MREN 203

Conceptual Design Report

Mar 3rd, 2024

Prepared for:
Kingston Fire and Rescue

Prepared By:

David Cheng
Coleman Farvolden
Josh Westlake

"We do hereby verify that this written report is our own individual work and contains our own original ideas, concepts, and designs. No portion of this report has been copied in whole or in part from another source, with the possible exception of properly referenced material."
03/03/2024

Table of Content

Executive Summary

The Conceptual Design Report for the LifeBot project represents a pivotal step forward in enhancing emergency response capabilities, particularly in scenarios such as cardiac arrests. Throughout the project the team has worked hand in hand in partnership with Kingston Fire and Rescue, with the initiative aiming to address the critical need for swift access to life-saving equipment in indoor environments where traditional response times may be compromised. By integrating some of the most cutting-edge technologies like Raspberry Pi, Arduino UNO WiFi Rev 2 boards, and ROS2 packages, the LifeBot project endeavors to create an autonomous robotic solution capable of deploying an AED autonomously.

At the heart of the LifeBot's functionality lies various sophisticated PID controllers, meticulously engineered to ensure precise motor control and speed adjustments. As a result of the support from ROS2 navigation packages and RPLidar, the LifeBot has been designed to adeptly navigate indoor environments, swiftly reach predetermined destinations to provide timely assistance. Additional information such as a comprehensive cost-benefit analysis, will provide stakeholders with valuable insights into the economic viability and potential advantages of implementing the LifeBot system. The addition of a product deployment plan will ensure that the product is rolled out in an effective manner. An analysis into Ontario rules and regulations will ensure the LifeBot is safe and legally viable. These analyses will not only emphasize financial and legal considerations but also underscore broader societal benefits and potential life-saving impacts.

In summary, the LifeBot project represents a significant advancement in emergency response technology, poised to redefine the delivery of critical medical aid in indoor settings. Through meticulous design, integration of cutting-edge components, and thorough analysis, the LifeBot initiative aspires to revolutionize the paradigm of emergency medical assistance, ultimately contributing to enhanced public safety and well-being.

1. Introduction

This document aims to provide a comprehensive update on the LifeBot project, detailing not only the recent advancements and challenges but also the future directions of the project. This document serves as a critical communication link between the LifeBot development team and stakeholders, ensuring alignment with project goals, progress, and expectations. This document will discuss the steps taken thus far to bring the LifeBot to reality. The conceptual design report will include a report on the state of software, control, autonomy, electrical, and mechanical aspects of the LifeBot. The report will encapsulate not only the latest advancements and challenges but also chart the future course of the project investigating a product implementation plan, regulations and safety standards, and cost benefit analysis.

2.Problem Definition and Scope

A cardiac arrest emergency represents an acute and life-threatening condition characterized by the sudden loss of heart function, breathing, and consciousness. Immediate medical response can often mean life or death, and due to the unpredictability of this condition, this emergency is often overlooked and only partially resolved by adding insufficient equipment to public buildings. In some scenarios even in a public environment such as a mall, without sufficient knowledge of their surroundings, a person cannot locate an AED quickly. This is especially dangerous as every minute a person does not receive AED, their chances of survival drop by 7-10% [1]. A mobile device such as the LifeBot is perhaps perfect for this situation as it could save minutes in delivery time of an AED, directly saving lives

2.1 Stakeholders

Relevant stakeholders in the design and decision-making process for LifeBot include:

- Patients in need and people affiliated with the patients
- Emergency responders
- K-town fire and rescue
- People with disability (blind people, deaf people, people with other disabilities)
- Engineers and designers of LifeBot
- Healthcare Professionals and Hospitals
- Insurance Companies
- general public, media, and public safety officials
- city or private property owner
- bystanders

2.2 Functional Requirements

2.2.1 Mobility and Navigation

Speed and terrain adaptation: The LifeBot robot must be able to travel (1.4m/s) to exceed human walking speed.

Autonomous navigation: The LifeBot must be able to navigate a slope of up to 15 degrees and overcome ground obstacles of up to 50mm, a common height for indoor floor obstacles.

2.2.2 Mechanical and Electrical Systems

Load Capacity: The LifeBot must be capable of carrying a 4-pound (the weight of an AED) [1] payload while traveling full speed in order to transport an AED effectively.

Motor Control Accuracy: Speed control accuracy must be accurate to within $\pm$5% of desired speed and turning accuracy must be within $\pm 5\%$ of desired angle

2.2.3 Software and Control Systems

PI Control System: The settle time of the speed adjustments should take less 2 seconds and have an error of less than 5% for speed and directional control.

Ros Integration: The Ros system should have a control latency of less the 100 milliseconds and the navigation must determine required path to site in less than 2 seconds.

Wireless communication: The system must maintain an internet communication link with of 99% reliability and a working range of at least 100m.

2.2.4 Communication and Emergency Response Integration

Emergency Communication: The time to process and respond to a signal (911 call or button press) should be less then 5 seconds to ensure rapid deployment.

Alert System: Sirens and emergency lights on the LifeBot should be visible and audible from a distance of at least 100m in an indoor environment. The siren must emit a noise of between **70-90 dB.**

2.3 Scope

Given the constraints imposed by both time and financial resources, the scope of the LifeBot necessitates the creation of a preliminary prototype with fundamental functionalities. This prototype will serve as a testament to the efficacy and prospective capabilities of the envisioned LifeBot system. The primary aim of this project is to design and implement an autonomously navigating robot capable of responding to user input. Specifically, the robot will be able to navigate to a predetermined door autonomously upon navigation. Additionally, to enhance its utility in emergencies, the prototype will feature an integrated alarm system to alert nearby individuals, emergency lights for heightened visibility, and an attached Automated External Defibrillator (AED) for immediate medical assistance. In addition to the basic prototype, the scope of the project will include a cost breakdown, relevant laws and regulations and a product deployment plan.

3. Conceptual Design Solution

3.1 Overview of Design

The final design solution for the LifeBot integrates both electrical, mechanical and software components to create a robust autonomous robot capable of navigating safely in indoor environments. Key electrical components include a Raspberry Pi, Arduino UNO WiFi Rev 2 board, motor shield, and custom mechanical components. The software employs PID controllers for motor control, while the navigation software utilizes ROS2 packages for SLAM mapping, path planning, and control. Communication is facilitated by ROS2 and SSH, enabling secure connections between devices. Serial communication allows data exchange between the Raspberry Pi, Arduino, and Lidar. This comprehensive design ensures efficient and safe navigation, with robust communication and control capabilities.

3.2 Electrical

Most key components on the prototype have been connected to the LifeBot, which includes the DC motors via motor shield, encoders, RPLidar and light sensors.

The motor controller is connected to the motors and to the Arduino and the motors run as intended. By providing a high signal and a low signal to the signal pins, a voltage difference allows the motor shield to provide either a positive or negative voltage to the DC motor, while the E pins determine the voltage strength, effectively allowing the control of power draw on the DC motor, thus controlling the speed of the motor. The pin layout is shown below in Table 1**Error! Reference source not found.**.

Table 1: Motor Control Pin Layout

Pin ID	Pin Number	Description
EA	3	Right wheel PMW pin
EB	5	Left Wheel PMW pin
I1	4	Right Wheel directions digital pin 1
I2	2	Right Wheel directions digital pin 2
I3	7	Left Wheel directions digital pin 1
I4	6	Left Wheel directions digital pin 2

Along with the motor shield pins, there are 17 more pins connected, 4 for the encoders attached to the DC motors on both sides of the robot. The encoder data shown in in Appendix 1 provides a speed estimation for each rear wheel and more precise control of robot turning and speed, allowing for free movement. The 4 pins include the Vcc and ground pins powering the encoder, while two digital pins allow the writing of the encoder. The encoder is connected to the Arduino by these 4 pins and sends back data based on rotations. The pin connections to the Arduino shield are shown below in Figure 1 1.

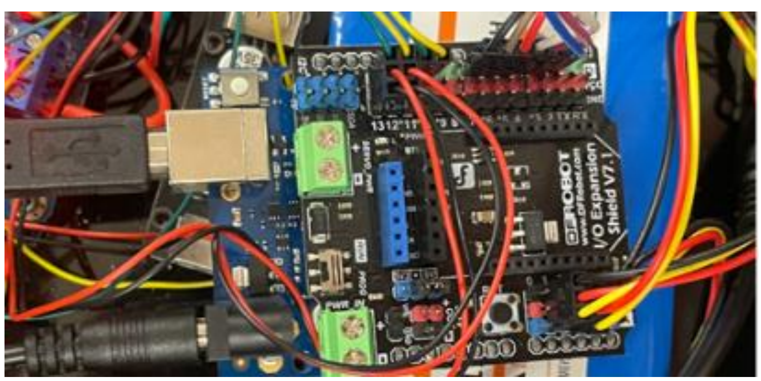


Figure 1: Arduino uno WIFI rev board with its shield on top and some of the pins layout

3.3 Mechanical

The proposed mounting solution for the AED device is depicted below in Figure 2**.** This detailed representation offers visual insight into the AED delivery in life-saving scenarios. The chassis will be mounted on the currently existing frame using nut and bolt fasteners allowing for easy installation and removal at any point. The design features a lightweight, and mechanically optimized hinge mechanism allowing for easy access to the AED device in emergencies.

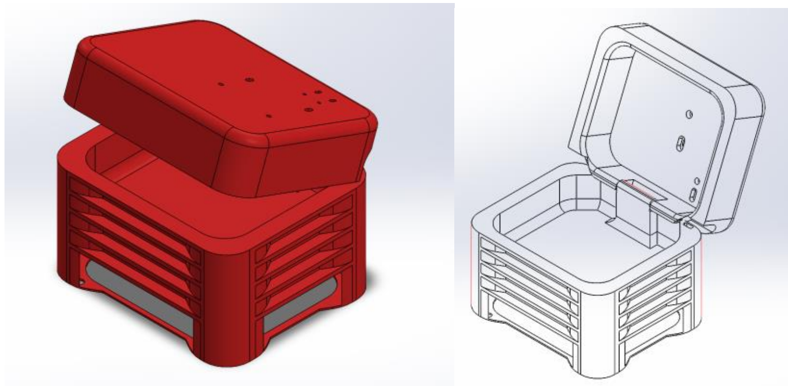


Figure 2: LifeBot AED Chassis

The AED chassis underwent rigorous testing to ensure it will withstand the mechanical stresses expected to be encountered during operation. The FEA simulation conducted on the AED Mount Assembly of the chassis was intended to test the structural integrity and suitability of the mount for its intended purpose. The chassis was specifically designed to securely house the AED device on top of the robot. With the primary objective of swiftly delivering AEDs to cardiac arrest emergencies, as the mount's design prioritizes stability and reliability. To ensure the prototype could be produced with a minimal cost while providing the structural integrity required for the part, PLA plastic was chosen as the material. Using the SolidWorks built-in simulations feature, various simulations were run to ensure the integrity of the chassis. The results found from the simulation demonstrate the ability of the chassis to endure the simulated mechanical loads. Furthermore, the maximum displacement of the chassis only varying between 0.000 mm and 2.530 mm, which highlights the ability of the chassis to maintain structural integrity under operational conditions. The results of the simulation ensure that the AED device remains safely and securely mounted, and ready for immediate deployment when required.

Table 2: Finite Element Analysis (FEA) testing results

Study	Type	Min Value	Max Value
Von Mises Stress Analysis	VON: von Mises Stress	9.644e+01	6.376e+06 N/m^2
Displacement Analysis	URES: Resultant Displacement	0.000mm	2.5300 mm
Strain Analysis	ESTRN: Equivalent Strain	3.77e-08	2.125e-03

Table 2 above provides a concise overview of the resultant forces, study results, and key metrics obtained from the FEA simulation, highlighting the chassis' performance under various loads and conditions. The full FEA report has been included in Appendix 2 to provide further insight into the reliability of the chassis.

3.4 Software

3.4.1 Controller

The PI controller dynamically refines the motor PMW (Pulse width modulation) commands, allowing it to respond 'proportionally' to variances between the desired wheel speed, and calculated wheel speeds. The main loop orchestrates the calculation of wheel angular rates from the encoder data and calculates the appropriate PMW motor signals to align the vehicle's speed with the predefined target speed.

The team has implemented real-time monitoring through means of the serial monitor and serial plotter imbedded in the Arduino IDE. These readings provide insight into the wheel velocities as time goes on to verify the speed of the wheel is operating as Intended. Figure 3 showcases the results of the speed controller, showcasing a controlled decrease in speed from 1.1m/s to 0.6m/s.

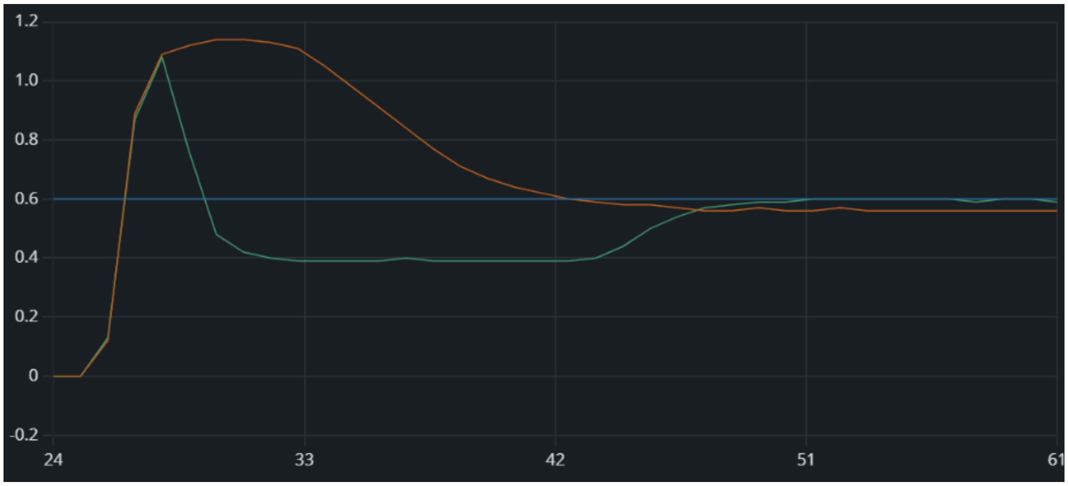


Figure 3: Desired Speed PI Controller Simulation - Blue line target Speed, Orange and Green lines are controlled regulation

Further measures have been taken to ensure that the wheels operate at the same speed to provide the LifeBot with an accurate trajectory. Due to deficiencies with the provided motors each of the motors operates at slightly different rates causing discrepancies between the speed of the wheels. The implementation of an additional PI system tasked with minimizing the error between the rate of the left and right wheel speeds inspires further confidence in the navigational control of the robotic system.

3.4.2 Navigation

The LifeBot software will use a variety of ROS2 packages in order to navigate autonomously in an indoor environment. The LifeBot will use the **SLAM** package to build a 2D map of the environment and determine its position, then the **NAV2** package will create a cost map of the environment and find the path of least cost which are then sent as instructions to **ROS2 Control** to tell the hardware what to do.

3.4.2.1 SLAM

SLAM **(**simultaneous localization and mapping) is a technique for creating a map of an environment and determining robot position simultaneously [2]. To perform an accurate and precise SLAM on the LifeBot, the robot uses a laser scanner, the (**RPLIDAR**) and an odometry system consisting of a geared motor with an optical encoder (**HN-GH12-1634T**). The LifeBot uses SLAM, lidar and encoders to build a map of an indoor space and determine the position of the rover within the space as shown in Figure 4.

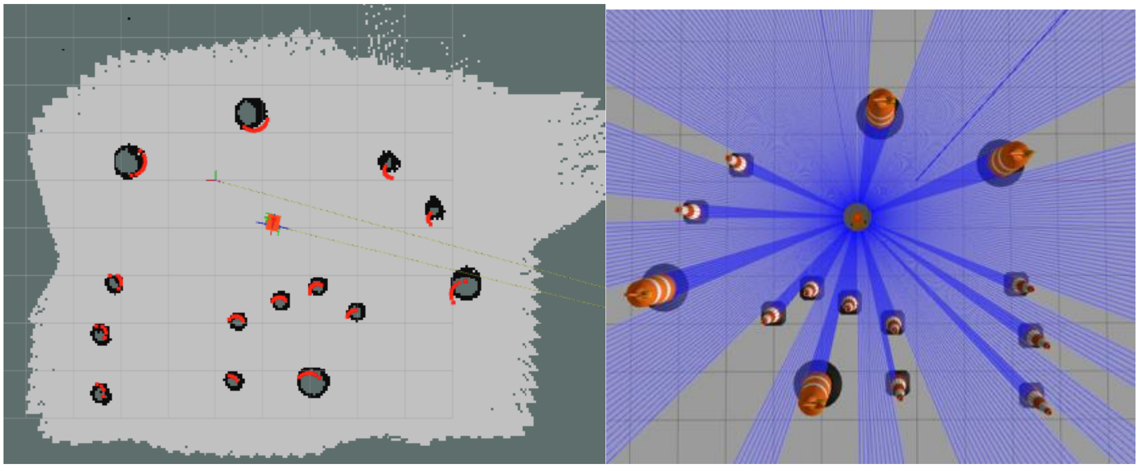


Figure 4: SLAM LifeBot Gazebo Simulation with map

3.4.2.2 NAV2

NAV2 provides ROS2 robots with the ability to navigate through complex environments autonomously and complete user-defined tasks. NAV2 provides perception, planning, control, localization, and visualization to build autonomous systems in ROS2. NAV2 achieves this by building an environmental model based on input data and dynamically planning a path, computing velocities, and avoiding obstacles [3]. The LifeBot uses NAV2 in conjunction with SLAM to create a cost-map with obstacles incurring a high cost and open space incurring a low cost as shown in Figure 5. When the LifeBot is told to go to a specific location upon receiving an SOS signal, the LifeBot will calculate the lowest cost path to the location using the cost map and autonomously navigate to the desired location.

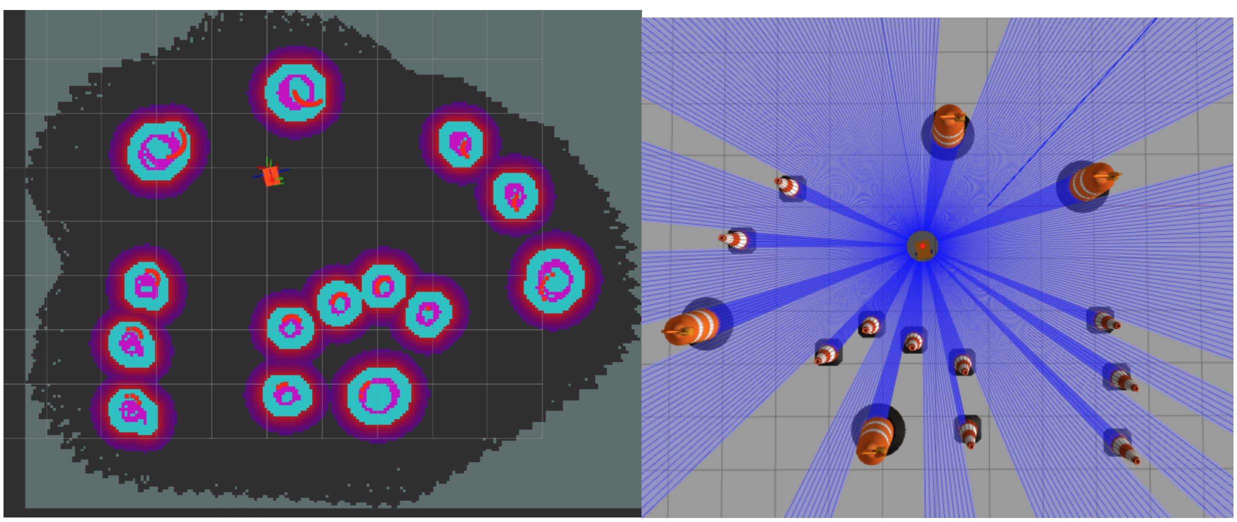


Figure 5: NAV2 LifeBot Gazebo Simulation with cost-map

3.4.2.3 ROS2 Control

ROS2 control is a framework designed to streamline the process of controlling different kinds of hardware in robotics. ROS2 control standardizes control and state information, transmits data much faster than ROS topics and is simple to integrate using URDF and YAML files [4]. The LifeBot uses a differential drive controller integrated with ROS2 control.

3.4.2 Communication

ROS2 tools are essential for communication as it would be unreasonable to develop all communications from scratch. ROS2 communication can connect computers over a network and connect serially to an Arduino that is wired to a variety of hardware and control the Robot as shown below in Figure 6.

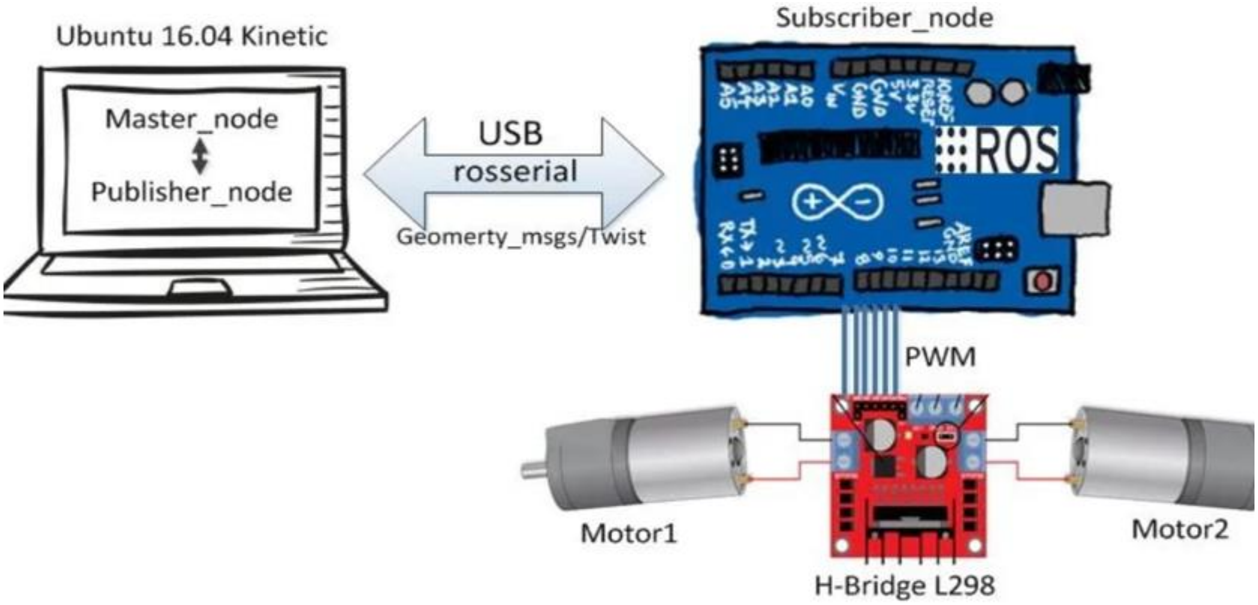


Figure 6: Communication between Arduino and PC over ROS

3.4.2.1 Internet Communications

The LifeBot uses SSH (Secure Shell Protocol) to connect two computers safely over an unsecured internet network as shown in Figure 7 below. By utilizing SSH a powerful base station computer connects to the LifeBot allowing for complete control of instructions to the LifeBot over the terminal.

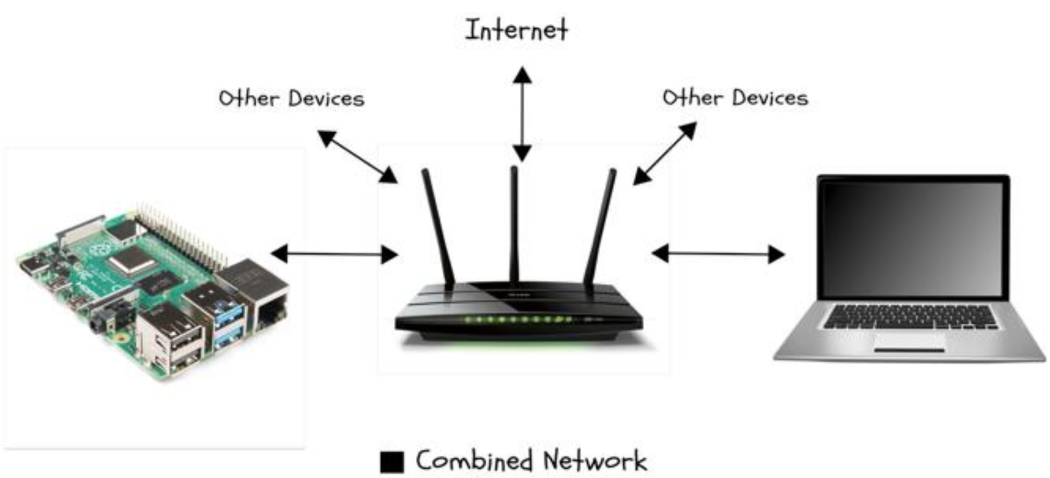


Figure 7: Raspberry Pi to Basestation connection [5]

The Raspberry Pi has limitations in processing power for tasks such as SLAM and NAV2. This heavy computational workload is offloaded to the base station, complex algorithms are executed, and the results are shared with the Raspberry Pi as shown below in Figure 8.

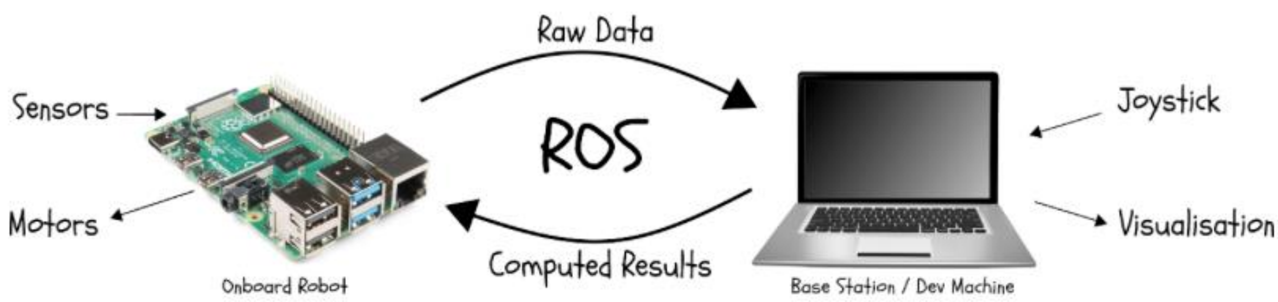


Figure 8: ROS Network [5]

This Raspberry Pi and base station have a variety of ROS2 nodes which are small programs all running at once. The nodes publish a message to a topic via ROS2 Topics and messages [6]. These topics are then shared between the Raspberry Pi and Basestation. Once complex programs are run on the base station, the Raspberry Pi can read the output data from the ROS2 topic and quickly execute control commands to the hardware for robot movement. This system architecture leverages computational resources to allow a powerful algorithm to be used and the LifeBot to operate quickly in real time.

3.3.2.2 Serial Communications

Serial communications are used to communicate between microcontrollers and other devices. The connected devices send single bits one by one (Serially) at a certain clock rate, these bits turn into bytes and turn into instructions as shown in Figure 9 below [7].

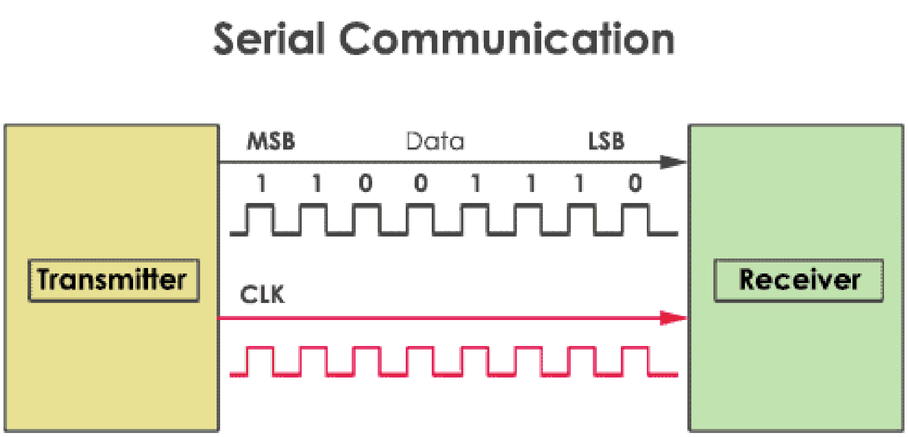


Figure 9: Serial (Shawn, n.d.)

The Arduino on the LifeBot is connected to the motors, encoders, and various other sensors. The Raspberry Pi is connected to the Arduino serially (USB-A to USB-B) at a baud rate of 115200 (essentially the clock of the data). The Raspberry Pi receives encoder data serially from Arduino and determines desired motor outputs and sends these outputs back to the Arduino which then powers the motors as desired. This can be viewed in Figure 10.

The Lidar (RPLIDAR) is connected to Raspberry Pi through serial as well. The laser scan data is sent serially from the Lidar board to Raspberry Pi (USB-A to michroUSB) and the data is published to a laser scan topic called /Scan. This setup can be seen below in Figure 10.

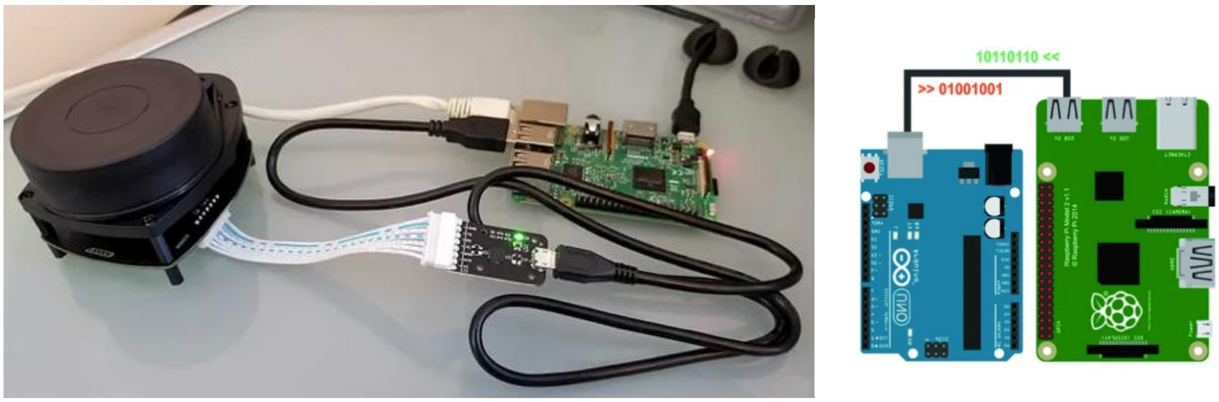


Figure 10: Lidar and Arduino Serial Connection [8]

4. Product Deployment Plan

The deployment of the LifeBot prototype requires considerable planning to ensure successful integration into the existing emergency response systems. The first stage of the deployment plan revolves around assembling a multidisciplinary team, comprising mechanical, electrical and software engineers. Procuring necessary hardware components such as the LynxMotion robot chassis, RPLidar laser scanner, Raspberry Pi, and Arduino UNO Rev4 WIFI is essential for the assembly process of the prototype. Simultaneously, the design of the 3D-printed AED chassis and software development are of the upmost importance, focussing on the motor control algorithms, SLAM mapping, path planning, and communication protocols. The updated project schedule of the LifeBot AED Delivery robot is further detailed in a Gantt Chart found in Appendix I. This Gantt chart highlights all key milestones, assigns responsibilities to various members of the team, and the status of distributed tasks.

Once assembled, further testing of the prototype is necessary to identify and rectify any identified deficiencies. The testing process will evaluate the mobility and navigational ability, mechanical and electrical system functionality, as well as explore further room for improvements that can be made to the overall prototype. The deployment strategy for the system involves identifying key target locations based on various factors such as population density and emergency response times. The implementation of these devices with existing emergency and rescue infrastructure will require extensive controlled system deployment meaning that the robot will be deployed into low-risk places, with predictable environments which will facilitate realistic responses. Allowing for continuous monitoring and maintenance activities ensuring optimal LifeBot performance and readiness for emergencies before the complete deployment of the product. The reiterative deployment plan for the LifeBot is shown below in Figure 11.

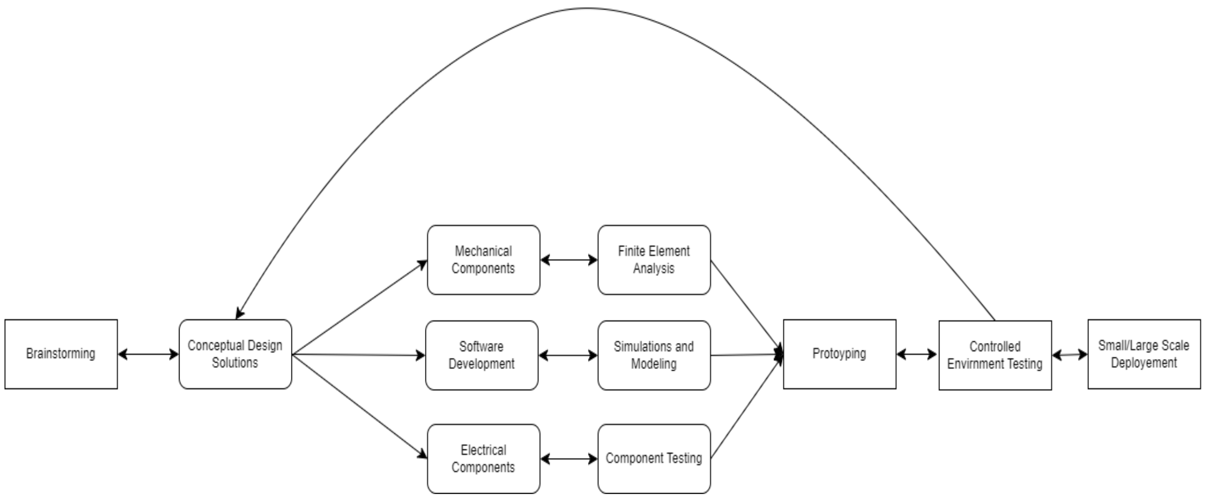


Figure 11: Deployment Plan Flow Chart

Following a small-scale deployment, ongoing evaluation and feedback collection from the public, users, and all other stakeholders will be crucial in implementing improvements to the LifeBot platform. Upon successful small-scale deployment, a gradual expansion to additional locations will continue, alongside further investments to improve the technology to adapt to the always-evolving needs and regulations of Ontario.

5. Regulations and Safety Standards

5.1 Ontario Medical Device Licensing (Food and Drugs Act)

5.1.1 Section 19

No person shall sell any device that, when used according to directions or under such conditions as are customary or usual, may cause injury to the health of the purchaser or user thereof [9]. The LifeBot cannot harm in any way people using or around the device.

5.1.2 Section 20

No person shall label, package, treat, process, sell or advertise any device in a manner that is false, misleading, deceptive or is likely to create an erroneous impression regarding its design, construction, performance, intended use, quantity, character, value, composition, merit, or safety [9]. The advertisement for the LifeBot must be 100% accurate and not misleading.

5.1.2 Section 21

Where a standard has been prescribed for a device, no person shall label, package, sell or advertise any article in such a manner that it is likely to be mistaken for that device, unless the article complies with the prescribed standard [9]. LifeBot must be advertised as a standalone unmistakable device.

5.2 Accessibility for Ontarians with Disabilities Act (AODA)

5.2.1 Design of Public Spaces Standard

Ensuring that a public indoor space is navigable and accessible for individuals with physical disabilities would fall under the principles outlined in these AODA publish accessibility standards [10]. To accommodate this the LifeBot will be strategically placed in a building in order to not obstruct movement of persons with disabilities.

5.2.2 Information and Communications Standard

This standard requires that information and communications be made accessible to people with disabilities [10]. To accommodate this the emergency buttons for calling the LifeBot will have brail engravings. In addition, the LifeBot will flash lights and a siren to accommodate communicating with people who are blind or def.

5.2.3 Ontario's Environmental Protection Act

Producer Responsibilities:

LifeBot is involved in the distribution of battery-powered devices in Ontario and considered a "producer" under regulation. LifeBot would have responsibilities for the end-of-life management of batteries, including collection and recycling or proper disposal of batteries used in its devices [11].

Collection of Batteries:

As a producer, LifeBot inc. would need to establish and operate a collection system for the batteries once they are no longer usable. This includes setting up collection sites or arranging for collection services that allow consumers to return used batteries [11].

Management of Batteries:

LifeBot would need to ensure the proper management of collected batteries. This involves either refurbishing for reuse or ensuring that the batteries are recycled in a manner that meets the regulatory requirements, including achieving certain recycling efficiency rates [11].

5.3 Ontario Fire Code

5.3.1 Electrical Safety

LifeBot is powered by electricity , it must meet electrical safety standards to prevent fire risks due to electrical malfunctions. This includes using components that are certified for safety by recognized testing laboratories and conforming to Canadian Electrical Code requirements [12]. The LifeBot has to have safely designed electronics with safe and reliable parts.

5.3.2 Flammability of Materials

Materials used for construction of LifeBot should be non-combustible or limited combustible materials, especially if the robot is intended for use in sensitive environments like healthcare facilities or schools. The Ontario Fire Code specifies the types of materials that are permissible in various settings [12]. The LifeBot should use minimal combustible materials and non-toxic burning plastics.

5.3.3 Emergency Procedures

LifeBot should not obstruct emergency exits or access to fire-fighting equipment. As a mobile unit, it should be programmed to comply with emergency evacuation procedures and not impede human evacuation or the operations of emergency responders [12]. The LifeBot should be placed in a strategic location at installations to not block any emergency exits or emergency equipment.

6. Cost-benefit Analysis

An estimated cost analysis for the first 4 years of LifeBot is shown below in Figure 12Figure 12 and justified basis below. The analysis is assuming: #LifeBots sold = [#years * 100], Each LifeBot will be sold for 2000$ and there will be a 100$ a month upkeep charge for power, cellular connection, maintenance, and software updates for each LifeBot.

COMPANY NAME	LifeBot			DATE CONDUCTED		02/03/2024
PROPOSED PRODUCT / INITIATIVE / SERVICE	AED Robot			YEARS		2024 - 2028
CONSTANT OR CURRENT DOLLARS	Canadian $					
SYSTEM LIFE COST PROFILE						
COST CATEGORY	YEAR 1	YEAR 2		YEAR 3	YEAR 4	TOTAL
Projected number of LifeBots sold	100	200		300	400	1000
Initial Development Costs:						$ -
Hardware Development	$ 100,000	$ 200,000		$ 300,000	$ 400,000	$ 1,000,000
Software Devolpment	$ 60,000					$ 60,000
Operational Costs:						$ -
Connectivity	$ 88,300	$ 176,600		$ 264,900	$ 353,200	$ 883,000
Energy Consumption	$ 7,000	$ 21,000		$ 42,000	$ 70,000	$ 140,000
Maintenance Costs:						$ -
Regular Maintenance	$ 47,500	$ 142,500		$ 285,000	$ 475,000	$ 950,000
Software Updates	$ 15,000	$ 7,500		$ 3,750	$ 1,875	$ 28,125
Implementation Costs:						$ -
Training	$ 5,000	$ 10,000		$ 15,000	$ 20,000	$ 50,000
Installation	$ 25,000	$ 12,500		$ 6,250	$ 3,125	$ 46,875
TOTAL PROJECTED COST	$ 347,800	$ 570,100		$ 916,900	$ 1,323,200	$ 3,158,000
COST PER LIFEBOT	$ 3,478	$ 1,900		$ 1,528	$ 1,323	$ 3,158
PROFIT PER LIFEBOT SOLD	$ (278)	$ 633		$ 672	$ 677	$ 1,242
MEMBERSHIP FEE PER LIFEBOT	$ 1,200	$ 1,200		$ 1,200	$ 1,200	$ 1,200
TOTAL REVENUE	$ 320,000	$ 760,000		$ 1,320,000	$ 2,000,000	$ 4,400,000
TOTAL PROFIT	$ (27,800)	$ 189,900		$ 403,100	$ 676,800	$ 1,242,000

Figure 12: Cost analysis

6.1 Initial Costs

6.1.1 Hardware

- LynxMotion Robot chassis: 800$
- RPLidar Laser scanner: 115$
- Raspberry Pi 4 Model B/8GB: 105$
- Arduino Uno Rev4 WIFI: 40$
- 4 hours of assembly: 100$

Cost per unit every year = 1160$

6.1.2 Software Development

An estimated 1000 hours will be spent on the initial software of the product. According to the Economics Research Institute the average Hourly wage for a Robotics Software Engineer is 60$/hr .

Year 1 Software Development cost = 60,000 $

6.2 Operational cost

6.2.1 Connectivity

The LifeBot needs to maintain a constant connection to the internet, this connection needs to be very reliable so the LifeBot should have its own cellular data plan. With a cost of 7.36$ per GB in Canada [18], the LifeBot will use an estimated 10 GB a month for downloads and SOS connection with the cost coming to **73.6$** a month or **883$** a year for each LifeBot

6.2.2 Energy Consumption

The energy consumption of the LifeBot will primarily be used when the robot is in standby mode. This energy will primarily be used to power the Raspberry Pi and Base Station computer. A Raspberry Pi will consume around **5W** of power in a normal state . Computers generally consume around **50W** of power. In total, the LifeBot will consume around **55W** of power to operate on standby. The average cost of power in Ontario is 0.141 $/KWhr [21].

55W*24hrs*356days = 481,800Whrs = 481.8KWhr * (0.141 $/KWhr) = **70$ per year**

6.3 Maintenance cost

6.3.1 Regular Maintenance

A technician will check on the LifeBot and AED once a month and charge a **30$** fee. It will be assumed that one part on the LifeBot needs to be replaced every year. To be conservative It will be assumed the most expensive part the RPLidar Laser scanner: **115$** will need to be replaced. This leads to a total yearly regular maintenance cost of **475$.**

6.3.2 Software Updates

Initially in the first year 250 hours will be spent on software updates. The estimated number of hours spent on software updates will be halved for each consecutive year as the software will eventually be perfect. According to the Economics Research Institute, the average Hourly wage for a Robotics Software Engineer is 60$/hr [17].

Year 1= 15,000 $ **Year 2 = 7,500 $** **Year 3 = 3,750$** **Year 4 = 1,875**

6.4 Implementation cost

6.4.1 Training

The LifeBot will require training of personal where they were installed. It will be estimated that each LifeBot will come with 2 hours of needed training for the operators of the building. This will be estimated to be **50$** per LifeBot.

6.4.2 Installation

Initially in the first year there will be major installation costs of things such as charging ports, emergency buttons and EMS system integration. The estimated cost of installation and integration will be halved for each consecutive year. The cost will initially start at 25,000.

Year 1= 25,000 $ **Year 2 = 12,500 $** **Year 3 = 6,250$** **Year 4 = 3,125**

7. Conclusions

The LifeBot project, a collaboration with Kingston Fire and Rescue, exemplifies innovation in emergency medical response. Through the integration of advanced technologies such as Raspberry Pi, Arduino UNO WiFi Rev 2 board, and ROS2 packages, the LifeBot is designed to autonomously navigate and swiftly deliver Automated External Defibrillators (AEDs) rapidly within indoor environments. This capability is crucial in critical cardiac arrest scenarios where every second counts.

This comprehensive design report has thoroughly addressed the technical specifications and operational scenarios where the LifeBot can make a significant difference. It has outlined the development process, from conceptualization to prototype testing, which has successfully demonstrated the feasibility and effectiveness of the LifeBot as a lifesaving tool. In essence, the LifeBot is poised to bridge the gap between emergency onset and medical intervention, marking a step towards a future where technology and healthcare come together to save lives.

Moving forward, the LifeBot project seeks ongoing partnerships with stakeholders to refine the prototype, enhance its capabilities, and seamlessly integrate it into existing emergency response systems. This collaborative effort promises to reshape emergency medical services and establish a new standard for rapid medical assistance.

As authors, we proudly affirm that this report encapsulates our collective efforts and innovative spirit. We are committed to the continuous improvement and eventual implementation of the LifeBot, aspiring to make a meaningful and long-lasting difference to public safety and health outcomes.

References

[1] "AVIVE AED," [Online]. Available: https://avive.life/guides/importance-of-time-to-defibrillation/. [Accessed 03 03 2024].

[2] H. Docs, "ROS2-tutorals," [Online]. Available: https://husarion.com/tutorials/ros2-tutorials/8-slam/. [Accessed 1 03 2024].

[3] O. NAVIGATION, "Nav2," [Online]. Available: https://navigation.ros.org. [Accessed 01 03 2024].

[4] J. Newans, "mobile-robot-12-ros2-control," Articulated Robotics, [Online]. Available: https://articulatedrobotics.xyz/mobile-robot-12-ros2-control/. [Accessed 02 03 2024].

[5] J. Newans, "Getting Ready for ROS Part 2: Networking," [Online]. Available: https://articulatedrobotics.xyz/ready-for-ros-2-networking/. [Accessed 02 03 2024].

[6] J. Newans, "ROS Overview," Articulated Robotics, [Online]. Available: https://articulatedrobotics.xyz/ready-for-ros-4-ros-overview/. [Accessed 02 03 2024].

[7] Shawn, "RS232 vs TTL: Beginner Guide to Serial Communication," [Online]. Available: https://www.seeedstudio.com/blog/2019/12/11/rs232-vs-ttl-beginner-guide-to-serial-communication/. [Accessed 02 03 2024].

[8] D. Industries, "Installing the RPLidar Lidar Sensor on the Raspberry Pi," Medium, [Online]. Available: https://medium.com/robotics-with-ros/installing-the-rplidar-lidar-sensor-on-the-raspberry-pi-32047cde9588. [Accessed 02 03 2024].

[9] "Justice Laws Websire," 22 12 2023. [Online]. Available: https://laws-lois.justice.gc.ca/eng/acts/f-27/page-2.html#docCont. [Accessed 03 03 2024].

[10] "Accessibility for Ontarians with Disabilities Act," [Online]. Available: https://aoda.ca/. [Accessed 03 03 2024].

[11] "Ontario Environmental Regulations," [Online]. Available: https://www.ontario.ca/laws/regulation/r20030. [Accessed 03 03 2024].

[12] "Ontario Fire Code," [Online]. Available: https://www.ontario.ca/laws/regulation/070213. [Accessed 03 03 2024].

[13] "Lynxmotion - A4WD3 Rugged Wheeled Rover Kit," RobotShop, [Online]. Available: https://ca.robotshop.com/products/lynxmotion-a4wd3-rugged-wheeled-rover-kit?srsltid=AfmBOopRQCGG9ZNE5KU3rrZM7Ez3GBZD4cyBvnZbPDcqVrgVMRPmzDeUUGU. [Accessed 02 03 2024].

[14] "RPLidar A1M8 - 360 Degree Laser Scanner Development Kit," RobotShop, [Online]. Available: https://ca.robotshop.com/products/rplidar-a1m8-360-degree-laser-scanner-development-kit?gad_source=1&gclid=CjwKCAiAuYuvBhApEiwAzq_YiTUAH_Hsg3cbZURMv44SiGcZq6jDW2xtDePNcOTirmPMtiMFJbfQEBoCuL4QAvD_BwE. [Accessed 02 03 2024].

[15] "Raspberry Pi 4 Model B/8GB," PiShop, [Online]. Available: https://www.pishop.ca/product/raspberry-pi-4-model-b-8gb/?src=raspberrypi. [Accessed 02 03 2024].

[16] "Arduino Uno Rev4 Wifi," RobotShop, [Online]. Available: https://ca.robotshop.com/products/arduino-uno-rev4-wifi?gad_source=1&gclid=CjwKCAiAuYuvBhApEiwAzq_YiVBoVJM4RMnACxBA4MV5_2LvPTBcKGtdql0O5iEO5CF87fMrwC5mQBoCP38QAvD_BwE. [Accessed 02 03 2024].

[17] "Robotics Software Engineer Salary in Canada," Economic Research Institute, [Online]. Available: https://www.erieri.com/salary/job/robotics-software-engineer/canada. [Accessed 02 03 2024].

[18] Bloomberg, "Canada is the tenth most expensive country in the world for mobile data: study," [Online]. Available: https://www.bnnbloomberg.ca/canada-is-the-tenth-most-expensive-country-in-the-world-for-mobile-data-study-1.2041658#:~:text=The%20study%2C%20conducted%20by%20financial,mobile%20data%20in%20the%20world.. [Accessed 02 03 2024].

[19] "Power Consumption Benchmarks," [Online]. Available: https://www.pidramble.com/wiki/benchmarks/power-consumption. [Accessed 02 03 2024].

[20] "How many watts does a computer use?," [Online]. Available: https://www.energysage.com/electricity/house-watts/how-many-watts-does-a-computer-use/. [Accessed 02 03 2024].

[21] "Electricity Prices in Canada 2023," [Online]. Available: https://www.energyhub.org/electricity-prices/#:~:text=The%20average%20cost%20of%20electricity%20in%20Ontario%20is%20%240.141%20per,monthly%20usage%20of%201%2C000%20kWh.. [Accessed 02 03 2024].

[22] t. youngblood. [Online]. Available: https://www.allaboutcircuits.com/projects/how-to-use-a-rotary-encoder-in-a-mcu-based-project/.

[23] Aditat. [Online]. Available: https://atadiat.com/en/e-rosserial-arduino-introduction/.

[24] AdrieSentosa, "Raspberry Pi - Arduino Serial Communication," Instructables, [Online]. Available: https://www.instructables.com/Raspberry-Pi-Arduino-Serial-Communication/. [Accessed 02 03 2024].

[25] "ChatGPT," [Online]. Available: https://chat.openai.com/. [Accessed 03 03 2024].

Appendix 1:

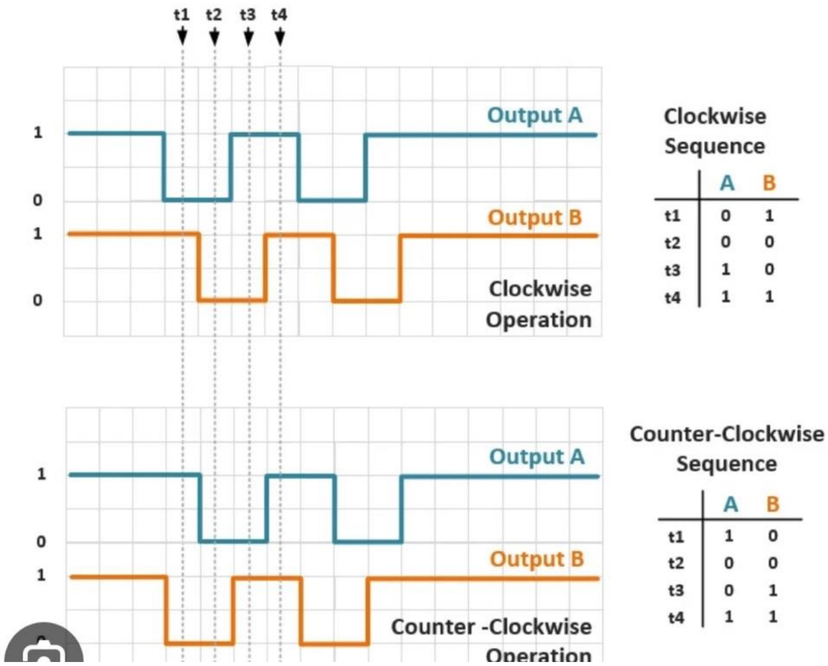
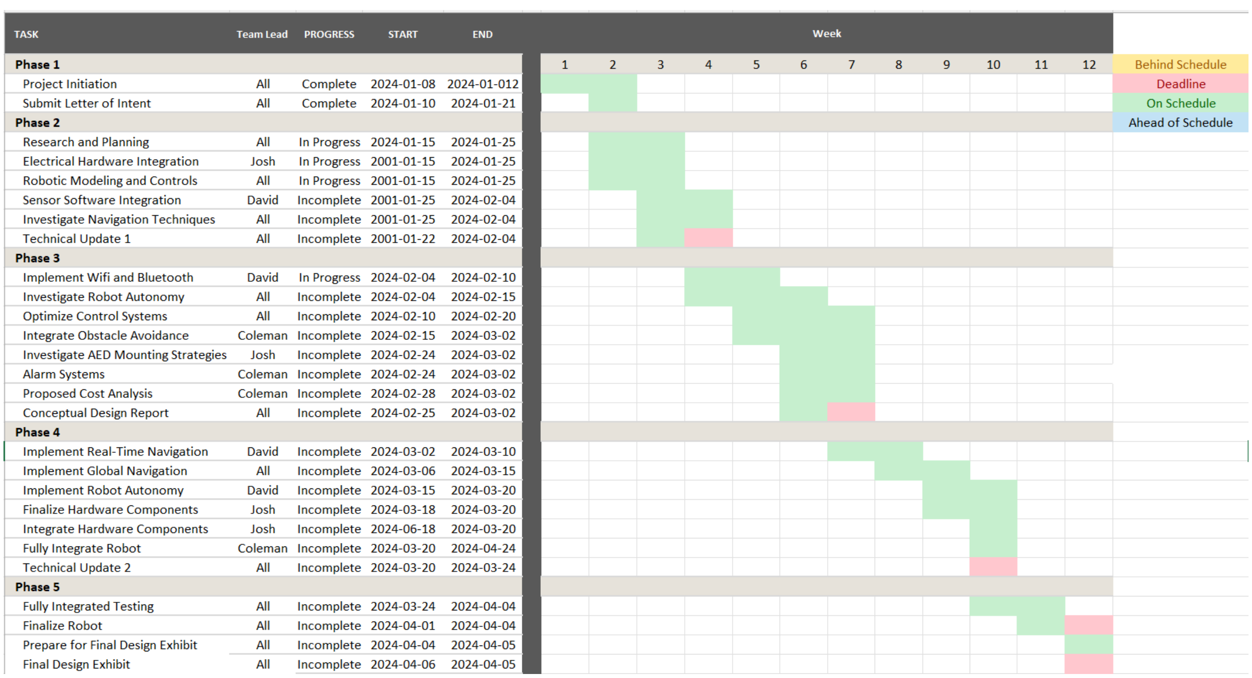


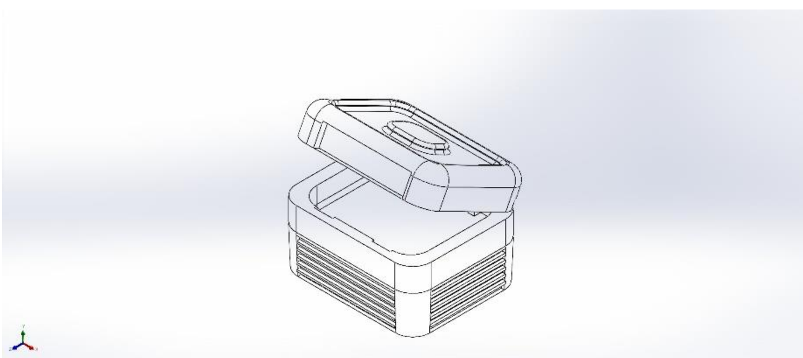
Figure 13: Encoder data to Arduino [22]



TASK	Team Lead	PROGRESS	START	END
Phase 1				
Project Initiation	All	Complete	2024-01-08	2024-01-012
Submit Letter of Intent	All	Complete	2024-01-10	2024-01-21
Phase 2				
Research and Planning	All	In Progress	2024-01-15	2024-01-25
Electrical Hardware Integration	Josh	In Progress	2001-01-15	2024-01-25
Robotic Modeling and Controls	All	In Progress	2001-01-15	2024-01-25
Sensor Software Integration	David	Incomplete	2001-01-25	2024-02-04
Investigate Navigation Techniques	All	Incomplete	2001-01-25	2024-02-04
Technical Update 1	All	Incomplete	2001-01-22	2024-02-04
Phase 3				
Implement Wifi and Bluetooth	David	In Progress	2024-02-04	2024-02-10
Investigate Robot Autonomy	All	Incomplete	2024-02-04	2024-02-15
Optimize Control Systems	All	Incomplete	2024-02-10	2024-02-20
Integrate Obstacle Avoidance	Coleman	Incomplete	2024-02-15	2024-03-02
Investigate AED Mounting Strategies	Josh	Incomplete	2024-02-24	2024-03-02
Alarm Systems	Coleman	Incomplete	2024-02-24	2024-03-02
Proposed Cost Analysis	Coleman	Incomplete	2024-02-28	2024-03-02
Conceptual Design Report	All	Incomplete	2024-02-25	2024-03-02
Phase 4				
Implement Real-Time Navigation	David	Incomplete	2024-03-02	2024-03-10
Implement Global Navigation	All	Incomplete	2024-03-06	2024-03-15
Implement Robot Autonomy	David	Incomplete	2024-03-15	2024-03-20
Finalize Hardware Components	Josh	Incomplete	2024-03-18	2024-03-20
Integrate Hardware Components	Josh	Incomplete	2024-06-18	2024-03-20
Fully Integrate Robot	Coleman	Incomplete	2024-03-20	2024-04-24
Technical Update 2	All	Incomplete	2024-03-20	2024-03-24
Phase 5				
Fully Integrated Testing	All	Incomplete	2024-03-24	2024-04-04
Finalize Robot	All	Incomplete	2024-04-01	2024-04-04
Prepare for Final Design Exhibit	All	Incomplete	2024-04-04	2024-04-05
Final Design Exhibit	All	Incomplete	2024-04-06	2024-04-05

Figure 14: Updated Gantt Chart Detailing the Scheduled TimeLine for the Project

Appendix 2: AED-Mount Simulation

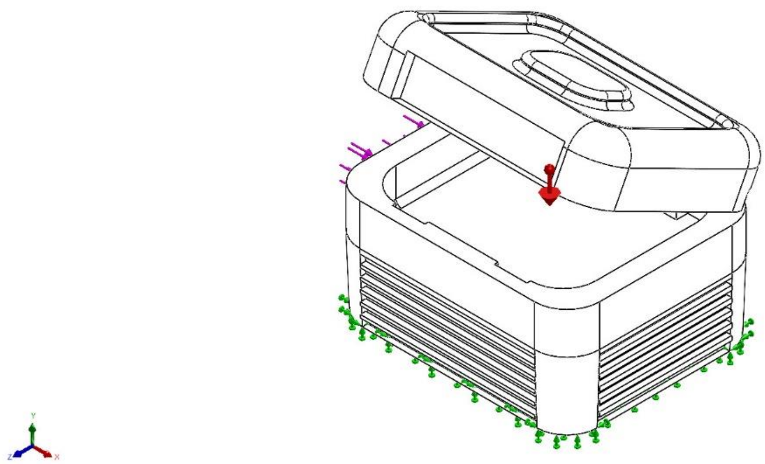


Simulation of AEDMountAssembly

Date: March 2, 2024
Designer: Solidworks
Study name: Static 1
Analysis type: Static

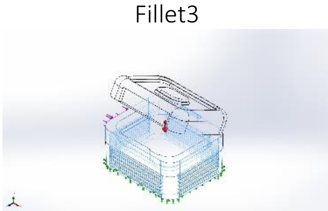
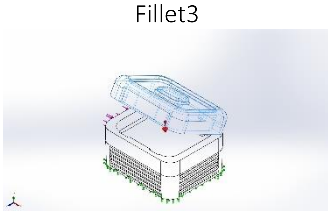
Table of Contents

Model Information



Model name: AEDMountAssembly
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Fillet3 	Solid Body	Mass:9.61767 kg Volume:0.0094291 m^3 Density:1,020 kg/m^3 Weight:94.2531 N	C:\Users\westy\OneDrive - Queen's University\Second Year\First Semester\AutoDrive\Base.SLDPRT Mar 1 19:28:50 2024
Fillet3 	Solid Body	Mass:4.80251 kg Volume:0.00470835 m^3 Density:1,020 kg/m^3 Weight:47.0646 N	C:\Users\westy\OneDrive - Queen's University\Second Year\First Semester\AutoDrive\Lid.SLDPRT Mar 1 19:32:05 2024

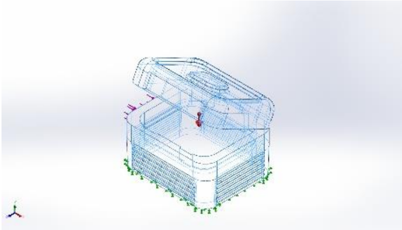
Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\westy\OneDrive - Queen's University\Second Year\First Semester\AutoDrive)

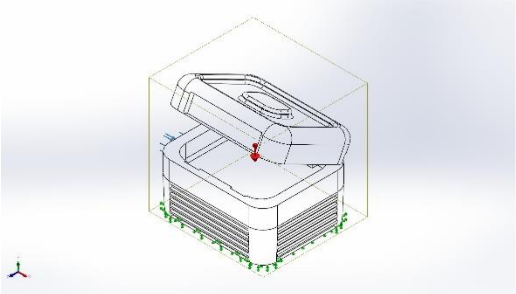
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	Name: **ABS** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Tensile strength: **3e+07 N/m^2** Elastic modulus: **2e+09 N/m^2** Poisson's ratio: **0.394** Mass density: **1,020 kg/m^3** Shear modulus: **3.189e+08 N/m^2**	**SolidBody 1(Fillet3)(Base-1), SolidBody 1(Fillet3)(Lid-1)**
Curve Data:N/A		

Interaction Information

Interaction	Interaction Image	Interaction Properties
Global Interaction		**Type:** **Bonded** **Components:** **1 component(s)** **Options:** **Independent mesh**

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	51.221 mm
Minimum element size	4.20952 mm
Mesh Quality	High
Remesh failed parts independently	Off

Mesh information - Details

Total Nodes	42188
Total Elements	22387
Maximum Aspect Ratio	173.2
% of elements with Aspect Ratio < 3	62.4
Percentage of elements with Aspect Ratio > 10	5.63
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:08
Computer name:	JOSH-G15

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-5	153.823	-2.6226e-06	153.904

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

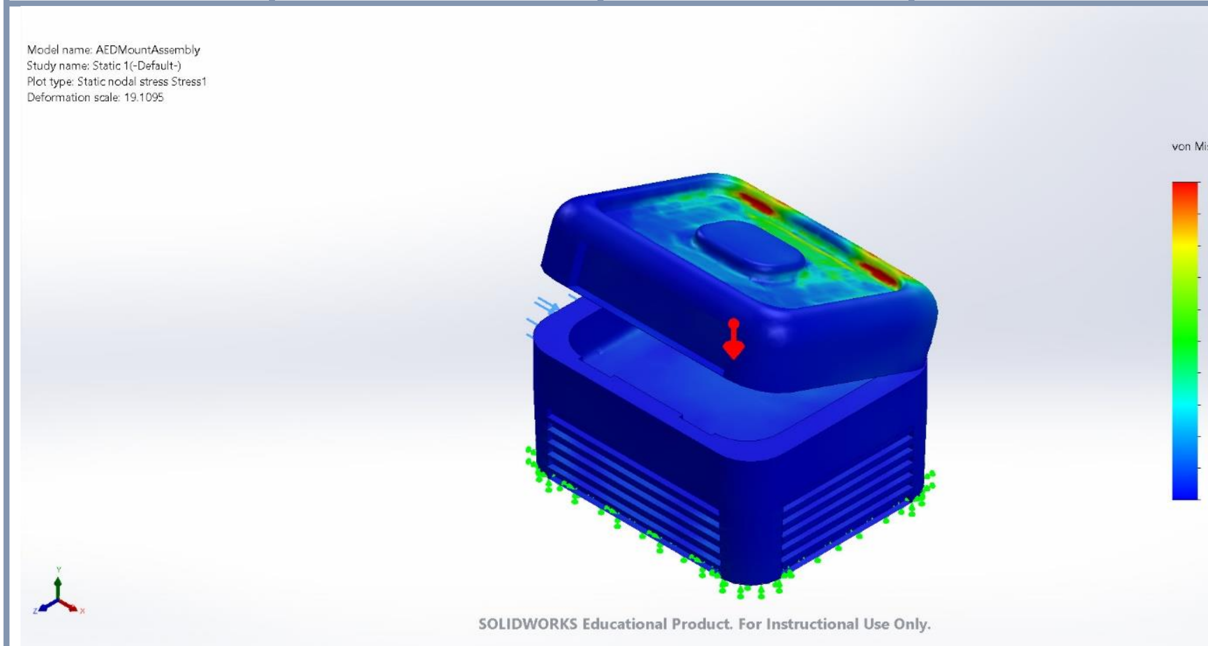
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-7.1524e-07	106.632	-1.43051e-05	106.632

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

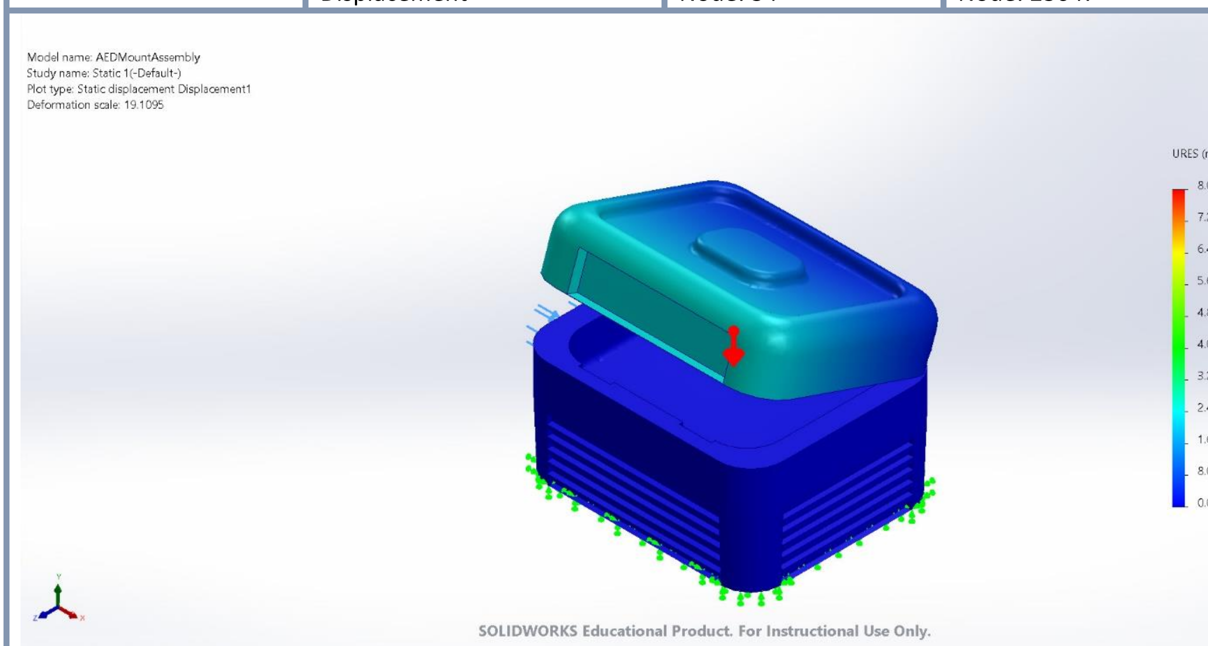
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	9.644e+01N/m^2 Node: 1499	6.376e+06N/m^2 Node: 27676



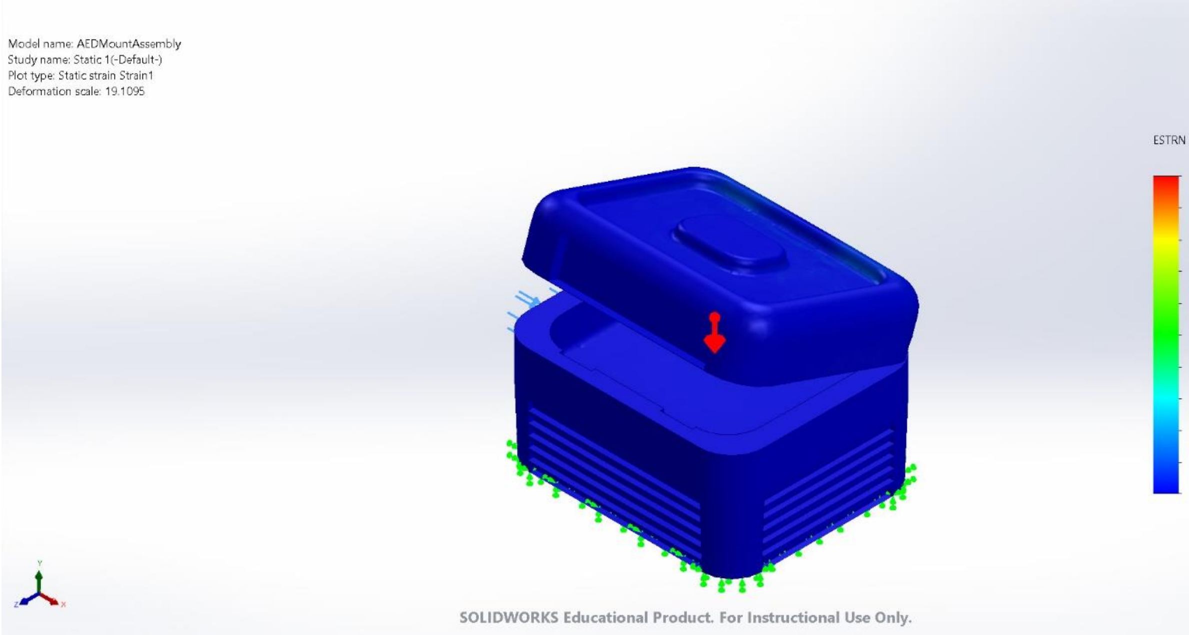
AEDMountAssembly-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 34	2.530e+00mm Node: 23647



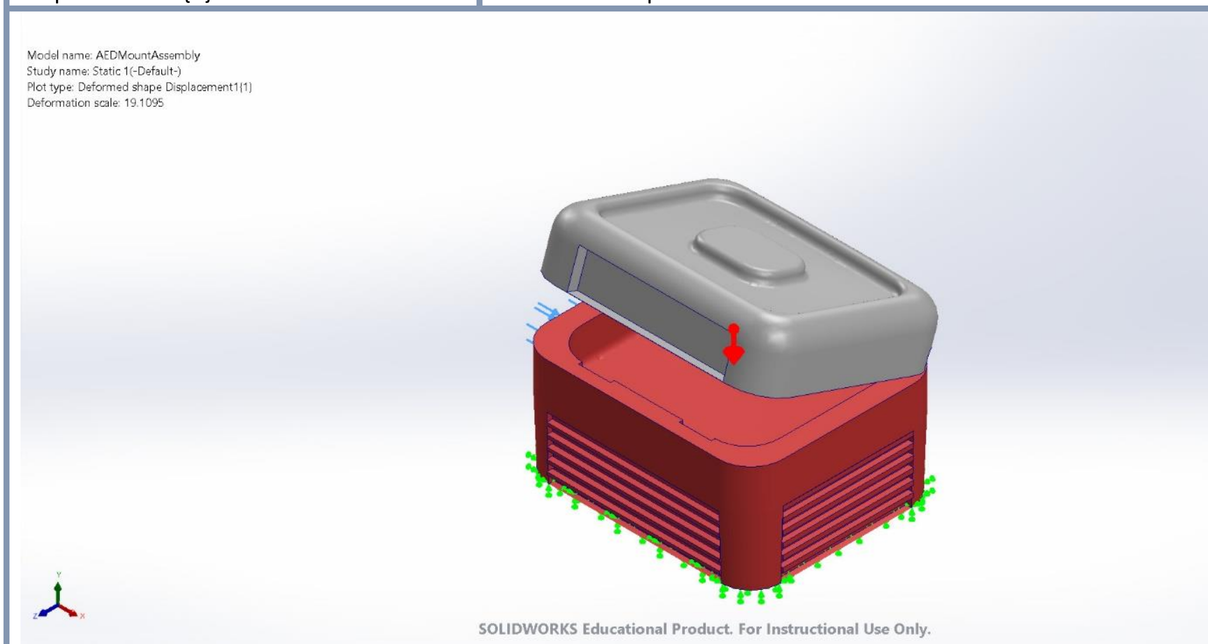
AEDMountAssembly-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.770e-08 Element: 376	2.125e-03 Element: 22326



AEDMountAssembly-Static 1-Strain-Strain1

Name	Type
Displacement1{1}	Deformed shape



AEDMountAssembly-Static 1-Displacement-Displacement1{1}