Automated Salt Spreader Robot

Design Document

sdmay26-07
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Executive Summary

The issue that our solution addresses is the danger and and inconvience of de-icing driveways and sidewalks during the Winter. This is normally only accomplished through doing it yourself or through expensive, paid services. In our context, this particularly concerns those who are mobility limited, such as the elderly, as this could be very dangerous for them to do themseleves or working adults which would benefit from the convenience and time savings.

The salt spreading robot needs to be able to spread and contain enough salt to spread up to 2000 sq. ft, have an accuacey of +/- 5 cm at any given point during the operations, detect if it does not have enough salt or batter life to complete the task, operate in temperatures as low as 5 ℉, while traversing icy conditions and navigating slopes as well as shielding from the writers elements such as water or corrosion.

In terms of design, this solution takes the form of a small, mobile robot solution compromised of a drivetrain, salt spreading mechanism, collision avoidance and positioning sensors, and a control center. These subsystems utilize a range of mechanical components, GPS, computer vision, electrical distribution, and software. We are developing this design through a staged approach of high level design, subsystem proof of concepts, detailed design, software testing platform prototype, and then MVP prototype.

As of now we are in the proof of concept phase, in which we are building and testing each individual subsystem in isolation. We currently tested motor controler and motor functions, battery/buck-converter implementation, client & server relationship on the arduino uno R4 wifi, drive train implementation, mobile app development for controlling the salt spreading robot. Testing the object detection using the ESP 32 - Cam and setting up differential GPS module.

Our design meets the requirements and user needs through detailed milestones that ensure viable functionality (such as positioning accuracy and environmental resistance) and cater to our target audience (ease of maintence, autonomous function, salt capacity).

Our next steps include completing testing of each subsystem and beginning integration tests, which would include the interactions between the mechanical and electrical systems, the integration of the power distribution system and the control system, and establishing final standards for communications between the sensors, main controller, and distributed controllers.

Learning Summary

Development Standards & Practices Used

- IEEE 7009:2024 – Fail-safe Mechanisms for Autonomous Systems
- ISO 13482:2014 – Safety Standards for Service Robots
- FCC Part 15 – Regulations on Wi-Fi and Bluetooth Communications

Summary of Requirements

- Carry enough salt for 2000 sq-ft
- Localazation accuracy +/- 5 cm
- Moniter salt levels remotely
- Resistant to corrosion and water
- Develop a working prototype
- Total cost should be less than $1000
- Ensure Robot has emergency shutoffs

Applicable Courses from Iowa State University Curriculum

- CpRE 288: Embedded Systems I
- CpRE 388: Embedded Systems II
- EE 230: Electronic Circuits and Systems

New Skills/Knowledge acquired that was not taught in courses

Throughout our project team members had to develop skills that were not areas covered in our courses.

- Mechanical Design
- Water & Dust Resistance
- Market Analysis
- Designing for Winter/Cold Environments
- Autonomous Navigation
- Computer Vision

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1. Introduction

1.1. Problem Statement

In regions that experience freezing temperatures during the Winter, homeowners, businesses, and cities alike have to deal with keeping their sidewalks and driveways clean of snow and ice in order to provide a safe environment for pedestrians and vehicles.

While snow removal is a major component of this process, it has a large amount of dedicated equipment and technology that makes this process a breeze. However, de-icing remains a largely manual process, especially for homeowners. The task of de-icing via salt spreading requires time, labor, and greatly benefits from specific timings, which may or may not be convenient for the user (middle of the night, during work, etc). Additionally, if the de-icing is required in conditions such as packed snow or after freezing rain, the task is not just inconvenient; it can be dangerous.

We believe that this task can be performed safely, without the user present, and at any time of the day, by employing an autonomous salt-spreading mobile robot solution that intelligently spreads salt or other ice-combatting solutions across sidewalks and driveways before and after ice may present itself.

1.2. Intended Users

In our analysis of intended/potential users for our proposed solution, we identified three primary groups and developed personas to represent those groups for use-case analysis.

1. Middle to High-Income, Working Adults
    a. Characteristics: This group is busy, on a schedule, highly values their time, has disposable income, and may often be exhausted from their work.
    b. Need Statement: High-earning, working adults need a way to save time and energy de-icing their property because it takes up valuable time out of their already busy, draining schedules.
    c. Value Creation: Our solution will serve these users by performing the task of spreading salt before and after ice formation. This frees up time in their day by completely clearing their driveway during light snowfall or ice, or only requiring basic levels of shoveling or hired snow removal after heavier snowfall. Due to its autonomous function, without the need for user presence, this can provide value to their life, even while they are sleeping or at work.

2. Elderly, Disabled, or Other Mobility-Limited Individuals
    a. Characteristics: This type of user is largely defined by either a lack of mobility or a general increased fall risk. They have larger risks associated with navigating around ice in the Winter. The potential consequences of falling on the ice are much greater for these individuals.
    b. Need Statement: The elderly and other mobility-limited individuals need a readily available way to have their sidewalks and driveways cleared of ice without putting themselves in danger.

    c. Value Creation: Our solution allows this group to have their property de-iced at the press of a button, without relying on the schedules of others, such as relatives or hired companies, or putting themselves in danger. This grants them the freedom to clear and navigate their sidewalks and driveways without the risk of falling, which could have major consequences for this demographic group.
3. Cities and Universities
    a. Characteristics: Universities and certain cities have a large area of sidewalks and walking paths that experience a large amount of foot traffic as compared to other areas. They have to employ a large amount of resources and potentially expensive labor in order to clear ice from these areas.
    b. Need Statement: Universities and cities need cheaper, more efficient ways to de-ice their expansive sidewalks and walking paths when winter conditions cause full ice coverage.
    c. Value Creation: Universities and dense cities could use fleets of these autonomous salt spreading robots to both pre-treat and post-treat their sidewalks and walking paths without the need for large amounts of labor to either complete the task manually or operate equipment. This could reduce labor costs, reduce the need for temporary/on-call labor, and improve working hours for the existing workforce, as this could reduce the need for certain employees to work during the late hours of the night in anticipation of a night or morning ice storm.

2. Requirements, Constraints, And Standards

2.1. Requirements & Constraints

Functional Requirements:

1. The mobile robot must be able to spread salt autonomously over a pre-defined area up to 2000 sq. ft. (constraint).
2. The tracking system must be able to use a combination of sensors, absolute and relative, for localization with positional accuracy within ∓5 cm at any given point during operation (constraint).
3. The system must be able to detect when it does not have enough salt/ice melt on board to complete a task.
4. The system must be able to operate in temperatures as low as 5 °F, or the minimum effective temperature of most ice melt solutions (constraint).

Physical Requirements:

1. The design must be able to carry enough salt to cover the majority of residential driveways and sidewalks without being refilled (constraint).
2. The drivetrain must be able to traverse icy conditions and navigate within typical sizes and slopes of sidewalks and driveways.
3. The electronic systems must be shielded from moisture and unaffected by wet environments and temperature cycling.
4. Materials must resist corrosion, even when exposed to moisture or salt.

Environmental Requirements:

1. The system must not use too much salt or misplace salt in such a way that would produce excess runoff or significantly damage vegetation.

UI/UX Requirements:

1. The salt reservoir must be easily refilled by the user.
2. The user interface must be simple. It must be intuitive, even to those who are not familiar or overly competent with technology, such as the elderly.

2.2. Engineering Standards

By utilizing engineering standards from various organizations, we are able to guide the creation of our requirements such that our design will be safe, user-friendly, ethically sound, and avoid interference with the ever-growing world of technology. Below, we have listed three of the standards that have the most impact on our design choices.

1. IEEE 7009-2024
    a. This set of standards provides methodologies and tools for developers to design and implement fail-safe mechanisms for autonomous and semi-autonomous systems that are efficient, robust, and transparent. Being that our solution is a

fully autonomous mobile robot, we will need to implement these standards into our physical and software designs to allow for effective fail-safes to maintain safety wherever our system is in operation.

2. ISO 13482:2014
    a. This document covers a wide range of safety standards in relation to service robots (as opposed to industrial robots, which our system would not be considered). It covers general safety requirements and methodologies for developing and testing safety requirements unique to its context. We will need to refer to this to responsibly develop our own requirements for systems such as navigation and create a sound testing framework.
3. FCC Part 15
    a. This regulation governs how devices utilizing Wi-Fi and Bluetooth communicate to ensure that there is no unnecessary or harmful interference to other radio services. We will need to follow these guidelines to ensure that our systems, whether communication with the robot or differential positioning systems, do not interfere with nearby systems that also rely on these technologies.

3 Project Plan

3.1 Project Management/Tracking Procedures

Our team uses an **Agile-Scrum workflow** managed through **Atlassian Jira and Confluence**. We run **weekly sprints**, each beginning with a planning session where tasks are broken into Jira issues under their respective subsystem epics (Platform/Mechanics, Power & Electronics, Sensors/Navigation, Software/Compute, and Salt System). Each issue includes an assignee, description, and acceptance criteria.

- **Sprint master:** Isaac Blandin (rotates weekly)
- **Progress tracking:** Each member updates Jira daily; Confluence is used for documentation, design logs, and meeting minutes.
- **Meetings:** The team meets with the faculty advisor (Dr. Stoytchev) every **Thursday at 4:30 PM** for progress review and feedback. A second **team-only weekly check-in** reviews individual blockers, assigns next-week tasks, and ensures balanced workload.
- **Version control:** Code, CAD, and documents are stored in a private **GitHub repository** linked to Jira for traceability.

This structure keeps the project adaptable for parallel electrical and computer subdivisions that will form later in the semester.

3.2 Task Decomposition

Subsystem	Major Tasks	Sub-Tasks	Dependencies
Platform & Mechanics	Base chassis and enclosure design	CAD modeling, ground-clearance verification, waterproofing, gearbox evaluation	Required before power integration
Power & Electronics	Battery selection and power distribution	Temperature tests, wiring harness, motor driver integration	Requires chassis dimensions
Sensors & Navigation	Localization and perception	RTK-GNSS testing, IMU + camera fusion, MicroPython/CircuitPython driver validation	Requires compute interface
Software & Compute	Embedded control and ROS 2 setup	Motor PWM control, sensor data parsing, path logic, telemetry dashboard	Requires functional sensors
Salt System	Dispensing mechanism	Hopper design, flow-rate calibration, motor feedback, clog testing	Depends on platform frame

Subsystem	Major Tasks	Sub-Tasks	Dependencies
Integration & Testing	System bring-up	Bench tests, interface validation, field test with sand media	Cross-subsystem
Documentation & Reporting	Weekly report and Confluence updates	Sprint summary, advisor notes, QA review	Ongoing

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Milestone	Metric / Evaluation Criterion	Target Date
Sensor library validation	Each sensor communicates successfully via MicroPython or CircuitPython	Oct 25 2025
Component procurement complete	100 % parts ordered & delivered	Oct 31 2025
Mechanical prototype (MVP) ready	Robot frame assembled & motors operational	Dec 1 2025
Navigation + drive test	Path accuracy ≤ 15 cm error	Feb 2026
Dispensing calibration	Flow rate 50–250 g/min ± 15 % uniformity	Mar 2026
Full system demo	Autonomous run ≥ 1 km continuous operation	Apr 2026

Metrics combine quantitative (accuracy, runtime, flow rate) and qualitative (ease of use, advisor feedback) measures.

3.4 Project Timeline/Schedule

Fall 2025

- Weeks 1–6: Sensor library testing on personal devices; complete SIC 3D-printing training.
- Weeks 7–9: Finalize CAD chassis design, order components (before Halloween).
- Weeks 10–15: Assemble and test first MVP prototype; log results in Confluence.

Spring 2026

- Weeks 1–8: Integrate navigation and dispensing subsystems; conduct bench and field tests.
- Weeks 9–13: Refine software and fusion algorithms; complete Beta field demo.
- Weeks 14–16: Finalize documentation and present final demo.

3.5 Risks and Risk Management/Mitigation

Risk	Probability	Impact	Mitigation
Battery performance drops below 15 °F	0.5	High	Thermal insulation and battery chemistry tests before integration
Motor torque insufficient on ice	0.4	High	Add gearbox or select higher-torque motors after bench tests
Sensor fusion or firmware incompatibility	0.5	High	Parallel testing of MicroPython vs CircuitPython drivers
3D printer training delays (SIC)	0.6	Medium	Schedule training early; outsource print if delayed
Component shipping delays	0.4	Medium	Order before Halloween deadline with backup vendors
Software bugs affect motion control	0.3	Medium	Version control with branch testing and peer review

3.6 Personnel Effort Requirements

Team Member	Role / Focus	Weekly Hours	Semester Total (≈ 15 weeks)
Isaac Blandin	Sprint master, mechanical CAD, gearbox evaluation	7	105
Dylan Bunting	Power systems, motor drivers, battery integration	7	105
Hoyt Dzwoniarski	Sensor testing (MicroPython/CircuitPython), navigation prototype	7	105
Thomas Huedepohl	Chassis design, 3D printing coordination, assembly	7	105

Team Member	Role / Focus	Weekly Hours	Semester Total (≈ 15 weeks)
Mikhail McDade	Software architecture, ROS 2 planning, telemetry	7	105
Shobhit Singh	Documentation, QA tracking, risk register updates	7	105

Total Effort: ~630 person-hours (Fall 2025)

3.7 Other Resource Requirements

Facilities: Student Innovation Center (SIC) 3D printing lab, ETG filament supply, campus outdoor walkway testing site.

Hardware: Li-ion batteries, motor drivers, RTK-GNSS module, IMU, camera sensor, Raspberry Pi or Jetson controller.

Software: Jira and Confluence (Atlassian), GitHub repo, MicroPython/CircuitPython SDKs, ROS 2 middleware.

Miscellaneous: Safety gear (E-stop switches, fuses), weatherproof materials, adhesives, Loctite.

4 Design

4.1 Design Context

4.1.1 Broader Context

Our design problem exists as a service robot that can improve the safety and well-being of users by allowing them to avoid the potentially dangerous task of spreading salt after ice formation, along with saving time and energy for users as well. However, there are considerations that we must make while designing this system, as if poorly implemented, our solution could produce negative effects simultaneously. Users and others in the area of our solution's deployment could be at safety risk if our system were not designed with collision avoidance in mind. Additionally, misuse of salt or other ice-melting solutions can often be hazardous to people and animals if it were to come in direct contact with their skin or are ingested (however, this remains an issue with most other substitutes). Our product also has the potential to displace or eliminate current employment opportunities if it becomes a viable substitute for hired ice-removal services. Ultimately, we believe that our solution, if implemented with these considerations in mind, will provide societal and customer value through improved safety, comfort, and time savings for individual customers and communities that far outweigh the potential downsides.

We believe that our solution does not have a significant impact on the global, cultural, or social aspects of society, other than the indirect potential of reducing the market share of traditional snow removal service providers, which are often small or family-owned businesses. We believe that these negative impacts can also be offset by our solution if we make it a viable economic option for these businesses to implement, reducing their costs in the process.

In terms of environmental context, we again have some considerations that we must make in the process of our designs. Due to the ability for over-salting to cause harm to vegetation and water sources in the nearby area, we must use due diligence in developing our salt-spreading solutions to ensure environmentally sustainable amounts are distributed, along with implementing fail-safes against accidental dispersal.

Within an economic context, our most important consideration is that of being economically viable, and at that, being able to compete with the main substitute good of snow-removal services. We must, then, design our solution to be cost-friendly enough to compete with this substitute or pose ourselves as a complementary good instead of a substitute, via designing for commercial usage.

4.1.2 Prior Work/Solutions

During our team's research on prior work, we discovered that we would actually be first-movers in the specific niche that our product is targeted to compete within, meaning that we did not have direct, similar products to research. As a result, we looked at current solutions in other industries or niches that would serve as reference materials for different subsystems or problems that we expect to encounter. In this search, we found three main products: a large commercial snow-clearing robot with an optional salt-spreading attachment, a personal snow-blowing service robot, and autonomous lawn-mowing robots. Our analysis of these solutions are as follows:

Left Hand Robotics Snowbot Pro [1]:

Description:

- This robot is a large, autonomous snow-removal robot designed for commercial or municipality usage, being around the size of a ride-on lawn mower. It has a variety of attachments, including one designed for spreading salt.

How Ours Stacks Up:

- Pros:
    - Our solution is targeted at coming at a much smaller cost (<$5000 vs $35000)
    - More capable of handling smaller or more congested spaces
    - Capable of more residential or personal usage
- Cons:
    - Our solution would not be viable for the commercial snow-clearing operations that the Snowbot Pro is designed for.
    - Our robot does not possess larger snow-clearing capabilities, such as plowing or brushing.
- Conclusion:
    - The Snowbot Pro and our solution, while accomplishing some of the same tasks, are not designed to fill the same niche. Ours is a personal/residential service robot, while theirs is an industrial robot. However, we are still able to use this solution as a reference while we tackle design challenges such as salt-spreading mechanisms, navigation, and handling winter conditions.

Yarbo Snow Blower [2]:

Description:

- The Yarbo Snow Blower is a personal service robot that autonomously clears residential driveways and sidewalks of snow. It is one of the options for attachments that is built on the Yarbo Core platform, which is a multi-usage autonomous robot that can serve multiple needs across all seasons.

How Ours Stacks Up:

- Pros:
    - Our design is capable of de-icing driveways
- Cons:
    - Our design is reliant on the snow being removed before we are able to spread salt effectively.
    - Not built on a platform that is as versatile or useful for all seasons.
- Conclusion:
    - One of the main takeaways from our analysis of this product is that we would likely actually be positioned as a complementary good to a product such as the Yarbo Snow Blower, allowing one to implement both solutions for a fully autonomous

snow removal and de-icing system. Additionally, we were able to take a lot of inspiration from this system as it was a proven system for a small service robot to be deployed in the Winter conditions.

Husqvarna Automower [3]:

Description:

- The Husqvarna Autonmower is an autonomous service robot that mows lawns and is positioned for personal, residential usage. It implements various navigational systems, including underground boundary wires.

How Ours Stacks Up:

- Due to serving a significantly different purpose and task, we did not feel the need to draw direct pros and cons against the product. We researched this due to it being one of the cheapest and most mass-produced outdoor service robots that we found on the market. We found that this would be a good reference for how they were able to bring down costs, along with the general knowledge from their navigation and other mobile robot-related functions.

Prior Work Research References:

[1] T. Cozzens, "Autonomous Snowbot Pro hits the sidewalk," *GPS WORLD*, May 13, 2019. [Online]. Available: https://www.gpsworld.com/autonomous-snowbot-pro-hits-the-sidewalk/. [Accessed Oct. 28, 2025].

[2] "Yarbo Snow Blower," *yarbo.com*. [Online]. Available: https://www.yarbo.com/products/snow-blower-robot?srsltid=AfmBOopBsykaTng7mL1GXIdoekc9fM0DQVTO1UuS27EhjqroopcLO02d. [Accessed Oct. 28, 2025].

[3] "Automower 450X," *husqvarna.com*, [Online]. Available: https://www.husqvarna.com/us/robotic-lawn-mowers/automower-450x/. [Accessed Oct. 28, 2025].

4.1.3 Technical Complexity

As our project is a mobile robot solution, our design includes a large set of complex subsystems ranging from areas including physical, software, and electrical, we believe that there is an adequate amount of technical complexity in both breadth and depth. The subsystems that are currently planned are as follows:

- Control
    - As the brain of our solution, our control subsystem must be able to combine sensor, navigation, and collision-detection data in order to effectively command our drive and salt spreading subsystems to accomplish the task.
- Navigation/Positioning

    - Using both absolute and relative position sources, such as GPS, correction data, and local information, this subsystem needs to be able to feed reliable and accurate positional data to be used in path-finding and following algorithms.
- Collision Detection
    - This subsystem combines computer vision, bump sensors, and time-of-flight sensors to detect potential collisions before the robot causes any damage to itself or its surroundings. This subsystem uses this to make navigation decisions or trigger fail-safes.
- Salt Spreading
    - This subsystem is required to both physically spread the salt through motor control and to control and monitor the amount of salt being spread at any given time.
- Power
    - This subsystem maintains and monitors the on-board battery to detect when the system needs to return. It is also responsible for distributing and supplying the correct voltage that each subsystem or electronic component requires.
- Drivetrain
    - This system is primarily made of a few parts: motors, motor control, and the physical method of moving, considering the needs of navigating in winter conditions.
- Mobile App
    - This app is used to monitor or deploy our system through a user interface that is both sufficient in detail and intuitive enough for all of our target users.

We believe that this project meets the requirements of sufficient technical complexity, as the range of subsystems is able to provide a challenge for each of our distinct specializations, and the integration of all subsystems will be a challenge in itself. As our project is exploratory in nature, we will also need to navigate through many unforeseen challenges and adapt to them in stride.

4.2 Design Exploration

4.2.1 Design Decisions

Though we have had a large number of decisions and yet have many still to come, there were three primary design decisions that we felt were both complex and crucial to our design as it is today. These decisions are as follows:

1. Drivetrain: Tracks vs Wheels
    a. This was one of the first decisions that we made as a team, since it would form the base for all of the other designs around it, along with being a large enough investment that we could not effectively change our decision down the line due to budget constraints. This decision was ultimately made through a combination of benefit comparison, along with referencing other winter-oriented mobile robot solutions. We were able to determine that tracks experience a higher efficiency with lower slip, which is important in winter's low-friction conditions. Other winter-oriented service robots, such as the Yarbo Snow Blower (see 4.1.2), also use this drive system and have seen success.

    b. Later on, this decision was reversed due to economic constraints. Tracks proved to not be economically viable under our development budget, and thus, we had to change
2. Positioning Sensors
    a. Since our solution will never be successful without accurate and reliable positioning data, this was and still is one of the most crucial design decisions to ensure the viability of our project. This required a deep cost-benefit analysis of each solution and combinations/permutations of each solution via sensor fusion.
3. Power System
    a. As a fully-electric robot solution, our power system is a critical subsystem of our robot that must be done correctly for us to create a viable solution, along with being able to integrate all of our subsystems into a single cohesive system. This decision is still being researched, and the decision-making process is being driven by factors such as safety, cold-weather performance, capacity, weight, and cost.

4.2.2 Ideation

One decision that we had to identify multiple outcomes for and had a large weight placed on making the correct decision for in our design was the set of sensors that we would use for positioning data to drive our navigation system. This decision was made even harder by the large number of sensor option candidates that existed in this space and the potential for a combination of sensors via sensor fusion. Our top-five candidates are listed below:

1. Differential GPS
    a. Positional data only from differential GPS for all of our positioning.
2. Differential GPS + Dead-Reckoning
    a. Sensor-fusion of differential GPS with dead-reckoning, depending on the confidence in the GPS signal.
3. Dead Reckoning Only
    a. Usage of dead-reckoning only via both wheel encoders and an IMU.
4. IR/RF Beacons
    a. Usage of stationary IR or RF beacons, in which the rover determines its relative position based on differential timing analysis.
5. Computer Vision Image Targets
    a. Usage of computer vision targets that can be used to determine orientation and relative position from each target.

4.2.3 Decision-Making and Trade-Off

The following figure is a weighted decision matrix that we used to select the positioning sensor option for our project. It weighs cost, accuracy, uptime, and ease of implementation.

	Affordability	Accuracy	Up-Time	Ease-of-Implementation	Total
Criteria Rating	3	5	4	2	
DGPS	4	4	3	3	
Weighted	12	20	12	6	50
DGPS + Dead Reckoning	3	5	5	2	
Weighted	9	25	20	4	58
Dead Reckoning	5	2	5	5	
Weighted	15	10	20	10	55
IR/RF Beacons	2	5	4	1	
Weighted	6	25	16	2	49
CV Image Targets	4	3	4	3	
Weighted	12	15	16	6	49

Figure 4-1: Weighted Decision Matrix for Positioning Sensor Selection

Using this matrix, we were able to determine to use a combination of differential GPS and dead-reckoning through sensor fusion as this scored the highest through our matrix, primarily through its high accuracy and outstanding uptime.

4.3 Proposed Design

4.3.1 Overview

Our current high-level design is driven by our initial sketches and brainstorming that we went through while creating the charter for our project and in the development of our requirements and user needs. It is made of a set of distinct subsystems that are all integrated into a single mobile robot and mobile app. The base of this robot is our drivetrain, which is composed of electric motors and a tracked system that will allow for traversal of the environment, even in the challenging environments that may be present during the winter. This supports the main functional component of the robot, which is a large storage hopper for salt or other ice-melting agents with a powered salt dispersal disk. These functions are driven by a control subsystem that handles planning the routes with the help of many sensors, including GPS and a camera. All of this is powered by an onboard battery and systems to distribute this power to all other subsystems.

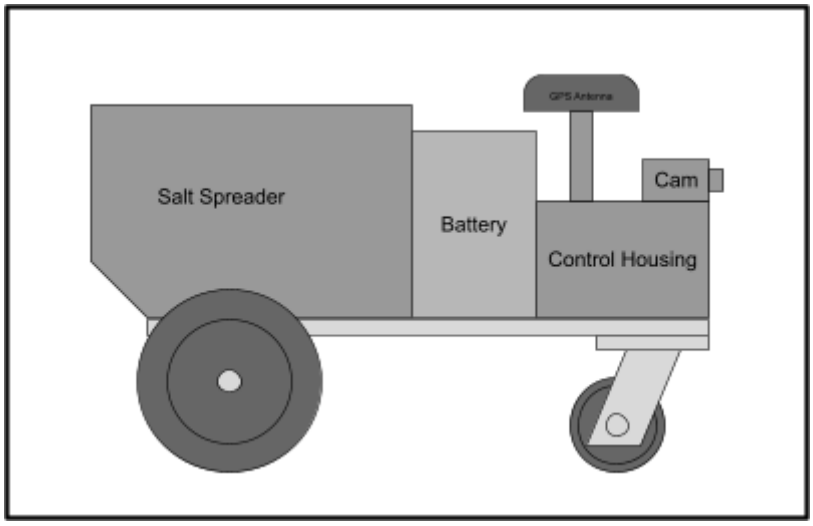


Figure 4-2: Simple High-Level Design Diagram

4.3.2 Detailed Design and Visual(s)

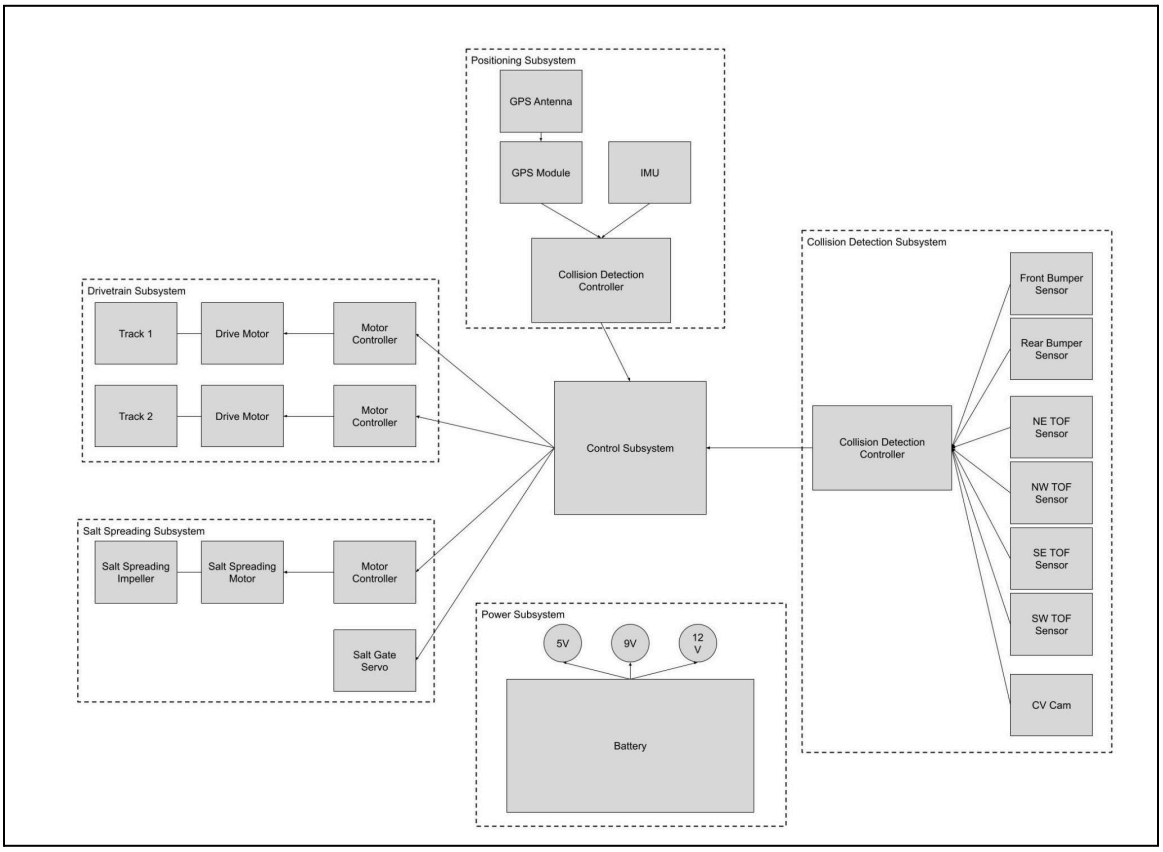


Figure 4-3: Subsystem Organization Block Diagram

Subsystems Details:

1. Control
    a. Function: This subsystem is designed to handle all of the centralized data computation and control algorithms for navigation for the robot. It will use sensor data to distribute commands while also handing all fail-safes.
    b. Design Details: This subsystem's primary component will be a low-cost microcontroller platform, which is currently planned to be an Arduino UNO, which will be running all navigation and mission-critical control code, such as adjustments and fail-safes. This subsystem will also include other smaller processors and boards to offload the computational strain of functions like wireless communication from the app.
2. Positioning
    a. Function: This subsystem has the sole function of providing accurate, high-time positional information and data to the control system.
    b. Design Details: This subsystem will be implementing both IMU-based dead-reckoning and RTK Differential GPS solutions through sensor-fusion algorithms to provide positional data. The GPS provides this system with accurate, real-time, and absolute position, while read-reckoning can provide position

information when there is interference from factors such as cloud cover or entering under an overhang. This subsystem will provide its own computational ability for sensor fusion to reduce the load on the main control subsystem.

3. Collision Detection
    a. Function: This subsystem is responsible for detecting unexpected obstacles and collisions to avoid safety issues or damage to the robot or its surroundings.
    b. Design Details: This system will use a combination of limit switch-based bumpers, time-of-flight sensors, and computer vision in order to detect any hazards in the environment and send potential hazard data to the control system to trigger action if deemed necessary.
4. Salt Spreading
    a. Function: The salt-spreading subsystem is responsible for salt storage, distribution, and monitoring of the salt levels.
    b. Design Details: This subsystem is equally mechanical and electrical in nature. It will include a large storage reservoir for salt, a mechanism that uses an electric motor to disperse salt, and sensors to determine the amount of salt available to complete the task. This includes supporting components such as motor controllers and a gate mechanism for fully cutting off the salt dispersion.
5. Power
    a. Function: This subsystem distributes power to all other subsystems that require it.
    b. Design Details: This subsystem is comprised of two main components. The first is the battery used to power the entire system. The second is a set of voltage control boards to allow us to provide the correct voltage to each type of electronic that will make up the other systems onboard the robot. Long-term this would include supporting systems such as battery management, power management, and charging solutions.
6. Drivetrain
    a. Function: This system is used to actually move the robot and traverse the conditions of the outdoors during the winter, whether it is icy, snowy, or a combination.
    b. Design Details: This subsystem is also made of two main components: the mechanical drive system and the motors/motor control side of it. The mechanical drive system will be that of a track-based drivetrain that must be able to both gain friction in wintery environments and support the weight of a large store of salt. Additionally, there will be the motors and motor controllers that drive the mechanical system based on commands from the control subsystem.
7. Mobile App
    a. Function: The mobile app is designed to allow the user to monitor and control the deployment of the mobile robot.
    b. Design Details: This mobile application will wirelessly connect to the robot to present diagnostic data, such as warnings, battery, or salt levels. Additionally, it will grant the ability to schedule or immediately deploy the robot. Due to one of our target audiences being the elderly population, this will be based on a very intuitive and simple user interface.

4.3.3 Functionality

The intended functionality of our solution can be described by a set of steps that are either accomplished by the user or the robot itself:

1. If not charged enough for a full run, charge the robot.
2. If not filled with salt to an adequate level as indicated by the app, add more salt to the reservoir.
3. Once there has been ice accumulation and most of the snow has been cleared, if needed, use the app to trigger deployment of the robot.
4. The robot will then exit its resting place and go to its path's starting point.
5. The robot will open its salt gate and salt spreading impeller.
6. The robot will continue along its path, avoiding obstacles or warning the user through the app if it cannot resolve the issue itself.
7. Upon completion of the path, it will return to its resting place.
8. The robot will notify the user if it needs to be charged or refilled with salt before its next run.

4.3.4 Areas of Concern and Development

Our current design is well capable of accomplishing its task at a surface level, as it would be capable of spreading salt autonomously. This thus provides safety, time savings, and convenience to our target users. This solution also contains all of the theoretically needed sensors to maintain safety and avoid damage to people or property.

However, a concern that we are currently facing is that due to the explosive nature of the project, we have not been able to determine the horizon of our goals and thus a solid timeline or scope. Additionally, we have not had a good chance to get an understanding of how conditions such as heavy snow or cloud cover could affect our ability to maintain tracking and safety. We will be consulting our faculty advisor on some of these concerns in the near future as he has experience in this field.

4.4 Technology Considerations

While most of the technologies we are using in our design are well established and have been proven to be functional, the primary technology tradeoffs that we have been having to consider are the cost-benefit tradeoffs due to our budget constraints. While there are highly accurate positioning systems available to us, we have had to reduce our expected accuracy as the best systems are far from affordable. This also applies to a lot of our collision avoidance needs; the high precision sensors or sensors such as advanced computer vision or Lidar have not come down in cost enough for them to be economically viable for us.

We have been combating this issue through smart implementation of lower-cost solutions through methods such as sensor fusion and lower-computational-need grid and graph-based algorithms.

4.5 Design Analysis

Currently, our design has not materialized physically due to having to pivot at the beginning of the semester from one project to another.

Our current stage is developing our high-level and detailed design of our systems, such that we can drive our component choice, create an initial BOM, and place our order for the components of our first prototypes.

We have had some design challenges already in our process, as we have been able to determine that we will likely face large constraints from our budget as a student-led project, and have had to scale back some of our requirements, scope, and general expectations.

Our long-term plans for this project are to soon place these orders so that we can do proof-of-concept testing for each subsystem in a parallel development environment. Following that, we will integrate the subsystems into a single, first prototype. At this point, we will be able to determine integration issues and any other issues that we were unable to identify in the subsystem development period. We will then start a new development cycle based on this data to create our second prototype, which would be a little less developed than an MVP

5 Testing

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, power system, or software.

The testing plan should connect the requirements and the design to the adopted test strategy and instruments. In this overarching introduction, give an overview of the testing strategy and your team's overall testing philosophy. Emphasize any unique challenges to testing for your system/design.

In the sections below, describe specific methods for testing. You may include additional types of testing, if applicable to your design. If a particular type of testing is not applicable to your project, you must justify why you are not including it.

When writing your testing planning consider a few guidelines:

- Is our testing plan unique to our project? (It should be)
- Are you testing related to all requirements? For requirements you're not testing (e.g., cost related requirements) can you justify their exclusion?
- Is your testing plan comprehensive?
- When should you be testing? (In most cases, it's early and often, not at the end of the project)

5.1 Unit Testing

Due to the multifaceted nature of our project, we will utilize a wide range of tools to test each component or subsystem that comprises the mobile robot application.

Hardware-wise, unit tests will be performed using physical tests such as the drivetrain's ability to drive (likely using a simplified version of the code during early development) and testing the power distribution system using a multimeter. Each power rail will have identified test points and expected voltage values and tolerances.

Software-wise, the unit tests will take many forms. Sensors with their own computational abilities, such as the GPS module, will be tested for accuracy and reliability independently of the whole system using the OEM's software tools. Similar tests will be conducted to evaluate the ESPCam's ability to detect approaching obstacles. Less complicated functions, such as the ability for the bump sensors to interrupt the code, will be tested in conjunction with our Arduino using the ArduinoUnit library through more traditional unit test structures (asserts and the Serial Monitor). All core logic (calculations and data processing) will be structured such that it can be tested without hardware and integrated into a set of unit tests.

5.2 Interface Testing

Our interface testing will be primarily designed around the communication between sensors and controllers on the robot. For each protocol/connection, data will be transmitted from point to point. When possible, sample data will be sent, and an assertion will verify that it was transmitted and received correctly. When sample data is not possible (e.g., from the GPS unit) data will be verified to be the same as reported to the PC-based software manually. PWM for motor control will have to be tested during integration testing.

Two wireless tests are to be conducted: a test to ensure the main controller can connect to an RTCM server and a test to verify that two-way communication can be established with the mobile app.

5.3 Integration Testing

Our system involves multiple integrated systems, especially in our control system. Communication tests will verify whether each sensor or distributed processor can report its data to the main controller and produce the correct trigger or interrupt within the main control loop. All of these communications from the sensors will be run through their respective data processing, if needed, and assertions will check the validity of the pre- and post-processing data. All of these communication tests will need to be verified through monitoring/logging and manual checks, as the use of real sensor data would not allow for the expected values. However, assertions will be implemented to check for signals outside of acceptable ranges.

Tests will also verify that the main controller produces the correct physical response from each physical subsystem (drivetrain or salt spreading mechanism). These will have to be tested through visual inspection.

The electrical system is to be tested under load after integration of the other systems to verify the appropriate power draw and to assess voltage regulation. This will be tested using a multimeter under simulated loads on the robot, as measuring voltages and currents on a moving robot would be challenging.

5.4 System Testing

System testing will involve unit testing of each component according to requirements (e.g. does the GPS unit report <5cm accuracy), along with each integration test once the full system is created. These tests will be run concurrently whenever possible to stress-test our computational and power needs. Once these conditions are met, we will run tests on the main functionality of the mobile app, specifically using it to trigger a de-icing job at a known test site. We will monitor the combination of sensors, navigation, driving, obstacle avoidance, and salt distribution.

5.5 Regression Testing

To ensure software quality does not regress, we will set up a testing pipeline for all of our unit tests that can be automated.

For tests that cannot be automated, such as those involving physical components or real sensor data, we will rerun related tests according to a dependency map*. For example, if a more powerful controller were added, we would retest the power system. Similarly, if we changed our GPS data, we would retest the GPS unit and all downstream integration tests.

*Our dependency map would be a visual representation of how each piece of software or hardware relates to each other, as shown in a condensed, text-based form below.

GPS module -> 5V rail -> power distribution sub-system (test current draw)

GPS module -> i2c -> positioning code -> navigation code

5.6 Acceptance Testing

Our acceptance testing will primarily take the form of continuous testing throughout our design process, with an emphasis on ensuring that each requirement is addressed by at least one test. All relevant testing results will be reported to our advisor, and milestone tests will be presented live to our advisor. System testing, according to requirements, will be our ultimate acceptance test.

5.7 User Testing

For user testing, we plan to implement two main components. First, we will test the user interface of the mobile app by conducting an unguided user interface test with a sample of users of varying technology skill levels and ages. Without prior knowledge of the app, we would record the time, the number of touches required, and the accuracy for each test subject to accomplish a task or locate a piece of information.

Next, we would run demonstrations of the full functionality and have independent observers grade the quality of salt spreading.

5.8 Results

Due to the current phase of the project, we have had limited time to run formal tests, as we are in the proof-of-concept and exploration phase.

However, we have been able to verify our ability to detect oncoming objects using our ESPcam and achieve centimeter-level accuracy in static GPS tests.

6 Implementation

Describe any (preliminary) implementations of your design thus far. Support any general, descriptive text with relevant images. If your project has inseparable activities between design and implementation, you can list them either in the Design section or this section.

7 Ethics and Professional Responsibility

Use this section to describe your considerations of engineering ethics and professional responsibility. Most importantly how are you defining engineering ethics and professional responsibility in the context of your project and what steps are you taken to ensure ethical and responsible conduct. Each section references one type of ethical/professional responsibility considerations. You may also use this introductory section to note any overarching ethical philosophy among your team.

7.1 Areas of Professional Responsibility/Codes of Ethics

This discussion is with respect to the paper by J. McCormack and colleagues 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

Area of Responsibility	Definition	Relevant IEEE Code	How Our Team Has Addressed the Area
Work Competence	Professional and quality work	"Seek and accept honest criticism of technical work..." (Item 5) "To maintain and improve our technical competence." (Item 6)	We are choosing to iterate over many prototypes and validating the systems
Finacial Responibility	Create a financial resonable product and save costs were applicable	"To be honest and realistic in stating claims or estimates based on available data." (Item 5)	One of our primary decision factors in many choices was economically based.
Communication Honesty	Be honest with our claims, and offer full transparency on our project	(Item 5)	We are openly communicating issues we run into and fixes that may help
Health, Saftey and	Ensuring the safety of	"To hold paramount	We added bump

Well-Being	users and their environments	the safety, health, and welfare of the public... and to disclose promptly factors that might endanger the public or the environment" (Item 1)	sensors, object based detection, and emergency stop features
Sustainability	Minimize the negative environmental impact	"... or the environment" (Item 1)	We optimized battery usage for time and power usage, and plan to salt the minimum to help the environment
Social Responsibility	The product should benefit society and treat all fairly	(Item 1)	Our product will be useful to home and business owners

We are performing well both in financial and social responsibility. Our team evaluates numerous options, with affordability being one of the key considerations when selecting a part. Without including work hours, we have managed to keep our design more financially plausible.

Our sustainability is an area that needs improvement and re-examination. We are actively working on making a design that works as more of a proof-of-concept, and we haven't devised a more efficient salt distribution method that is eco-friendly.

7.2 Four Principles

Broader Context	Beneficence	Nonmalificence	Respect for Autonomy	Justice
Public Safety and individual users	Our primary purpose is to aid users in de-icing their driveways and sidewalks.	We are using object based detection and bump sensors, as well as a low drive speed to prevent harm	The robot will follow users directions and remain in gps region	Reliable quality salt distribution for owners
Social, global and cultural	We are trying to create a reliable method of de-icing for those without the means.	Avoiding unreliable, expensive designs or anything that may be stigmatized or offensive	Control of the device over the app allows users to customize use, and the basic design is unoffensive	Ensures consistent performance regardless of driveway type, neighborhood or user.
Enviromental	By using parts that an owner	Attempting to mitigate salt use	Users can choose eco-friendly salt	Environmental impact

	can order and install, it promotes repairing vs replacing a device. Ability to optimize sale usage reduces run-off	to preserve the environment, but poor tuning could lead to excess use.	alternatives and adjust minimum-spread settings.	considered across different regions
Economic	Provides a solution for people not capable of using traditional de-icing methods.	Minimizes manufacturing waste where feasible and promotes repairing.	Users can integrate with different regional salt types or standards.	Strives for cost fairness by using standard components and avoiding proprietary lock-ins.

Individual Users - Beneficence

Our robots' main benefit is reducing injury risk and providing a solution for the elderly or physically impaired. To ensure this we focused on safe autonomous naviagiton, and an even distribution of salt.

Environmental - Nonmaleficence

If improperly set up, our robot could provide increased salt usage and environmental damage.

7.3 Virtues

Team Virtues

Our team has defined the following virtues as important to us.

- **Communication** – Due to our larger team meeting in groups, communication between those groups is important for our team to succeed.
- **Time Management** – Our team has had a shorter schedule then the others, leading us to needing to be more efficient with our time. We have attempted to do so, but will need to put more focusing into this next semester.
- **Perseverance** – Our original project was ended, and we had to change lanes quickly. Through this we attempted to catch up and find stable footing, while also being diligent about the choices we made.

Dylan Bunting

Virtue Demonstrated – Communication: This semester I have been able to demonstrate my communication and flexibility with group meetings and what I have worked on.

Virtue Not yet Demonstrated – Time Management: I have not been able to demonstrate my ability to manage time effectively this semester. While we were making up ground on lost time, I wasn't able to manage my time effectively enough to get everything done.

Hoyt Dzwoniarski

Virtue Demonstrated: I have been able to demonstrate the virtue of communication this semester. I was able to effectively communicate with my team members about what is needed for us to continue moving forward.

Virtue Not yet Demonstrated: This semester I haven't demonstrated the virtue of consistency. My work per week on the project has fluctuated up and down throughout the semester as a result of changing workload from other classes.

Issac Blandin

Virtue Demonstrated: This semester, I have been able to demonstrate general organizational skills and leadership along with building better testing skillsets.

Virtue Not yet Demonstrated: Some virtues that I struggled with this semester was time management and timeliness at meetings.

Mikhail McDade

Virtue Demonstrated - collaboration : I was able to effectively help other members and aid in the process of the computational aspects between EE and cpre as well as get work in before the deadline.

Virtue Not yet Demonstrated: Things that I have not demonstrated yet are better time management and keeping up with information.

Shobhit Singh

Virtue Demonstrated: I demonstrated responsibility this semester. I was always able to accomplish my tasks on time and my progress helped to move our group forward.

Virtue Not yet Demonstrated: There were times this semester where I struggled to communicate all of my progress to the group.

Thomas Huedepohl

Virtue Demonstrated: Time management, I was on time to every meeting and completed everything asked in a timely manner.

Virtue Not yet Demonstrated: Organization: I was often not up to date with wat other group mates were doing.

8 Closing Material

8.1 Conclusion

So far our group has developed most of the subsystems to get most of the proof of concept prototype done, moving towards our objective. Our goals are still to create a robot that can navigate autonomously and spread salt over a driveway or sidewalk. During this semester our group did research on components for our robot and moved forward with purchasing them. Each subsystem group then begun working on their individual parts. Time has been are biggest constraint, but the team has worked hard on catching up. Overall the current implementation of our plan has been proven to be a strong foundation for the next semester as we work on delivering a MVP solution.

8.2 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE). See link:
https://ieee-dataport.org/sites/default/files/analysis/27/IEEE%20Citation%20Guidelines.pdf

8.3 Appendices

Websites:

[1] Uline, “Ice Melt Rock Salt” uline.com [Online]. Available: https://www.uline.com/Product/Detail/S-7125/Grounds-Maintenance/Ice-Melt-50-lb-Bag?pricode=WB0870&gadtype=pla&id=S-7125&gad_source=1&gad_campaignid=21817469039&gbraid=0AAAAAD_uetMwZBmhPKFY5P5RqjBCIX7py&gclid=CjwKCAiAxc_JBhA2EiwAFVs7XCHLeK6D7Jeg16s3kDRDKmSpuHSGglY02537WrWP5SbfShqh6810fx0C_PoQAvD_BwE. [Accessed Nov. 6th 2025]

Equations:

[2] Equation to determine theoretical top speed: Circumference * RPM:

$$144\ mm\ *\ \pi\ *\ 223\ RPM\ /\ (60\ seconds\ *\ 1\ meter)\ =\ 1.681\ m/s$$

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc., Software bugs etc.

9 Team

9.1 Team Members

- Hoyt Dzwoniarski
- Mikhail McDade
- Dylan Bunting
- Thomas Huedepohl
- Isaac Blandin
- Shobhit Singh

9.2 Required Skill Sets for Your Project

- Mobile Robot Design
- Electrical Design
- Software Design
- Sensor Integration
- Mobile App Development
- Mechanical Design
- 3D Printing

9.3 Skill Sets covered by the Team

- Mobile Robot Design - Hoyt, Thomas, Isaac
- Electrical Design - Hoyt, Dylan, Thomas
- Software Design - Mikhail, Isaac, Shobhit
- Sensor Integration - Isaac, Shobhit
- Mobile App Development - Mikhail, Isaac, Shobhit
- Mechanical Design - Hoyt, Thomas, Isaac
- 3D Printing - Dylan, Thomas, Isaac

9.4 Project Management Style Adopted by the team

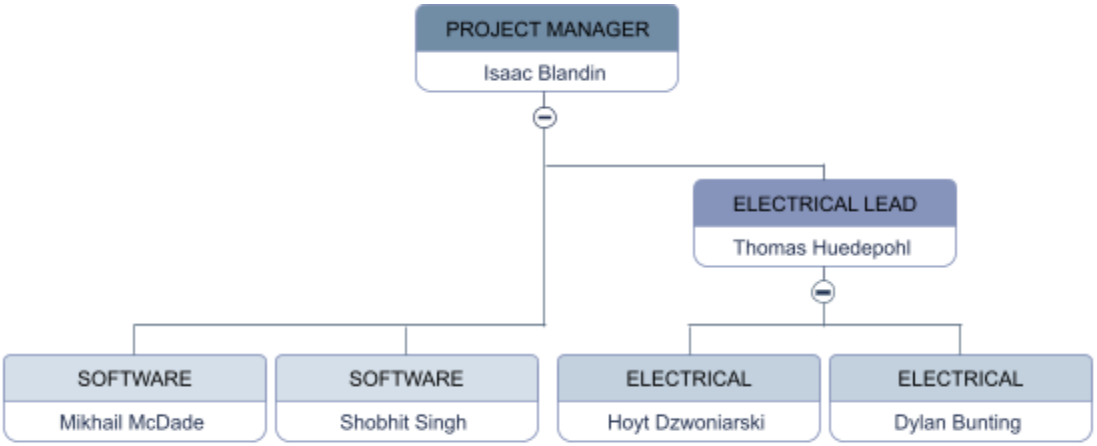
Our team adopted an agile framework as our project management style due to the highly exploratory nature of our project. We expect setbacks and revisions to the design over time, so an agile framework was needed for its flexibility.

9.5 Initial Project Management Roles

Isaac Blandin - Project Manager/Software Team Lead

Thomas Huedepohl - Electrical Team Lead

We are organized as shown in the following organizational chart



5

9.6 Team Contract

Team Members:

1) Hoyt Dzwoniarski
2) Thomas Huedepohl
3) Mikhail McDade
4) Isaac Blandin
5) Dylan Bunting
6) Shobhit Singh

Team Procedures

1. Day, time, and location (face-to-face or virtual) for regular team meetings:
    a. All meetings with clients should take place face-to-face to allow for the fastest feedback and guaranteed attention.
    b. Team meetings will take place virtually for improved flexibility unless face-to-face is considered necessary for any specific meeting.

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):
    a. Discord will be used for group communication and communication with the client.
    b. Outlook calendar will be used to track the scheduling of group members and organize meetings efficiently. Members are expected to keep their calendars updated with classes and all other time commitments.

3. Decision-making policy (e.g., consensus, majority vote):
    a. Consensus will be the desired and ideal decision-making policy for group decisions; however, if we are at a standstill, majority vote will be used to break the tie.

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):
    a. All meeting minutes should be recorded by the team member holding the role of Secretary and placed in the team drive once compiled following each meeting.

b. Each member shall still be responsible for recording any information important for their work during meetings.

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings:
    a. Team members are expected to attend all team meetings and actively participate in all group discussions unless an excruciating circumstance presents itself.
    b. Members should contact the group if they cannot attend a meeting as far in advance as possible.
    c. If members miss a team meeting for more than two consecutive weeks, we will work together to figure out a solution to allow for a more conducive meeting time.

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:
    a. Team members should each contribute a relatively equal amount of work to the culmination of the final project.
    b. Certain members may have more of a focus on certain aspects of the project (such as client relations, technical design, organization, planning, etc); however, the hours and work contributed should be generally evenly distributed across all team members.

3. Expected level of communication with other team members:
    a. Team members should reply promptly to all team messages and emails. Members should aim to respond within 24 hours to any given message.
    b. When a question is posed to the whole group, a written response may not always be necessary; however, members should at a minimum acknowledge the message (reacting to the message on Discord, etc).

4. Expected level of commitment to team decisions and tasks:
    a. Members will all have an equal opportunity to contribute to team decisions and tasks.
    b. If a member has been infrequent in their contribution to the project recently (missed a meeting, unresponsive to messages, etc) they may forfeit some of their decision-making power in favor of members who have been actively leading and contributing to the project.
    c. Members who fail to properly contribute to the project will be confronted if the rest of the group finds their behavior inadequate.

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):
    a. **Hoyt:** Creative Design/Planning
    b. **Isaac:** Project Manager / Software Team Lead
    c. **Mikhail:** Communications & Client Liaison
    d. **Shobhit:** Meeting moderator & Secretary (keeping tabs and minutes)
    e. **Thomas:** CAD Co-lead, Electrical Team Lead
    f. **Dylan:** Electronics and QA testing

2. Strategies for supporting and guiding the work of all team members:
   Weekly checkups to see how well each team member feels about the project, and if there is a bigger issue, then we can try to discuss a solution as a team, but any other questions or concerns will probably end up in a Teams or Discord chat.

3. Strategies for recognizing the contributions of all team members:
   By setting specific goals and tasks for each team member, we can monitor progress via weekly checkups and or progress reports via Teams meetings

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.
   a. **Hoyt**: EE major with experience in circuit design, digital logic, and a focus on VLSI
   b. **Isaac**: CPRE Major with experience in: microprocessor usage, sensor integration, sensor fusion, low-computational power algorithm creation, parametric modeling, system simulation, 3D printing, CNC manufacturing, rapid prototyping.
   c. **Mikhail:** CprE major, with a background in networking, cybersecurity, Circuit design, embedded systems programming, CPU MIPS architecture, and a familiarity with running and monitoring Linx servers
   d. **Shobhit**: A CPRE major, with background in cybersecurity protocols, embedded systems programming and an interest in pursuing quantum computing research. Thorough understanding of embedded level programming protocols and principles along with networking models and encryption algorithms. This project is connected to the history of computing which made me interested in it.
   e. **Thomas:** EE major with experience in embedded systems, cad, 3d printing, CNC
   f. **Dylan**:EE major with a background in digital logic, semiconductors, circuit design, embedded systems, 3D printing, and CAD.

2. Strategies for encouraging and supporting contributions and ideas from all team members:
   a. Assigning tasks based on interests and expertise, along with always keeping check on other team members through an accountability buddy system. Communicating about new ideas as well as facing a block in the Discord, so that no one is ever out of the loop in any situation.
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?)
   a. Clear communication that one feels that they are not being provided the means to contribute is the first step in this situation. If an inclusion concern is brought up, it shall become the first talking point at the next team meeting.

Goal-Setting, Planning, and Execution

1. Team goals for this semester:
   a. Improve documentation and communication skills in the context of an engineering project.
   b. Effectively communicate and collaborate on tasks to optimize productivity as a team rather than as an individual.

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

a. Create a scrum board (or similar) for team tasks, assigning story points to all tasks
b. Perform workload planning for all members per sprint based on story points.
c. Consider outside obligations, such as exams, in each member's workload capacity for any given planning cycle. (e.g., Allow for a lighter workload for a member during a week that they have multiple exams without viewing them as contributing less).

3. Strategies for keeping on task:
    a. The assigned Scrum tasks with deadlines provide a focused task that must be worked towards.

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?
    1st time: Respectful conversation with the rest of the team.
    2nd time: Team will discuss consequences.
    3rd time: Consequences implemented.

2. What will your team do if the infractions continue?
    If infractions continue following communication and/or consequences from the team, instructors will be contacted 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) Isaac Blandin DATE 09/11/2025
2) Hoyt Dzwoniarski DATE 09/11/2025
3) Thomas Huedepohl DATE 09/11/2025
4) Mikhail McDade DATE 09/11/2025
5) Dylan Bunting DATE 09/16/2025
6) Shobhit Singh DATE 09/16/2025