of the LCD screen.

8.1.4 Standards

The IEC 63181-2 standard applies to this requirement. It specifies measuring methods for LCD multi-screen display terminals. The specified measurement items are: gap, splicing deviation, installation deviation, luminance uniformity and chromatic uniformity.

8.1.5 Priority

High

8.2 Pump

8.2.1 Description

A hydraulic pump will be needed to move the liquid paint out of the container.

8.2.2 Source

CSE Senior Design Project Specifications

8.2.3 Constraints

The amount of liquid paint that will be pumped out of the container will depend on the size of the tube connected to the pump.

8.2.4 Standards

Rotodynamic pumps for pump intake design (ANSI/HI 9.8-2018).

8.2.5 Priority

Critical

9 Future Items

9.1 Parking Stall Versatility

9.1.1 Description

As of now, the rover is designed to stripe 90 degree straight-in parking stalls. In the future, it should be able to stripe other various types of parking stalls such as angle parking (45-60 degrees), parallel parking (90 degree, parallel to border), etc.

9.1.2 Source

Parking Lot Striping 101 - Integrated Snow Removal, Inc

9.1.3 Constraints

Dimensions of the parking lot layout.

9.1.4 Standards

Must be in accordance to the Texas Accessibility Standards.

9.1.5 Priority

Future

REFERENCES

[1] Asphalt Kingdom. Asphalt Kingdom Line Stripers.
[2] National Pavement. Parking Lot Striping: Everything You Should Know, 2019.
[3] New Stripe. Parking Lot Striping Equipment.
[4] Texas Parking Lot Striping. Texas Parking Lot Striping
[5] Line Stripping Arlington. Parking lot striping arlington.