AUTONOMOUS MOBILE SALT SPREADING ROBOT

Team sdmay26-07

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DESIGN

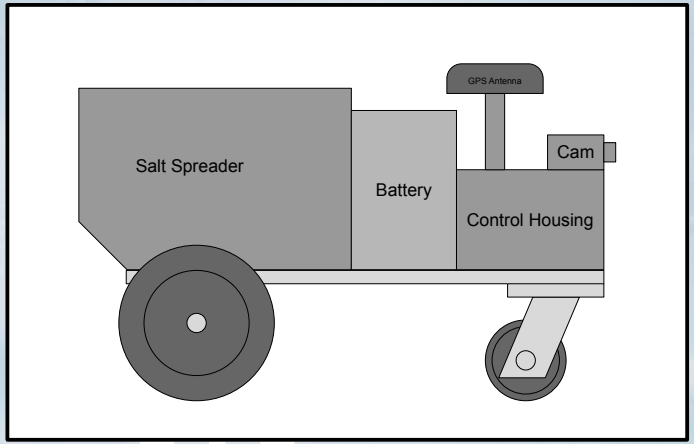
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NEXT STEPS

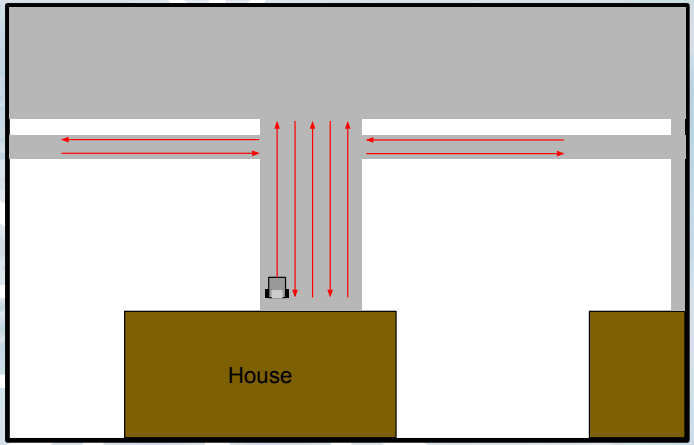
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01

PROJECT OVERVIEW

What We Are Doing. How We Are Organizing.



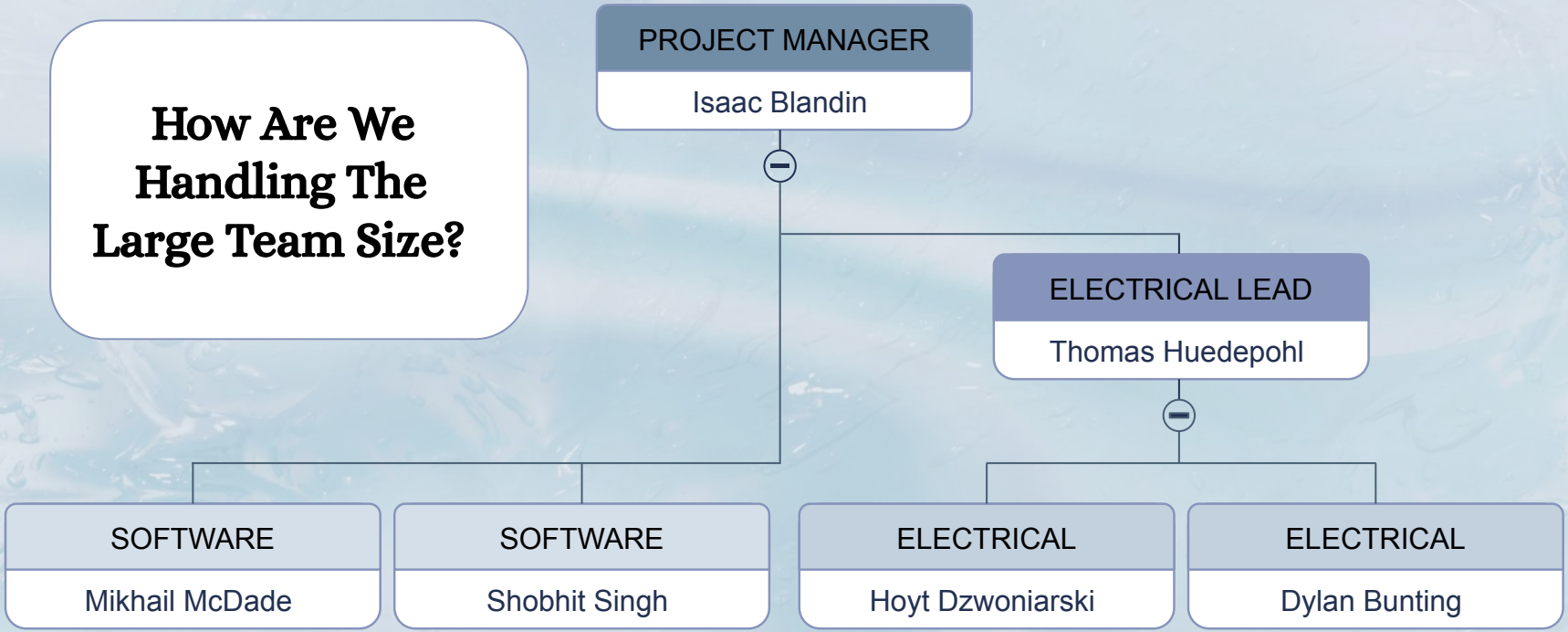


PROJECT OVERVIEW

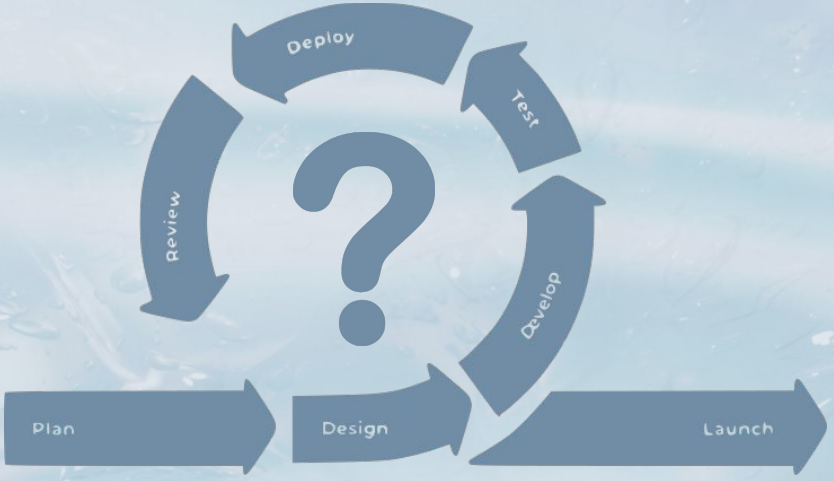
- Salt Spreading
- Autonomous Driving
- Sensor Fusion Localization & Navigation
- Mobile App
  - Highly Intuitive User interface

TEAM ORGANIZATION

How Are We Handling The Large Team Size?



Project Management Methodology



AGILE

Project Characteristics:

- Highly Exploratory
- High Likelihood of Revisions
- A Lot of Uncertainty

PROJECT TIMELINE

Month	September		October		November		December		January		February		March		April		May
Sprint	1-1	1-2	1-3	1-4	1-5	1-6	1-7	1-8	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9
Initial Project (Had to Switch Projects)																	
Project Chartering / Requirements Creation																	
Research Modules																	
Design Modules																	
Proof of Concepts Construction / Testing																	
Prototype 1 / Testing																	
Prototype 2 / Testing																	

02

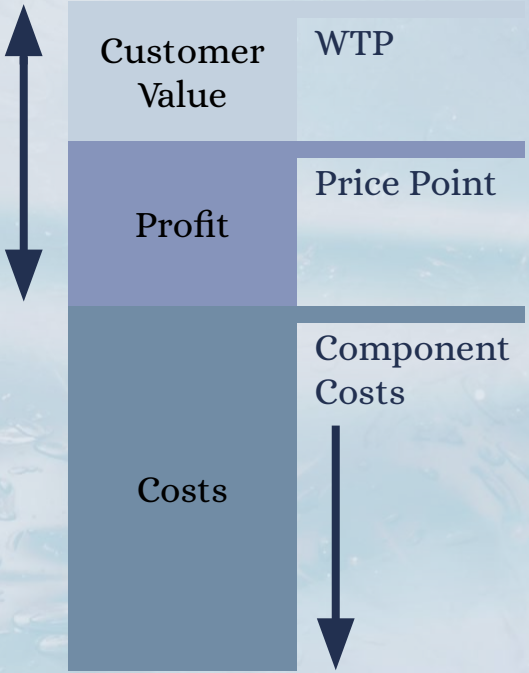
DESIGN CONSIDERATIONS

The “Whys”



TARGET AUDIENCES

- Elderly / Mobility-Limited
  - Need A Safer Method To De-ice
- High Workload Working Adults
  - Benefit From Time Savings
- Campuses/Municipalities (Future Goal)
  - Could Use A Fleet of Our Solution



VALUE PROPOSITION

What Are The Product Substitutes?

- Doing It Yourself
- Snow Removal Services

Value Creation:

- Convenience
- Safety
- Buy-to-Own
- Available On-Demand

REQUIREMENTS

FUNCTIONAL REQUIREMENTS	
Driveway Area Serviceable	Must be able to spread salt over an area of up to 2000 sq. ft.
Tracking System	Localization must have accuracy +/- 5 cm at any given point during operations.
Salt / Battery Level Monitoring	The system must be able to detect if it does not have enough salt or battery to complete its task
Temperature Tolerance	The system must be able to operate in temperatures as low as 5 ℉ (minimum effective temperature for ice melt solutions)

PHYSICAL REQUIREMENTS	
Salt Capacity	Must be able to carry enough salt to meet driveway area requirement (2000 sq. ft)
Winter Conditions Traversal	The drivetrain must be able to traverse icy conditions and navigate within typical slopes of driveways and sidewalks
Waterproofing	The electronic system must be shielded from moisture and unaffected by wet environments
Corrosion Resistance	Materials must resist corrosion, even when exposed to moisture or salt

REQUIREMENTS

ENVIRONMENTAL REQUIREMENTS	
Excess Salt	The system must not spread too much salt or misplace salt in order to reduce runoff and vegetation damage

UI/UX REQUIREMENTS	
Salt Reservoir Access	The salt reservoir must be easy to refill by the user
Intuitive User Interface	The user interface must be simple and intuitive for users who are not overly familiar with technology



ENGINEERING STANDARDS

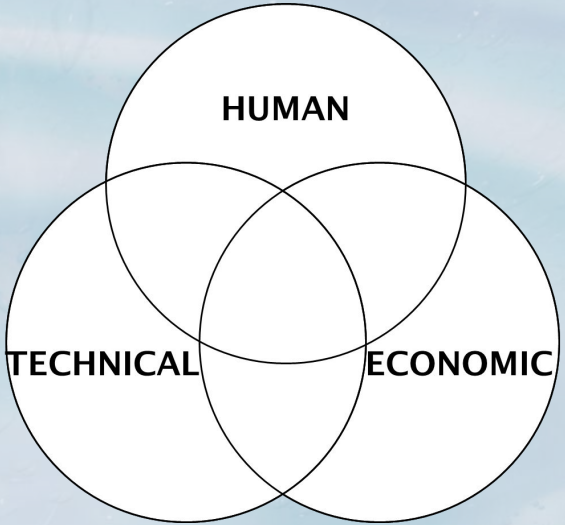
IEEE 7009:2024
- Fail-Safe Mechanisms For Autonomous Systems

ISO 13482:2014
- Safety Standards for Service Robots

FCC Part 15
- Regulations on Wi-Fi and Bluetooth Communications.

DESIGN TRADEOFFS

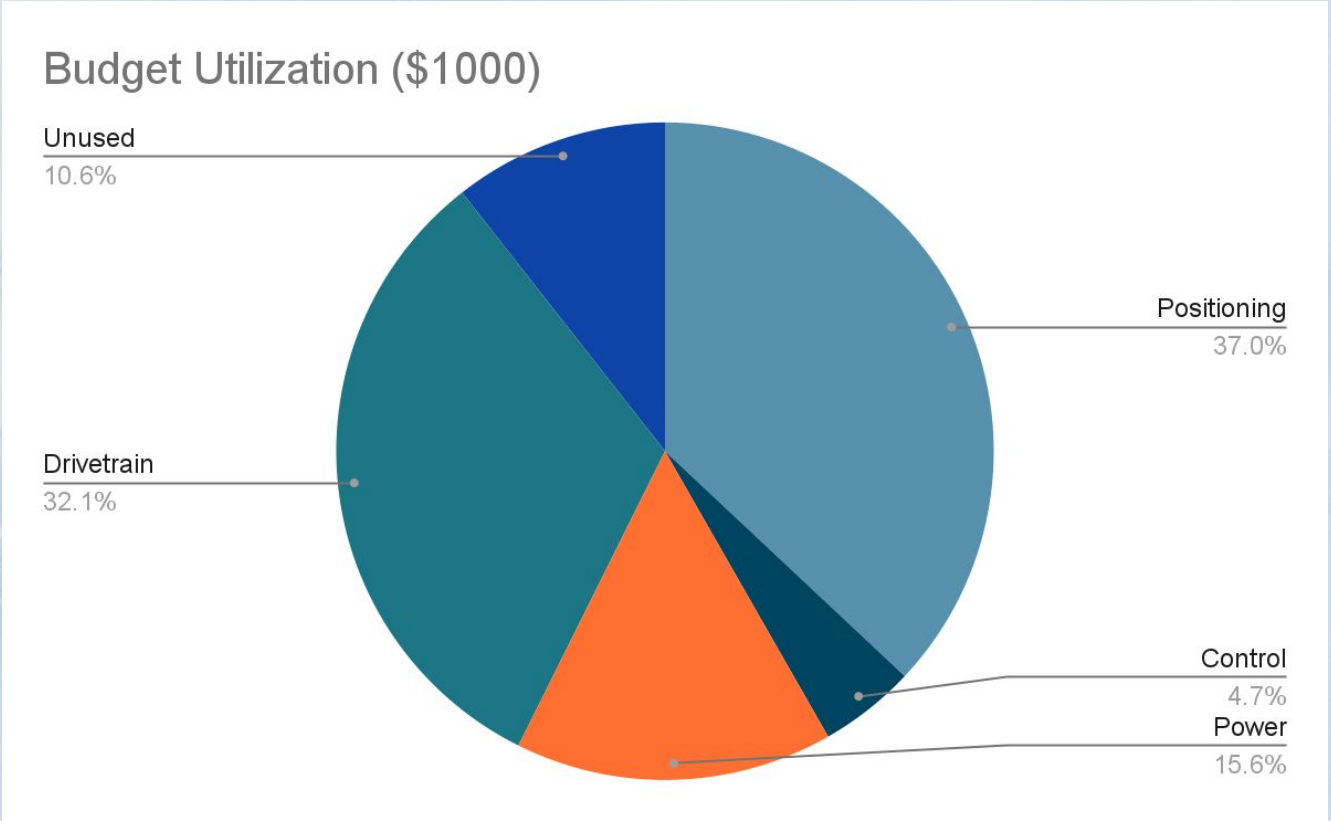
- Autonomous Function
- Intuitive User Interface
- Simple Maintenance



- Limit and monitor scope throughout project.
- Utilize team members' strengths.

- Must Minimize Development Costs.
- Must Have Greater NPV Than A Paid Service
- Value Through Novelty

BUDGET UTILIZATION



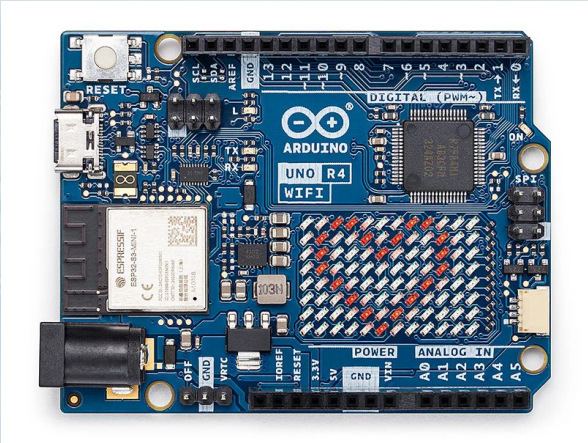
03

DESIGN

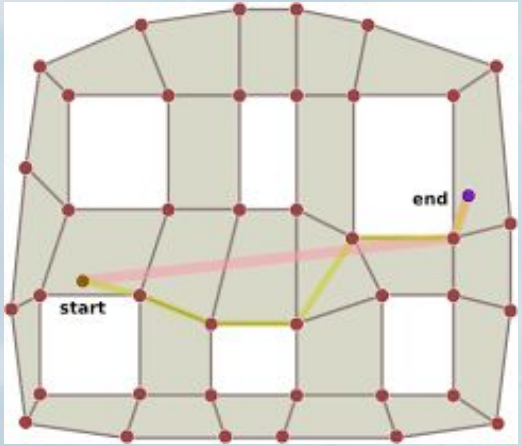
A Deep Dive Into The Project Work

CONTROL & NAVIGATION

arduino uno R4 Wifi

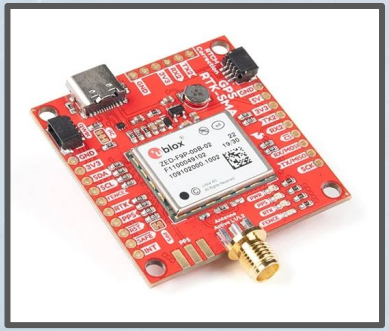


Grid based navigation



POSITIONING

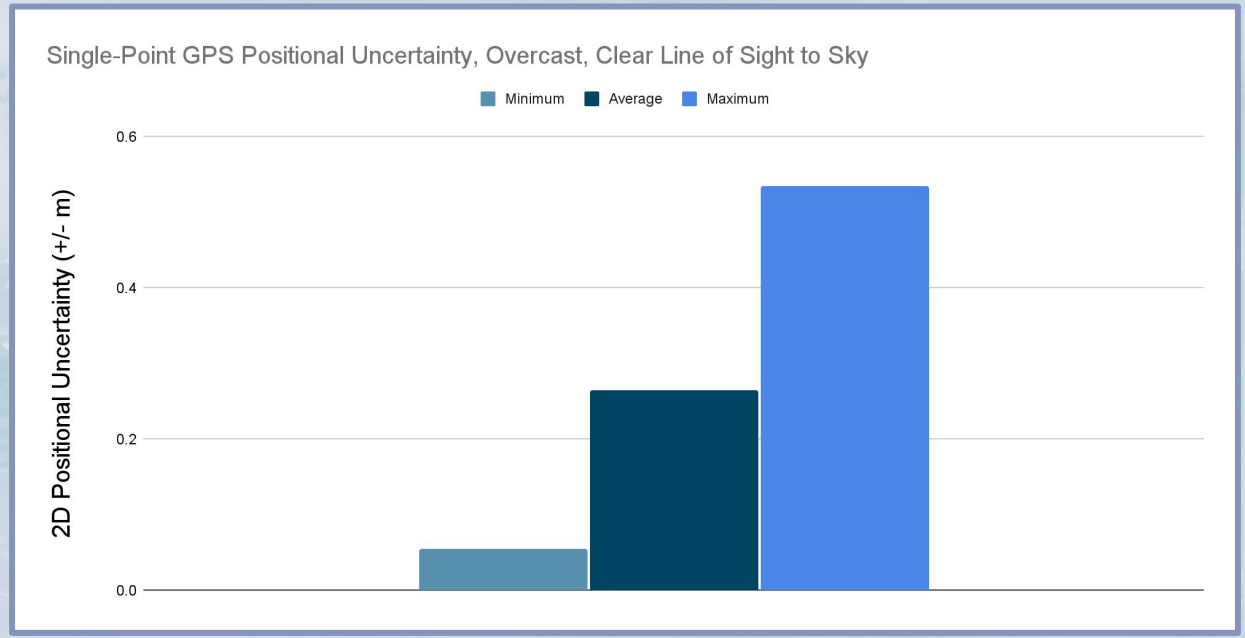
- Chose To Use Differential GPS + IMU Sensor Fusion
- Balanced Decision Based on Cost, Accuracy, Up-Time, and Ease-of-Implementation.



	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

POSITIONING (CONT.)

- Tested Single-Point GPS To Verify If Differential GPS Was Necessary
- Takeaway: Single-Point GPS Cannot Meet Our Centimeter-Level Accuracy Requirements
- Solution: Sensor Fusion with IMU & Differential GPS



COLLISION AVOIDANCE

Requirements :

detect outdoor obstacles in real time (<150 ms) without cloud links, maintain sub-70 mA draw for battery life, stay within ESP32-CAM cost&size envelope, and expose telemetry for fleet tuning



Available Approaches :

1) Cloud vision offload (high accuracy, but cellular latency and data fees)

2) Ultrasonic/LiDAR array (robust range sensing, extra BOM cost and dead zones)

3) On-device vision (Leverage camera already present, runs progressively on edge)

Why On-Device Vision Won

•Fast brains on board •No extra hardware to mount •Privacy: video never leaves the robot



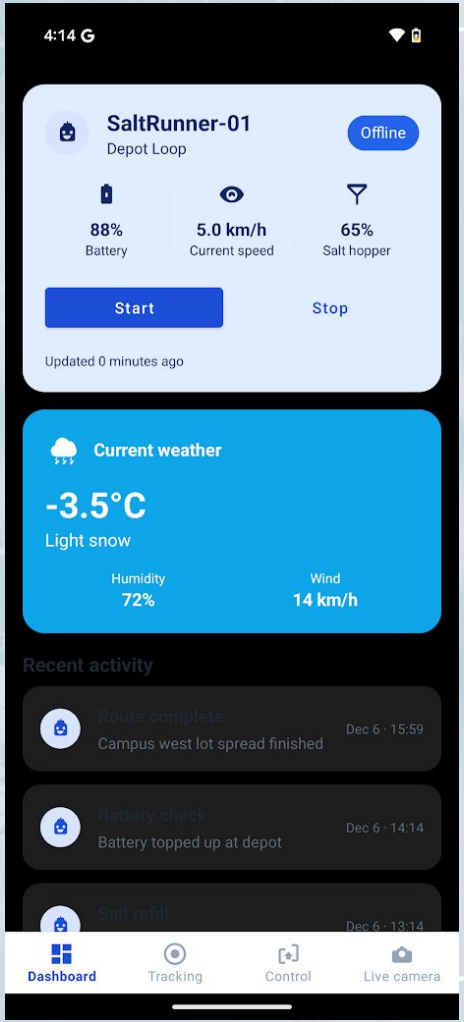
EDGE IMPULSE

Edge Compute Pipeline : LoG edge filter + cascade classifier run entirely on ESP32-CAM, so no frame leaves the robot. Latency stays <150 ms from capture to vehicle response; uplink only carries alerts/telemetry.

TinyML : MSR01/MNP01 object cascades occupy ~150 kB flash plus 60 kB RAM, Camera stream downsampled to 320×240 grayscale to hold ~12 fps while leaving PSRAM for buffering.

Processor Constraints : ESP32-S3 @ 240 MHz dual core with 8 MB PSRAM and 4 MB flash. ~70 mA peak draw leaves tight thermal margin, so vision pipelines target <60% CPU to keep Wifi stable.

Future & Results : Current pipeline flags obstacles with ~82% precision at 2 m; next plans include quantizing a <1 MB object-detection CNN for better recall and adding OTA updates after bundling the detection headers.

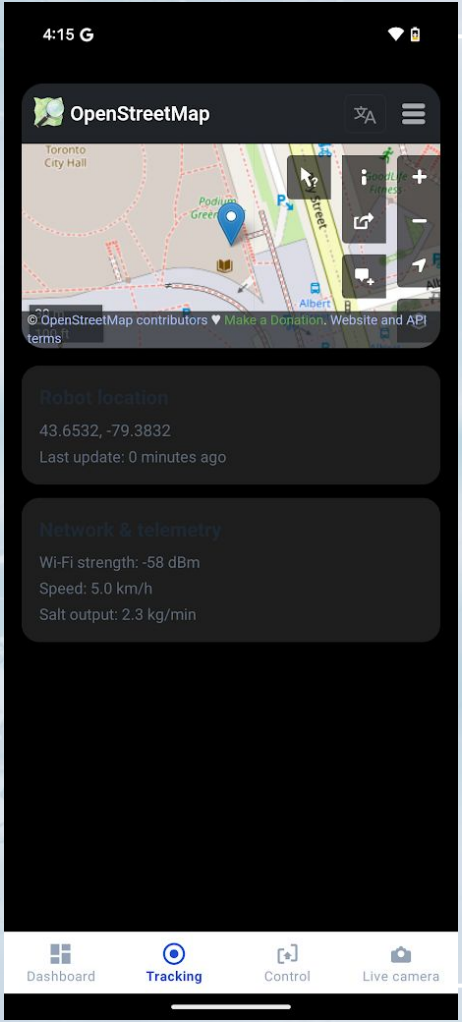


MOBILE COMPANION APP

Real-time dashboard for robot telemetry (battery, hopper, speed, route updates)

Live GPS tracking with map preview and status timeline

Weather-aware operations: pulls current temp, wind, and conditions via Open-Meteo



MOBILE COMPANION APP

Command center:
start/stop/pause/resume robot
configurable base URL for different deployments

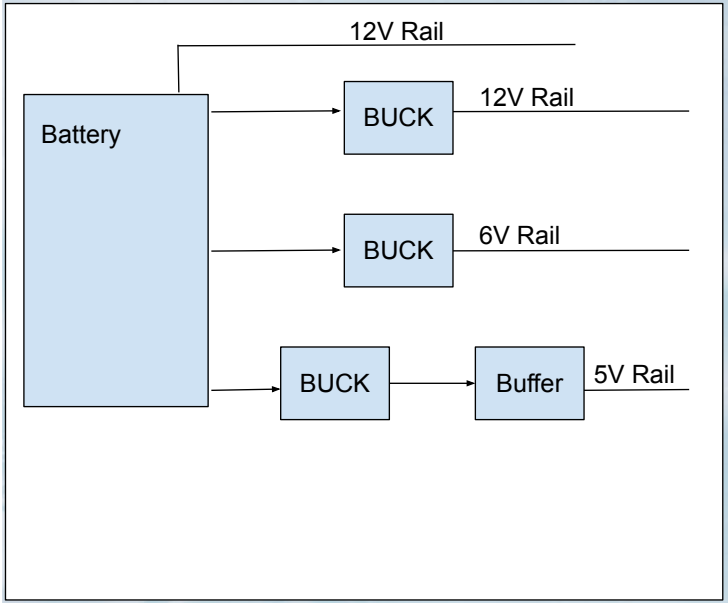
Camera integration :
built-in viewer for robot stream plus ad-hoc testing page



SALT DISTRIBUTION

- Electronic spinner rotates dispensing salt
- Average two-car driveway is ~500 square feet
- Story County minimum is 20 ft wide
- Uline Ice Melt recommends 1-4 lbs per 500 sq-ft
- Hopper is designed to carry 16 lbs to cover up to 2000 sq-ft

Uline Menards



POWER SUPPLY & DISTRIBUTION

- Lead vs Lithium Ion
- Lead is cheaper, $120<$300
- 12V-18AH lead acid
- MP1584EN buck convertor
- System draws up to ~700 mA



DRIVETRAIN

- Tires over treads due to budget constraints
- ~$100 vs ~$170
- Tires have a diameter of 144 mm
- Brushed DC motor spin up to 223 RPM
- Target Speed: .5 m/s
- 452.4 mm * 223 / (60 s * 1000 mm) = 1.681 m/s with no load



04

NEXT STEPS

What we are doing. How we are organizing.

PROTOTYPE 1

- Platform for Research & Testing
  - Navigation Software Development
  - Object/Collision Avoidance
  - Salt Distribution
- Physical Design Inspired By Line Following Robots
- Compromising On Physical Construction & Waterproofing

PROTOTYPE 2

- Near-MVP Level Solution
- Waterproofing/Dust/Salt Resistance
- Winter-capable Drivetrain (Treads)
- Verify Final Economic Feasibility

05

CONCLUSIONS

What We Learned. What We Need To Do Going Forward.

KEY TAKEAWAYS & LESSONS LEARNED

ORGANIZE FIRST

Organizational issues are harder to combat later

ALIGN INTERESTS

The biggest motivator is interest.

COMMUNICATION

Communication needs to be the first priority.

RESILIENCY

Exploratory work is filled with setbacks. Work through them.

INTEGRATION STRAIN

Dedicate work to integration planning. Think on a system level.

THANKS!

QUESTIONS?