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Queen's Project Management Corporation
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Regarding your recent Request for Proposals,

Ventus Robotics is a leading environmental monitoring company.”Ventus”, Latin for ”wind”, conveys the company's specialization in monitoring air quality and illustrates the elegant yet dynamic nature of their robotic solutions.

Core competencies include:

- Design and iterative development of agile robotic solutions for condition monitoring using modern frameworks
- Integration of easy-access web-based responsive user interfaces which communicate with our systems
- Collection of requirements for complex consulting solutions
- Engineering communications and project documentation

Ventus Robotics seeks Q-PMC's support for developing a prototype mobile robot for remote environmental monitoring of buildings.

This robot will allow for the assurance that air quality in buildings owned by Q-PMC adheres to the Occupational Health and Safety Act. Exposure to carbon dioxide levels over 1000 ppm for 24 hours can lead to mucus membrane and respiratory problems decreased work performance, and neuro-physiological symptoms [1]. The majority of carbon dioxide is from occupants' respiration. Thus, air quality should be measured to ensure the safety of workers, maintain trust in Q-PMC by renters, and assure legal security with respect to health and safety.

The solution should be practical (quiet and avoidant of obstacles and people), cost-effective, novel, safe, and have a sustainable life-cycle. A single working prototype of the robot will be constructed. The prototype will adhere to the aforementioned functional requirements. The robot must monitor carbon dioxide levels and may additionally monitor temperature, carbon monoxide, and other properties related to air quality which affect the safety of occupants. The robot should know its location at a given time and be able to navigate through a single floor of the building that it is monitoring using sensors and actuators. The robot should be identifiable in the dark to avoid collision. The robot does not need to be fully autonomous but should be capable of sampling data continuously. It is assumed that the robot need not open doors or enter isolated rooms and will only operate in indoor environments. The robot will able to avoid obstacles but will not need to move in a vertical direction. The robot is for commercial use only and will not be designed for personal dwellings or military purposes. Not all code, sensors, mechanical parts, and data processing will be produced by Ventus Robotics. It will be the requirement of Q-PMC to take action on the data collected via the robot.

The project's main stakeholders include Q-PMC, business owners, and employees. Q-PMC's interests are safety, legal security, and customer satisfaction. The effect on Q-PMC is a reduction in the legal risk of being sued by customers and increased customer satisfaction, as well as differentiation in the leasing market due to safety precautions, and finally a potential loss of investment if the project is unsuccessful. Business Owners' interests are the safety of buildings and legal security; the effect on them is improved trust and reduced legal risk. Employees' interests are personal health and lack of disruption to work; the effect on them is personal health and lack of disruption.

The following sections describe the technical plan for the mobile air-quality monitoring robot.

Navigation: The onboard Arduino will be used to code directional movement functions for the rover. A USB host shield and a Bluetooth dongle will be used to connect a PS4 controller to the robot, allowing for the use of the controller's buttons and joysticks as inputs. A pilot will drive the rover around each building floor while the LiDAR sensor is creating a 2D map. After completion of the map, the rover will now be able to autonomously traverse the building collecting air quality data.

Mapping: Data collection will be done using the ROS LiDAR packages. The data will then be visualized using Rviz, a 3D visualization program for ROS, to better understand the data. To build the map, the HECTOR-Slam ROS package will be used. Hector-SLAM is an algorithm that uses laser scan data to create a map and doesn't require odometry data. The rover will be run multiple times on the same floor to build a more accurate map using the SLAM technique, which involves both mapping and localization of the rover in the unknown environment [2]. The robot will be tested on the main, second, and third floors of Beamish-Munro Hall, Kingston, Ontario.

Air Quality Monitoring: Air quality will be measured using a CO_2, temperature and humidity sensor, and a volatile organic compounds (VOCs) sensor. Data will be sent to the Raspberry Pi to be processed into usable data. Data will be separated into levels/ppm of various compounds and humidity.This data will be cross-referenced with safe air quality standards as per Occupational Health and Safety Act (OHSA) in Ontario, Canada. The data will be used to create a heat map of the room. A function will be coded to check if the data is within safe air quality standards.

User Interface: The user interface will be a web app that allows users to monitor air quality in a building by logging in with a code. The app displays a heat map of the selected floor or area with a color-coded indicator of safety (green = safe, yellow = safe for limited time, red = unsafe). The app can be accessed by any employee and includes a building selection page and a login page using company single sign-on. Hovering over the indicator shows a description of the room or floor's safety. If data is unsafe, a warning notification is sent to all building employees.

Software: Python will be used for programming the Raspberry Pi, which will be responsible for communicating the organized sensor data to the website. Arduino will be used to control the movement and functions of the robot. React, a JavaScript library, will be used for developing the user interface, allowing for easy access and visualization of the air quality data. ROS (Robot Operating System) will be used for LiDAR mapping. Gazebo will be used for simulation and map generation, allowing for testing and development of the rover's navigation and mapping capabilities. The team will use Github for code collaboration, and Notion for documentation and task management. Official documents are to be written in LaTeX using Overleaf.

Stretch Goals: Given the completion of non-autonomous navigation and building mapping, further functionality will be pursued. This includes developing the ability for the rover to move up and down stairs, implementing omni-directional wheels for better maneuverability, and increasing the autonomy of the rover. The autonomy will be developed in levels, with the first level being the ability to save a path when previously driven with the PS4 controller, then following that path autonomously. In the second level, the rover will be able to create a LiDAR map and drive autonomously around the building. Remote control of the robot using Wifi rather than Bluetooth may be pursued. Additionally, a charging dock may be developed, the charging dock will be 3D printed and designed so the robot can easily drive into it and align the charging ports.

Additional Components: The robot will be equipped with 4 purple LED light strips such that the robot will be visible in dark environments. Hardware components on the robot will be organized using 3D printed parts made using the Creality Ender 3.

The team will meet 4 times weekly for 6 hours total, including workshop sessions on Mondays and Tuesdays, Wednesday afternoons, and Saturdays as needed. Individual work will be assigned at meetings. All team members are expected to fulfill their roles, respect colleagues, and ensure the safety, effectiveness, and quality of their work, as well as provide proper documentation. A plan including the deliverable dates and expected feature-implementation timeline is displayed in **Figure 2**. The plan is subject to change pending results from the iterative design stages. Ventus Robotics' core members' technical roles are as follows.

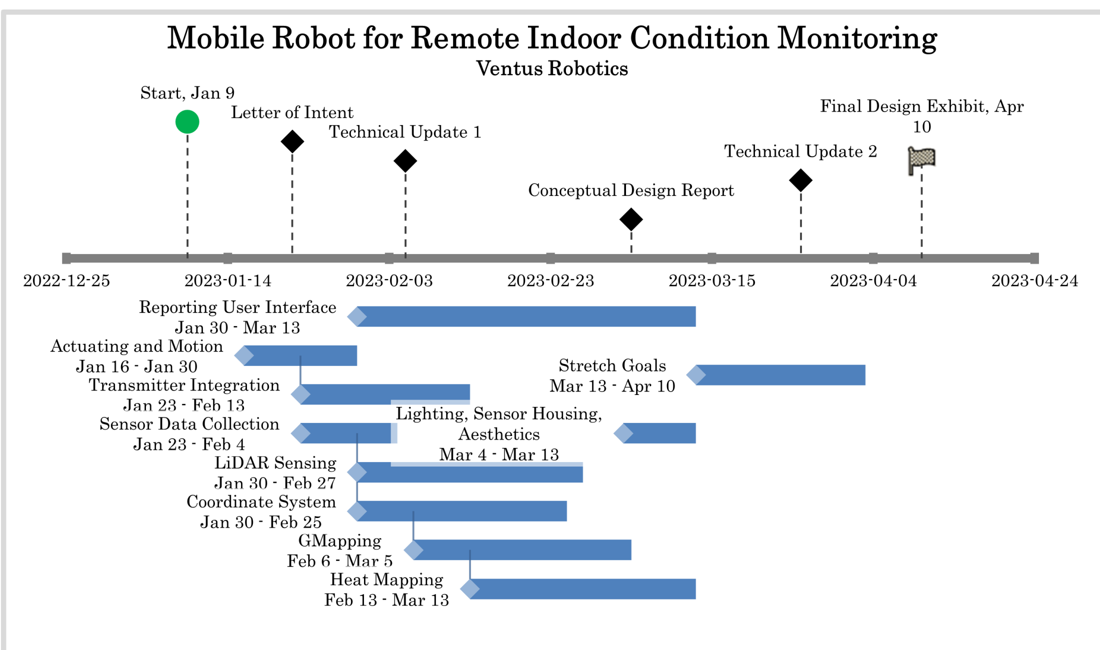

Figure 2. A gantt chart depicting the desired timeline for the project, including major "umbrella" tasks and key deliverables.

A high-level systems diagram can be found in **Figure 3**. This is subject to change based on the stretch goals and desired functionalities achieved.

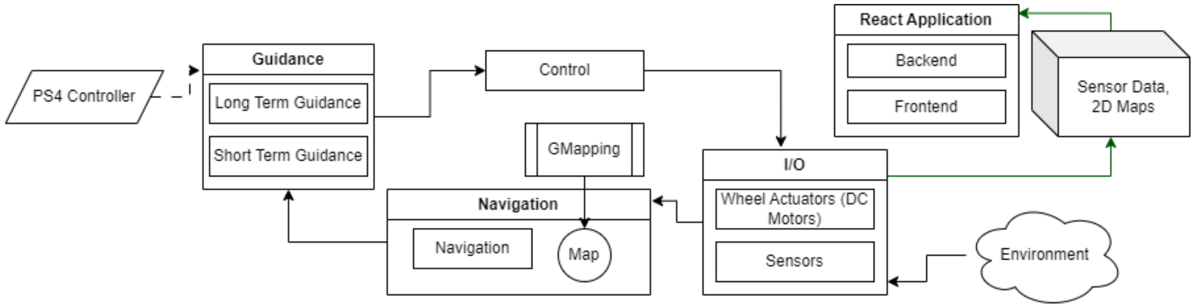

Figure 3. A preliminary systems diagram of the proposed mobile robot for monitoring CO2 in remote environments solution.

Sabrina Button, Chief Technical Officer of Embedded Software and Control (CTO-ESC): Translate sensor data into usable information for the CTO-SII to visualize, as well as create algorithms to drive the actuators based on inputs, obstacles, and objectives.

Luke Major, Chief Technical Officer of Software Integration and Interfacing (CTO-SII): Utilize the data and visualizations from the robot and create a responsive front and back-end web interface for viewing data. The CTO-SII will work closely with the CTO-ESC to create G-Mapping functionality and create usable data with the LiDAR.

Daniel Dubinko, Chief Technical Officer of Hardware Integration (CTO-HI): Design the external transmitter, and any other additional hardware, and organize these devices' communications with the robot.

The following for seen challenges may delay the project timeline or alter the individual roles of the team.

1. Appropriate hardware that meets quality, price, and feature requirements will be selected. To ensure the system remains functional, countermeasures like protective shells or software may need to be implemented. Carefully considering the integration of the system's hardware and implementing software such as ROS will help mitigate compatibility concerns. As hardware ages, batteries and motors may experience a decline in performance; therefore, parts will be module for easy replacement. The stability and mobility of the wheels may impact the accuracy of actuator control which may require the implementation of a stabilizer.

2. Regarding software, performance may be affected by limitations in battery life and processing power. Identifying the proper microcontroller for each process will ensure the system is as efficient as possible. Creating a user-friendly data storage and retrieval interface will be challenging and require multiple revisions. Developing and exporting virtual maps of buildings may also prove difficult, particularly due to a lack of experience with LiDAR and ROS.

3. In terms of the environment, the robot's ability to navigate through areas with doors and stairs will be a key obstacle, and dealing with unpredictable objects in the robot's working spaces will require a robust avoidance system.

4. Finally, the project may be delayed by the time-consuming task of learning and implementing new concepts and skills.

Ventus Robotics is committed to growth and expansion, and we are currently seeking new opportunities to expand our reach and further develop our product and service offerings. We look forward to working with you and contributing to your success.

Please let us know if you have any questions or need additional information.

Sincerely,

VENTUS ROBOTICS

Ventus Robotics

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References

[1] D. Smith, "Everything you need to know about carbon dioxide (CO2)," Kaiterra, 02-Sep-2022. [Online]. Available: https://learn.kaiterra.com/en/resources/carbon-dioxide-co2: :text=If indoor carbon dioxide levels,and may struggle to concentrate. [Accessed: 22-Jan-2023].

[2] A. automaticaddison, "How to build an indoor map using ROS and lidar-based Slam," Automatic Addison, 22-May-2021. [Online]. Available: https://automaticaddison.com/how-to-build-an-indoor-map-using-ros-and-lidar-based-slam/. [Accessed: 22-Jan-2023].