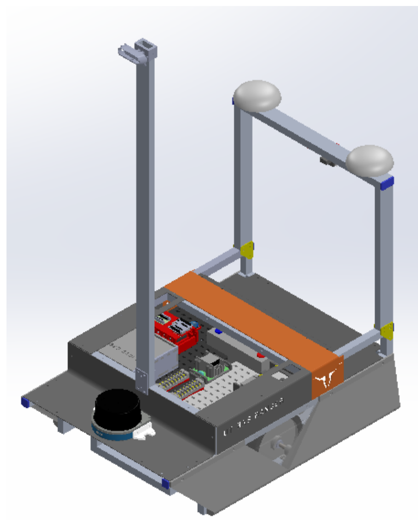
Robotics and Automation Society – IGVC

The University of Texas at Austin

“Ranger”

Submitted May 15th, 2025



I hereby certify that the development of the vehicle, Ranger, as described in this report, is equivalent to the work involved in a senior design course.

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Design Process, Team Identification and Organization

Introduction

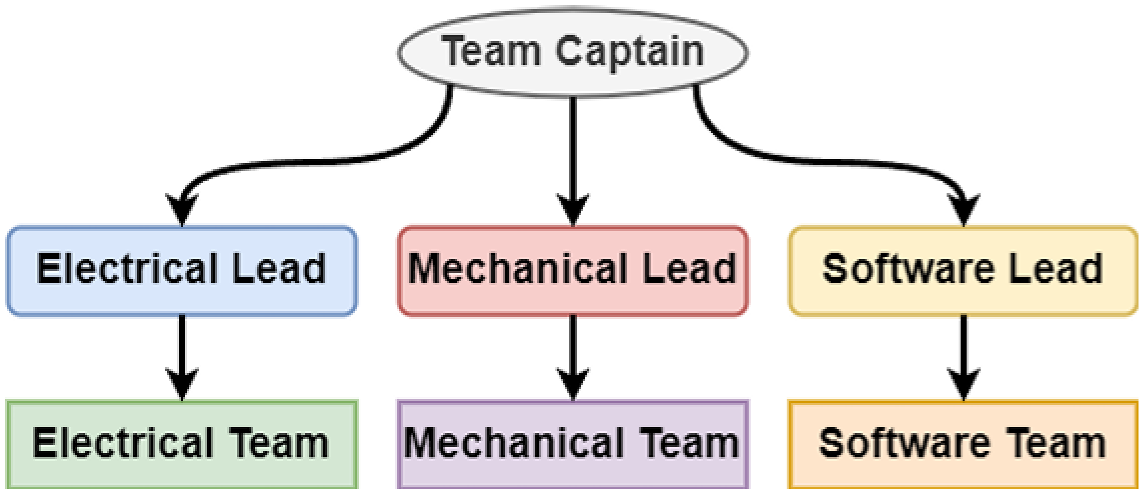
RAS IGVC Robotics, representing the University of Texas at Austin, is proud to present Ranger, the team's entry for the 2025 IGVC AutoNav competition. The university faculty advisor is Dr Lilly Chin, the head professor for the Texas Robotics Minor. While Ranger brings many innovations and upgrades. UT Austin has not participated in the Intelligent Ground Vehicle Competition (IGVC) since 2014. We are continuing from where the previous team ended. Our goal is to lay the foundation for future IGVC teams. For the 2025 competition, we improved the old 2014 robot by redesigning it solely for the Intelligent Ground Vehicle Competition. We focused on replacing components with upgraded systems, streamlining the design, and implementing processes necessary for the competition. The 2024-2025 IGVC team took an outdated robot and turned it into something competition worthy.

Organization

The team is organized into electrical, software, and mechanical sub-teams, each led by an experienced member or upperclassman who guides the team members in completing their tasks. Sub-team leads regularly checked in with their members to ensure tasks were being completed sufficiently and to provide assistance when needed. Sub-team leads report to the team captain to ensure alignment and progress in the robot's design and development. The team's total hour contribution is listed in the table.

Subteam	Subteam Hours (per week)	Number of Members	#of Weeks	Total Man hours
Electrical	4	6	20	480
Mechanical	2	4	20	160
Software	3	5	20	300
			Total Team Hours	940

As well as our team's organizational hierarchy is also included below



Design Assumptions

The goal of this IGVC team was to satisfy all the requirements to qualify for the competition while staying within our very limited budget. In October 2024, we rediscovered the 2014 competition chassis as it passed the requirements for qualification. We fully disassembled this old IGVC robot as well as go through the “Junk bin” from that year to gain perspective on how the previous IGVC team engineered their robot. Upon reconstruction, we had a basic chassis which required major modifications. We then applied our discoveries from the reassembled chassis to our current in-progress chassis from 2019. In doing so we designed the remainder of the robot based on ease of usability and cost effectiveness. To stay within our budget, the mechanical team recycled materials from the other two robots. With the limited funds, we then proceeded to repurpose old sensor equipment as well as take in unused laptops, cameras, and batteries from other robotics teams and labs on campus.

Design Process

The team’s design process is structured around constant refinement, with continuous iteration and testing of solutions. As shown in the included figure, the team begins by defining the high-level problems and then breaking them up into smaller research tasks. After each sub-team conducts their research, the team comes together and designs solutions collaboratively. Once designs, models, and documentation are ready, the team moves to the build stage, where these ideas are created. Building often spans multiple months, and involves ongoing refinement as solutions are tested. Finally, the solutions are implemented and final testing is performed. If the implementation fails to meet the requirements, the team returns to the problem definition stage. This process enables the team to create robust, innovative robots that can be continuously adjusted based on environmental factors and team conditions.

Bill of Materials

Ranger's total production cost can be calculated from the yearly allocated budget that our head RAS parent club allocates to us. Each year we are allocated $800 to take into account any and all purchases made for IGVC.

ITEM	UNIT COST (USD)	QUANTITY	BUDGET COST (USD)
Alienware 15 R3	$750.00	1	$0
Trimble BD982	$2,000.00	1	$0
Trimble LV59	$400	1	$0
LiDAR MRS1000	$5,500.00	1	$0
Mighty Max Battery BATTERY,12V,35AH	$75.00	2	$0
Sabertooth 2x60	$125.00	1	$125.00
PhidgetSpatial Precision	$100	1	$100
Intel Realsense Camera	$180	1	$180
FlySky RC Controller & Reciever	$45.00	1	$45.00
DieseRC Relay Switch w/ 2 Fobs	$20.00	1	$0

Battery Jumper Terminals W/Cable & Mounting Bracket	$30.00	1	$0
ELEGOO MEGA R3 Board ATmega 2560	$20	1	$0
500 Watt Pure Sine Wave Power Inverter	$60	1	$60
DROK DC Buck Converter	$20.00	1	$0
Solid/Flashing Signal Light	$15.00	1	$0
CoolYeah 4" Swivel Plate PVC Caster Wheel	$30.00	4	$90.00
MY1018Z Unite 450W, 24V DC Brushed Gear Motor, 440 RPM	$90.00	2	$180.00
6793K117 Steel Machinable Bore	$20	1	$20.00
Acryllic Sheet	$15.00	2	$30.00
Aluminum			
Misc. Electrical	$80	1	$80.00
Misc. Mechanical	$100	1	$100
Total Cost	**$9,575.00**	**N/A**	**$1010**

System Architecture of Vehicle

This year's platform builds upon previous iterations by reinforcing power reliability, simplifying wiring, and integrating key sensory upgrades. The basic build includes two levels, where the base holds the chasis and batteries. The second level encases the electronics and IMU sensor. The mechanical chassis incorporates CoolYeah 4" swivel casters and two chain-sprocket powered wheels for maneuverability. Vibration damping systems have been implemented to reduce interference with sensors and electronics. A raised sensor mast holds the GNSS and vision systems to improve visibility over obstacles and maintain precise localization.

Significant Power and Electronic Components

The Alienware 15 R3 laptop serves as the primary computing platform, responsible for high-level processing, sensor fusion, and navigation logic. It interfaces directly via USB with all major sensing components, including the Intel RealSense camera, MRS1000 LiDAR, PhidgetSpatial IMU, and the Trimble BD982 GPS receiver with LV59 antenna. These sensors provide comprehensive data on the vehicle's surroundings, orientation, and position.

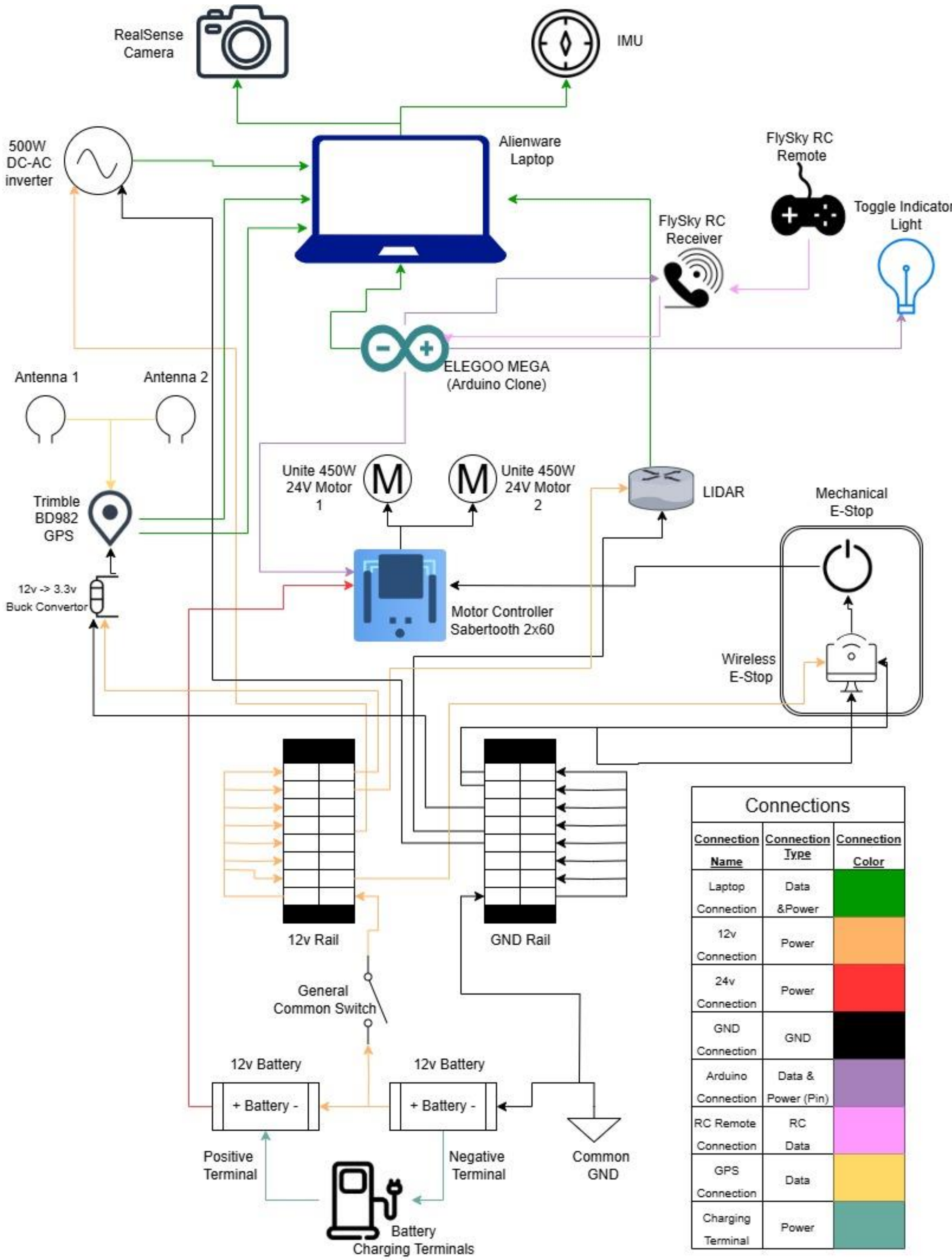
A ELEGOO MEGA R3 board (Arduino ATmega2560) acts as an intermediary controller between the laptop and actuators, handling low-level signal management. The motors are driven by a Sabertooth 2x60 motor controller, which receives drive commands from the Arduino and includes built-in thermal and overcurrent protection.

Control redundancy and safety are enforced by a dual-layer emergency stop system. A DieseRC relay switch wirelessly receives shutdown commands from a paired fob, while a hardwired mechanical E-stop is connected in series to ensure physical cutoff capability. Additionally, a FlySky RC controller is used for manual control during testing and fallback operations.

Power management is structured to segregate high-current and low-voltage systems. Two 12V 35Ah Mighty Max sealed lead-acid batteries wired in series provide a dedicated 24V DC rail for motor power. All remaining electronics operate off a 12V rail tapped from the first battery, feeding into a DROK buck converter for 5V devices like the GPS receiver. A 500W pure sine wave inverter draws from the same 12V rail to supply AC power to the laptop.

A signal light system is mounted on the vehicle to indicate its current mode of operation (manual or autonomous), enhancing visibility and safety around judges and other participants.

The complete wire diagram is attached below:



Connections

Connection Name	Connection Type	Connection Color
Laptop Connection	Data &Power	
12v Connection	Power	
24v Connection	Power	
GND Connection	GND	
Arduino Connection	Data & Power (Pin)	
RC Remote Connection	RC Data	
GPS Connection	Data	
Charging Terminal	Power	

Computing and Processing

- Alienware 15 R3 laptop serves as the primary computing platform, processing sensor data and making navigation decisions
- ELEGOO MEGA R3 Board (Arduino) functions as an intermediary command relay between the laptop and motor controller

Sensory Systems

- Intel Realsense Camera provides visual input for lane detection
- MRS1000 LiDAR generates point cloud data for obstacle detection
- PhidgetSpatial Precision IMU supplies orientation data
- Trimble BD982 GPS receiver with LV59 antenna delivers precise location information

Power Management

- Dual Mighty Max 12V 35AH batteries connected in series provide 24V power
- 500W Pure Sine Wave Inverter converts DC to AC for laptop power
- DROK DC Buck Converter steps down voltage for components requiring 5V

Control Systems

- Sabertooth 2x60 motor controller drives the vehicle's motors
- FlySky RC Controller enables manual operation
- DieseRC Relay Switch with wireless fobs functions as the emergency stop system

Safety Devices

- Safety is paramount in our design, implemented through both hardware and software:
- **Mechanical E-Stop**: A button wired in series with the wireless E-stop to ensure a quick and decisive power cut to the motor controller should Ranger malfunction.
- **Wireless E-Stop System**: The DieseRC Relay Switch with two fobs provides mandated emergency shutdown capability with a range exceeding competition requirements.

- **Signal Light System**: The solid/flashing signal light indicates the vehicle's operational state (autonomous vs. manual control), ensuring visibility to judges and bystanders.
- **Power Protection**: The motor controller includes built-in current limiting and thermal protection to prevent damage to electronics and potential hazards.

Mechanical Design

In this section, we describe the chassis of the robot. The materials and construction method were chosen to create a modular robot that is easy to repair. The modular design will make for easy modification by future teams. First, we describe the construction of the chassis, then we explain its design. The chassis was designed for both strength, and ease of modification and repair. The chassis is made of extruded aluminum square tubing and aluminum sheet metal braces that are fastened together. The aluminum tubing and sheet metal braces were chosen because they are easy to modify with basic tools, a circular saw with a non-ferrous metal cutting blade and a jigsaw with a metal blade, respectively. The fasteners are easy to replace and install with a hand drill and a wrench. The materials can be sourced from most local hardware stores. The materials being easily sourced and the use of a small number of power tools tends towards an easily repaired and modular chassis. The chassis was designed to house the wheels, motors, and batteries on one level; and the electronics, LIDAR, and camera stand on the second level. The wheelbase was initially designed to use a tank drive system. Each side would have three wheels that are powered by one motor and a chain-and-sprocket system. The team changed this design to a four-wheel drive, where to wheels on the side are powered and the front/back of the vehicle are supported with castor wheels. Figure 1 below indicates the general layout of the wheels and motors.

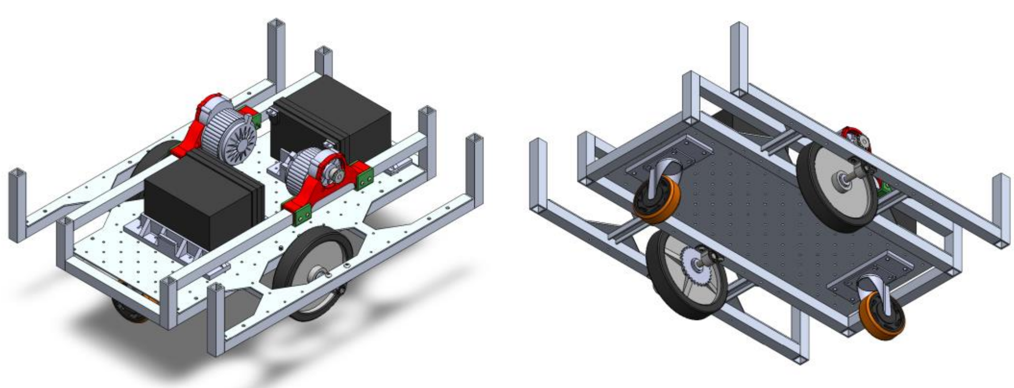


Figure 1. Inside look of battery and motor-gearbox positions (left) and the wheelbase position (right)

As seen in the image, the motors are mounted using a 3-D printed part (red and green part). After attaching the gear and sprocket assembly, the motors were slid till the chain was taught. After doing so, the team drilled holes in the metal channel and fastened the motors in place. This type of modular design was utilized in various places throughout our robot. This process allows for fast implementations and alterations while the team created the robot.

The next level to the vehicle was the electronics housing. As seen in Figure 2 below, the electrical module is attached to a base plate that is housed by sheet metal on all sides. The base plate was created to facilitate modularity in the assembly process of the electronics. Since the team is divided into 3 sub teams (software, electrical, and mechanical), mechanical team needed to ensure they could fit the electronics in any configuration. Therefore, a slotted base plate allowed for easy placement and space management for the electronic modules. Additionally, the electronics are surrounded by sheet metal and an acrylic cover. The cover acts as a weather resistant shield and the acrylic allows for quick safety diagnosis of the electronics. Figure 2 also depicts the location of the LIDAR sensor. The sensor is placed in the forward-most position to scan the surroundings of the robot during competition. Lastly, the sheet metal surface in the backside of the robot is intended to house the payload. This payload will be strapped on and secured to the robot during the competition.

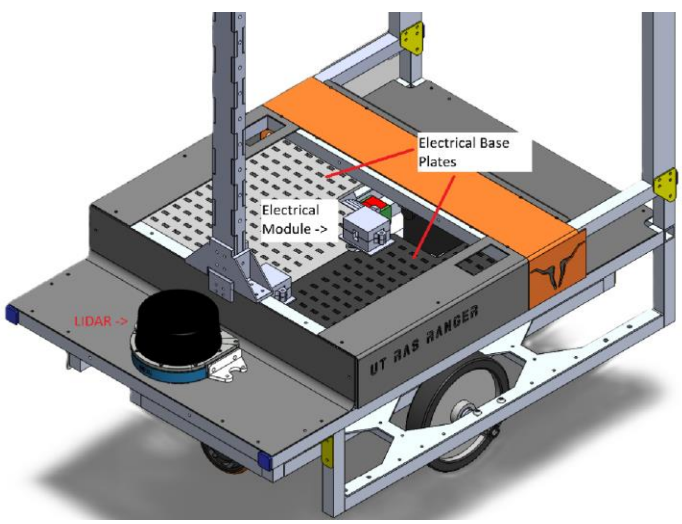


Figure 2. Second level of robot design

Finally, the robot has two vertical structures. The first structure houses the Real Sense camera and the second houses the E-stop and GPS receivers (Figure 3). As seen in Figure 3, the camera stand—scaling to 4ft off the top of the robot —has multiple holes which align with the Real Sense camera mount, providing a big range for the software team to play with. The camera mount also has a hinge that is fastened using a nut and bolt. This assembly was designed in a way to assist the software team with testing the optimal camera height and angle for peak performance. On the other hand, the second vertical assembly contains the GPS receivers and the E-stop. The mechanical team created such a big structure to ensure the GPS receivers would be at a high point and clear of any obstructions, hence providing optimal results. Additionally, the E-stop was added at this location for easy access by the operator.

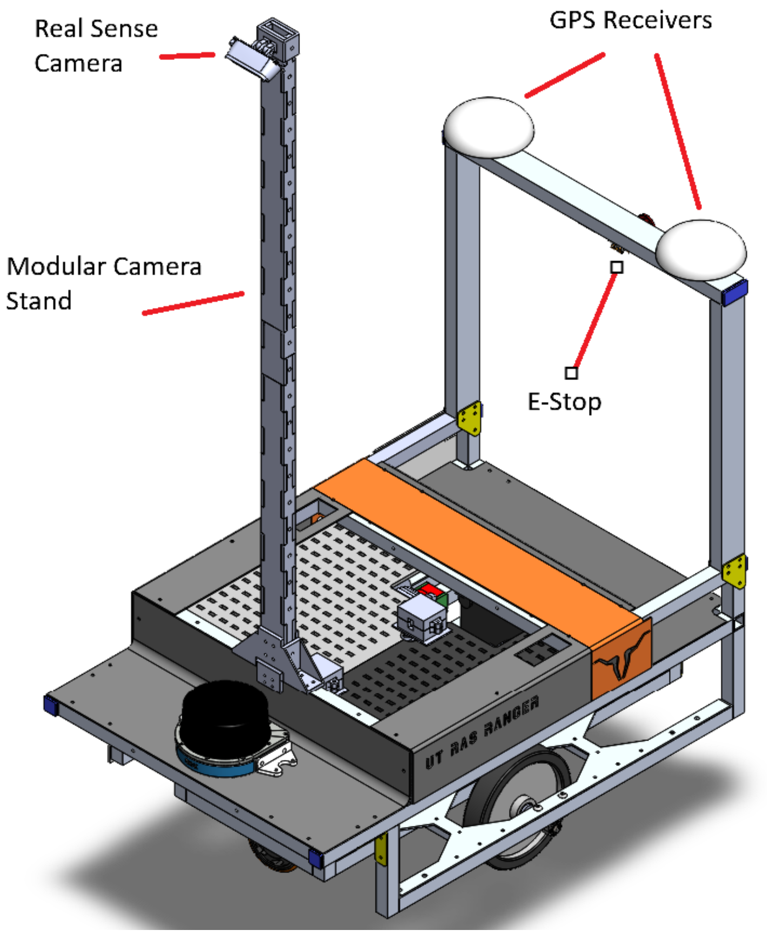


Figure 3. Camera, GPS receiver, and E-stop mounts

Overall, the robot was created for modularity in assembly, providing quick testing and simplicity in design. Majority of the heavy components—like the batteries, motors, and payload— were placed near the bottom of the vehicle to ensure more stability. Furthermore, the tall camera stand was supported using guywires that helped dampen the vibrations observed in the camera during the drive. Lastly, the use of two powered wheels and two caster wheels created more mobility, but at the cost of some stability.

Power Distribution System/Method

The power architecture centers around two 12V 35Ah SLA batteries connected in series to provide a nominal 24V DC rail for motor power. This high-current rail supplies the Sabertooth 2x60 motor driver, which handles up to 60A per channel and drives the twin MY1018Z motors.

Peripheral systems—including the control electronics, sensors, and auxiliary hardware—operate off a 12V line directly tapped from the first 12V battery. This line powers the buck converter (for 5V needs), as well as other mid-power devices such as indicator lights and the wireless relay E-stop system. Circuit protection is provided via automotive blade fuses for both the 12V and 5V rails.

An off-the-shelf 500W pure sine wave inverter is wired to the 12V rail and is used to power the Alienware 15 R3 laptop, which handles all high-level processing tasks such as sensor fusion and autonomous navigation.

Power draw from the motors is indirectly monitored through Sabertooth telemetry, while voltage levels are manually checked during operation. Based on empirical testing and estimated loads, the system draws:

- **Nominal power**: ~600W (motors + electronics)
- **Full-load power**: ~1200W (peak during motion or uphill drive)

Battery Type	Sealed Lead Acid (SLA)
Voltage Rating	24v (2 x 12V Series)
Capacity	35Ah
Discharge Current Rating	~30A
Nominal Runtime	~75 minutes
Full Load Runtime	~35 minutes
Charge Time	~45 minutes

Software Architecture

The software architecture for Ranger emphasizes simplicity, robustness, and modularity. Leveraging the Robot Operating System (ROS), the software stack is structured around a publisher-subscriber model where each subsystem (perception, localization, planning, and control) operates semi-independently. This approach enhances reliability by isolating faults and allows for rapid prototyping and debugging. The software team focused on camera-based navigation, lane and obstacle detection, and autonomous path planning.

Ranger uses two **Intel RealSense RGBD cameras** as perceptual sensors. The depth and RGB image streams are processed to extract environmental features relevant to autonomous driving. This is done using a HSV filter used to distinguish the lane and obstacles from the road. This filter identifies all colors in the range [0, 0, 50] to [179, 50, 200] as the road, and all others as the lane and obstacles. The filtered image is passed through a ROS pipeline, which is used in two main pathways: visual odometry and mapping, both of which feed into the localization pipeline. We use a **Hector SLAM** due to its superior performance in real-time visual odometry using only the camera data.

Hector SLAM is a 2D SLAM approach designed for high update rates and light computational loads. It is well-suited for our camera-driven platform because it:

- Utilizes scan matching and occupancy grid alignment from camera-based depth projections
- Requires no odometry or IMU inputs, ideal for reducing system complexity
- Provides real-time **pose estimation** and **map generation** with high fidelity

The robot's pose output from Hector SLAM is passed to the **Planner module**, which uses occupancy grid updates and odometry feedback to determine safe navigation trajectories. The planner outputs motor velocity commands that are relayed to the embedded controller for actuation.