ELG4913 | Winter 2024

Group 5: Final Project Report

ELG 4913

Search and Rescue Remote-Controlled (RC) Car with LiDAR Mapping and Life Detection

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1. Project Charter

1.1 Charter Introduction

1.1.1 Document Change Control

Revision Number	Date of Issue	Authors	Brief Description of Change
1.0	[2024-02-29]	Fatmah Bayrli, Geoffrey Hooton, Papa Kane, Walid Rashad, Moktar Abdillahi-Abdi, Julien Kapro	Creation of the document.
2.0	[2024-04-08]	Fatmah Bayrli, Geoffrey Hooton, Papa Kane, Walid Rashad, Moktar Abdillahi-Abdi, Julien Kapro	Updating document as required for final report.
3.0	[2024-10-21]	Fatmah Bayrli, Geoffrey Hooton, Papa Kane, Walid Rashad, Moktar Abdillahi-Abdi, Julien Kapro	Updated document for ELG4913 midterm progress report.

1.1.2 Executive Summary

This project was initiated as part of the Capstone course for Electrical Engineering at the University of Ottawa (ELG 4912 and ELG 4913). Our team plans to complete the design of a remote-controlled (RC) car that can detect life (humans buried in rubble after an earthquake or explosion) in cases where modern sensors would fail to do so. The final deliverable of this project will be submitted to the professor of the course as part of the fulfilment of course requirements. The main parties that will be impacted should this project be successful are organizations that specialize in disaster relief.

1.1.3 Authorization

Geoffrey Hooton

2024-10-21

Project Team Lead

Fatmah Bayrli

2024-10-21

Team Member

Walid Rashad

2024-10-21

Team Member

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Moktar Abdillahi-Abdi

2024-10-21

Team Member

Julien Kapro

2024-10-21

Team Member

1.2 Project Overview

1.2.1 Project Summary

1.2.2 Project Goals, Business Outcomes and Objectives

No.	Goals	Objectives	Business Outcomes
1.	Decrease hazard for first responders	Design an RC car capable of navigating through rubble and tight spaces, eliminating the need for first responders to enter a collapsed building.	Increased safety for first responders
2.	Disaster navigation efficiency	Utilize sensors and mapping technologies to allow the car to navigate through debris in a timely manner.	Faster navigation
3.	Improved search and rescue operations	Equip the car with life detecting technologies to detect people stuck under debris.	Increase survival rates after disastrous situations

1.2.3 Business Case:

- A **business case** typically justifies the investment in a project by addressing the financial, technical, and operational reasons for pursuing it.

- **Problem:**
  Current search and rescue operations expose first responders to hazardous conditions and are time-consuming.

- **Solution:**
  A remote-controlled car equipped with advanced sensors (LiDAR, thermal, and seismic) to detect life and map environments in disaster areas. This system can navigate dangerous terrain without risking human life.

- **Market Demand:**
  Increasing natural disasters globally (earthquakes, building collapses) highlight the need for safer, more efficient rescue tools. Search and rescue organizations are actively seeking solutions that improve safety and operational effectiveness.

Example: In recent years, the increase in natural disasters like wildfires, earthquakes, and hurricanes has created an urgent need for improved search and rescue tools. For example, during the 2023 earthquake in Turkey and Syria, traditional search and rescue efforts were hampered by unstable buildings and hazardous conditions, resulting in delays and increased risks to rescue teams. A solution like our RC Car, equipped with **LiDAR** and **thermal sensors**, could have been deployed to safely navigate rubble, map collapsed structures, and detect survivors more efficiently, speeding up rescue efforts while keeping responders safe. This growing need for safer, faster solutions in disaster response presents a significant opportunity for our product.

- **Financial Viability:**
  The automation of search tasks reduces personnel costs and speeds up rescue operations, resulting in significant cost savings for search and rescue organizations. The system's adaptability makes it suitable for multiple disaster scenarios, increasing its market potential.

Example: For financial viability, a concrete example would be the cost savings achieved by reducing the number of personnel and time required for search and rescue missions. Typically, deploying a large search and rescue team can cost between $10,000 to $50,000 per day, depending on the operation's scale and location.

By using our remote-controlled car, equipped with **LiDAR**, **thermal**, and **seismic sensors**, the number of personnel required on-site can be significantly reduced, as the car handles initial scouting and hazard detection. This could cut labor costs by 30-40%. Additionally, since the car can navigate disaster zones faster and more efficiently, it shortens mission times by 20-30%. For a typical 5-day mission, this could result in savings of up to $100,000 or more, while reducing risk to human lives. Thus, the upfront investment in our RC Car is quickly offset by the reduced operational costs, making it a financially sustainable solution for rescue organizations.

- **Competitive Advantage:**

Our solution integrates multiple technologies (LiDAR, thermal, and seismic sensors) into a single, rugged, portable platform, offering a unique combination of life detection and environmental mapping that current tools lack.

- **Social Impact:**

Reduces risk to first responders and increases the likelihood of saving lives, aligning with government and NGO goals of improving disaster response efficiency.

Example: A concrete example of the social impact of our RC Car would be its use during an earthquake. In a post-earthquake scenario, collapsed buildings often trap survivors, and traditional search and rescue teams face immense risks entering unstable structures. Using our RC Car, equipped with LiDAR, and thermal sensors, rescuers can quickly map the debris, locate trapped individuals by detecting their body heat, and assess the stability of the environment without putting human lives at risk.

This not only speeds up rescue efforts but also minimizes injuries to first responders. In previous earthquake situations, such as in Nepal in 2015 or Haiti in 2010, delayed responses due to unsafe conditions resulted in more casualties. With our RC Car, rescue missions can be executed faster, increasing the chances of saving lives and reducing risks for all involved. This aligns with the broader goals of disaster response organizations and governmental bodies, as it directly contributes to the protection of both responders and survivors.

1.2.4 Project Scope

1.2.4.1 Scope Definition

Our project encompasses the development of an R/C prototype vehicle intended to function as an innovative instrument for seismic rescue operations. With LiDAR technology, this vehicle can navigate through rubble and is specifically designed to function in situations where standard sensors would struggle. Its ability to detect life beneath the debris is improved with the addition of thermal imaging cameras and vibration-detecting sensors. The car's tracks provide better traction, and its concentration on flexibility to uneven terrain makes it a vital tool for search and rescue teams operating in disaster-affected areas.

1.2.4.2 Boundaries

See sections 2.2.1 and 2.2.2 in the Requirements section.

1.2.5 Milestones

No	Project Milestone	Description	Expected Date
1.	Create project proposal	The team worked together to pick the project topic.	2024-01-26
2.	Research Stage	In-depth research on necessary technologies and existing solutions.	2024-02-2
3.	Design	Selection and assembly of the RC car, sensors, and control station components.	2024-03-18
4.	Implementation	Implementation of hardware, onboard software, control software for hardware, remote control software.	2024-11-25
6.	Testing	Create specific test cases and do Simulation.	2024-12-5

1.2.6 Deliverables

The table below outlines the project deliverables. A description of each deliverable, an acceptance criterion, and a due date are mentioned:

Project Deliverable 1: Project Proposal
Description: Document outlining the description of the project.
Acceptance Criteria: Include enough general information with only high-level information and a brief plan.
Due Date: Jan 26, 2024
Project Deliverable 2: Midterm Presentation
Description: Presentation outlining the project goal, requirements, constraints, use case, design, budget, risk-management, and business case.
Acceptance Criteria: Follow the presentation requirements outlined on the course Brightspace page.
Due Date: Feb 15, 2024
Project Deliverable 3: Midterm Report

Description: Report outlining the project charter, system requirement specifications, conceptual design, work breakdown structure, schedule with milestones, and estimated budget, hazard identification and risk assessment, safety and risk management plan, and contribution list.
Acceptance Criteria: Follow the report requirements outlined on the course Brightspace page.
Due Date: Feb 29, 2024
Project Deliverable 4: Final Presentation
Description: Presentation outlining the project goals, business case, requirement specifications, detailed design, anticipated risks, proof of concept, test plan, schedule and budget outlook. Like the midterm report, but at the end of the course.
Acceptance Criteria: Follow the report requirements outlined on the course Brightspace page.
Due Date: March 28, 2024
Project Deliverable 5: Final Report
Description: Document outlining the project charter, system requirements specification, detailed design, updated Gantt chart, work breakdown structure, schedule with milestones and estimated budget, updated risk management plan, test plan, proof of concept, detailed contribution list, post-performance analysis, references, and code version control system. Like the midterm report, but at the end of the course.
Acceptance Criteria: Follow the report requirements outlined on the course Brightspace page.
Due Date: April 10, 2024
Project Deliverable 6: Midterm Progress Report
Description: Document outlining the project charter, system requirements specification, detailed design, updated Gantt chart, work breakdown structure, schedule with milestones and estimated budget, updated risk management plan, test plan, proof of concept, detailed contribution list, post-performance analysis, references, and code version control system. It's an updated version of our last semester Final report.
Acceptance Criteria: Follow the report requirements outlined on the course Brightspace page.
Due Date: October 21, 2024

1.2.7 Project Cost Estimation and Source of Funding

1.2.7.1 Project Cost Estimation

The following budget overview table outlines costs for various components necessary for the project.

Component	Costs
Slamtec RP LiDAR Sensor	$0.00
MLX90640 Thermal Camera	$100.21
Geophone SM-24	$87.68
Ultrasonic Sensor	$0.00
Servo Controller	$0.00
ON/OFF Switch	$0.00
Acrylic glass base with 3 pairs of wheels	$0.00
Battery 7.4V	$0.00

Voltage Regulator	$0.00
Servo Motor Driver	$0.00
Ethernet Cable(100ft)	$25.88
Onboard Computer (Raspberry Pi)	$0.00
ADS1115 ADC	$20.32
Software simulation environment	$0.00
Total	**234.09**

The estimated budget for the RC car development project encompasses all critical phases including project initiation, design, and development, and testing and refinement. This comprehensive financial plan is designed to ensure that all necessary resources and materials are adequately funded to achieve project objectives without unnecessary overspending.

The total estimated budget for the RC rescue car development project is $237.93. This budget is meticulously planned to cover all phases of the project, from initial planning and design to comprehensive testing and final refinements. The allocation of funds is carefully considered to balance the need for quality and efficiency with cost-effectiveness. Regular budget reviews and updates will be essential to manage expenses effectively and adapt to any changes in the project scope or requirements. This financial planning aims to ensure the successful completion of the project within the allocated budget, maximizing value while minimizing unnecessary expenditures.

1.2.7.2 Source of Funding

Our project's funding will be jointly contributed by our group. We have agreed to share the financial responsibilities equally, ensuring that all necessary materials and resources for our project are covered.

1.2.8 Dependencies

Our project does not currently have any dependencies but may have some in the future.

Dependency Description	Critical Date	Contact
N/A	N/A	N/A

1.2.9 Project Risks, Assumptions, and Constraints

1.2.9.1 Risks

No.	Risk Description	Probability (High, Medium, Low)	Impact (High, Medium, Low)	Residual Risk Level	Planned Mitigation
1.	Laser Hazards	Low	Low	low	Avoid looking directly at laser for a prolonged period
2.	Battery Depletion	high	High	Medium	Ensure batteries are fully charged prior to use
3.	Loss of Connection	High	high	Medium	Verify communication protocol efficiency and test stability
4.	Sensor Malfunction	Medium	High	Low	Integrate ROS with multiple sensors for redundancy
5.	Navigation Mistakes	Medium	High	Medium	Calibrate and test navigation systems using ROS
6.	Group Member Sick	High	Medium	Low	Shift work to others
7.	Data integrity issues	Medium	Medium	Low	Encrypt all data transmitted via I2C using ROS security packages. Set up local backup systems that periodically sync with the main data repository to prevent data loss.
8.	Critical Components failure (e.g servo motor,	Medium	High	Low	Select high-reliability components tested for compatibility with ROS. Set up ROS-based telemetry to monitor real-time performance and predict failures before they occur.

1.2.9.2 Assumptions

No.	It is assumed that:
1.	All members can shoulder an equal portion of the funding
2.	Workstation is available upon demand
3.	All required materials are available when needed
4.	Documentation and support online should cover conception challenges
5.	Feedback will be available on project updates

1.2.9.3 Constraints

No.	Category	Constraints
1.	Deadlines	- Reports and presentations
2.	Work Location	- Exclusively in the Lab
3.	Legal	- No copyright infringement
4.	Finance	- Taxes and inflation
5.	Program Restrictions	- Project must involve electrical engineering elements

1.2.8.4 Legal Compliance and Risk Management for RC Car Project

The RC car project must strictly follow environmental regulations related to battery usage during testing phases to ensure adherence to current laws and promote ecological sustainability. Aside from environmental issues, the project needs to comply with all relevant mechanical and electrical safety standards. This is vital not only for preventing accidents but also for protecting the students involved in the project. Regular safety audits will be performed to uphold compliance and guarantee continuous safety. Furthermore, a comprehensive evaluation of potential liabilities arising from malfunctions is essential. This entails implementing strict testing protocols and incorporating emergency stop features to effectively reduce any risks. Keeping accurate records of all project modifications and approvals is also required. Such documentation is crucial for ensuring transparency, aiding legal compliance, and allowing the project to move forward without encountering legal barriers.

1.3 Project Organization

1.3.1 Project Governance

Decisions for the project will be collectively determined through group consensus. When a decision is required, the team will convene to find a solution, either through a democratic vote or mutual agreement. Additionally, our group leader will act as the primary source for communication with our professor, teaching assistant, and technician, ensuring streamlined and effective coordination.

1.3.2 Project Team Structure

Our project team consists of a team leader and five other group members. All members contribute equally to decisions made for the project, and the team leader will help guide the decisions and mediate in such a way that the team can come to a consensus on decisions.

1.3.3 Roles and Responsibilities

	Project Role					
	Team Leader	Group Member				
Responsibilities	• Team management • Conflict resolution, planning, • Keeping pace with schedule • All other responsibilities of a “Group Member”	• Participating in labs • Communicating progress on assigned work documenting work • Contributing to the schedule regularly • Creating test plans for prototypes • Updating SRS regularly • Assisting in testing and documenting results • Updating budget				
Assigned to	Geoffrey Hooton	Fatmah Bayrli	Papa Kane	Walid Rashad	Julien Kapro	Moktar Abdillahi-Abdi

1.3.4 Project Facilities and Resources

All facilities used to create our prototypes will be provided by the University of Ottawa. This includes lab spaces, classrooms, etc. No work involving lab equipment will be done at home. If, for example, soldering is required at any point for the project, the group will use the faculty of engineering’s laboratory soldering stations. Some resources for the project will also be provided by the university. These resources will be discussed with the lab technician prior to use and signed out appropriately. Once the project has finished, these resources will be returned to the University of Ottawa.

1.4 Project References

[1] T. Huang, “RPLIDAR-A3 Laser Range Scanner_ robot laser range scanner,” SLAMTEC, https://www.slamtec.com/en/lidar/a3 (accessed Oct. 20, 2024).

[2] “MLX90640 thermal camera breakout,” PiShop.ca, https://www.pishop.ca/product/mlx90640-thermal-camera-breakout/ (accessed Oct. 20, 2024).

[3] M. #90138 and M. #1435539, “Geophone - SM-24, with insulating disc,” SEN-11744 - SparkFun Electronics, https://www.sparkfun.com/products/11744 (accessed Oct. 20, 2024).

[4] “1-48 of over 2,000 results for ‘servo+controller’ sort by: Featured price: Low to high price: High to low avg. Customer Review Newest Arrivals Best Sellers Sort By:featured go,” Amazon.ca : servo+controller, https://www.amazon.ca/s?k=servo%2Bcontroller&hvadid=604602885586&hvdev=c&hvlocphy=9000682&hvnetw=g&hvqmt=e&hvrand=2628889066026886449&hvtargid=kwd-297828339961&hydadcr=1503_13517072&tag=googcana-20&ref=pd_sl_4daf10fesk_e (accessed Oct. 20, 2024).

[5] V. Mazzari, “Lidar integration with ROS: Quickstart Guide and Projects Ideas,” Génération Robots - Blog, https://www.generationrobots.com/blog/en/lidar-integration-with-ros-quickstart-guide-and-projects-ideas/?srsltid=AfmBOoq_WMHLZ1bdY-M53TMPA4H9bkithk156MEiX9Mjxu0lkpdQgBCb (accessed Oct. 20, 2024).

[6] “1-48 of 754 results for ‘rc+battery+7.4v’ sort by: Featured price: Low to high price: High to low avg. Customer Review Newest Arrivals Best Sellers Sort By:featured go,” Amazon.ca : rc+battery+7.4v, https://www.amazon.ca/rc-battery-7-4v/s?k=rc%2Bbattery%2B7.4v (accessed Oct. 20, 2024).

[7] “1-48 of over 2,000 results for ‘ethernet+cable+100ft’ sort by: Featured price: Low to high price: High to low avg. Customer Review Newest Arrivals Best Sellers Sort By:featured go,” Amazon.ca : ethernet+cable+100ft, https://www.amazon.ca/s?k=ethernet%2Bcable%2B100ft&hvadid=604602884800&hvdev=c&hvlocphy=9000682&hvnetw=g&hvqmt=e&hvrand=9144125791765948724&hvtargid=kwd-302309428951&hydadcr=1528_13517070&tag=googcana-20&ref=pd_sl_18zkois3ih_e (accessed Oct. 20, 2024).

[8] “ADS1115,” ADS1115 data sheet, product information and support | TI.com, https://www.ti.com/product/ADS1115?utm_source=google&utm_medium=cpc&utm_campaign=asc-null-null-GPN_EN-cpc-pf-google-ww_en_cons&utm_content=ADS1115&ds_k=ADS1115&DCM=yes&gad_source=1&gclid=CjwKCAjw1NK4BhAwEiwAVUHPUBfMPAQQYVVCJPeKoIiNkxNzGte81uqPS7Xn-xBZI-K4vvSWJsoBZxoCKFoQAvD_BwE&gclsrc=aw.ds (accessed Oct. 20, 2024).

1.5 Glossary and Acronyms

Terms, Acronyms, abbreviations	Definitions
RC	Remote Controlled
WBS	Work Breakdown Structure
GPR	Ground Penetrating Radar
LWIR	Long-Wave Infrared
LiDAR	Light Detection and Ranging

2. System Requirement Specification

2.1 Introduction

Due to the limits of current sensors, recovering victims trapped beneath collapsed structures following earthquakes is a difficult task. Our project focuses on creating a cutting-edge remote-control prototype car to address this important issue. This vehicle is designed to maneuver through the intricate structures of fallen buildings, where traditional sensors might become unreliable. Our remote-controlled vehicle (RC car) incorporates cutting-edge technologies including LiDAR, vibration-sensing sensors, and thermal imaging cameras to facilitate efficient search and rescue missions in difficult terrain.

2.2 Scope

2.2.1 Will Do:

1. Implement a user interface for remote control on a central computer (laptop).
2. Provide an intuitive remote-control UI with easy steering and acceleration controls.
3. Display a detailed, real-time 2D map of the vehicle's surroundings for navigation.
4. Ensure reliable communication of sensor data to the operator.
5. Detect human movements/vibrations underground.
6. Detect heat signatures underground.
7. Design a rugged and durable car.
8. Enable navigation in constrained environments and over uneven terrain.

2.2.2 **Implement a reliable Rocker-Bogie suspension/chassis (~~Utilize tracks for improved traction on irregular surfaces~~)**

2.2.2 Will Not Do:

1. Detailed mapping of the entire collapsed structure (focus on immediate surroundings).
2. Interaction with objects other than detecting signs of life.

2.2.3 Assumptions:

- The car's design will incorporate a remote emergency shut-off mechanism.
- The vehicle will have a physical on/off switch and a start command on the central computer.
- The system will be portable and easily deployed to support ongoing rescue efforts.
- The RC car will be properly grounded to eliminate the possibility of sparking.
- The car's chassis will include emergency lighting LEDs for enhanced visibility.
- The vehicle's design will adhere to Canadian safety standards for electrical and material safety.

2.3 Characteristics of the RC Car:

The functional and non-functional features of the radio-controlled car define its capabilities. Its functionality includes a basic remote-control interface that makes steering and acceleration straightforward. While real-time 2D mapping facilitates navigation across terrain, robust conveyance of sensor data back to the operator increases overall efficacy. Among other non-functional characteristics, servo motor control and decreased latency in UI map refreshes provide real-time responsiveness. The system's minimum 3-hour battery life, high accuracy human presence detection, and adherence to safety rules are indicative of its robust design and performance.

2.4 Overall Description:

The challenges faced in earthquake rescue missions are the source of the RC car's general design and objective. Detection of vital signs and advanced sensor technologies for effective navigation through debris are among its capabilities. The car's robust design and adaptability to various terrain types ensure its dependability under demanding circumstances. Strict specifications, including safety features, portability, and compliance with Canadian safety regulations, highlight our commitment to creating an automobile that not only meets the highest performance standards but also prioritizes the safety of rescue personnel and the successful completion of ongoing missions.

2.5 Functional Requirements:

1. **User Interface:** The RC car's functional requirements emphasize an intuitive user interface accessible from a central computer (laptop) for remote control, ensuring ease of operation for steering and acceleration.
2. **Real-time 2D Map:** A significant characteristic is the ability to provide the operator with a detailed, real-time 2D map of the car's surroundings, enhancing navigation through terrain.
3. **Reliable Sensor Communication:** The system is characterized by its capability to reliably communicate sensor data to the operator, enhancing the overall effectiveness of the RC car.
4. **Detection Capabilities:** The RC car is designed to detect human movements/vibrations and heat signatures underground, showcasing its adaptability for search and rescue operations.
5. **Durability and Navigational Adaptability:** Ruggedness and adaptability to navigate constrained environments and uneven terrain are essential characteristics, ensuring the RC car's robust performance.

2.6 Non-Functional Requirements

1. **Latency Considerations:** A 2D UI map will update with a latency of no more than 500ms.
2. **Latency Considerations:** The operator can control the car's servo motors with a latency of less than 30ms.
3. **Latency Considerations:** Sensor data will be transmitted with a latency of at most 30ms.

4. **Accuracy in Human Presence Detection:** The system should exhibit high accuracy (at least 95%) in detecting human presence, highlighting its reliability in critical scenarios.
5. **Power and Battery Management:** The RC car's non-functional aspects encompass power-related characteristics, such as being powered by a 7.4V battery ensuring sustained operation.
6. **Power and Battery Management**: The battery life should be at least 3 hours.
7. **Compact Size and Terrain Traction:** The car's size (smaller than 20cm in width and 15cm in height) and the inclusion of tracks contribute to its non-functional characteristics, providing compactness and improved traction on uneven terrain.

2.7 Constraints

1. The car's design will incorporate a remote emergency shut-off mechanism.
2. The vehicle will have a physical on/off switch and a start command on the central computer.
3. The system will be portable and easily deployed.
4. The RC car will be properly grounded to eliminate the possibility of sparking.
5. The car’s chassis will include emergency lighting LEDs for enhanced visibility.
6. The vehicle’s design will adhere to Canadian safety standards for electrical and material safety.

To summarize, this System Requirements Specification (SRS) provides detailed information about a new remote-controlled prototype automobile designed for earthquake rescue operations. The car is made to maneuver around obstacles in collapsed structures using thermal imaging cameras, vibration-detecting sensors, and LiDAR technology. The functional requirements prioritize dependable sensor data delivery to a central computer, real-time 2D mapping for navigating terrain, and an intuitive remote control user interface. Non-functional criteria emphasize tiny but efficient design, low latency, and excellent detection accuracy. Some limitations are emergency shut-off systems, transportability for quick deployment, and compliance with Canadian safety laws. In summary, the SRS establishes a solid foundation for the development of a technologically advanced, agile remote-controlled vehicle which will be a crucial component of efficient and secure earthquake victim rescue efforts.

Some notable changes include the change from the traditional tracks to the famous “Rocker-Bogie” suspension system to minimize shaking during operation on irregular or rough terrain. In addition, the thermal camera has been swapped for a more affordable one.

Figure: Primitive Chassis designed in ELG4912 vs advanced chassis designed in ELG4913

3. Detailed Design

3.1 Objective

This section will provide a detailed view of the system hardware and software architecture along with component choices and possible alternatives.

3.2 Components Overview

3.2.1 Vehicle Breakdown

This section outlines the components that will be included on the vehicle. This includes the vehicle's key features and control systems.

3.2.1.1 Vehicle Breakdown Summary

Component	Purpose	Proposed Component	Possible Alternatives
LiDAR Sensor	2D mapping of the vehicle's environment.	Slamtec RPLIDAR	Benewake TF-Luna 8m LiDAR Distance Sensor
Thermal Imaging Camera	Detecting buried heat signatures (life detection).	MLX90640 Thermal Camera	FLIR Lepton LWIR Micro Thermal Camera Module
Ground Penetrating Radar	Detecting underground vibrations (life detection).	SM-24 Geophone	Infineon XENSIV™ 60GHz Radar
Servo Motor Driver	Controlling the servos attached to the car's wheels/tracks.	PCA9685 16-Channel 12-bit PWM Servo Driver	L9110S DC Stepper Motor Driver Board H Bridge 4 channel drive DC motor drive board motor drive

Onboard Computer	Sensor data processing and servo control.	Raspberry Pi 4 Model B	Jetson Nano, VisionFive2
ON/OFF Switch	Physical option for powering on and off vehicle.	- A basic Rocker or slide switch	-
Chassis	Housing sensors, Raspberry Pi, wheels/tracks, and servos.	See 3.2.8	-
Ethernet Cable	Long range serial communication	Generic 100-meter ethernet cable	-

Table 3.2.1.1.1: Vehicle Breakdown Summary

3.2.1.2 LiDAR Sensor

The LiDAR sensor will provide real-time, two-dimensional mapping of the search area. The generated map will be presented to the operator, who will use it to navigate. We have chosen Benewake TF-Luna 8m LiDAR Distance Sensor because it provides an accurate and stable detection range of 8m, as well as adapting multiple adjustable configurations and works well in the complex scenarios our project demands.

A possible alternative LiDAR sensor would be the Slamet RPLIDAR, however the high cost makes it a more difficult choice for our project. In future designs, investing in a higher precision LiDAR sensor like the Slamet RPLIDAR could be a strong choice.

3.2.1.3 Thermal Imaging Camera

For life detection, we decided to use the MLX90640 Thermal Camera due to its convenient interface, and expansive community support/documentation. This thermal camera also offers a wide-lens model which will allow us to see thermal data for a wider area to better notice heat signatures.

A possible alternative to the MLX90640 is the FLIR Lepton LWIR thermal imaging camera. This camera is often preferred to a normal thermal camera because the longer wavelengths leveraged by the camera have a stronger possibility of detecting heat through surfaces. Unfortunately, the FLIR Lepton is significantly outside the project budget.

3.2.1.4 Ground Penetrating Radar (GPR)

Ground penetrating radars are popular choices for detection of underground bodies. There is currently significant research using GPRs to detect human remains in cemetery graves. GPRs can detect both stillness and motion with strong anti-interference abilities. The radar that we decided on is the SM-24, which supports serial input and output control.

A possible alternative to the SM-24 geophone is the Infineon XENSIV™ 60GHz Radar, however similarly to the LiDAR sensor, the high cost makes it difficult to justify for our project. The Infineon radar sensor specializes in power efficiency within a small form factor, and should another, higher-budget iteration of our project come to fruition, it would be a great choice for the GPR.

3.2.1.5 Servo Motor Driver

The PCA9685 servo controller can manage up to 16 servos with precise movement which will easily allow the operator to control the car’s tracks for navigation. This component was selected due to its popularity and ease of purchasing online from Adafruit. That said, there are many great options for servo controllers and any other reliable servo controller, like the L9110S DC Stepper Motor Driver, could be used.

3.2.1.6 Raspberry Pi

The Raspberry Pi 4 Model B is a powerful and cost-effective microcontroller that can handle tasks including controlling sensors in real time. The Raspberry Pi 4 is the most popular version in the Raspberry Pi series and offers easily enough computing power for our application. It is widely used by professionals and hobbyists alike and offers plenty of documentation online to help in the project implementation. The Raspberry Pi supports four serial ports, which is perfect for our three primary sensors. A possible alternative for the onboard computer could be the Jetson Nano or VisionFive2, however the accessibility and cost to performance ratio of the Raspberry Pi 4 is unmatched.

3.2.1.7 ON/OFF Switch

An on/off switch is a component that can control the power supply to the vehicle’s electronic system. This will serve as an additional level of redundancy while powering on the vehicle to ensure safety.

3.2.1.8 Chassis

A large chassis (pictured in *Figure 3.2.1.8.1*) capable of housing up to six wheels, the Raspberry Pi, six servo controllers, and the vehicle’s three sensors has been obtained from the University. This is what our prototype will be built on.

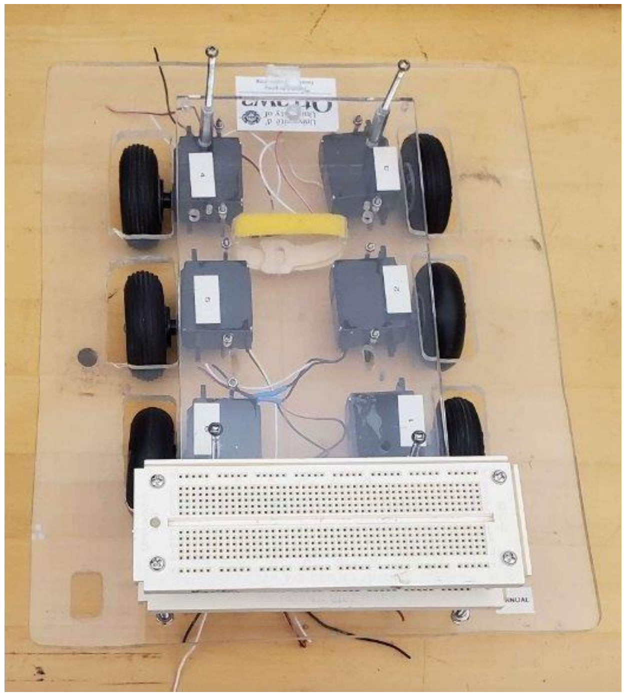


Figure 3.2.1.8.1 Chassis Obtained from the University

3.2.1.9 Ethernet Cable

A 50m ethernet cable will be sufficient to give a long enough range for the RC car, while still permitting communication without loss of data.

3.2.2 Power System Summary

This section outlines the components that will be included in the system's power system. These components are crucial for powering all the car's sensors/computers/motors.

3.2.2.1 Power System Breakdown Summary

Component	Purpose	Proposed Component	Possible Alternatives
Battery 7.4V	Supplying power to the system.	Generic 18650 Li-ion battery Pack	NiMH battery pack
Voltage Regulator	Maintaining consistent voltage to the vehicle's components.	L7812CV voltage regulator	-
Servo Motor Driver	Controlling power supplied to the servo motors	PCA9685 16-channel 12 bits PWM Servo Driver	L9110S DC Stepper Motor Driver Board H Bridge 4 channel drive DC motor drive board motor drive

Table 3.2.2.1.1: Power System Breakdown Summary

3.2.2.2 Battery 7.4V

The rechargeable battery we will use is a generic 18650 Lithium-ion battery with 7.4V. This is a good choice because it offers a high-capacity lithium battery with integrated protection while charging or discharging. This prevents overcharging, extending the battery's lifespan. A viable alternative is the NiMH battery pack which undergoes rigorous testing to ensure quality. The trade-off is that these battery packs are much more expensive.

3.2.2.3 Voltage Regulator

The L7812CV is a fixed-output voltage regulator that can output anywhere from 5V to 18V. In our design, this regulator will help us step down the battery voltage to 5V to power the Raspberry Pi. The L7812CV is very robust and is designed to handle input voltages up to 35V and deliver up to 1.5A of current. It is a popular choice because it is reliable and easy to use. The L7812CV is favored for its straightforward application, availability, and affordability, making it a constant 12V supply.

3.2.2.4 Servo Motor Driver

See 3.2.1.5

3.3 System Architecture

3.3.1 ***Hardware Architecture***

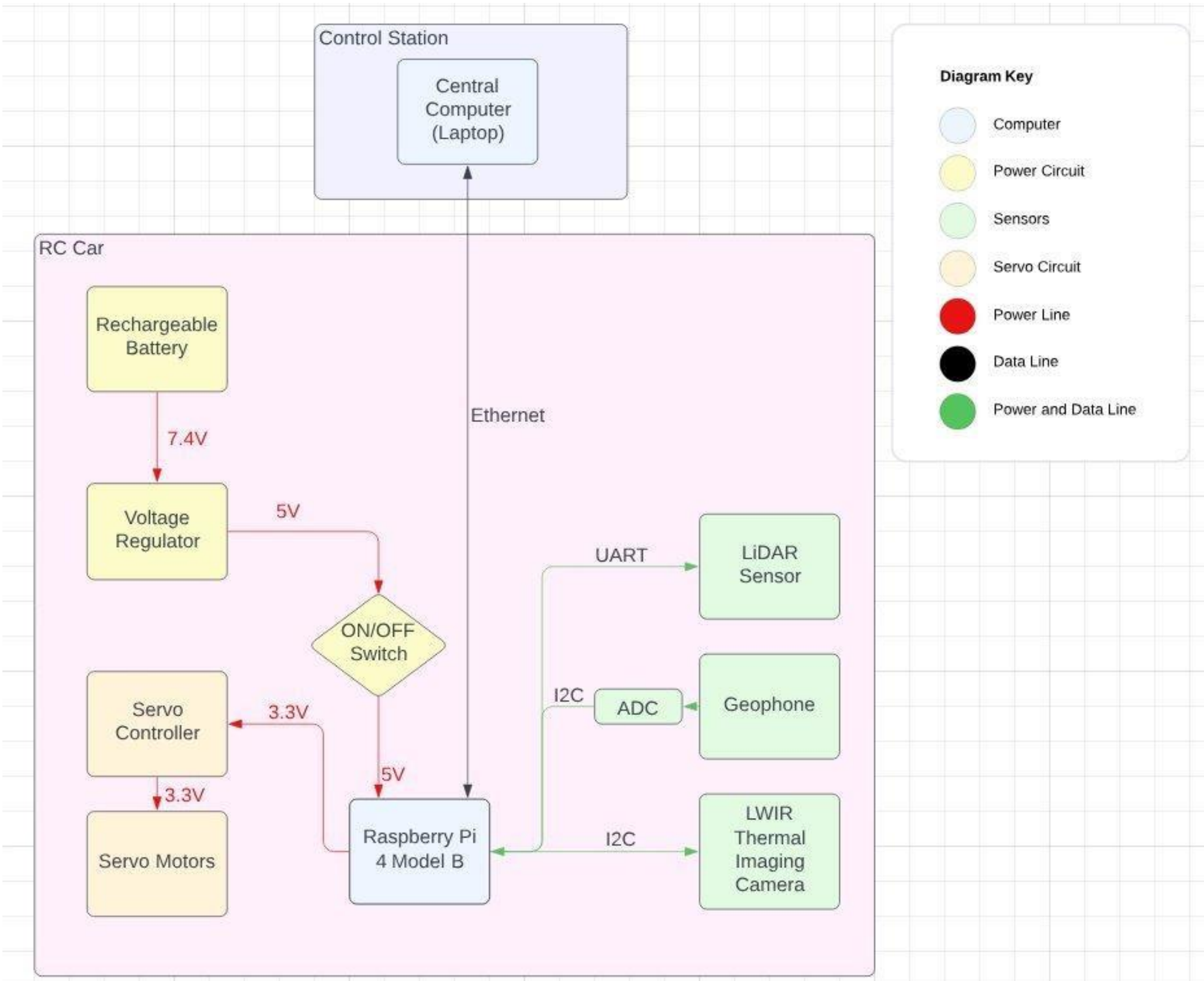


Figure 3.3.1.1 Hardware Architecture

The above block diagram outlines a high-level view of the hardware architecture given the components listed in sections 3.2.1 and 3.2.2. The system will rely on ethernet communication between the central computer (laptop) and Raspberry Pi, and a mixture of I2C and UART between the Raspberry Pi and external sensors. The serial protocols are outlined in *Figure* **3.3.1.1** above. The servo motors and sensors will all be powered by the Raspberry Pi. To ensure a long battery life and low power losses, the vehicle will be powered by an onboard 7.4V. The battery will directly power the Raspberry Pi after being stepped down to 5V using a voltage regulator. Previously in the midterm report we had intended to power the central computer and Raspberry Pi microprocessor using a larger centralized battery, however after speaking with the lab technician, concerns were raised about potential power losses when trying to transmit power over a long, wired connection from the control station to the vehicle. Another change suggested by the lab technician was removing the battery management system which was deemed unnecessarily complex for a prototype.

3.3.2 Software Architecture

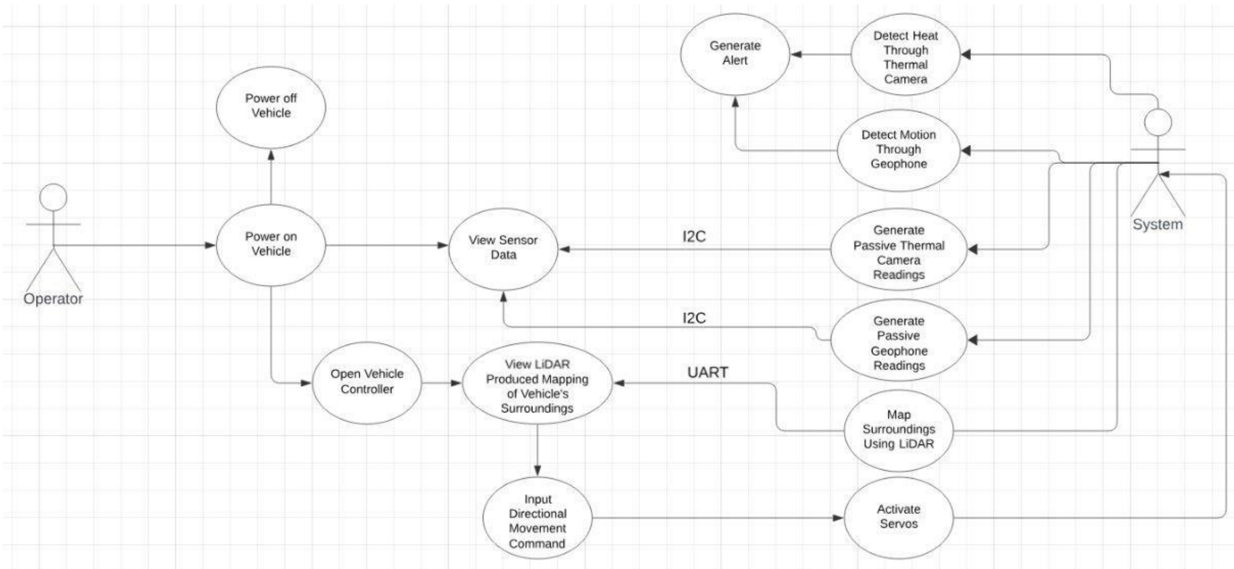


Figure 3.3.2.1 Software Use Case Diagram

The software for our project will be written in Python and will be very basic. The main purpose of the software in our project is to tie together the sensor data into a single application with some additional alert features if the sensor picks up any unusual values. The software should also give a basic user interface for control of the servo motors. The functionalities of the software are displayed in the use case diagram depicted in *Figure 3.3.2.1* above. The operator will log into the central computer (likely to be a laptop), after which they will be able to power on and off the vehicle, view LiDAR/Thermal Camera/Ground Penetrating Radar sensor data and open the vehicle controller. The vehicle controller will present the operator with a 2D map of the vehicle's surroundings generated by LiDAR visualization software (see section 3.4). In this view, the operator can also input directional movement commands, which will send commands to the Raspberry Pi to activate the servo motors. On the system's side, the onboard sensors will be passively generating readings that will be displayed to the operator at their request. If, however, the system detects abnormal readings through its sensors (high temperature/significant movement), the system will generate an alert, which will be presented to the operator. It will be up to the operator's best judgement whether to act on the alerts presented.

3.4 LiDAR Visualization Software

When it comes to available open-source software that can create real-time LiDAR maps of a sensor's surroundings, we will be using ROS2 and RVIZ

3.5.1 RVIZ and ROS: https://github.com/ros-visualization/rviz

RVIZ is a graphical interface that allows real-time visualization of sensor data including LiDAR sensor data. RVIZ operates on the Robot Operating System (ROS) framework, an open-source software used widely in the robotics industry among hobbyists and professionals. RVIZ is a good option for our project because of its community support and online documentation. RVIZ paired with ROS2 will be useful for other aspects of the project's implementation.

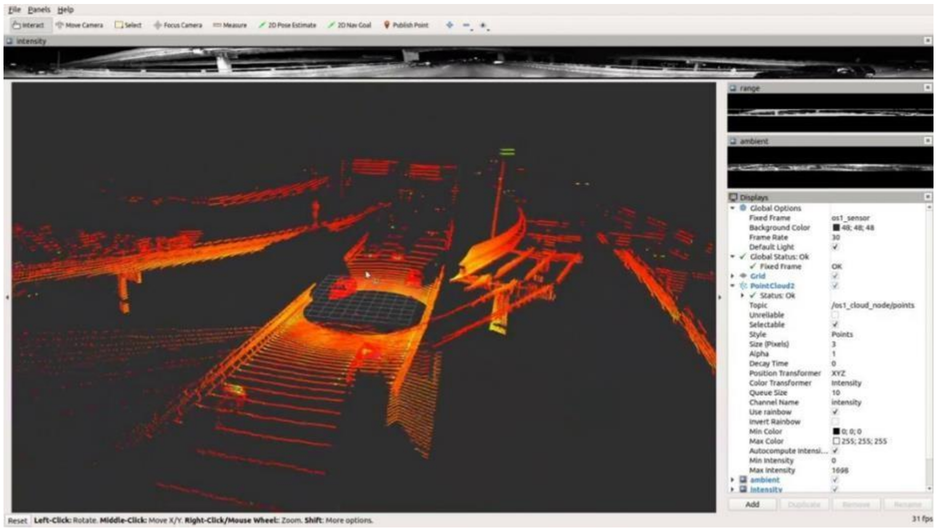


Figure 3.5.2.1 LiDAR Produced Map Using RVIZ [11]

3.6 Safety Considerations in Design

Considering how the primary goal of our RC car is for it to operate in disaster zones, there are many safety aspects of the design that should be taken into consideration. One important consideration is that the final design of the vehicle should be portable and easily deployed. This is important as to not impede ongoing rescue efforts or endanger rescue personnel working in the affected areas. Additionally, to increase safety and visibility in chaotic environments, the car will be equipped with hazard LEDs. In case the vehicle ends up in a compromising position, or is damaged such that its mobility is compromised, the controller on the central computer will have an emergency shutdown button that will halt all power to the vehicle. Furthermore, to avoid accidents and injuries during deployment, the car will have a physical ON/OFF switch as well as a software power-up button. The vehicle will not start unless both have been toggled on. This provides two layers of redundancy and will hopefully reduce the possibility of accidental power-ups. Finally, to ensure a basic level of safety, the vehicle will adhere to all Canadian IEEE and CSA safety standards for electrical and material safety.

UI Design Integration with ROS and LiDAR

1. Data Visualization

LiDAR Point Cloud Representation: Leverage ROS to process and display LiDAR data as a 3D point cloud or a 2D map within the user interface. This visualization assists operators in observing the car's surroundings in real-time, enhancing navigation and obstacle avoidance.

ROS enables real-time updates of the LiDAR data displayed in the UI. The interface can continuously showcase the latest environmental details.

2. Map Integration

Mapping and Positioning: Employ ROS to execute SLAM (Simultaneous Localization and Mapping) using LiDAR data. The user interface can then exhibit this map to enhance situational awareness, indicating where the car has traveled and its current position relative to the mapped area. Interactive Map Options: Permit users to engage with the map (e.g., zooming, panning, setting waypoints) directly within the UI. Such interactivity is crucial for planning paths or missions directly from the control dashboard.

3. Control and Command Interface

Sensor Configuration: Offer UI components to modify the LiDAR sensor settings via ROS, such as changing the scan range or frequency. This can be accomplished through sliders, dropdown menus, or text input fields in the interface. Command Status: Present the status and feedback from ROS regarding the commands issued to the car, including movement instructions or other sensor adjustments. This might encompass success notifications, error messages, or real-time status indicators.

4. Current Project Progress

4.1 Progress Overview

4.1.1 Completed Tasks

Below is a summary of the project tasks that have already been completed.

- Ordered/Received components
- Raspberry Pi dev environment
- Built battery circuit
- Initial thermal camera test
- Initial LiDAR test
- Initial Geophone test
- First iteration of data acquisition system
- Design of vehicle suspension

4.1.2 Tasks to be Completed

Below is a summary of the project tasks that need to be completed.

- Integrate all sensors with Raspberry Pi simultaneously
    - Code
    - Circuit (I2C components must be connected on the same line)
- Controlling vehicle motors with Raspberry Pi
- Continue building chassis
- Design UI for controlling the vehicle and integrate with motors

- Integrate sensors with ROS2
- Allows us to transmit data from Raspberry Pi to main computer using ethernet (ROS2)
- Continue developing data acquisition system for all sensors

4.1.3 Task Distribution

Table 4.1.3 outlines what tasks group members have already completed and what they are working on next.

Table 4.1.3 Team Task Distribution

<table>
<tr><th>Group Member</th><th>Tasks Completed</th><th>In Progress/Next Task</th></tr>
<tr><td>Moktar</td><td>Power circuit
Progress Review Presentation
Introduction
Project Goal
Customer and how/ where is the project used?</td><td>Controlling motors
Simultaneous sensor integration</td></tr>
<tr><td>Papa</td><td>Suspension Optimization
Progress Review Presentation
Introduction
Business Case
WBS, Schedule</td><td>Chassis Design
Vehicle Controller/UI
Suspension and wheel design</td></tr>
<tr><td>Fatmah</td><td>LiDAR Initial Test
Progress Review Presentation
Risk Analysis Plan
Legal Team Approval Status
Test Plan
LiDAR/ROS Integration Summary</td><td>ROS2 Development
Vehicle Controller/UI</td></tr>
<tr><td>Walid</td><td>Rocker-Bogie Suspension Design
Progress Review Presentation
Requirement Specification</td><td>Chassis Design
Vehicle Controller/UI</td></tr>
<tr><td>Julien</td><td>Temperature data analysis and storage in CSV files
Progress Review Presentation
Schedule and Budget Outlook
Data Acquisition System Demo</td><td>Further developing data analysis tools</td></tr>
<tr><td>Geoffrey</td><td>Raspberry Pi Dev Environment
LiDAR Initial Test
Thermal Camera Initial Test
Geophone Initial Test
Progress Review Presentation
Progress Overview
Sensor Demos</td><td>Simultaneous sensor integration
ROS2 Integration</td></tr>
</table>

4.2 Sensor Progress

Initial implementations for each of the three sensors were created to determine that each sensor was working correctly and to determine how data is presented in each case. As the project progresses, these initial surveys of the sensors will be extended to more properly match our use case. Particularly our sensors will send data to the Raspberry Pi computer where some light analysis will occur, after which the data will be sent off to the primary computer to be displayed.

4.2.1 Thermal Camera

An initial test was conducted which includes connecting the I2C thermal camera to the correct pins on the Raspberry Pi computer. The setup can be seen in *Figure 4.2.1.1* Using the PiThermalCam python library, a live thermal video of the camera's view was displayed on the Pi. An example image can be seen in *Figure 4.2.1.2*.

Figure 4.2.1.1 Thermal Camera Setup with Raspberry Pi Over I2C

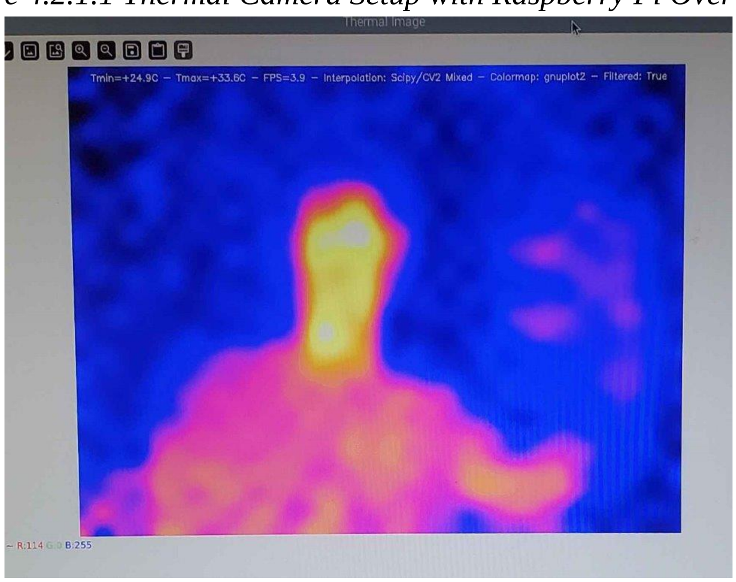


Figure 4.2.1.2 Example Thermal Image from MLX90640 Thermal Camera Using the PiThermalCam Library

At the top of the image, some statistics are displayed including the temperature of the hottest pixel and of the coldest pixel. The PiThermalCam library also allows us to toggle interpolation on and off and offers a variety of colormaps.

4.2.2 LiDAR

An initial survey was also conducted for the Slamtec RPLidar. This test was set up by following the instructions and tests provided by the manufacturer. This allowed us to use the LiDAR to scan the room it was located in and generate an accurate 2D map of its surroundings. An example image can be seen in *Figure 4.2.2.1*. The configuration for this test simply involved connecting the LiDAR to a Windows computer using a USB cable.

Figure 4.2.2.1 Example 2D Recreation of Room Using the Slamtec RPLidar

This test configuration can accurately track movement in real time and was able to accurately track movement of people and objects around the room. The downside to this test is that it is being run on a different operating system than it will be in the final product. Ideally the map will be produced using ROS2 and RVIZ, however we are still working on setting up ROS2. In future we will create a similar interface in order to allow the LiDAR to map its surroundings using ROS2 running on the Raspberry Pi computer.

4.2.3 Geophone

A geophone test was run successfully on the Raspberry Pi computer. Using I2C connections, we were able to produce live data of the geophone's data. The setup can be seen in *Figure 4.2.3.1*. The sensor was able to successfully detect ground vibrations and plot them in real time. An example plot can be found in *Figure 4.2.3.2* below. Smaller spikes represent footsteps while the large spike is the consequence of a person jumping. The code for this geophone project was provided by Core Electronics and can be found at the following link: https://core-electronics.com.au/guides/geophone-raspberry-pi/.

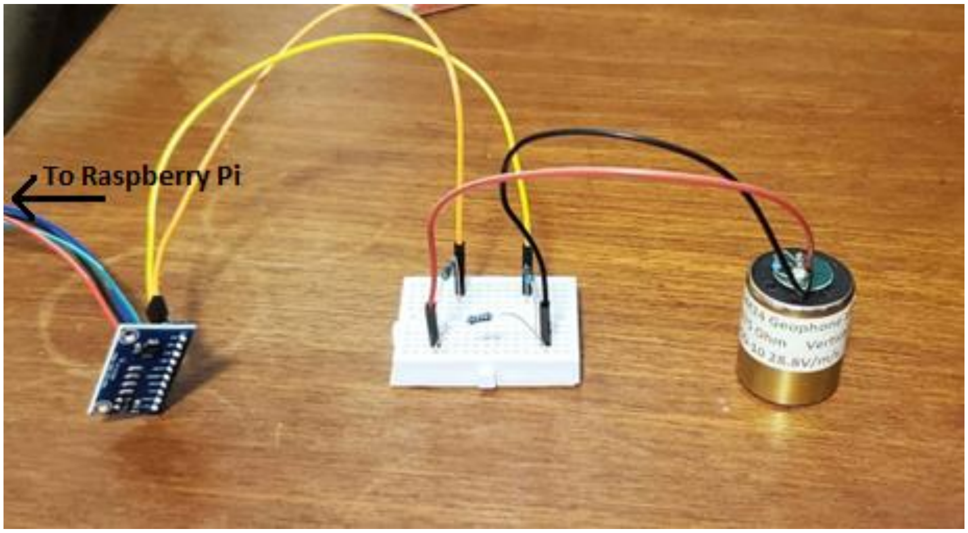


Figure 4.2.3.1 Geophone Test Setup

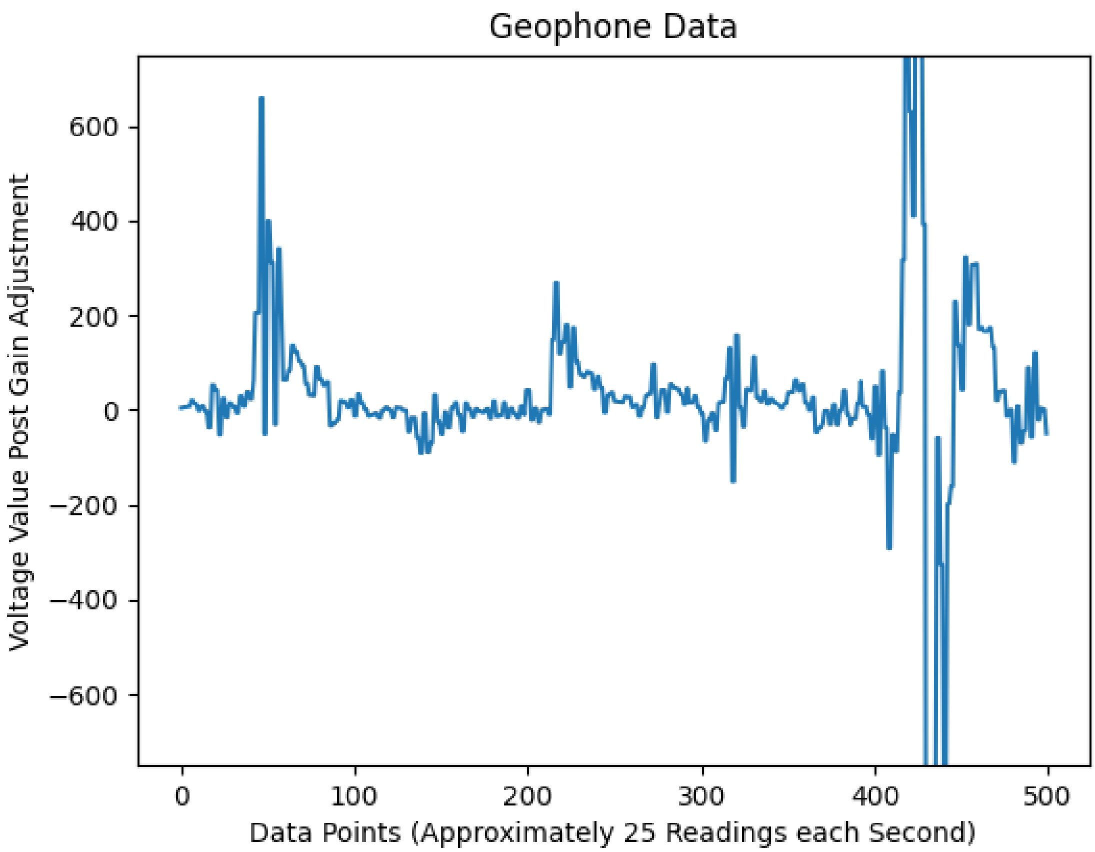


Figure 4.2.3.2 Example Geophone Output

4.2.4 Data Acquisition System (DAQ)

We have completed the first iteration of the data acquisition system (DAQ). This DAQ aims to collect and store data, but also to process and analyze the data in real time using python scripts and an analog to digital converter to provide immediate feedback, such as temperature readings and heartbeat recognition. This real-time data manipulation allows for faster human life recognition. Our DAQ will enable the driver to navigate the RC car more efficiently with the temperature readings collected from the thermal camera frame, helping the driver to avoid fire hazards, and guiding the car toward detected frequency signals, such as heartbeats, with data collected from the geophone.

Currently we only have the DAQ functionality for the thermal camera sensor. Our DAQ collects the average temperature of the frame every 5 seconds and outputs it to a CSV file with a message. This message notifies the operator if there may have been a human detected, which would prompt the operator to go further in that direction, or it notifies the operator of a potential fire ahead, letting them know to avoid going any further in that direction.

```python
#Thermal Cam DAS

import pithermalcam as ptc
import csv
import time
import board
import busio

#Need to initialize the camera connected to the i2c bus
i2c_bus = busio.I2C(board.SCL,board.SDA,frequency=800000)
mlx = ptc.pi_therm_cam.adafruit_mlx90640.MLX90640(i2c_bus)

def write_csv(data, filename = 'avg_temp.csv'):
    with open(filename, mode = 'a', newline = '') as file:
        myWriter = csv.writer(file)
        myWriter.writewrow(data)

write_csv(["Date & Time", "Avg temp C", "Message"])
#The camera frame is a 32x24 matrix, so we initialize to 768=32x24
frame = [0]*768
while True:

    #Calculating the avg temp in a frame
    mlx.getFrame(frame)
    avg_temp_C = sum(frame)/len(frame)
    message = 'N/A'
    if avg_temp_C > 30 and avg_temp_C<50:
        print("There may be a human there.")
        message = "There may be a human there."
    elif avg_temp_C >200:
        print("Don't go further. There may be a fire up ahead.")
        message = "Don't go further. There may be a fire up ahead."
    date_time = time.strftime('%Y-%m-%d %H:%M:%S')

    app_row = [date_time, avg_temp_C, message]
    write_csv(app_row)
    #Get data every 5 seconds
    time.sleep(5)
```

Date & time	Avg temp C	Message
2024-10-06 18:26	27.92964153	N/A
2024-10-06 18:26	27.95298826	N/A
2024-10-06 18:26	27.94995239	N/A
2024-10-06 18:26	28.48186942	N/A
2024-10-06 18:27	28.72624848	N/A
2024-10-06 18:27	27.53844653	N/A
2024-10-06 18:27	28.80652479	N/A
2024-10-06 18:27	28.85844877	N/A
2024-10-06 18:27	34.8917658	There may be a human there.
2024-10-06 18:27	35.52517178	There may be a human there.
2024-10-06 18:27	27.55785042	N/A
2024-10-06 18:27	27.20409141	N/A
2024-10-06 18:27	29.13072519	N/A
2024-10-06 18:27	31.88137963	There may be a human there.
2024-10-06 18:27	29.44009885	N/A

Figure 4.2.4.1 Python Code for Thermal Data Acquisition & Outputed Information

In the figure above, we can see that code used for the thermal data acquisition and manipulation as well as what the program outputs, which is a csv file with information on the right. All of this is done in real time.

5. Test Plan

Introduction:

Our team is developing a remote-controlled car with cutting-edge sensor technologies in response to the pressing demand for efficient search and rescue operations in catastrophe scenarios. The goal of this research is to solve the difficulties emergency responders encounter when entering and evaluating disaster-affected areas, especially when conventional approaches are insufficient. Our objective is to develop a flexible and dependable instrument that can identify life signs, navigate through intricate settings, and expedite rescue operations by utilizing several sensor technologies such as LiDAR, thermal imaging, and geophone. Our goal is to improve the efficacy of disaster response operations by guaranteeing the robustness, functionality, and integration of our remote-controlled car through meticulous testing and validation.

9. **Functionality Test**:
   - **Case 1: Basic Car Functionality**:
     - **Simulation**:
       - Utilize Python code to simulate car movements in different directions.
       - Verify responsiveness to commands and accuracy of movements.
     - **Hardware Test**:
       - Examine the movement of the remote-controlled car in a safe setting.
       - Analyze how well it responds to instructions.
     - **Expected Result**: The car moves accurately and responsively as commanded.
   - **Case 2: LiDAR Technology Test**:
     - **Simulation**:
       - Use simulated LiDAR data to validate obstacle detection and mapping algorithms.
       - Ensure accuracy in identifying obstacles and generating a 2D environmental map.
     - **Hardware Test**:
       - Perform LiDAR scans in a regulated setting with pre-established barriers.
       - Check the precision of the mapping and obstacle detection.
     - **Expected Result**: LiDAR accurately detects obstacles and generates a comprehensive environmental map.
10. **Sensor Integration Test**:
    - **Case 1: Integration Verification**:
      - **Simulation**:
        - Simulate the integration of LiDAR, vibration sensors, and thermal cameras using Python scripts.
        - Validate seamless data interpretation and decision-making capabilities.
      - **Hardware Test**:
        - Integrate sensors into the remote-controlled car and conduct tests in a controlled environment.
        - Confirm efficient data interpretation and decision-making using a combination of sensor data.
      - **Expected Result**: Sensors work together seamlessly, providing accurate data interpretation and decision-making.

11. **Navigation Test**:

- **Case 1: Route Planning and Obstacle Avoidance**:
  - **Simulation**:
    - Use simulated rubble and obstacles to test the car's navigation algorithms.
    - Evaluate the accuracy of route planning and obstacle avoidance.
    - Use a python script to detect obstacle :

```
# Parameters
room_size = (10, 10, 3)  # dimensions of the room in meters (width, length, height)
num_objects = 10  # number of objects to place in the room
lidar_position = (5, 5, 1.5)  # position of the LiDAR in the room
num_points = 360  # number of points in one rotation of the LiDAR

# Generate random objects in the room
objects = np.random.rand(num_objects, 3) * room_size

# Room corners (for mapping the room)
corners = np.array([[0, 0, 0], [room_size[0], 0, 0], [room_size[0], room_size[1], 0],
                    [0, 0, room_size[2]], [room_size[0], 0, room_size[2]], [room_size[

# Simulate LiDAR scan
angles = np.linspace(0, 2*np.pi, num_points)
scan_points = []
```

  - **Hardware Test**:
    - Navigate the car through a simulated obstacle course.
    - Assess the accuracy of route planning and obstacle avoidance algorithms.
  - **Expected Result**: The car navigates through obstacles accurately and avoids collisions.

12. **Thermal Imaging Test**:

- **Case 1: Life Sign Detection**:
  - **Simulation**:
    - Simulate thermal imaging data in various environmental conditions.
    - Verify the thermal camera's ability to detect signs of life.
  - **Hardware Test**:
    - Test the thermal imaging camera's performance in detecting heat signatures in controlled environments.
    - Verify the accuracy of temperature readings and heatmaps.
  - **Expected Result**: Thermal imaging camera accurately detects signs of life and provides accurate temperature readings.

13. **Geophone Test**:

- **Case 1: Vibration Detection**:
  - **Simulation**:
    - Simulate seismic data using Python scripts to test the geophone's vibration detection capabilities.

```python
# Function to generate random voltage values, occasionally simulating spikes
def generate_voltage():
    if random.random() < 0.005:  # 0.5% chance to generate a spike
        return random.uniform(-50, 50)  # Spike voltage between -50mV and +50mV
    else:
        return random.uniform(-1, 1)  # Regular voltage between -1mV and +1mV
```

- Validate sensitivity and reliability in detecting vibrations.

▪ **Hardware Test**:
- Test the geophone's performance in detecting simulated vibrations in various scenarios.
- Evaluate sensitivity and reliability under different surface materials and noise conditions.

▪ **Expected Result**: Geophone accurately detects vibrations, demonstrating sensitivity and reliability.

14. **Robustness Test**:

o **Case 1: Environmental Stress Test**:

▪ **Simulation**:
- Python scripts can be used to simulate harsh environmental conditions in order to evaluate the car's durability.
- Verify its ability to withstand extreme temperatures, humidity, and vibrations.

▪ **Hardware Test**:
- Subject the remote-controlled car to extreme environmental conditions in a controlled setting.
- Examine dependability and durability in challenging circumstances.

▪ **Expected Result**: The car withstands environmental stressors without malfunctioning.

15. **Range and Connectivity Test**:

o **Case 1: Communication Reliability**:

▪ **Simulation**:
- Simulate remote control range and wireless communication reliability using Python scripts.
- Validate reliable communication between the operator and the vehicle.

▪ **Hardware Test**:
- Examine the wireless connectivity and range of the remote control in different settings.
- Analyze how well communication works in various interference scenarios.

▪ **Expected Result**: Reliable communication is maintained between the operator and the vehicle under varying conditions.

By conducting these comprehensive tests, we aim to ensure the remote-controlled car's functionality, sensor integration, navigation capabilities, and reliability in real-world scenarios.

Conclusion:

To sum up, our remote-controlled car's development and testing reflect a major advancement in disaster response technology. Through the integration of cutting-edge sensor technology and resilient navigation algorithms, we have developed a flexible and dependable instrument that can effectively tackle the distinct difficulties presented by emergency situations. We have established the functionality, integration, and dependability of our system through extensive testing and validation, providing the framework for its implementation in actual emergency scenarios. We're still dedicated to improving and optimizing going forward in order to save lives and lessen the effects of disasters on impacted areas.

6. WBS, Schedule

6.1 Work Breakdown Structure (WBS)

The updated Work Breakdown Structure (WBS) for the project, which outlines the timeline and key milestones, has been organized into a clear and structured format. This structure is divided into three primary phases:

6.1.1 Project Initiation and Planning:

This initial phase, set to span two weeks, encompasses the foundational activities required to start the project. Key tasks include the official project kickoff, gathering of requirements, sketching of initial designs, and development of the project plan. These steps are critical for setting the project's direction and ensuring all team members are aligned with the project's goals and timelines.

6.1.2 Design and Development Phase:

Over three weeks, this phase focuses on the comprehensive design and preparation for the construction of the RC rescue car. It begins with the completion of detailed designs, including mechanical, electrical, and software components, evidenced by developed CAD models, electrical schematics, and software architecture plans. Following the design completion, the phase continues with the selection and procurement of necessary components, ensuring that each part meets specific performance criteria and budget considerations. The final part of this phase involves the development of control software crucial for the RC car's operation, integrating sensor data for enhanced navigation and life detection capabilities.

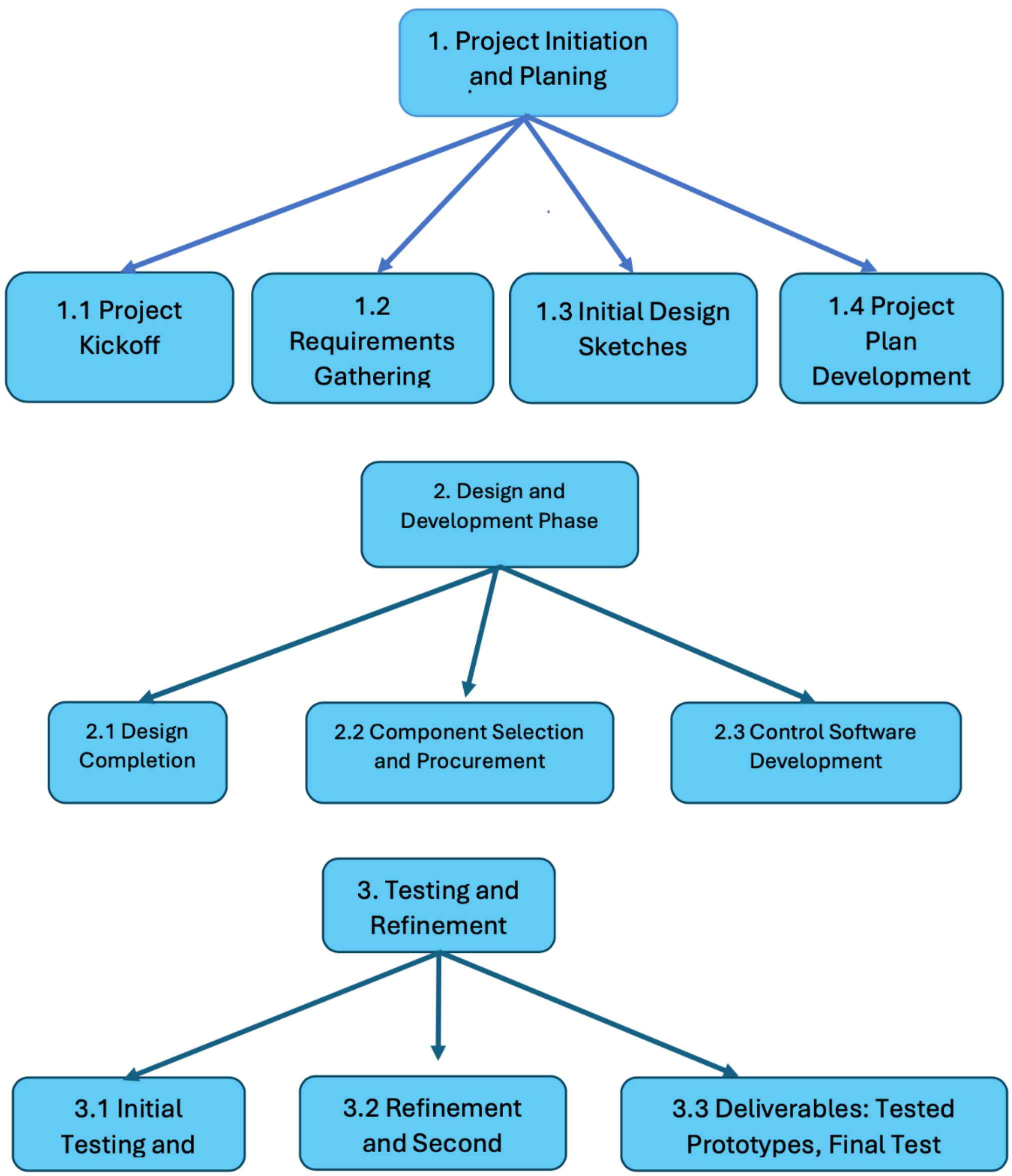
6.1.3 Implementation Phase:

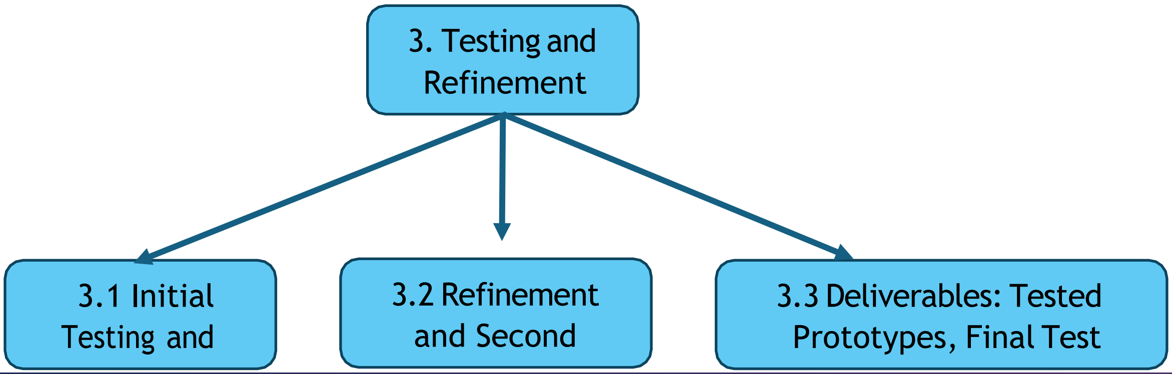
This phase should start around Sep 9, 2024, and be completed by Oct 21. This will be the first stage in which we will start to notice any serious design flaws, if any. We will be utilizing any tools necessary to assemble all the components, build the needed parts, and assemble the prototype.

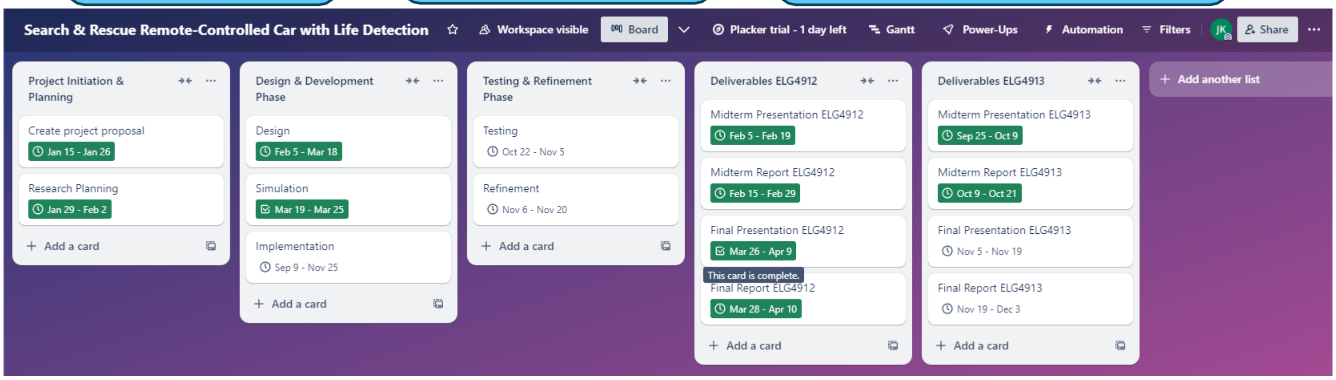
6.1.4 Testing and Refinement Phase:

Although the duration is not specified, this phase is pivotal for evaluating the RC rescue car's functionality and performance. Initial testing assesses navigation, life detection capabilities, and communication systems. Based on the results, the project moves into refinement, where the design undergoes necessary adjustments, and a second prototype is constructed. The phase concludes with detailed testing in simulated disaster environments, allowing for final adjustments before the project's completion.

This structured breakdown into distinct phases and tasks facilitates clear project tracking and management, ensuring all objectives are met systematically and efficiently. The WBS document serves as a vital tool for understanding the project's scope and sequence, guiding team members through the project lifecycle from inception to completion.




3. Testing and Refinement
3.1 Initial Testing and
3.2 Refinement and Second
3.3 Deliverables: Tested Prototypes, Final Test


Search & Rescue Remote-Controlled Car with Life Detection
Workspace visible
Board
Placker trial - 1 day left
Gantt
Power-Ups
Automation
Filters
Share
Project Initiation & Planning
Create project proposal
Jan 15 - Jan 26
Research Planning
Jan 29 - Feb 2
Add a card
Design & Development Phase
Design
Feb 5 - Mar 18
Simulation
Mar 19 - Mar 25
Implementation
Sep 9 - Nov 25
Add a card
Testing & Refinement Phase
Testing
Oct 22 - Nov 5
Refinement
Nov 6 - Nov 20
Add a card
Deliverables ELG4912
Midterm Presentation ELG4912
Feb 5 - Feb 19
Midterm Report ELG4912
Feb 15 - Feb 29
Final Presentation ELG4912
Mar 26 - Apr 9
This card is complete.
Final Report ELG4912
Mar 28 - Apr 10
Add a card
Deliverables ELG4913
Midterm Presentation ELG4913
Sep 25 - Oct 9
Midterm Report ELG4913
Oct 9 - Oct 21
Final Presentation ELG4913
Nov 5 - Nov 19
Final Report ELG4913
Nov 19 - Dec 3
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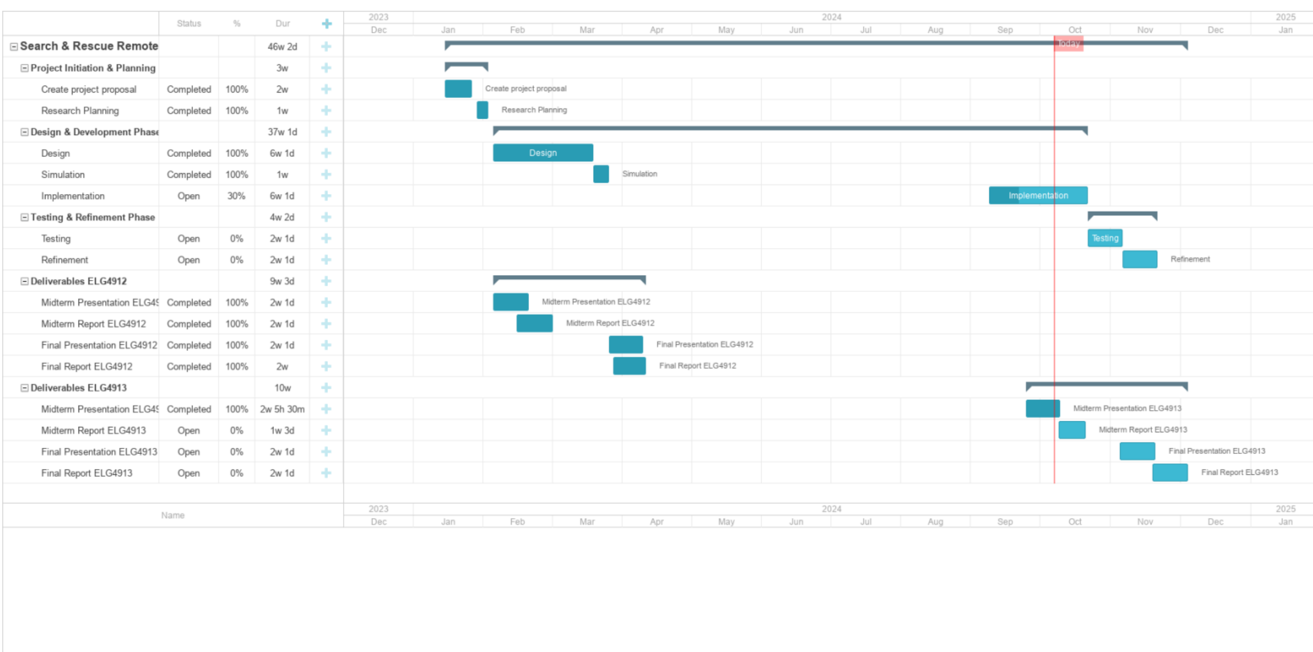
Add another list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Project Initiation & Planning
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Design
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6w 1d
Simulation
Completed
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Testing & Refinement Phase
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Testing
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Refinement
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Deliverables ELG4912
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Final Presentation ELG4912
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Final Report ELG4912
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6.2 Internal Releases:

The internal releases for the project delineate crucial checkpoints and deliverables critical for the development of the remote-controlled (RC) car. Here's a summary of each release:

6.2.1 Concept Design Release:

This initial phase aims to present the foundational designs, including preliminary sketches and basic CAD models, highlighting the layout, track system, sensor placements, and control system concepts. The goal is to obtain feedback on the design's feasibility and identify areas requiring further research or modification.

6.2.2 Detailed Design Release:

In this phase, the project moves forward with the presentation of detailed design documents and refined models. This includes comprehensive schematics and plans for all RC car components. The expected outcome is the approval of these detailed designs and the green light to commence component procurement.

6.2.3 Sensor Integration Design Review:

This release focuses on the integration of essential sensors into the RC car, ensuring optimal functionality and reliability. The objective is to confirm that the design meets operational requirements and to plan for effective data integration.

6.2.4 Modular Design and Repairability Review:

This stage evaluates the RC car's design for modularity and ease of repair, which are vital for its longevity and operational efficiency in field conditions. The expected outcome is an enhanced design that supports easy field repairs and component replacement.

6.2.5 Final Design Approval Release:

The aim here is to obtain final approval on the complete design package, marking the end of the design phase and the beginning of the procurement and assembly phases. This signifies readiness for prototype construction and subsequent testing.

6.2.6 Design Review Release:

This release involves presenting and reviewing the completed preliminary designs, ensuring they are feasible and ready for the next development phase. Feedback obtained here will guide the procurement and prototype development processes.

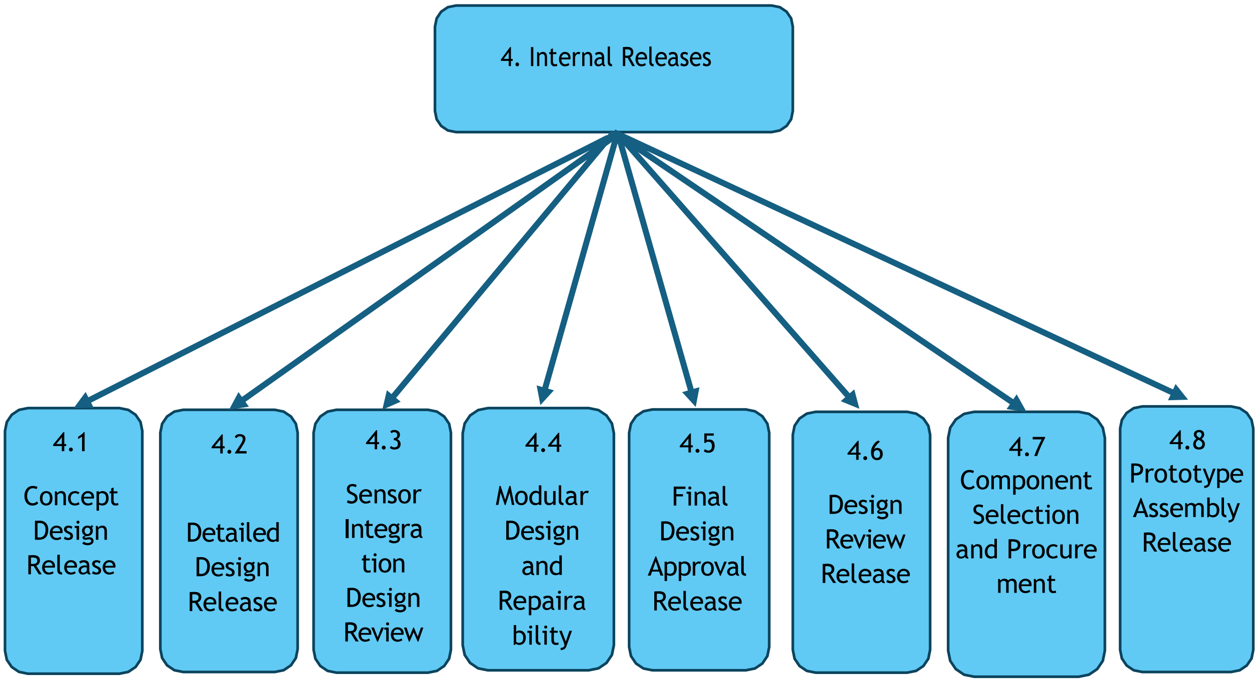
6.2.7 Component Selection and Procurement Release:

The focus is on finalizing and approving the list of necessary components for the prototype, ensuring all parts meet specified requirements and are ready for assembly.

6.2.8 Prototype Assembly Release:

Marks the completion of the initial prototype assembly, showcasing the functional integration of all components. This stage aims to demonstrate basic functionality and identify any potential issues or areas for improvement before moving into functionality testing.

Each release serves as a strategic milestone, ensuring the project progresses in a structured and efficient manner, from conceptual design through to the assembly and testing of the RC car prototype.



The total estimated budget for the RC rescue car development project is $350. This budget is meticulously planned to cover all phases of the project, from initial planning and design to comprehensive testing and final refinements. The allocation of funds is carefully considered to balance the need for quality and efficiency with cost-effectiveness. Regular budget reviews and updates will be essential to manage expenses effectively and adapt to any changes in the project scope or requirements. This financial planning aims to ensure the successful completion of the project within the allocated budget, maximizing value while minimizing unnecessary expenditure

7. Contribution List

Section	*Contributors*						*Total*
	Geoffrey Hooton	*Fatmah Bayrli*	*Papa Kane*	*Moktar Abdillahi-Abdi*	*Walid Rashad*	*Julien Kapro*	
Project Charter	5%	15%	5%	5%	5%	65%	100%
System Requirement Specification	10%	-	-	90%	-	-	100%
WBS, Schedule	-	-	85%	-	-	15%	100%
Detailed Design	50%	35%	-	-	-	10%	100%
Risk Management	-	50%	-	-	50%	-	100%
Budget	-	90%	-	-	-	10%	100%
Test Plan	-	-	-	100%	-	-	100%
Current Project Progress	60%	-	-	-	-	40%	100%