A Robotic Sensing System for Gas Emission Measurement

DESIGN DOCUMENT

sdmay22-42
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Executive Summary

Development Standards & Practices Used

- Waterfall+agile hybrid project management style
- Object oriented programming
- Coding best practices
- Customer focused development
- IEEE standard P260.1 – letters and symbols
- IEEE standard P802.16 – acceptable channels and connections
- IEEE standard P802.11 – communications between devices
- IEEE standard 1625-2008 – rechargeable batteries
- 7.8 IEEE - Code of Ethics

Summary of Requirements

- Modify an existing commercially available robot to complete greenhouse gas emissions testing
- Apply an existing NDIR CO2 sensor for soil greenhouse gas emissions testing
- The robot must be able to traverse wetland conditions
- The robot must be able to automatically travel to a designated area using a GPS module
- The robot must be able to drill into the ground and collect data using sensors
- The robot must be able to communicate the data to the user
- A user interface must be created so that the user can see and extract the data sent from the robot
- The robot must be able to reliably repeat the measurement procedures

Applicable Courses from Iowa State University Curriculum

- CprE 288: Embedded Systems
- EE 230: Electronic Circuits and Systems
- EE 333: Electronic System Design
- SE 309: Software Development Practices

New Skills/Knowledge acquired that was not taught in courses

- Motors and motor controllers
- Linear rails
- I/O interface and PCB design
- Drilling mechanisms and forces
- Mechanical design and implementation
- 3D printer assembly and control systems
- Sensors and sensor applications
- Soil composition and environmental impacts
- Typical soil sample collection techniques
- In depth robotics systems
- GPS module utilization
- Wireless circuit design

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List of figures/tables/symbols/definitions

1 Team

1.1 Team Members

- Robert Wedan
- Jason Grunklee
- Chimzim Ogbondah
- Freedom Clark
- Animesh Shrouti
- Tzu-Chien Liu

1.2 Required Skill Sets for Your Project

- Experience with microcontrollers
- Robotics design and assembly experience
- Programming and Communication experience
- Experience with motors and motor controllers
- Technical writing
- Experience with sensors and data recording
- Data acquisition from sensors
- Team communication
- Consumer oriented mindset

1.3 Skill Sets covered by the Team

- Experience with microcontrollers
  - Chimzim and Jason have experience working with microcontrollers from their coursework
- Robotics design and assembly experience
  - Jason has some robotics experience from high school robotics
- Programming and communications experience
  - Chimzim has programming experience and a little experience with communications
- Experience with motors and motor controllers
  - Robert and Jason have a little bit of knowledge regarding motor control
- Technical writing
  - Robert has work experience writing technical documents
- Experience with sensors and data recording
  - All team members have minimal experience from coursework

- Data acquisition from sensors
  - All team members have minimal experience from coursework
- Team communication
  - All team members have experience from group projects and assignments in coursework and professional positions
- Consumer oriented mindset
  - Most team members have a general understanding of this concept from professional positions

1.4 Project Management Style Adopted by the team

- Waterfall+agile – Customer focused approach that will help us deliver the best product to the client

1.5 Initial Project Management Roles

- We will have one team member who will act as the project manager (Robert Wedan), and they will be responsible for keeping track of team progress, documentation, and interfacing with the client/faculty member on scheduling. This person will also be a floating member when idle
- We will have three members who are project leads and are responsible for each of the main parts of the project (Sensor Electronics (Animesh Shrouti), Robotics (Freedom Clark), and Data Collection/User Interface (Chimzim Ogbondah))
- We will also have two team specialists who will be tasked with providing contributions to more than one area of the project (Jason Grunklee and Tzu-Chien Lui). Team specialists will be valuable assets in helping groups with a heavier workload meet deadlines. These members are expected to be knowledgeable on all aspects of the project that they have been assigned to

2 Introduction

2.1 Problem Statement

Soil contributes about 20% of the total emission of carbon dioxide into the atmosphere. This happens through soil respiration and results in a reduction of the soil fertility and productivity. In addition to carbon dioxide, methane is also a large contributor to greenhouse gases. Wetland methane emissions are the largest source of natural and anthropogenic emissions contributing to about one third of the global methane budget. Our project attempts to design a robotic sensing system that will measure greenhouse gas emissions, with a focus on carbon dioxide emissions, in wetland soil.

Robotic sensing systems for greenhouse gas emissions presented in the problem statement currently exist in the world but most are large and very expensive. Our goal is to create a functional copy on a smaller scale and a much stricter budget.

Our idea is to use a preexisting robot to traverse the wetlands carrying our created sensing apparatus that drills into the soil and extracts useful data from the soil. Once data from the site is collected, the robot will then communicate that data to the user. Following the communication of the data, the robot will navigate using GPS and move on a predetermined path to the next test site. The data collection procedure will be replicated, and data will once again be sent to the user. The entire process will continue until there are no more test sites.

2.2 Requirements & Constraints

The robotic sensing system for greenhouse gas emissions consists of four components: a robot, a sensing attachment, a navigation unit, and a communication module. Each component presents different requirements and constraints.

<u>Functional Requirements</u>

- The robot must be able to traverse wetland conditions which involves plant life and bumpy terrain that is sometimes wet
- The robot must be able to carry the weight of the sensing attachment
- The robot must be able to withstand the torque of the drilling so that it will not slip on the terrain
- The sensing attachment must be able to drill into the soil and collect data from under the ground
- The sensing attachment must be able to be carried by the selected robot
- The sensing attachment must be able to read carbon dioxide in the soil

- The sensing attachment must have a USB interface
- The navigation unit must be able to communicate with the robot and move it on a set path using GPS
- The communication module must be able to send the data from the sensor to the user for manipulation

Non-Functional Requirements

- The user interface must be accessible by the customer and easy to interpret
- Best coding practices are used for easy future implementation and design changes
- The user must be able to designate a unique path for the robot
- Design and testing process should be well documented for future handoffs
- The robot should be able to reliability repeat its measurement process

Constraints

- The entire project must stay under the allotted budget of $5000
- The project needs to be completed in 1200 person hours (across two semesters)
- The sensing attachment must be able to detect 400 parts per million of CO_2 within the soil
- Robot development should begin at the latest the start of semester two
- The artificial testing environment is located at the ISU research farm which may have limited availability
- The ground must be soft enough to drill into

2.3 Engineering Standards

Engineering Standard	**Justification**
7.8 IEEE Code of Ethics	The code of ethics lays out a clear set of values, rules, and guidelines to follow so that everyone on the team is on the same page.
IEEE Standard P260.1	This standard covers letter symbols and units of measurements that will be used in this project
IEEE Standard P802.16	This standard covers acceptable channels to carry data across and best practices for good and bad connections
IEEE Standard P802.11	This standard covers protocols on how to communicate between devices
IEEE Standard 1625-2008	This standard covers the requirements for how to recharge batteries and transmitting data about the battery

Table 1: Engineering Standards

2.4 Intended Users and Uses

This project targets the lack of affordable robotic sensing systems for greenhouse gasses. This directly benefits researchers in the field that need a more affordable way to collect data in the field. The research they conduct will help us gain a better understanding of our environment which indirectly helps everyone on Earth.

This project will likely interest anyone that is invested in the environment or is involved in environmental research. The robotic sensing system may be used to test for greenhouse gasses when a person is unable to make it to the location themselves. On a very large scale there could be many of these robots that can collect samples in a variety of different locations at the same time.

3 Project Plan

3.1 Project Management/Tracking Procedures

We initially adopted the waterfall project management style but soon after changed to the agile management style. Where we landed can only be described as a hybrid of the two styles. The waterfall project style initially suited our need when we were focused on a sequential project design. However, a lot of the aspects of our project cannot be decided on individually. The agile project management style also suited our needs and allowed us to start in a broader direction and then adapt the design as needed. Combining the two resulted in us defining a target and preparing a design for that target while also giving us the flexibility we needed to skip the entirely sequential design process. Using a waterfall+agile hybrid as our project management style helped us sequentially complete our project while offering us the flexibility to change our design as the year progresses.

Our group will use discord as our main point of communication. It will also be extremely useful for tracking progress and storing documentation. For sharing documentation between team members, we will use google drive to distribute assignments and presentations. In addition to discord and google drive, the team may also use “Cybox” as a place to store documentation that our mentor and client can access. This may be implemented if required by the faculty member to facilitate easy access of documentation between the team and our advisor.

3.2 Task Decomposition

This project can be classified into three main design aspects and broken down further into six specific tasks that need to be completed for a successful project.

For the three main design aspects we first have the robotics of the system. Our project needs to have a working robot that can perform all the necessary tasks described in our project proposal. Next is the sensor apparatus. In order to complete its design, our system needs to have an attached sensor that can also transmit data received from the soil samples. Finally, a user interface needs to be created to allow data collection and also permit the user to interact with the received data.

The six tasks that make up our project’s composition include the following: Robotics and Sensor Selection, Drilling Mechanism Design and Application, Robotics and Sensor Applications, Data Collection and Navigation Software, Creation of the User Interface, and Completion of the Technical Writing.

Robotics and Sensor Selection will be a pivotal task in our project’s design because our whole system revolves around being mobile and retrieving data. The selection of the sensor and robot will be crucial in ensuring our project’s success.

The Drilling Mechanism Design and Application will be a difficult task that will need to be carefully considered. Understanding the various forces acting on the robot when drilling will be important to ensure that we can retrieve accurate data from the sensors.

Robotics and Sensor Application will be a task that is all about the implementation of the robot and sensor selected in the first task mentioned. This will be instrumental in the physical appearance of our robot along with the functionality during testing.

The Data Collection and Navigation Software will be a task that is coding heavy and is marked by the ability to send and receive data from the robot to the user. This completion of this task will play a big part in the functionality of the robot as intended.

Creation of the User Interface should be a small task that is a quality-of-life addition to the sending and receiving of data. The user interface should be user friendly and should make it easy for the user to interpret the data sent from the robot.

Completion of the Technical Writing is a task that will be continually done over the course of the entire project. Its completion will ensure that all documentation of the project is properly completed.

Given the project requirements, our project's sequential progression can be broken up into five main sections that each contain subsections. Those five main sections are listed in sequential order as follows: Research and Brainstorming, Planning and Design, Building and Implementation, Testing, and Finalization. More information about these main parts and project progression can be found in section 3.3 and section 3.4 which features a Gantt chart.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

There will be key milestones to completing each of the main sections of the project that were mentioned in the section above.

For the research and brainstorming section completion of the team contract, the requirements, constraints, and engineering standards document, and other assigned documentation will signify a strong understanding of the project concept and surrounding knowledge as well as setting the standard for team conduct, communication, and cooperation.

For the planning and design section finalizing the drilling apparatus, robot selection, sensor selection, and all other design specifications with approval from client will be the main milestone for this section of the project.

For the building and implementation section of the project, there are many deliverables that will need to be completed. To summarize them into a single milestone, we wish to complete the entire build for the robot including all physical features, navigation, and data collection.

For the testing subsection our largest milestone would be to have a final product that can perform repeatable measurement in the ISU testbed.

Lastly, for the finalization section the main milestone would be to present and demo our finished product to our client. Complete of that last milestone would signify a completion of the project.

3.4 Project Timeline/Schedule

Below you will find our project schedule and timeline organized into a Gantt Chart. It highlights the five main steps in completing our project and how much time we anticipate each step taking in reference to the two semesters we are allotted to work on it.

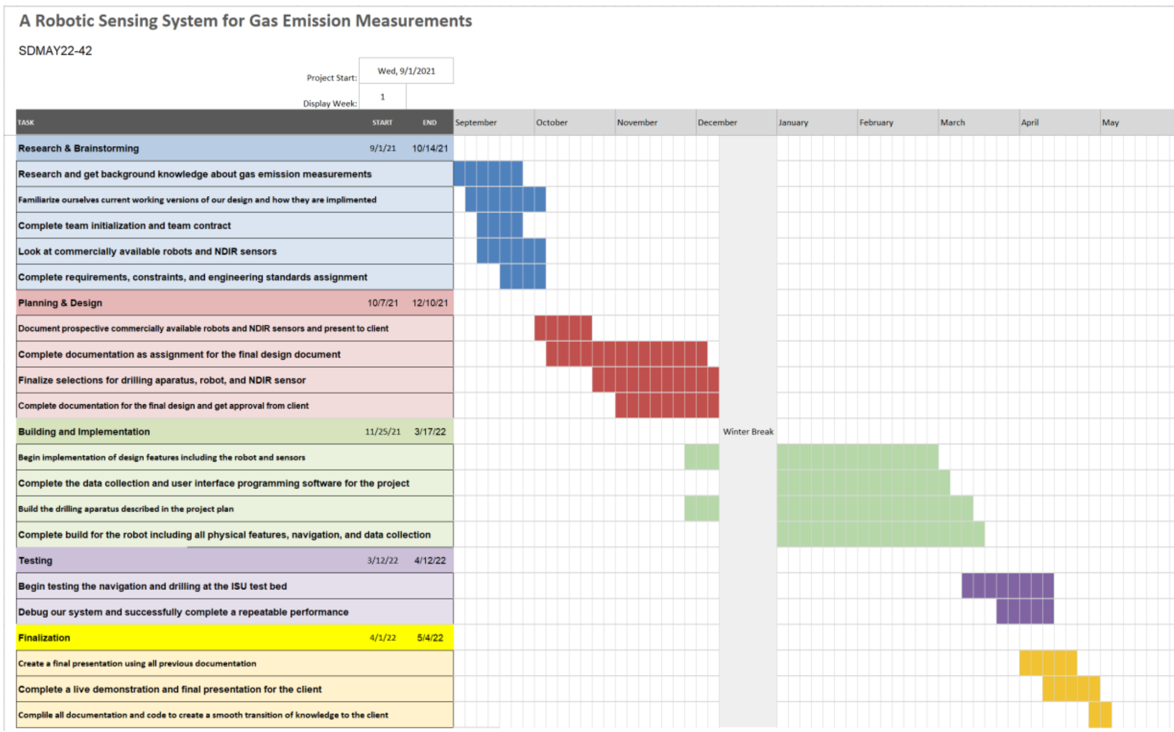

Figure 1: Project Timeline/Gantt Chart

Below is a closer look at the breakdown of each individual step and the parts that make up its completion including all major milestones.

TASK	START	END
Research & Brainstorming	9/1/21	10/14/21
Research and get background knowledge about gas emission measurements		
Familiarize ourselves current working versions of our design and how they are implimented		
Complete team initialization and team contract		
Look at commercially available robots and NDIR sensors		
Complete requirements, constraints, and engineering standards assignment		
Planning & Design	10/7/21	12/10/21
Document prospective commercially available robots and NDIR sensors and present to client		
Complete documentation as assignment for the final design document		
Finalize selections for drilling aparatus, robot, and NDIR sensor		
Complete documentation for the final design and get approval from client		
Building and Implementation	11/25/21	3/17/22
Begin implementation of design features including the robot and sensors		
Complete the data collection and user interface programming software for the project		
Build the drilling aparatus described in the project plan		
Complete build for the robot including all physical features, navigation, and data collection		
Testing	3/12/22	4/12/22
Begin testing the navigation and drilling at the ISU test bed		
Debug our system and successfully complete a repeatable performance		
Finalization	4/1/22	5/4/22
Create a final presentation using all previous documentation		
Complete a live demonstration and final presentation for the client		
Complile all documentation and code to create a smooth transition of knowledge to the client		

Figure 2: Task Specific View of Gantt Chart

3.5 Risks And Risk Management/Mitigation

To look at risks, we have broken the project into the six main tasks previously mentioned that potentially have risks associated with them. We will look at the risks that apply to each task and how to preemptively ensure that our project is risk adverse.

Task 1: Robotics and Sensor Selection

This task has a high amount of risk associated with it. An incorrect robot or sensor selection can put our team back weeks in production because of the time it might take to realize that we have made the wrong choice. To counteract this risk, we have devoted a lot of time and effort into this part of the project. Extensive research done by all members of the team will prove valuable to the success of our project. However, there is a chance that we still make the wrong choice. Due to the limited experience of our team in this field balanced with the extensive knowledge of our faculty advisor, we estimate that the probability of a wrong selection to be about 10%.

Task 2: Drilling Mechanism Design and Application

This task has the highest probably of failure due to the limited knowledge of the group. However, given the expertise of the faculty advisor we estimate the probability of failure to be about 30%. Luckily, this part of the project can easily be changed if caught early in the process. Extensive testing and understanding of field conditions, robot capabilities, and various numerical calculations can help lower the risk associated with this part of the project.

Task 3: Robotics and Sensor Applications

This task has a relatively low probability of failure due to the extensive time that we have given ourselves to complete this section. In our project schedule this portion of the project is the longest and includes winter break. Even though we have a long time, we are still novice robotics professionals. Given that we estimate the probability of failure to be about 30%.

Task 4: Data Collection and Navigation Software

This task will be difficult to complete because of the communication that needs to be established between the robot and the user. Along with the navigation of the robot, the data collection will be a software heavy task that will require a lot of debugging and attention to detail. We estimate the probability of failure to be about 60%. The high percentage is due to the fact that it is extremely essential to any success that we might have with our robot and the limited team experience in this area. To mitigate this risk, we will start the development of this process early and have well documented code that will make debugging easy to accomplish. We will also have multiple people working on this process at the same time to speed up the process and create a system of checks and balances.

Task 5: Creation of the User Interface

This task will be easier than the data collection and navigation of the robot but will still be a software heavy portion of the project. However, our team has some experience in this kind of work, and we are confident in our ability to properly complete this task with a failure probability of 30%.

Task 6: Completion of the Technical Writing

This task has the lowest risk among the tasks because it only involves time to complete. There is nothing overtly complicated about writing technical documents, but they do take up a considerable amount of time and deserve to be mentioned as a task that will involve some risk of noncompletion. The only way that we fail on this task is simply just a lack of time to complete these documents. We estimate the failure probability of this task to be <5%.

3.6 Personnel Effort Requirements

Below you will find a task-based list describing the effort requirements that our team must put forward in order to be successful in the completion of our project. While these numbers are just estimates, they represent the time our team believes each task will take and how many weeks are designated for each task.

Task	Person Hours Per Week (Est)	Number of weeks	Total Hours
Robotics and Sensor Selection	12	8	96
Drilling Mechanism Design and Application	15	13	195
Robotics and Sensor Applications	20	13	260
Data Collection and Navigation Software	20	12	240
User Interface	10	12	120
Technical Writing	8	40	320
Total Person Hours			1231

Table 2: Personnel Effort Requirements

3.7 Other Resource Requirements

This project will require many resources outside of funding to properly complete our objective. While not all of the materials have been finalized, we will need a commercially available robot, a commercially available NDIR sensor, some sort of motor to drive the drilling mechanism, a drill, a power source for the robot and drilling mechanism (most likely a battery), and many more specific parts and materials as we get further along in our design process.

4 Design

4.1 Design Context

4.1.1 Broader Context

Below is a table that analyzes the broader content of our design to help us understand how our project is situated in the world and how it stands to impact others. We specifically look at four main areas impacted that include ‘public health, safety, and welfare’, ‘global, cultural, and social’, ‘environmental’, and ‘economic’. As a group we have found that our project does not have many concerns regarding these four areas, and we are aware of the few implications that our project may have on the world and are making active strides to limit them.

Area	Description	Examples
Public health, safety, and welfare	This project could impact other researchers in the agricultural field who could benefit from the data we are receiving. A project like ours does not impose any impedances on the public. Our project also could benefit farmers who are interested in the CO_2 levels in their soil.	Our project does not increase or reduce exposure to pollutants or harmful substances but can accurately measure these potentially harmful substances to help stakeholder groups better assess their test beds/fields. The safety risks associated with our project are minimal but the drill on our design is a potentially dangerous aspect. The drill will be generally low power but can be dangerous if used improperly. Like most automation projects, the goal is to replace the need to physically go out and take the measurements by hand. This may reduce job opportunities if a lab worker has the responsibility of completing this measurement. In general, our robot will just save the lab time and allow them to complete their work more efficiently which can generate revenue for the lab. This in turn can help the lab afford to hire more people.

Global, cultural, and social	Our project is not directly affecting various communities, nations, or ethnic cultures. While other global and cultural places may adopt our technology, we are mostly developing this for use by the agricultural department at Iowa State. While a later revision of our work may involve other cultural considerations, this project does not. Our group believes that this project accurately reflects the values, practices, and aims of the profession we are attempting to aide.	Development or operation of our robot does not violate a profession's code of ethics or create an undesired change in the community and its practices.
Environmental	The acquisition of the materials for our product will have an environmental impact that is beyond our knowledge. We have little information regarding the sustainability of the products we purchase but our group is committed to building a sustainable product to the best of our ability under our budget constraints. Our product will require a power source that will most likely be a battery. While batteries are not always a sustainable solution, our group intends to use a rechargeable battery to save on waste. A better understanding of ground soil may create an environmental impact on the earth that is unintended by our product.	Our project will require the use of energy from nonrenewable sources as well as materials that are non-recyclable. However, we are going to make an environmentally conscious effort to reduce the use of these materials within our budget.

	Stakeholder groups may intend to change the soil composition based on the data provided by our sensing unit.	
Economic	Our project is receiving grant funding provided by our faculty client that is dedicated to the research completed by undergraduates at Iowa State. The allotted project total is $5000. The outside economic impacts of our project remain widely unknown. Depending on how successful our project is there may be a created demand for our product. In this case we would need to worry about the cost to consumers, the effects on community markets, and the products financial viability for production. However, our version of this project is not intended for commercial use.	This project is not being created for consumers but instead is being created for a specific target user. The high development cost exists because this product is not commercially available and is being created on this small scale for specific use. While risks are encountered, the money that will be used for development is dedicated to undergraduate research and does not propose a high risk for the organization.

Table 3: Design in Broader Context

4.1.2 User Needs

The user of our product needs to be able to set a path using GPS and receive data collected from the robot at each destination along the path because the user of our product is likely interested in the results of those findings for research purposes.

The client that we pass our work on to after completion needs to be able to read and understand our documentation on how the robot works and the code we have written because they likely intend to expand on our working design for further implementation.

4.1.3 Prior Work/Solutions

Robotic sensing systems for greenhouse gas emissions presented in the problem statement currently exist in the world but most are large and very expensive. Our goal is to create a functional copy on a smaller scale and a much stricter budget. Our client has detailed some of the solutions that already exist at Iowa State. Many of those solutions are very large in comparison to the system we are trying to build. These solutions are commercially available for tens of thousands to hundreds of thousands of dollars.

The advantage of using a small system like ours is that it will be much less expensive and will be easier to repair. While our product lacks the accuracy and precision that a state-of-the-art system has, it will not have as high of maintenance costs and will be easier to deliver to the field.

4.1.4 Technical Complexity

This project has sufficient technical complexity shown by the three main design aspects and our products ability to compete with current solutions on the basis of cost effectiveness.

Our product demonstrates sufficient technical complexity by having three main design aspects that utilize distinct scientific, mathematical, and engineering principles. It can be broken up into the robotics of the system, the sensor apparatus, and the data collection and user interface. Each section requires expertise in that part of the system and no system is complete without all three of these sections working in perfect harmony.

Another way our product demonstrates technical complexity is by challenging industry standards with a small and inexpensive version of the commercially available robotic gas emission sensing system.

4.2 Design Exploration

4.2.1 Design Decisions

There are many key design decisions that need to be made for this project to work as intended. These include selecting the right commercially available robot, selecting the right commercially available NDIR sensor, what drilling mechanism will we use to push the sensor into the ground, how will we attach the sensor to the drilling mechanism, how will we attach the drilling mechanism to the robot, how do we account for the torque of the drill, how will we send data from the robot to the user, how will we design the user interface to be accessible by the user, and many more.

4.2.2 Ideation

When selecting the right commercially available robot there are many things our group must consider. These include but are not limited to the price, programmability, dimensions, weight, payload, speed, and battery life of the robot. For all of these options we looked online for relevant solutions and have five options to consider.

	URL	Price	Programmability?	Dimentions	Weight	Payload	Speed	Battery life
2	https://www.supe	$1,500	Yes	21.6" x 17.8" x 6.0"	40 lb	90 lb	130 ft/min	2 - 5 hr
3	https://www.supe	$716	Yes	15.5" x 13.5" x 4.0"	13 lb	15 lb	110 ft/min	1 - 4 hr
4	https://www.supe	$1,030	Yes	19.3" x 18.4" x 4.0"	30 lb	50 lb	200 ft/min	2 - 4 hr
5	https://www.supe	$1,674	Yes	28.0" x 22.0" x 11.0"	70 lb	45 lb (up to 160lb)	319 ft/min	1 - 3 hr
6	https://www.supe	$2,168	Yes	24.2" x 19.7" x 8.0"	60 lb	200lb	200 ft/min	2 - 5 hr
7								

Figure 3: Robot Ideation Chart

(Prices on the pictures below are not accurate)

Number 1:

Figure 4: Robot 1

Number 2:

Figure 5: Robot 2

Number 3:

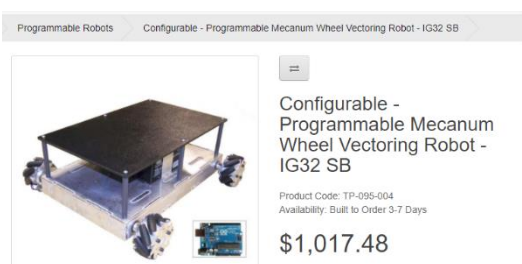

Figure 6: Robot 3

Number 4:

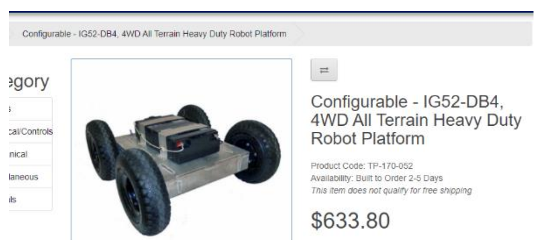

Figure 7: Robot 4

Number 5:

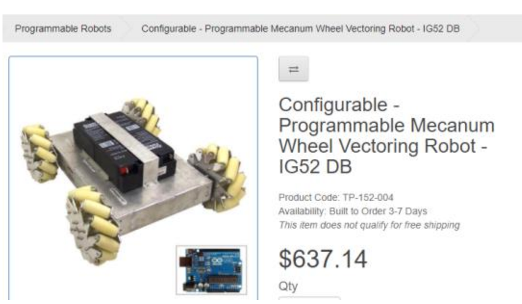

Figure 8: Robot 5

4.2.3 Decision-Making and Trade-Off

To identify the pros and cons of a potential robot we created several criteria to rank the robots by. These include non-negotiable requirements, ideal requirements, and preferred requirements. Our non-negotiable requirements are that the robot has sufficient load capacity to carry the equipment we need, its weight needs to be high enough to avoid moving while samples are being taken, and it needs to be programable. Next, our ideal requirements are that the robot has all terrain wheels for the best possible movement conditions and the cost of the robot is relatively low. Finally, our preferred requirements are that the robot has a long battery life and moves quickly.

While our final decision has not been reached quite yet we have narrowed down our search to a few possible options which we will evaluate using our weighted criteria as described above.

4.3 Proposed Design

4.3.1 Design Visual and Description

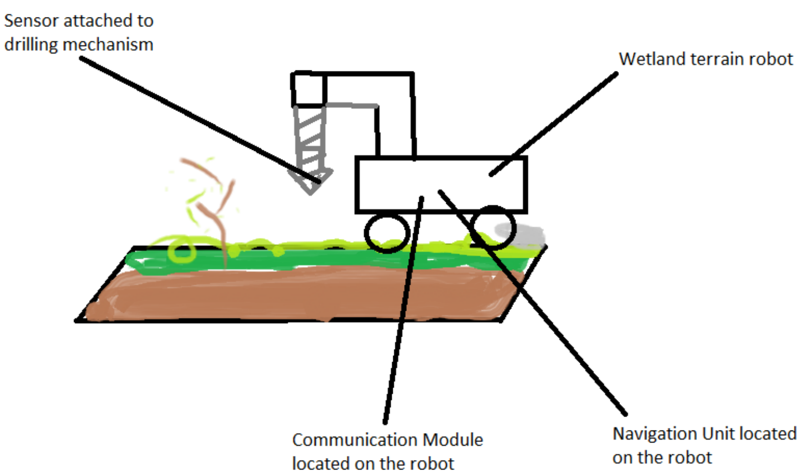

Figure 9: Basic Design Drawing

Figure 10: Drill Apparatus

Our original design was pictured to be as drawn in *Figure 9* which we decided to implement with a few different modules. The system we have in mind has three main systems. These systems are the robotics, the sensing system, and the navigation and data collection. Our robotics can be broken up into the drill apparatus, the drive train, and the systems microcontroller. We created our drilling mechanism by re-purposing a 3D-printer as our drill apparatus as seen in *Figure 10*. This will soon be attached to our robot's drive train allowing us to have a mobile drill. The drive train that we order will come with an Arduino that we will use to program and control all the necessary motors and sensors on our robot. The sensing system will consist of a drill attachment that enters the soil with 5 sensors that will be located at different depths for an appropriate measurement. These NDIR (Nondispersive Infrared) sensors will measure the CO_2 in the soil and record the data. Finally, our navigation and data collection system will control the movements of the robot with GPS and the communication of sensor data to the user. This section will involve an Arduino module, GPS module, and Wi-Fi/Cell module to ensure proper control and communication.

4.3.2 Functionality

At the start, the robot will be placed in a controlled test bed. A predetermined route will be programmed and followed by the robot using GPS. At each test site within the controlled environment, the robot will stop, drill into the ground, and record the sensor data received. After sending the data to the user, the robot will then take the sensor out of the ground and move to the next test site along the path and repeat the process until all test sites have been completed.

This current design completely satisfies all functional and non-functional requirements of our project as determined by our client. The process described above is a perfect implementation of the project prompt.

4.3.3 Areas of Concern and Development

Many of the concerns regarding the current design stem from the many key decisions that go into this project. All of these decisions must be made before we can reach the final product and they are not very straightforward. Our team has very little experience with the mechanical aspects of this project including the torque of the drill and how that needs to be offset by the weight of the robot.

Our immediate plan for developing solutions for these concerns is to get together as a team a decide how to proceed on this project. We have a few ideas on how to implement our design, but we must narrow our range and focus on completing the project. We also will seek approval from our faculty advisor on all key decisions we make throughout the semester to ensure we are on the right path.

4.4 Technology Considerations

For our drill apparatus we had to change our design a number of times due to the technology and resources available to us. We started with a fully customized design that would require handmade parts and machine work. As EE, CPRE, and SE students we do not have the training or authorization to use the tools we would need to successfully make a design of that caliber. As a result, we opted to modify an existing piece of technology to our benefit. One strength of this option is that the design is already flushed out and should be free of most mechanical errors.

A weakness of this option is the lack of customization that we are provided. This means that we are stuck with the parts we get, and we have less options for implementation.

This is just one example of a technical consideration that our project has faced, other considerations we will have to deal with include the robot and sensor selection as well as our future sensing apparatus.

4.5 Design Analysis

While we haven't gotten far in implementing our proposed design, we think that our extensive research on each aspect of the robot will be reflected in the results of the proposed design. We believe that our design will withstand implementation and will perform as anticipated.

We are currently finding difficulty in our design regarding how the sensors will physically breach the ground. The sensors are large compared to the drill and we are working on a solution to account for penetration while protecting the sensors from damage. We are working on a design to adhere to these project requirements while fitting within our budget and other design constraints.

4.6 Design Plan

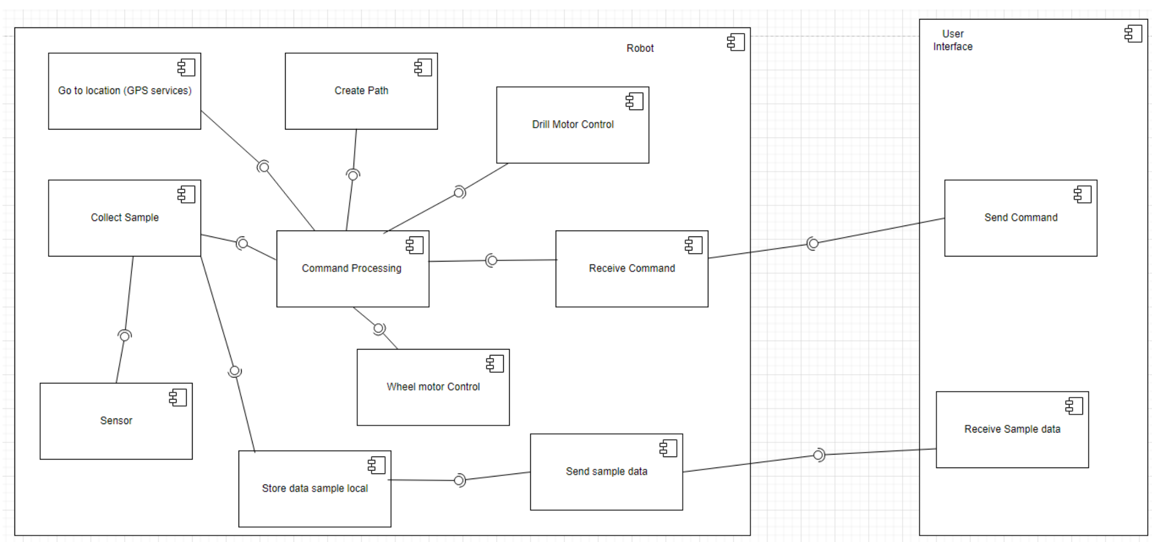

Figure 11: Component Diagram

Use case 1: User creates path for robot

Use case 2: User request data

Use case 3: User send Robot go to location command

Use case 4: User sends Collect sample command

Use case 5: robot stores collected sample data

Use case 6: Send sample data to user database

Use case 7: Robot begins drilling

For our design plan we created use cases 1-7 to understand how the user would interact with our robot and how it should interact/respond. From the use cases we were able to create different modules that hold different functionality of both or robot and front-end user application. We also consulted functional requirements: The sensing attachment must have a USB interface, to ensure it could interface with the Arduino module. We also consulted functional requirement: The navigation unit must be able to communicate with the robot and move it on a set path using GPS when we designed how the robot would communicate with the GPS module to go to certain locations and paths.

We also consulted functional requirement: The communication module must be able to send the data from the sensor to the user for manipulation we do this through the sending sample data module which interfaces with our Wi-Fi module and sends the data to the user via Iowa State Wi-Fi.

Our design also consulted nonfunctional requirements: The user interface must be accessible by the customer and easy to interpret which is why our user interface has a set of commands the user can user but is simplified to sending a command and receive data back from their command, The user must be able to designate a unique path for the robot which we do through the user interface which allows the user to keep sending commands to create the path and then the robot accepts and stores the path commands and create a path via interfacing with the GPS module.

5 Testing

5.1 Unit Testing

Each of the main components in our design are made up of units that will need to be tested. These units include our driving functionality, our load capacity, our sensor data, our navigational data, and our data communications. Each of these will have a different testing method to verify the unit. Our tests will all be variations of giving a test input and making sure that our results are correct.

An example of one of these tests is how we will test our driving functionality. This test could be performed by sending the robot a command to drive five meters and ensuring that the total distance is five meters.

5.2 Interface Testing

The interface we will be using in our design will be an Arduino, it will be used to store our code and run all the different functionality on the robot. The other interface we will have will be some form of base station where the end user will send commands to the robot and view the collected data.

The Arduino interface will be continually tested as we build the robot. It will be tested in everything we do because it is the core of the project that controls the robot and its actions. It will be tested when we try to run our code and we see if the robot responds the way we want it to. The units we will need to test on the user interface will be to see if the sent and received information is correct. The way we will test that is by sending information from the robot to the base station and vice versa and then verifying that the received information is what we anticipated it to be.

5.3 Integration Testing

There are a lot of integration paths that will need to be taken for our design to work. The main ones will be connecting our software and hardware to ensure that they work together and send our data to the end user. We will test these by writing the code we expect to complete the task and observing how the system responds. If it does not work, we will revise the code or hardware accordingly.

5.4 System Testing

Once we believe we have the different units of our system working together we will attempt to test the entire system. These tests will be derived from the requirements of our project. One of our main tests will be our sample collection and ensuring that the robot can drill into the soil without the robot sliding or moving on the ground. This system test will include units such as the drill mechanism, and the base of our robot. Another system test we will need to perform is sending the collected data to the end user. This system level test will include the sensor collecting data, the Arduino receiving that data, the Arduino sending that data, and the base station receiving and displaying that data.

5.5 Regression Testing

We will ensure that our new additions don't break old functionality by testing the old functionality as we progress. We will do this at regular intervals so that we catch any issues earlier in the design process. The core of our project that we need to make sure works includes the driving, the sample collection, and the data transmission. This is heavily guided by our requirements for the project and the goals of what we want to accomplish.

5.6 Acceptance Testing

We will either take a video of the robot operating as intended or we will show our client the functionality that it has in person. We will treat our functional requirements as a checklist to verify that we are meeting all the predetermined requirements. Our client is also our advising professor, and they will be continually involved in many of our decisions during the design process. This will help them continue to be aware of our progress. We believe that they will stay involved as we get closer to acceptance testing.

5.7 Security Testing (if applicable)

5.8 Results

We have only started to construct our design which means our preliminary tests will begin in the near future. While we have not completed any testing yet, we believe that our extensive research and design considerations will yield positive test results. When we do conduct our tests, we will analyze our results to ensure they relate to our projected results and comply with project requirements. If they do not satisfy the project requirements, we will start by troubleshooting the design to produce better results. If this does not prove successful, we may have to look more closely at our design to determine the problem.

6 Implementation

We are going to be implementing and testing the most feasible way to lower the drill and begin drilling. For this implementation we will be isolating the Arduino, motors, motor controllers, lift mechanism and the drill. Then once that has been decided the GPS module, Wi-Fi module and the Frontend application will then be integrated with the existing design to complete everything.

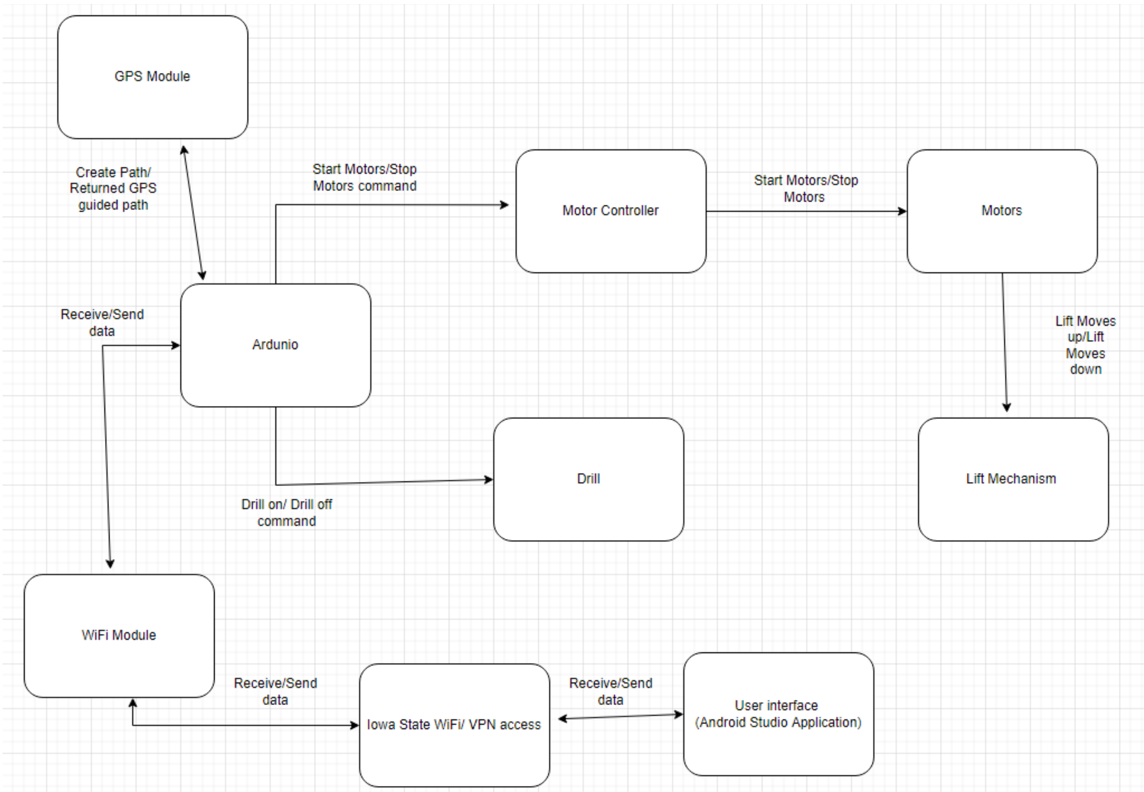

Figure 11: Implementation Diagram

7 Professionalism

This discussion is with respect to the paper titled "Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

For our project we have chosen to follow the IEEE code of ethics. Below is a table showing the areas of responsibility to be considered in the completion of our project. We have included definitions of each area and how the IEEE Code of Ethics covers that particular area with one or more points.

Area of Responsibility	Definition	NSPE Canon	IEEE Code of Ethics
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence. Avoid deceptive acts.	**7.8-6:** To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations. **Description:** We will not undertake tasks that we are not qualified for to ensure professionalism in the integrity of our work.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.	**7.8-4:** To reject bribery in all its forms. **Description:** We understand the financial responsibility we have to our client, and we will not engage in bribery to meet our project's expectations.

Communication Honesty	Report works truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.	**7.8-2:** To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist. **7.8-3:** To be honest and realistic in stating claims or estimates based on available data. **Description:** We will be honest in reporting our data and will disclose personal conflicts of interest if applicable.
Health, Safety, and Well Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.	**7.8-1:** To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment. **7.8-9:** To avoid injuring others, their property, reputation, or employment by false or malicious action. **Description:** We will conduct our research with the utmost care in regard to the health and safety of team members and others.

Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.	**7.8-7:** To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others. **Description:** We will properly credit contributions to our project and research to act as faithful engineers.
Sustainability	Protect environment and natural resources locally and globally.		**7.8-10:** To assist colleagues and co-workers in their professional development and to support them in following this code of ethics. **Description:** We will uphold our code of ethics and support others doing the same. In doing this we can help build a sustainable project and work environment.
Social Responsibility	Produce products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.	**7.8-5:** To improve the understanding of technology; its appropriate application, and potential consequences. **Description:** We understand the responsibility we have when working on our project to ensure that our project does not conflict

			with the best interests of society by deeply researching the consequences of our project.

Table 4: Areas of Professional Responsibility

7.2 Project Specific Professional Responsibility Areas

There are 7 areas of responsibility which Table 1 refers to. The first is Work Competence, this professionally applies to working with our project because the ultimate success of our project is determined by the quality of our work competence. Our team is performing highly in this department through meeting project deadlines such as providing extensive research regarding sensors and robotics at scheduled meetings, in addition to maintaining professional communication with our client. The second is Financial Responsibility, this professionally applies to our project because we have a monetary constraint placed upon our project. Our client has provided us with a $5000 grant for whatever parts and material may be needed to develop our project. As a result, our team has performed highly in extensively researching and budgeting parts that best meet our criteria. The third is Communication Honesty, this applies to our project as our success is highly determined by how well our team can all understand the scope of the project. As a result, our team is performing highly in communicating various parts of research and how parts may integrate with each other.

The fourth is Health, Safety, and Well-Being. Beyond following COVID protocols, as our project is still in the research phase, so this does not apply to us. The fifth is Property Ownership, as we are primarily developing an entirely new researched product not based on other products this does not apply to us. The sixth is Sustainability, this heavily applies to our project as our intent is to develop a robot which can detect CO_2 in farmland potentially providing data which can be used to deter climate change in the future. Our team is performing highly in this field as we are extensively researching sensors which may be able to provide this information. The seventh is Social Responsibility, this applies to our project because it is pivotal, we understand the usefulness of the data we provide. In providing incorrect data, we can potentially have disastrous impacts on the fields we are testing. Our team is performing highly to achieve this goal by being painfully conscious of our project social implications and how are results may be used to qualify wetland soil.

7.3 Most Applicable Professional Responsibility Area

One area of professional responsibility that is critical to our project is financial responsibility. The goal of our project is to create a low-cost robotic sensing system and that goal puts finances at close to the top of our priority list. It is also critical that we do not go over our project budget because our grant funded research has a solid cutoff. We have demonstrated proficiency in financial responsibility through the development of our project by ordering low-cost parts that fit well within our budget. These parts include parts for the sensing apparatus, parts for the drilling apparatus, parts needed to communicate with the robot, and the robot itself. Financial responsibility is a pivotal aspect of our project that we need to keep in mind at every step of development. It is a critical part that our team takes this extremely seriously, and we intend to meet these constraints while producing a product that fulfills our product requirements.

8 Closing Material

8.1 Discussion

For this semester we have very limited results, but many aspects of our project have been designed and are ready to be implemented into the build. In creating our design, we made sure to adhere to the project requirements through every step of the process. Our current design meets our project requirements, and we are expecting to produce most of our results next semester with the completion of our final build. Following this completion, we can enter the testing stage of our sequential development to receive and interpret the results of our tests. These results will be crucial in understanding whether or not our project actually meets the requirements.

8.2 Conclusion

Our project goal is to create a robotic sensing system for greenhouse gas emissions that can move along a wetland terrain, move automatically using a GPS module, drill into the ground, imbed the sensors into the ground at various depths to measure the gradient of the CO_2 emissions, send the data to the user, and repeatably perform them measurements. Once sent to the user we will have created a user interface to allow the user to see and export the data.

So far, we have designed much of how the system will work but have only begun the building of the drilling apparatus. Once the drilling mechanism is completely functional, we will purchase a robot that can withstand the torque and weight of the drilling apparatus. While the robot is being purchased, we will begin creating the sensor apparatus that will be attached to the drill for data collection. Following this, we can begin constructing the communication and navigation modules using the Arduino system attached to the robot. Finally, we will design a user interface that will display the results of each measurement and allow the user to export the data.

Our current goals are very achievable with the time that we have to complete them next semester. We currently have no ideas for changes in our design but will be sure to properly document them as they arise moving forward.

8.3 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

8.4 APPENDICES

8.4.1 Team Contract

Team Members:

1) ___Tzu-Chien Liu _______________ 2) ___Animesh Shrouti________________

3) ___Freedom Clark_______________ 4) ___Chimzim Ogbondah_____________

5) ___Jason Grunklee______________ 6) ___Robert Wedan__________________

Team Procedures

1. Day, time, and location (face-to-face or virtual) for regular team meetings:

- Regular Team Meetings Face to Face at 11:00 AM on Thursdays
- Meeting location subject to change

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

- Discord will be used as a means of communication among group members
- Email will occasionally be used as well to contact client/faculty member

3. Decision-making policy (e.g., consensus, majority vote):

- Decisions will be made by consensus first and if no final decision can be made it will go to a majority rule vote
- The faculty member will have the authority to veto a decision or select the option that they feel is best

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

- Meeting minutes will not be kept but the project manager will oversee keeping track of things discussed at meetings as well as check-ins with the project leads for record keeping of the project timeline

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:

- Attendance, punctuality, and participation is required at all meetings
- If there is a conflict, it needs to be disclosed to the team before the meeting is to take place
- A follow up after the meeting will be required with the project manager or another team member to get the information from the meeting

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

- Fulfilling team assignments, timelines, and deadlines are required by team members unless extenuating circumstances are presented
- Team members must notify the team of such circumstances as they arise to avoid missing deadlines

3. Expected level of communication with other team members:

- Team members are expected to have a high level of communication and must have punctual responses to ensure team cohesiveness

4. Expected level of commitment to team decisions and tasks:

- Team members are expected to be committed to the goals of this team and fulfill their duties to the best of their ability

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):

- Project Manager: Robert Wedan
- Sensor Electronics Project Lead: Animesh Shrouti
- Robotics Project Lead: Freedom Clark
- Data Collection/User Interface Project Lead: Chimzim Ogbondah
- Robotics and Sensor Electronics Team Specialist: Jason Grunklee
- Robotics and Data Collection Team Specialist: Tzu-Chien Liu

2. Strategies for supporting and guiding the work of all team members:

- Supporting and guiding the work of all team members will be easier given our management style that is built to accommodate the changing needs of the project with team specialist members available

- The project manager will also be responsible for aiding the team and keeping a regimented schedule for each project section to guide the work

3. Strategies for recognizing the contributions of all team members:

- Team contributions will be met with positive feedback from all team members and the project manager will be in charge of notifying the rest of the team of such accomplishments

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.

- Animesh Shrouti - Animesh has experience working with various robotics in manufacturing environments. Additionally, he has worked in multiple team environments, excelling in working with others to successfully achieve the team's goal. His background is studying Electrical Engineering.

- Chimzim Ogbondah - Chimzim has experience with frontend software development and embedded systems development, agile. This includes effective communication, problem solving and good teamwork abilities. These skills will be helpful to the team and project.

- Jason Grunklee - Jason brings a robotics background that includes good communication and teamwork skills along with the experience of developing a project from start to finish.

- Freedom Clark - Freedom has experience in software development and good communication between many people. She is detail oriented and motivated to work on interesting and educational projects. Additionally, her base-line knowledge of being a computer engineering student will prove useful for this project.

- Robert Wedan - Robert brings a history of leadership experience to the project as well as his ability to connect with others to develop strong relationships. His organizational skills and dependability make him an asset to the team's structure that fosters open communication and a positive environment.

- Tzu-Chien Liu - Gatsby brings experience of teamwork and communication skills from previous entrepreneurial projects and sales experience. Furthermore, he brings team value from the background of electrical engineering.

2. Strategies for encouraging and support contributions and ideas from all team members:

- Building a sense of community among team members will be crucial in creating a team environment that is encouraging and supportive of all ideas and contributions
- This will be done with open communication and positive feedback that promotes quality work at all levels of the project

3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)

- By building an inclusive environment for all members, team members will hopefully feel comfortable addressing the team about their concerns. However, if they are not comfortable talking to the team about it, they should either contact the project manager or faculty member to resolve the issues
- The project manager will act as a potential resource for team members to voice complaints about inclusion or issues of collaboration

Goal-Setting, Planning, and Execution

1. Team goals for this semester:

- Our goal this semester is to create a functional project that all members of the team can be proud of. By working hard and working together we aim to build a team environment that is full of positive energy and collaboration. This environment will bread innovation and will aid in the process of creating a successful project

2. Strategies for planning and assigning individual and team work:

- We will assign the work to the peer based on their role in our team management style
- Project Leads will be in charge of delegating tasks and assigning work to other team members
- The project manager will help project leads stay on track and will interface with the client to ensure that tasks are completed in accordance with client preferences

3. Strategies for keeping on task:

- Weekly meetings with client/faculty member and discord communication will be an important part of keeping team members engaged and on track

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?

- Infractions will be brought up promptly for discussion to see why it occurred and how we can prevent it from happening again in the future

2. What will your team do if the infractions continue?

- If the infractions continue and the team fails to find a solution to the problem. The situation will be relayed to the professor and advisor for further action

****

a) *I participated in formulating the standards, roles, and procedures as stated in this contract.*

b) *I understand that I am obligated to abide by these terms and conditions.*

c) *I understand that if I do not abide by these terms and conditions, I will suffer the*

consequences as stated in this contract.

1) ____Tzu-Chien Liu___________________________________ DATE _19.Sep.2021______

2) ____Jason Grunklee_________________________________ DATE __9/19/2021_________

3) ____Robert Wedan__________________________________ DATE __9/19/2021_________

4) ____Feedom Clark__________________________________ DATE _09/19/21__________

5) ____Chimzim Ogbondah_____________________________ DATE __09/19/2021_______

6) ____Animesh Shrouti_________________________________ DATE __9/19/2021_______