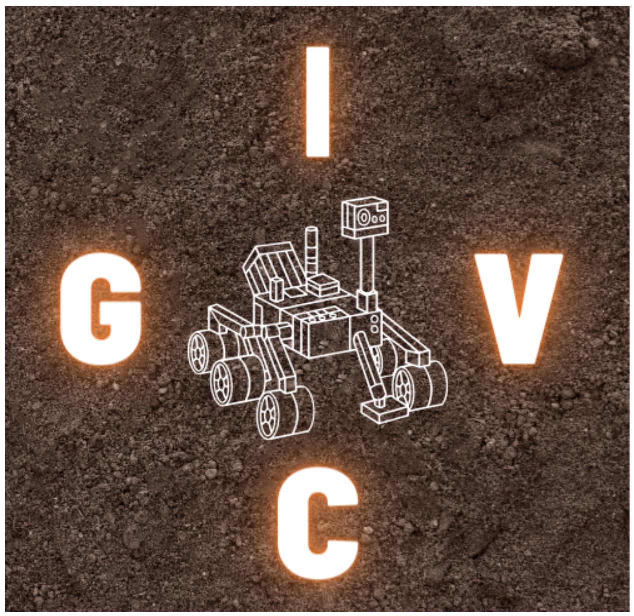
Department of Computer Science & Engineering
The University of Texas at Arlington

# System Requirements Specification
# CSE 4316: Senior Design I
# Summer 2024




# IGVC Engineers
# Intelligent Ground Vehicle Competition - Qualifier

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## Revision History

| Revision | Date | Author(s) | Description |
|---|---|---|---|
| 0.1 | 03.28.2024 | JS | Document creation |
| 0.2 | 04.14.2024 | JS, VC, AF | First Draft |
| 1.0 | 04.18.2024 | JS, VC, AF, SV, CB , CN | First Release |
| 2.0 | 07.18.2024 | DB, DG, HA, JC, NA | Second Release |

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# 1 Product Concept

The final product will be a vehicle that complies with the rules and regulations of the annual Intelligent Ground Vehicle Competition (IGVC) AutoNav Challenge. This section describes the purpose, use and intended audience of the vehicle in great depth. The vehicle is a collection of integrated systems that enables the ability of autonomous navigation. This ability will be utilized to perform at the competition. Developers and members of the project team may continuously build upon the established system while spectators and judges can discern it's ability to perform. Along with the vehicle, there will be thorough documentation for how future project members can ramp up in a timely manner.

## 1.1 Purpose and Use

The vehicle being developed will serve as a challenger representing the University of Texas at Arlington, and will perform to successfully compete in the IGVC. All necessary systems will be integrated together to participate in the AutoNav challenge within the IGVC.

The vehicle will be used annually at the competition hosted by Oakland University in Rochester, Michigan. While it is being built primarily for competing with all features and systems developed by the current team, it is anticipated the future project members will build on what the existing foundation and in some cases change features entirely. The current team had struggled with their initial foundation and thus are aiming to provide a rich, detailed collection of documentation that can resolve that issue for future project members.

## 1.2 Intended Audience

Spectators and Judges at the IGVC are the primary audience for the product. This is due to the nature of the event being a competition. However, there are several other groups that this product is intended for.

Future developers and project members will participate in product development by taking the final implementation and working forward from that state.

Outside of the IGVC, different variations of the product may find their way into the hands of select consumers for research and learning.

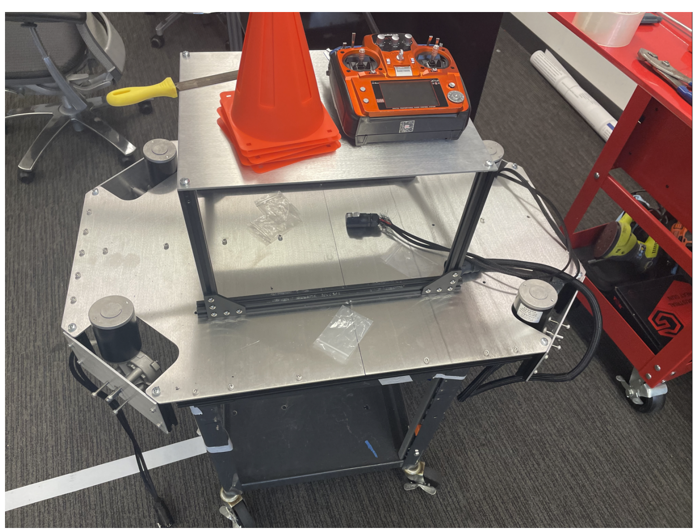

Figure 1: UTA IGVC 2024 - Side Profile

## 2 Product Description

This section provides the reader with an overview of the vehicle intended for the IGVC. The end product will be a vehicle made up of several components that allow it to navigate around a closed space. Vehicle components include the following:

- Computer Vision
  - The vehicle will have the capability to detect and avoid obstacles
  - The vehicle will have lane detection
- Platform
  - The vehicle will include a platform sufficient in size and support to carry a secured payload as well as support battery placement.
  - The vehicle will proceed along the course without dropping the payload.
- Drive and Motion
  - The vehicle will drive along the track with minimal pauses in motion.
- GPS
  - A Cube orange device is able to pinpoint GPS coordinates.

Documentation will associate the final product to aid in understanding and future development.

### 2.1 Features & Functions

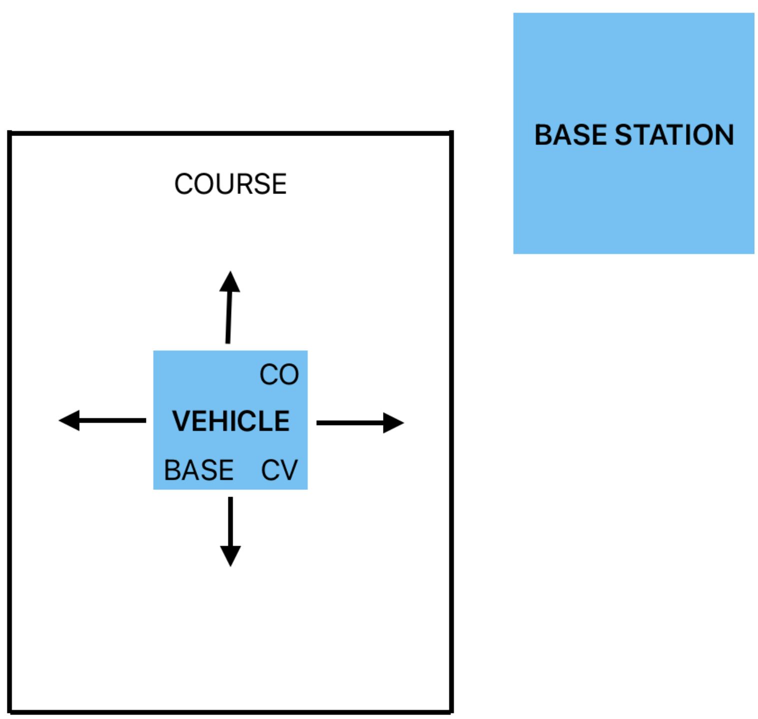


Figure 2: IGVC Basic Diagram

The product is not intended to act as a road vehicle. The vehicle will be rugged with several components being highly susceptible to damage due to an open frame as shown in Figure 1. From Figure 2, CO represents the cube orange that represents the GPS communication between the vehicle and the base station. CV is representative of the computer vision component that enables obstacle avoidance and lane following. The road on which the product operates will be a paved parking lot, but small bumps, winds, and light rain should be considered possibilities. This is roughly represented by the course in Figure 2.

## 2.2 External Inputs & Outputs

| Output/Input | Name | Description | Use |
|---|---|---|---|
| Input | Mission Planner | Manual Movement Instructions | Vehicle will follow sent movement instructions. |
| Input | Camera | Video feed | Continuous video stream sent to computer vision software for vehicle navigation. |
| Output | Website | Central Project Hub | Relay product information and documentation. |

Table 2: All external inputs/outputs to the IGVC vehicle

## 2.3 Product Interfaces

The vehicle and and related systems will have several endpoints where users can interact with. Interfaces will be divided among three categories, on-board, surrounding, and auxiliary.

- On-board
  - A Jetson TX2 will be attached to the vehicle to launch the computer vision software and run continuously until signaled to stop.
- Surrounding
  - To ensure the safety of those involved within the competition, a base station will be set up within close proximity to the vehicle providing the ability to take control of the vehicle and correct it's course. The base station includes a Windows PC and a transmitter that product maintainers can interact with.
- Auxiliary
  - Any user may interface with the vehicle indirectly via website. The website serves as a host to showcase product development, documentation, and promotion.
  - Developers who work on the product can access the code repository via Azure Devops organization to develop and/or maintain particular software. Administrators and non-development project members can access the repository to only view the software.

# 3 Customer Requirements

The product should meet all requirements listed found in the rules and regulations of the 2024 annual IGVC AutoNav challenge.

**NOTE:** Some of the requirements listed below are taken directly from the IGVC Official Competition Rules and are not altered.

## 3.1 Vehicle Configuration

### 3.1.1 Description

The AutoNav competition is designed for a small semi-rugged outdoor vehicle. Vehicle chassis can be fabricated from scratch or commercially bought. The vehicle must meet several strucural, functional, and safety requirements.

### 3.1.2 Source

IGVC 2024 Rules (1.2-1.3) [4]

### 3.1.3 Constraints

**Design**: Must be a ground vehicle (propelled by direct mechanical contact to the ground such as wheels, tracks, pods, etc. or hovercraft.

**Length**: Minimum length three feet, maximum length seven feet.

**Width**: Minimum width two feet, maximum width four feet.

**Height**: Not to exceed 6 six feet (excluding emergency stop antenna).

**Propulsion**: Vehicle power must be generated onboard. Fuel storage or running of internal combustion engines and fuel cells are not permitted in the team maintenance area.

**Average Speed**: Speed will be checked at the end of a challenge run to make sure the average speed of the competing vehicle is above one (1) mph over the course completed.
Vehicle slower than the minimum average speed will be disqualified for the run.

**Minimum Speed**: There will be a stretch of about 44 ft. long at the beginning of a run where the contending vehicle must consistently travel above 1 mph. A vehicle slower than this speed is considered to "hold-up traffic" and will be disqualified.

**Maximum Speed**: A maximum vehicle speed of five miles per hour (5 mph) will be enforced. All vehicles must be hardware governed not to exceed this maximum speed. No changes to maximum speed control hardware are allowed after the vehicle passes Qualification.

**Mechanical E-stop location**: The E-stop button must be a push to stop, red in color and a minimum of one inch in diameter. It must be easy to identify and activate safely, even if the vehicle is moving. It must be located in the center rear of vehicle at least two feet from ground, not to exceed four feet above ground. Vehicle E-stops must be hardware based and not controlled through software. Activating the E-Stop must bring the vehicle to a quick and complete stop.

**Wireless E-Stop**: The wireless E-Stop must be effective for a minimum of 100 feet. Vehicle E-stops must be hardware based and not controlled through software. Activating the E-Stop must bring the vehicle to a quick and complete stop. During the competition performance events (Autonomous Challenge and Navigation Challenge) the wireless E-stop will be held by the Judges.

**Safety Light**: The vehicle must have an easily viewed solid indicator light which is turned on whenever the vehicle power is turned on. The light must go from solid to flashing whenever the vehicle is in autonomous mode. As soon as the vehicle comes out of autonomous mode the light must go back to solid.

**Payload**: Each vehicle will be required to carry a payload throughout the entire run. The payload must be securely mounted on the vehicle. The payload specifications are as follows: 18 inches long, 8 inches wide, 8 inches high and a weight of 20 pounds.

#### 3.1.4 Standards

N/A

#### 3.1.5 Priority

Critical(must have or product is a failure)

### 3.2 Qualification

#### 3.2.1 Description

All vehicles must pass Qualification to receive standard award money in the Design Competition and compete in the Auto Nav performance events. To complete Qualification the vehicle must pass/perform all of the following criteria.

#### 3.2.2 Source

IGVC Rules (1.4) [4]

#### 3.2.3 Constraints

**Length**: The vehicle will be measured to ensure that it is over the minimum of three feet long and under the maximum of seven feet long.

**Width**: The vehicle will be measured to ensure that it is over the minimum of two feet wide and under the maximum of four feet wide.

**Height**: The vehicle will be measured to ensure that it does not to exceed six feet high; this excludes emergency stop antennas.

**Mechanical E-stop**: The mechanical E-stop will be checked for location to ensure it is located on the center rear of vehicle a minimum of two feet high and a maximum of four feet high and for functionality.

**Wireless E-Stop**: The wireless E-Stop will be checked to ensure that it is effective for a minimum of 100 feet. During the performance events the wireless E-stop will be held by the Judges.

**Safety Light**: The safety light will be checked to ensure that when the vehicle is powered up the light is on and solid. When the vehicle is running in autonomous mode, the light goes from solid to flashing, then from flashing to solid when the vehicle comes out of autonomous mode.

**Speed**: The vehicle will have to drive over a prescribed distance where its minimum and maximum speeds will be determined. The vehicle must not drop below the minimum of one mile per hour and not exceed the maximum speed of five miles per hour. Minimum speed of one mph will be assessed in the fully autonomous mode and verified over a 44 foot distance between the lanes and avoiding obstacles. No change to maximum speed control hardware is allowed after qualification. If the vehicle completes a performance event at a speed faster than the one it passed Qualification at, that run will not be counted.

**Lane Following**: The vehicle must demonstrate that it can detect and follow lanes.

**Obstacle Avoidance**: The vehicle must demonstrate that it can detect and avoid obstacles.

**Waypoint Navigation**: Vehicle must prove it can find a path to a single two meter navigation waypoint by navigating around an obstacle.

#### 3.2.4 STANDARDS

During the Qualification the vehicle must be put in autonomous mode to verify the mechanical and wireless E -stops and to verify minimum speed, lane following, obstacle avoidance and waypoint navigation. The vehicle software cannot be reconfigured for waypoint navigation qualification. It must be integrated into the original autonomous software. For the max speed run the vehicle may be in autonomous mode or joystick/remote controlled. Judges will not qualify vehicles that fail to meet these requirements. Teams may fine tune their vehicles and resubmit for Qualification. There is no penalty for not qualifying the first time. Vehicles that are judged to be unsafe will not be allowed to compete. In the event of any conflict, the judges decision will be final.

#### 3.2.5 PRIORITY

- Critical (must have or product is a failure)

# 4 Packaging Requirements

The final product will arrive in several components for assembly at the competition venue, including the wheeled base, computer vision system, and accompanying computer.

## 4.1 Wheeled Base

### 4.1.1 Description

The wheeled base is designed to be delivered in multiple parts, optimizing both the cost-efficiency and the ease of transport. This modular design not only reduces shipping costs by minimizing the package volume but also enhances portability, crucial for transportation to and from the Intelligent Ground Vehicle Competition (IGVC).

### 4.1.2 Source

N/A

### 4.1.3 Constraints

**Cost-Effectiveness:** The design must minimize expenses related to materials and shipping without compromising the integrity and functionality of the base.

**Assembly Simplicity:** Components must be easy to assemble with basic tools to facilitate quick setup by team members with varying levels of technical expertise.

**Transport Efficiency:** The modular components must be compact and lightweight to reduce shipping costs and improve handling ease.

**Protective Packaging:** Despite the need for compact packaging, adequate protection against impacts, vibrations, and environmental conditions during transit is essential.

### 4.1.4 Standards

ASTM D7386 - This is a standard that provides guidelines for testing the performance of shipping packages to ensure they can withstand the physical demands of parcel delivery systems, protecting their contents from damage during transport.

### 4.1.5 Priority

Critical (Components must arrive undamaged, on time, and cost-effectively) - must have or product is a failure.

# 5 Performance Requirements

The competition will be judged based on time taken to run the course. With the fastest time determining the winner.

Note: This list of requirements is ordered from highest to lowest in priority.

## 5.1 Speed

### 5.1.1 Description

The vehicle will have to drive over a prescribed distance where its minimum and maximum speeds will be determined. If the vehicle completes a performance event at a speed faster than the one it passed Qualification at, that run will not be counted.

### 5.1.2 Source

IGVC Rules (1.4) [4]

### 5.1.3 Constraints

- Minimum Speed: The vehicle must maintain a minimum speed of one mile per hour (mph) at all times during the course. This requirement is assessed in fully autonomous mode and verified over a 44-foot distance between the lanes while avoiding obstacles.
- Maximum Speed:The vehicle must not exceed the maximum speed of five miles per hour (mph) at any point during the competition. The maximum speed control hardware settings cannot be altered after qualification.

### 5.1.4 Standards

The vehicle must not drop below the minimum of one mile per hour and not exceed the maximum speed of five miles per hour.

### 5.1.5 Priority

Critical (must have or product is a failure)

## 5.2 Lane Following

### 5.2.1 Description

The vehicle must demonstrate that it can detect and follow lanes.

### 5.2.2 Source

IGVC Rules (1.4) [4]

### 5.2.3 Constraints

N/A

### 5.2.4 Standards

Each vehicle must navigate the course by remaining inside the course boundaries and navigating around course obstacles.

### 5.2.5 Priority

Critical (must have or product is a failure)

## 5.3 Obstacle Avoidance

### 5.3.1 Description

The vehicle must demonstrate that it can detect and avoid obstacles.

### 5.3.2 Source

IGVC Rules (1.4)

### 5.3.3 Constraints

N/A

### 5.3.4 Standards

Each vehicle must navigate the course by remaining inside the course boundaries and navigating around course obstacles.

### 5.3.5 Priority

Critical (must have or product is a failure)

## 5.4 Waypoint Navigation

### 5.4.1 Description

Vehicle must prove it can find a path to a single two meter navigation waypoint by navigating around an obstacle.

### 5.4.2 Source

IGVC Rules (1.4) [4]

### 5.4.3 Constraints

N/A

### 5.4.4 Standards

N/A

### 5.4.5 Priority

Critical (must have or product is a failure)

# 6 Safety Requirements

The Intelligent Ground Vehicle will be analyzed and tested by the judges during the competition. The safety requirements are part of the competition qualifications to ensure it complies with safety hazards.

Dual E-Stops: The vehicle must feature two Emergency Stop (E-Stop) mechanisms. The mechanical E-Stop is a red push button, centrally located, and positioned between 2 to 4 feet high. It must be hardware operated for immediate response in case of emergencies. Additionally, a Wireless E-Stop is required, capable of functioning within a range of at least 100 feet using an RC relay. Both E-Stops must effectively cut off power signals and bring the vehicle to an immediate stop upon activation.

Safety Lights: The vehicle should be equipped with safety lights to provide visual indication of its operating mode. When in standby mode, these lights remain solid to signal readiness. During autonomous mode, they switch to flashing mode to alert judges and other participants. Upon exiting autonomous mode, the lights return to a solid state.

These safety measures ensure that the vehicle can be quickly halted in emergency situations and that its operational status is clearly communicated to those in its vicinity. Such hazards include; interfering with another robot, degradation of the course or obstacles.

Other hazards are as follows.

Note: This list of requirements is ordered from highest to lowest in priority.

## 6.1 Laboratory equipment lockout/tagout (LOTO) procedures

### 6.1.1 Description

All tools and equipment provided for the project must follow safety procedures outlined by OSHA. Locks and tags will be put on any equipment that could be dangerous to use. Only the course instructor or assigned teaching assistants can take off a lock. Whenever equipment is not being used, locks will be put back on right away.

### 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 (must have or product is a failure)

## 6.2 National Electrical Code (NEC) wiring compliance

### 6.2.1 Description

The National Electrical Code (NEC), also known as NFPA 70, is the standard for safe electrical design, installation, and inspection. It is enforced across all 50 states to safeguard individuals and property

from electrical dangers.
All electrical wiring must meet the requirements outlined in the National Electric Code. This covers everything from how wires are installed to their insulation, grounding, enclosures, over-current protection, and any other specifications mentioned in the code.

### 6.2.2 Source

CSE Senior Design laboratory policy

### 6.2.3 Constraints

Safety Clearances: specific clearance distances for high voltage sources to prevent electric shock hazards.

Insulation Requirements: High voltage sources require insulation rated for the voltage levels present to prevent arcing and electrical breakdown.

Wire Sizing and Ampacity: NEC specifies the appropriate wire sizes and ampacity ratings for different electrical loads.

Grounding: NEC mandates proper grounding methods to ensure electrical safety.

Installation Locations: NEC provides guidelines for where electrical components can be installed, such as clearance requirements around electrical panels and proximity to water sources.

Circuit Protection: NEC specifies the use of circuit breakers or fuses to protect electrical circuits from overloads and short circuits.

### 6.2.4 Standards

NFPA 70

### 6.2.5 Priority

Critical (must have or product is a failure)

## 6.3 RIA robotic manipulator safety standards

### 6.3.1 Description

Safety standards for robotic manipulators, such as those produced by RIA (Robotics Industries Association), are crucial to ensure the safe operation of these machines in various industrial and commercial settings. Here are some common safety standards that may apply to robotic manipulators.

### 6.3.2 Source

CSE Senior Design laboratory policy

### 6.3.3 Constraints

Developing and implementing safety standards for robotic manipulators involves navigating various constraints. Technical limitations in sensor technology and integration challenges may delay compliance efforts, alongside economic concerns such as the cost of implementation and potential impacts on productivity. Regulatory complexities, including evolving standards and jurisdictional differences, while operational and cultural factors, such as compatibility with existing processes and organizational attitudes towards risk, also play significant roles. Overcoming these constraints requires collaborative efforts among stakeholders to balance safety requirements with technological feasibility, economic viability, and organizational realities.

#### 6.3.4 Standards

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

ISO/TS 15066 - This technical specification provides guidance on collaborative robot safety.

ISO 10218 - This is an international standard for the safety requirements of industrial robots and robotic systems.

#### 6.3.5 Priority

Critical (must have or product is a failure)

# 7 Maintenance & Support Requirements

The vehicle will be in communication with a base station to support GPS navigation via the software Mission Planner. The chosen software will be launched on a Windows machine. It is vital to the product that if Mission Planner is to be used in future iterations, a Windows machine is launching the software and that the software is up to date.

Continuous source code maintenance is required as there are new libraries and software updates that halt code compilation. Furthermore, rigorous vehicle inspection and analysis is mandatory after testing and live performance.

Note: This list of requirements is ordered from highest to lowest in priority.

## 7.1 Base Station & Mission Planner

### 7.1.1 Description

Mission Planner is a GPS software that can signal to remote devices via receiver and transmitter. This software is intended to run on Windows devices. The software must be kept up to date to ensure strong communication.

### 7.1.2 Source

[6] Installing Mission Planner

### 7.1.3 Constraints

If the host machine of choosing is a Linux system, Mission Planner can still be utilized. It is imperative that MONO, an open source .NET framework allowing Windows applications to be installed and run on Linux systems, is installed. [5]

Note that this approach is not without issues as it has been reported that bugs and crashes do occur. When both MONO and Mission Planner are installed on the Linux system, the user of the software is to navigate to the directory of Mission Planner and execute the command below.

```
mono MissionPlanner.exe
```

A version of the software is in development for Android but given the status of development it is not advisable to rely on the integrity of the application on an Android device.

### 7.1.4 Standards

ECMA-334 C# [3], ECMA-335 Common Language Infrastructure [2]

### 7.1.5 Priority

Critical (must have or product is a failure)

## 7.2 Source Code and Documentation Maintenance

### 7.2.1 Description

The vehicle must be inspected after any black-box testing and ensure parts and/or components are sufficient for performance. Full tear down is not required but may be necessary depending on test results. Full tear down and analysis is required to update worn down parts and upgrade components accordingly.

### 7.2.2 Source

N/A

#### 7.2.3 Constraints

N/A

#### 7.2.4 Standards

N/A

#### 7.2.5 Priority

Critical (must have or product is a failure)

### 7.3 Vehicle Inspection

#### 7.3.1 Description

The vehicle must be inspected after any black-box testing and ensure parts and/or components are sufficient for performance. Full tear down is not required but may be necessary depending on test results. Full tear down and analysis is required to update worn down parts and upgrade components accordingly.

#### 7.3.2 Source

N/A

#### 7.3.3 Constraints

N/A

#### 7.3.4 Standards

N/A

#### 7.3.5 Priority

High (very important to customer acceptance, desirability)

# 8 Other Requirements

All source code associated with the vehicle will be hosted on a remote repository managed and/or modified by product developers and maintainers. Product owners and sponsors can access the repository upon approval and permissions for them would be set to read only to minimize product failure.

Note: This list of requirements is ordered from highest to lowest in priority.

## 8.1 Source Code Hosting

### 8.1.1 Description

The source code for all software components of the product, including the website will be hosted on a single remote repository. The current remote repository is a git repository and can be found within the team Azure DevOps organization [1].

### 8.1.2 Source

N/A

### 8.1.3 Constraints

If another hosting platform is chosen, all source code found within the current repository must be backed up and moved accordingly to a new platform.

### 8.1.4 Standards

N/A

### 8.1.5 Priority

Moderate (should have for proper product functionality).

## 8.2 Vehicle Components & Hardware Storage

### 8.2.1 Description

Any tools, components and computer hardware associated with the vehicle must be stored in a secure location. The current location is located at The University of Texas at Arlington in the Engineering and Research Building (ERB), Room 202/203. Please refer to Section 6.1 of this document regarding the mandatory safety procedures when operating within the current lab space. Parts that are ordered via support tickets are delivered to ERB Room 208.

### 8.2.2 Source

N/A

### 8.2.3 Constraints

If another location is chosen for product development, it is required that all tools within the current lab space are kept there unless permission to move them is granted. It is also required that all components associated with the vehicle are to be moved to the new location to ensure efficient development.

### 8.2.4 Standards

N/A

### 8.2.5 Priority

Moderate (should have for proper product functionality).

## 9 Future Items

Given that the requirements are listed in detail and are found within the competition rules and regulations, there are no low-priority requirements to follow.

Any modifications to the vehicle will be in support of higher priority requirements.

## References


[1] Azure DevOps. Organization management overview, 2023. Accessed: 2024-04-18.

[2] ECMA. Ecma-335: Common language infrastructure (cli), 2012. Accessed: 2024-04-18.

[3] ECMA. Ecma-334: C language specification, 2023. Accessed: 2024-04-18.

[4] IGVC. Official competition details, rules and format, 2024. Accessed: 2024-04-18.

[5] Mono. Cross platform, open source .net framework, 2024. Accessed: 2024-04-18.

[6] Mission Planner. Installing mission planner, 2024. Accessed: 2024-04-18.