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GT Capstone Design
Vanderlande Dia-Bot
Final Report

Fall 2021

Operation Omega
Andrew Galant (ME), Catherine Kasper (CmpE), Jason Piotter (ME),
Hunter Present (ME), Connor Truono (CmpE), & Douglas Walker (ME)

MOVING YOUR BUSINESS FORWARD

Presentation Content

- Problem Statement
  - Function Tree
  - Specifications
- Design Methodology & Concepts
  - Software Features & User Interface
  - Electrical
  - Mechanical
- Prototyping Results
  - Demos
  - Innovation: Modular Design
- Conclusions: Impact and Applications
  - Final Results and Dia-Bot Application
  - Stretch Goals & Future Work

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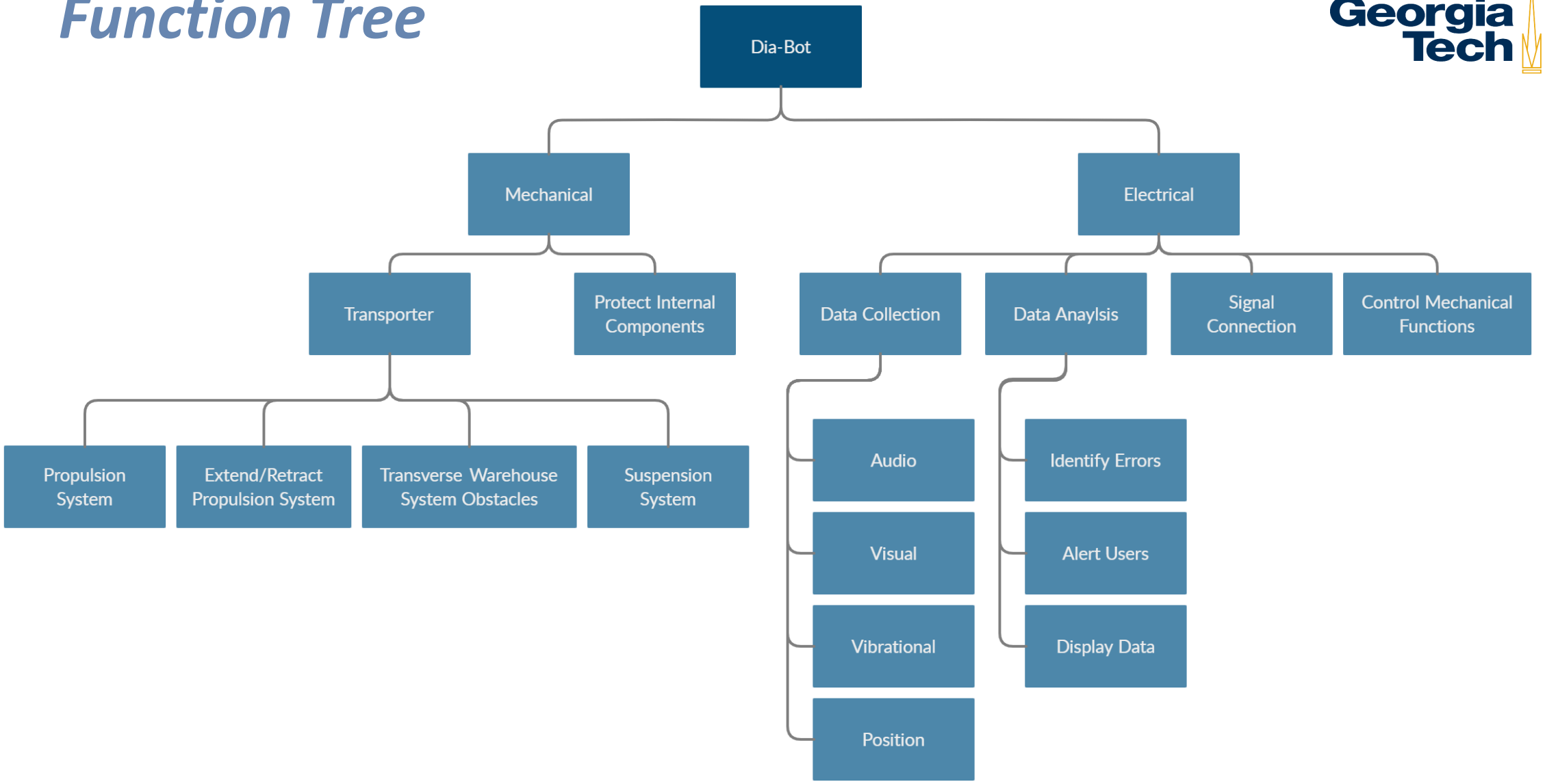
Problem Statement

Design and build a diagnostic robot (”Dia-Bot”) to identify potential installation issues in Vanderlande’s shuttle and conveyor systems

Function Tree



Specifications

The following will be considered in the design:

- Bot should be conveyable on **traditional conveyor surfaces** and **traverse normal transitions**
  - Belts, rollers, curves, diverts
  - Inclines, declines, merges, diverges
  - In addition to being conveyed, this bot must also traverse those **machines under its own power**
- **Robust** enough to withstand the vibration induced while navigating the system
- Must fit within a **620mm x 420mm footprint** within a **height of 300mm**
- Maximum weight of **35kg** allowed by conveyor systems
- On board **camera** remotely controlled to provide **360° rotation** and **vertical tilting**
- Ability to **track the bot's position** within the system to an accuracy of ± 10'
- Track **accelerative forces** seen by a product through normal handling
- Measure **vibration**, **sound levels**, and **temperature** to help identify potential problems

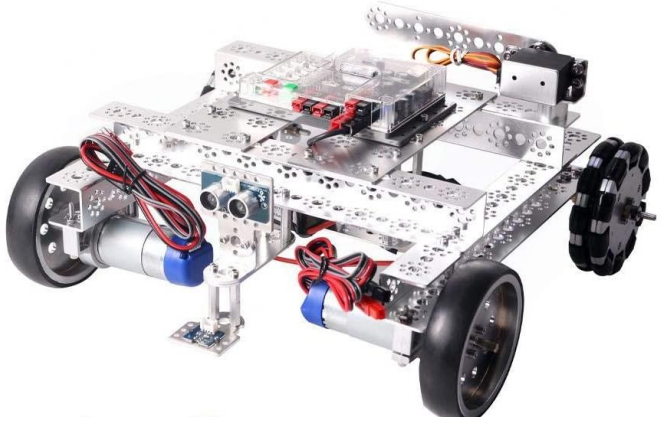
Competition and Prior Art

- Different commercially available products currently exist that could meet Vanderlande's needs for a diagnostic robot

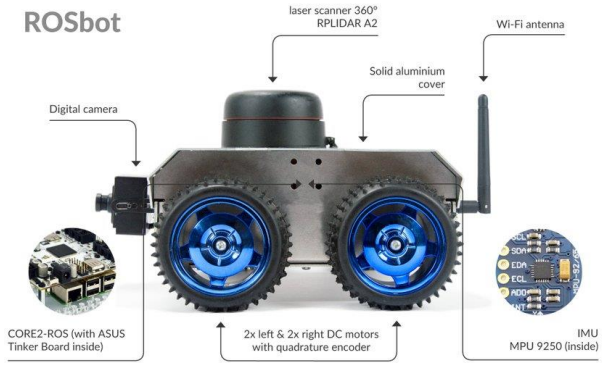
- Low-End Market
  - Cheap off the shelf components or modified RC Car
  - Limited battery life and range
  - Fragile
  - $50-$500

- High-End Market
  - Advanced protection and sensors
  - Direct wireless data feed
  - $3,000-$45,000

- Therefore, Dia-Bot's goal is to combine the **high-end functionality** with the **low-end price point**



Low End Market

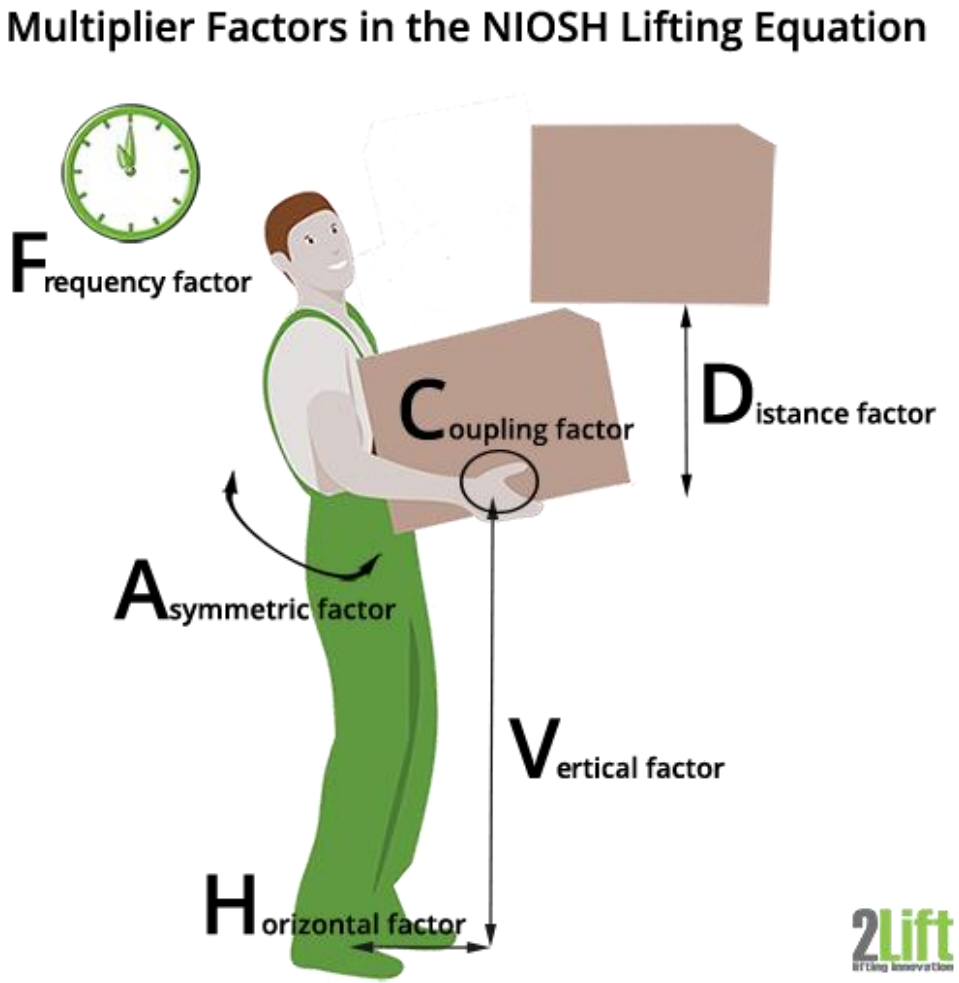


High End Market

Industry & Codes

- NIOSH Lifting Equation
  - No OSHA limit on object lifting weight
  - NIOSH equation predicts injury risk

- Response Robot Testing Standards
  - Visual Acuity (ASTM E2566)
    - Camera systems of remote-controlled robot
  - Variable Hurdle Obstacles (ASTM E2802)
    - Handling vertical obstacles
  - Radio Communications Line-of-Sight Range (ASTM E2854)
    - Maximum communication range for controlling response robot



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Design Methodology and Concepts

December 13, 2021

Design Methodology Overview

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Envisioning

- Identify specific parameters based on Dia-Bot environment
- List objectives
- Identify and define constraints

Planning

- Identify specific design details which must be satisfied
- Identify possible and alternate design solutions
- Design and plan appropriate structure

Developing

- Verify design with low-fidelity prototyping and simulations
- Integrate necessary electronic equipment and calibrate sensors

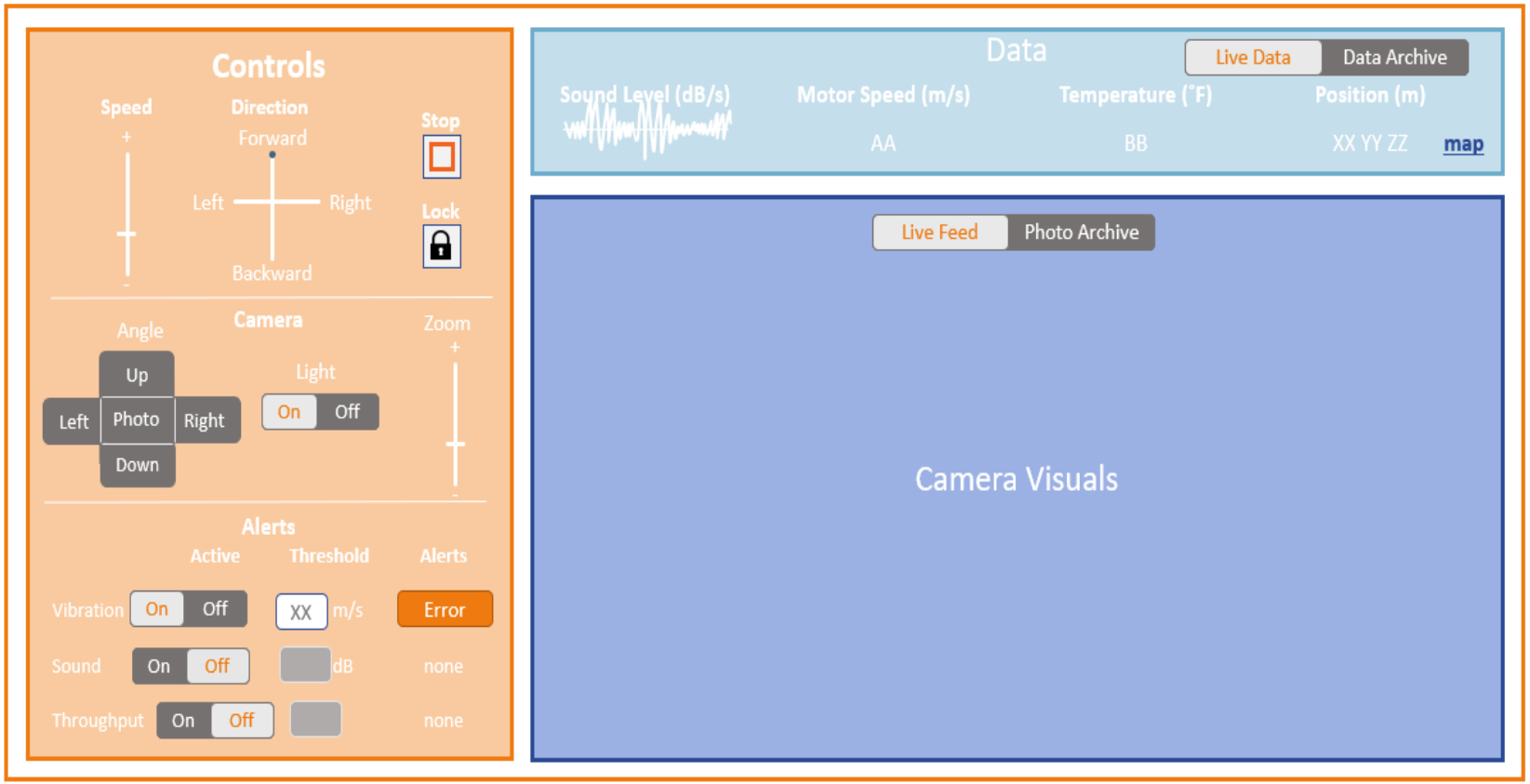
Test

- Test and troubleshoot design
- Determine how well design functions
- Decide if design can be improved

Design Concept: Features & User Interface

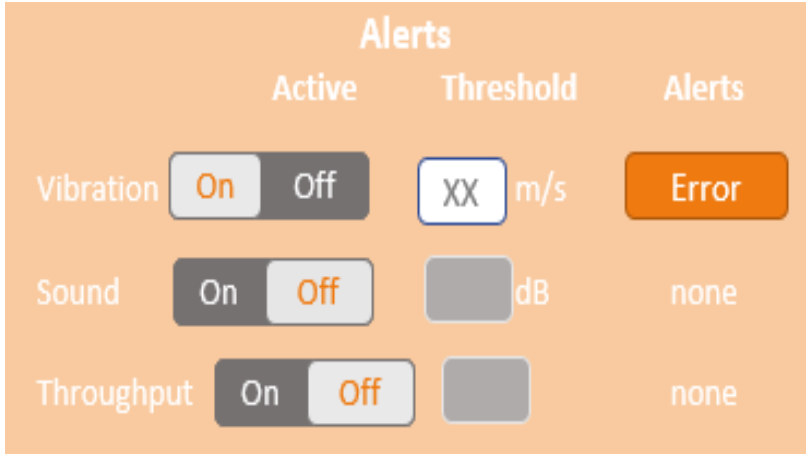
Features

- Movement
  - Speed and Direction
  - Raise Treads + Suspension Lock
  - Emergency Stop
- Camera Controls
  - Direction
  - Zoom
  - Light
- Live Data Streaming
  - Camera Feed
  - Sensors
- Problem Alerts
  - Preset and Custom Triggers

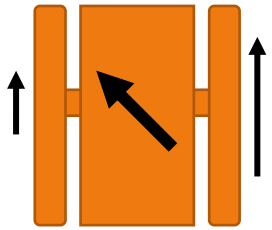
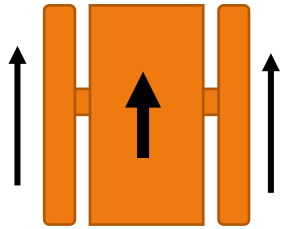
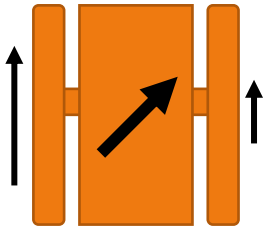
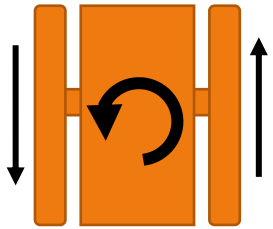
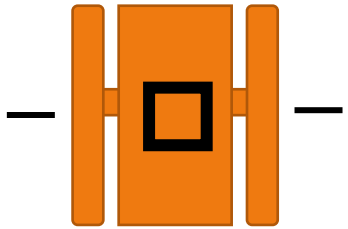
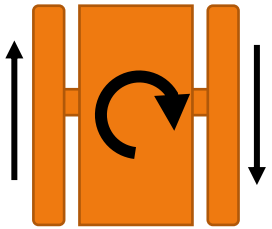
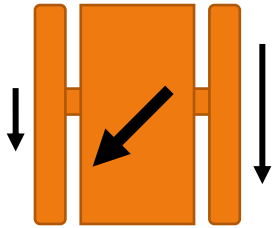
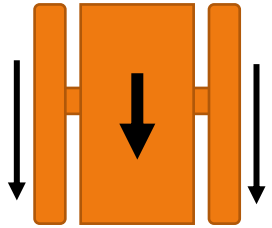
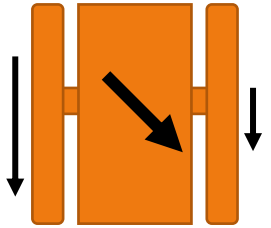


Problem Alert Examples

- Excessive force
  - Instantaneous accelerometer reading measures above a threshold
- Excessive vibration
  - Vibrational magnitude at certain frequencies above a threshold for a certain period of time
- Specific vibrational or combinational pattern detected
  - Ex. Resonant frequencies
- Sound levels
  - Excessive sound energy over a certain length of time



Design Concept: Movement Controls

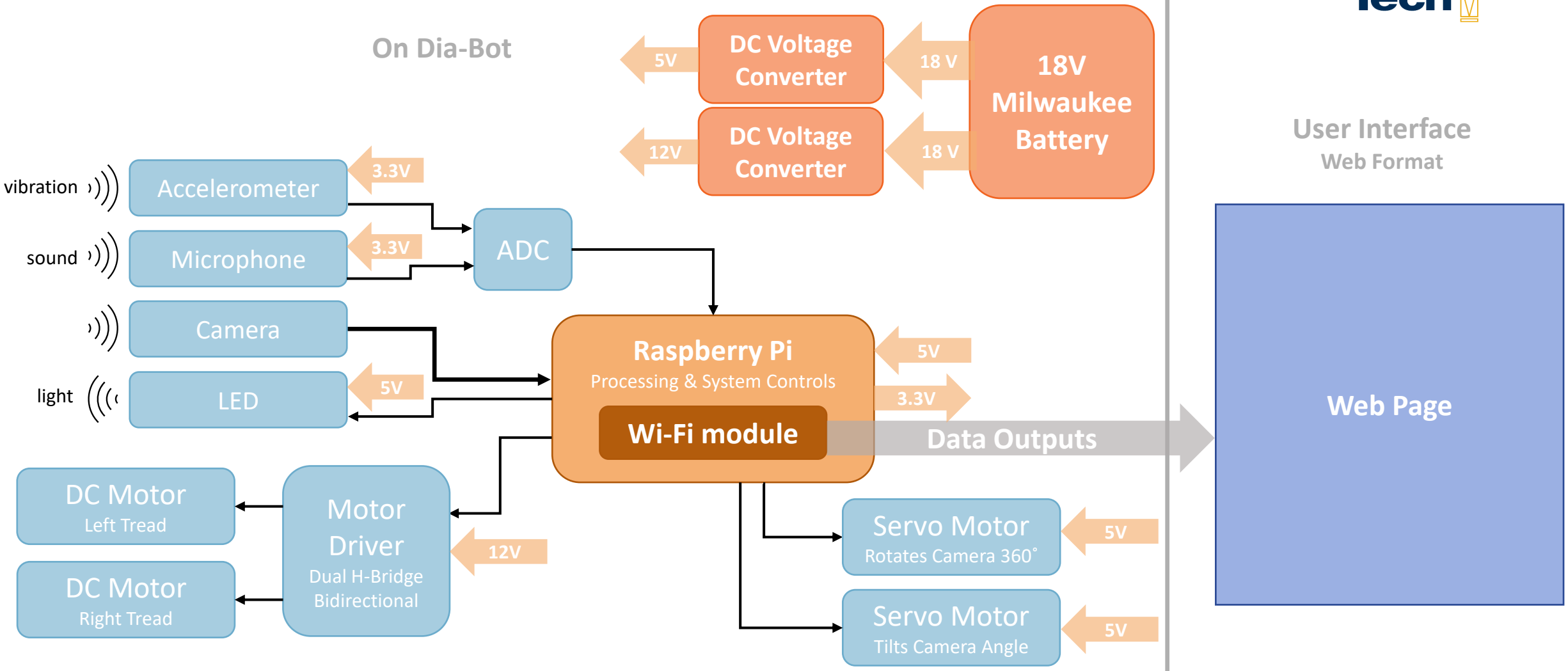
Forward-Left	Forward	Forward-Right
		
Left	Stop	Right
		
Backward-Left	Backward	Backward-Right
		

Design Concept: Electrical

Electrical Components Evaluation

Mandatory Criteria	Option 1	Option 2	Option 3
Location Positioning	GPS	**On Dia-Bot algorithm with navigation and system map**	Raw position data using telemetry
Movement Generation	**DC Motors** 	AC Motors 	Servo Motors 
Processing Center	Arduino UNO Rev 3 	**Raspberry Pi 4** 	Mbed (LPC1768 Cortex-M3) 
Power Source	**Rechargeable: Lithium-ion battery** 	Rechargeable: Lead Acid or SLA Batteries 	Non-rechargeable: Alkaline Cell Batteries (PP3) 
Real Time Access to Dia-Bot Data	**Wi-Fi** 	Bluetooth 	Extra Long Wires 
User Interface	Web server access via HTTP commands 	Remote control with push button interface 	**Direct MCU control with VNC Server & Viewer** 

Design Concept: Electrical



November 30, 2021

Please note: all elements are grounded and bold lines represent bus connections that include the power source.

Mechanical Design Concept: Chassis

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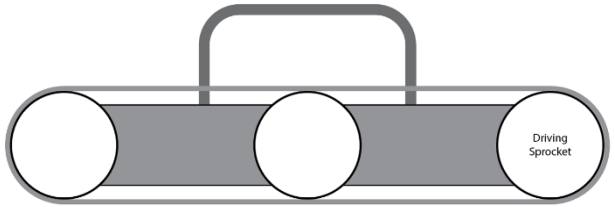
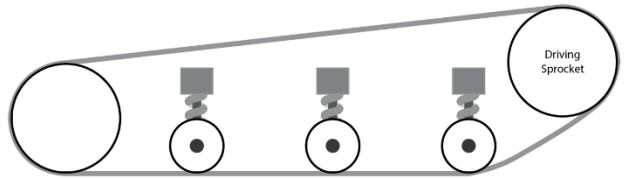
Analysis of Continuous Track vs. Wheels:

	Continuous Track	Wheels
Advantages	• Power Efficiency • Traction • Moving Over Rough Terrain • Weight Distribution • Complicated Suspension	• Lower Cost • Speed • Simplicity • Lightweight • Maneuverability
Disadvantages	• Lower Speed • Friction	• Driving Over Obstacles

Concepts 1: Symmetric without Suspension

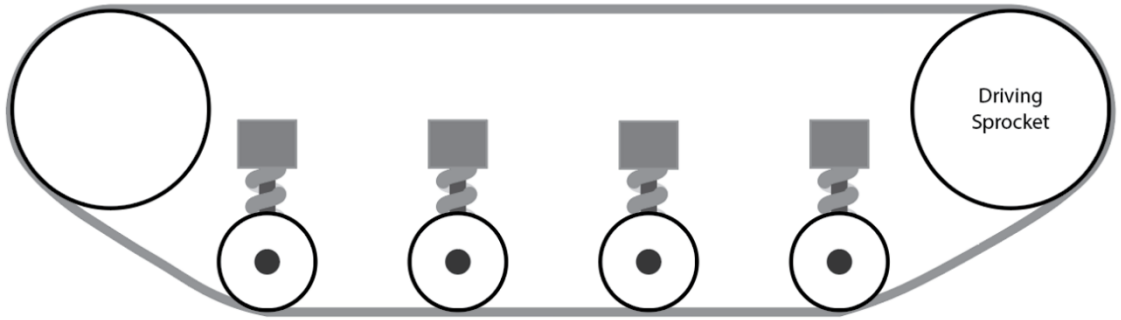


Concepts 2: Asymmetric with Suspension

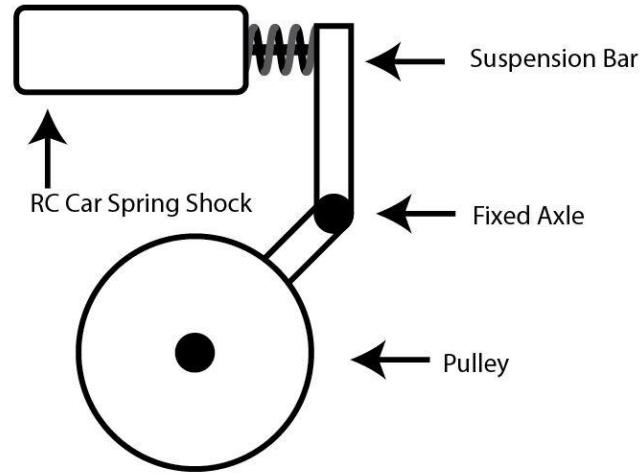


Selected Design

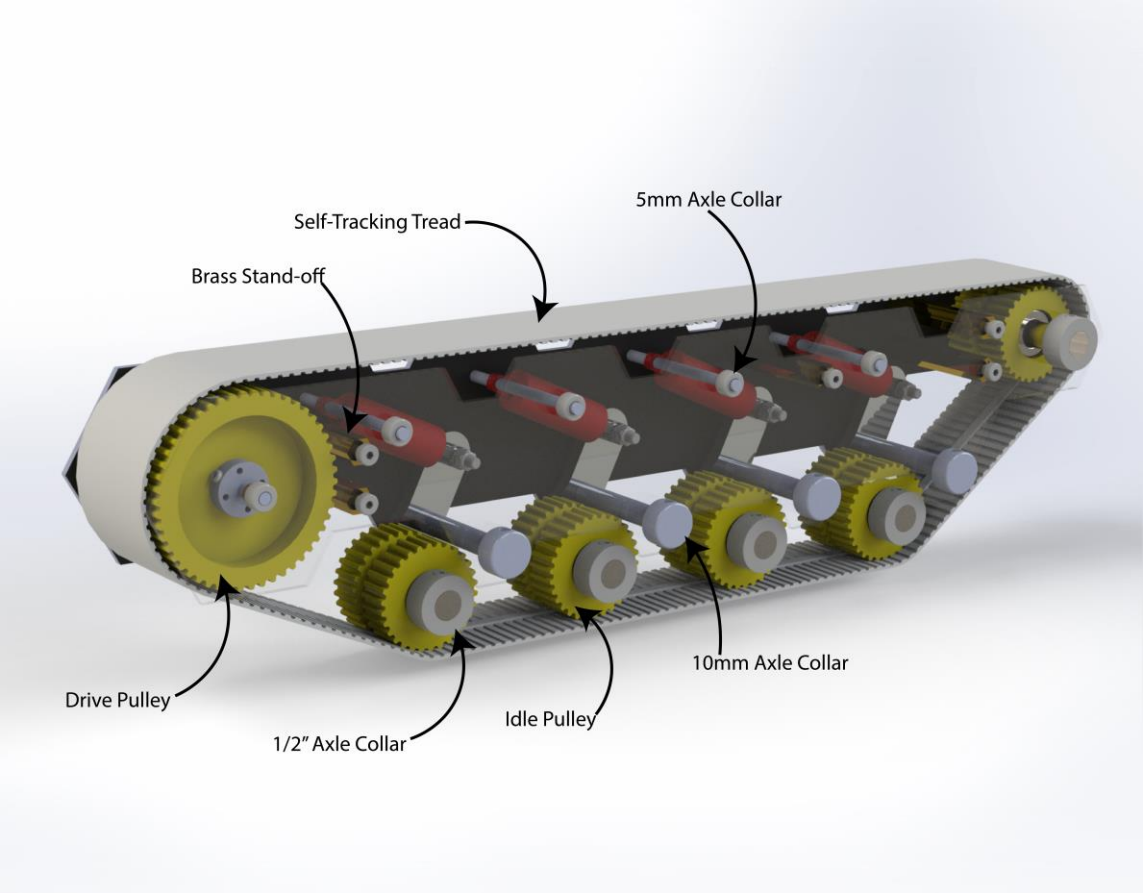
Concept 3: Symmetric with Suspension

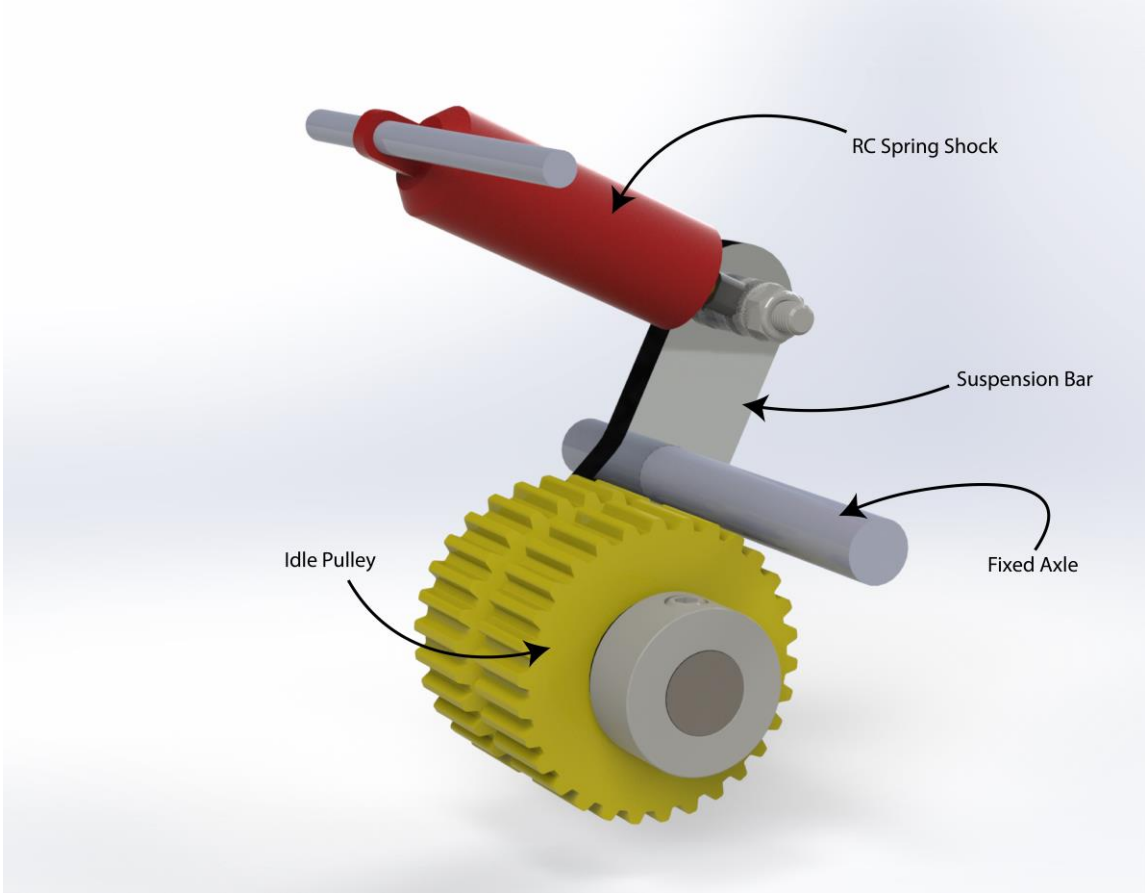


Suspension Concept:



Chassis Assembly: Main Body and Suspension





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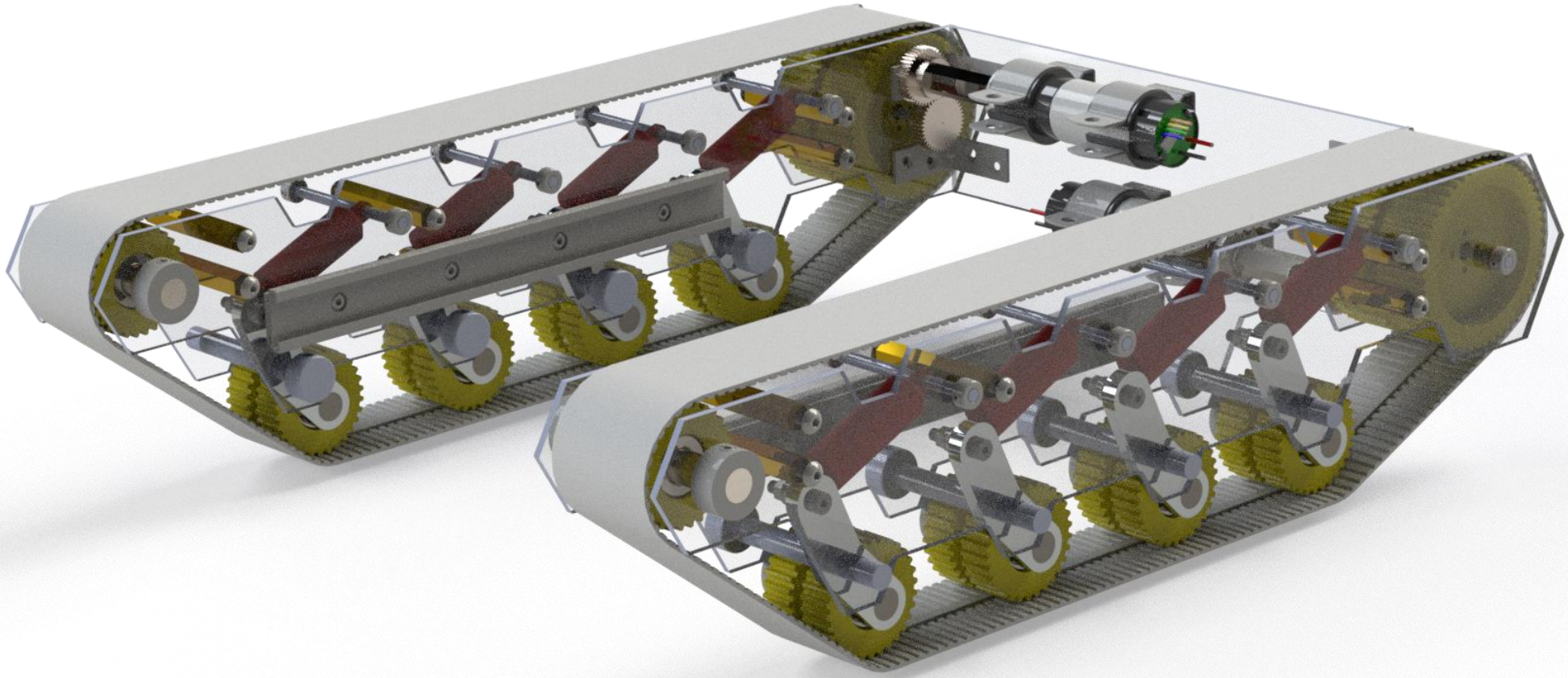
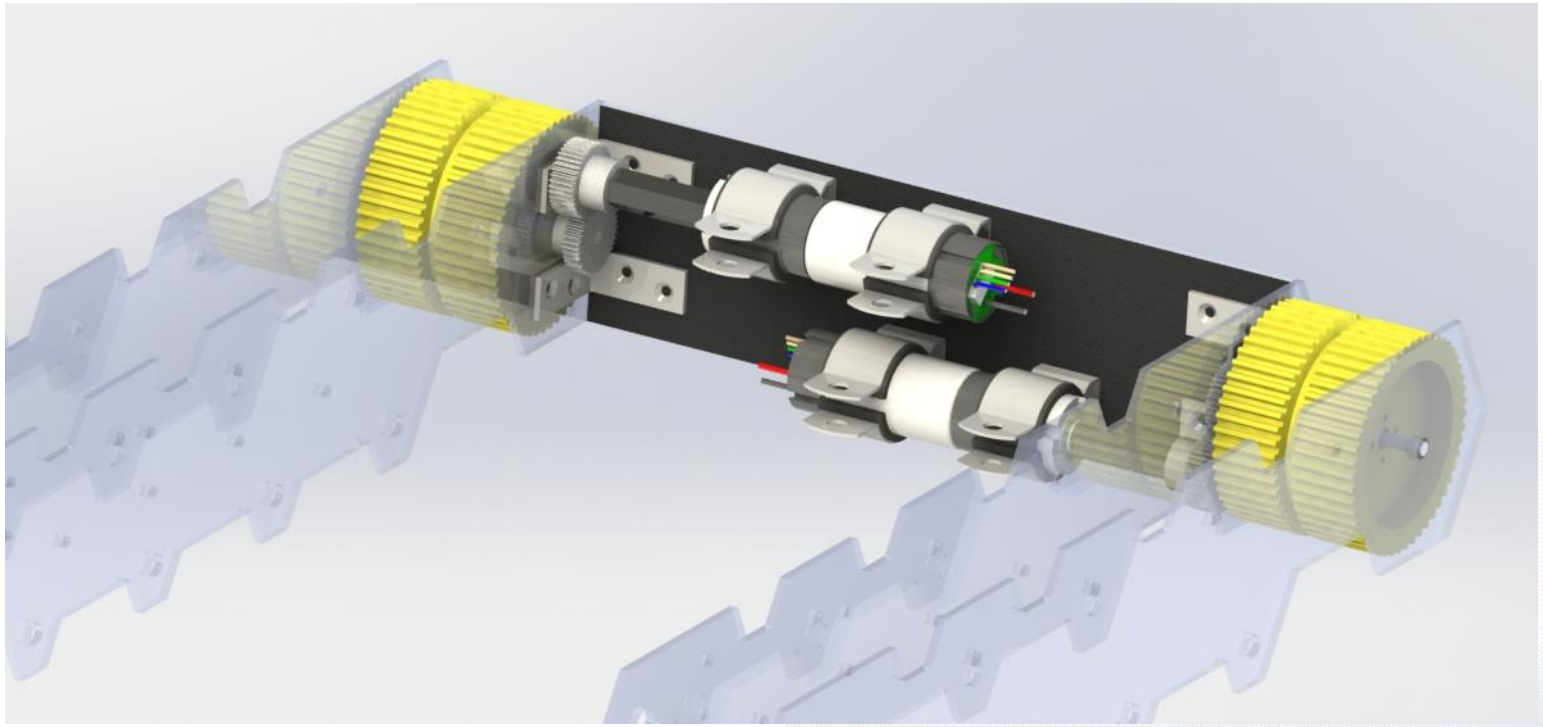
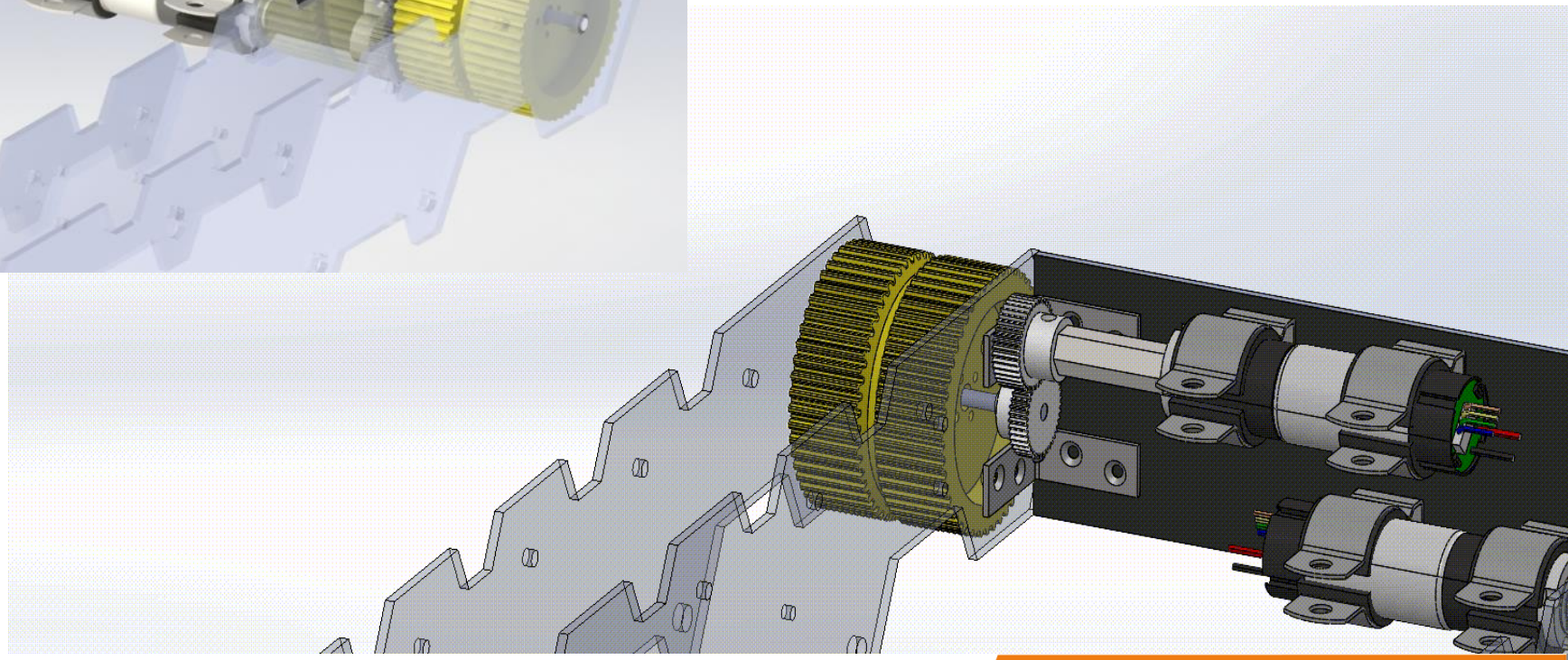


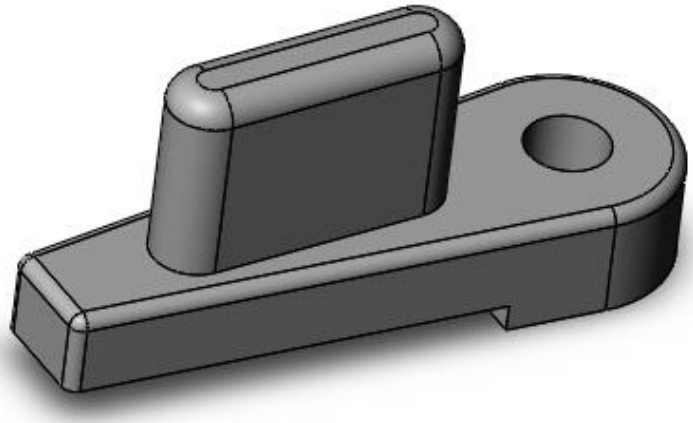
Mechanical Design: Motor System

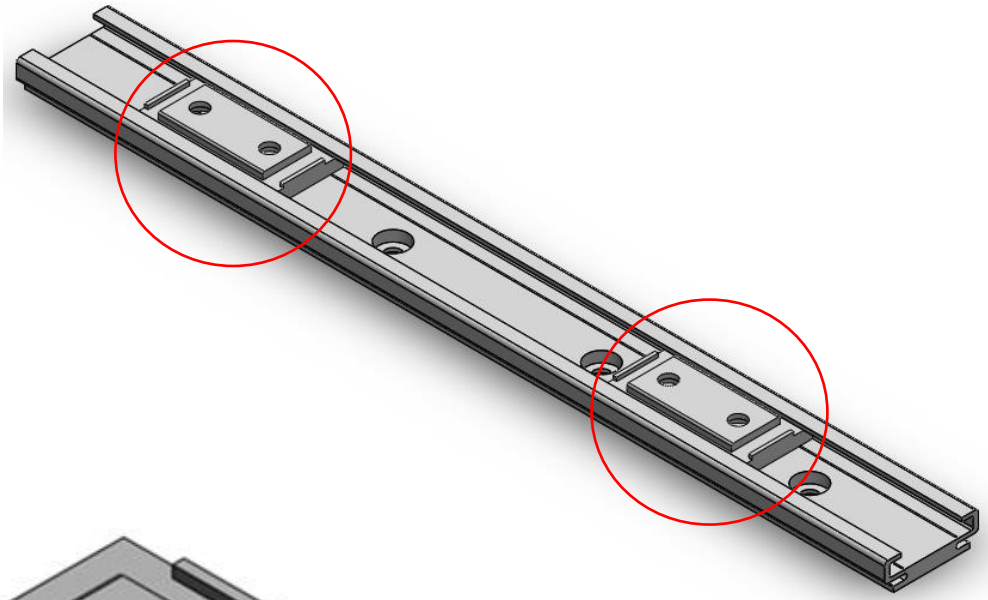


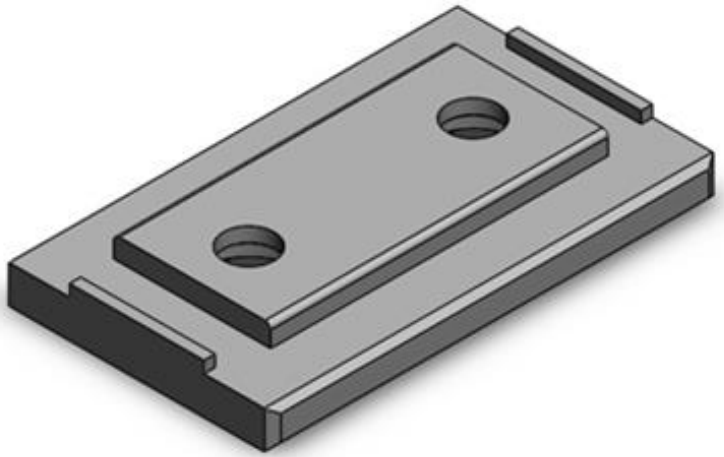


Modular Attachment Assembly

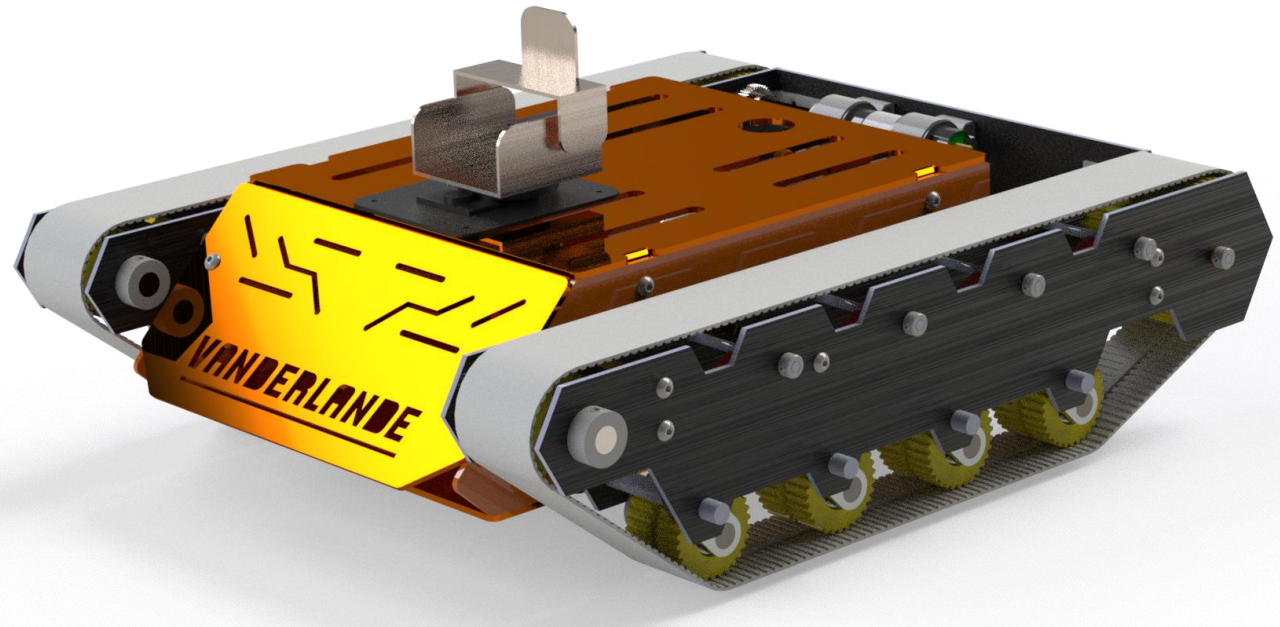
Modular Attachment Assembly

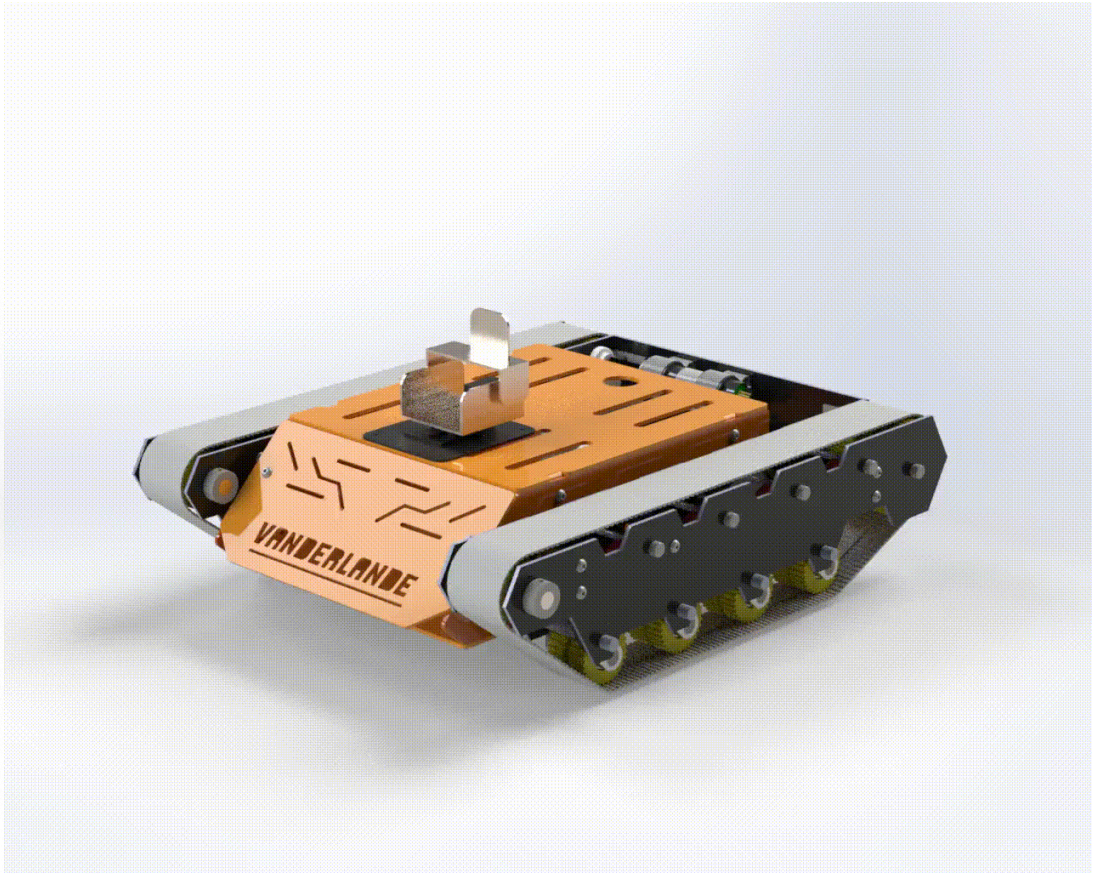




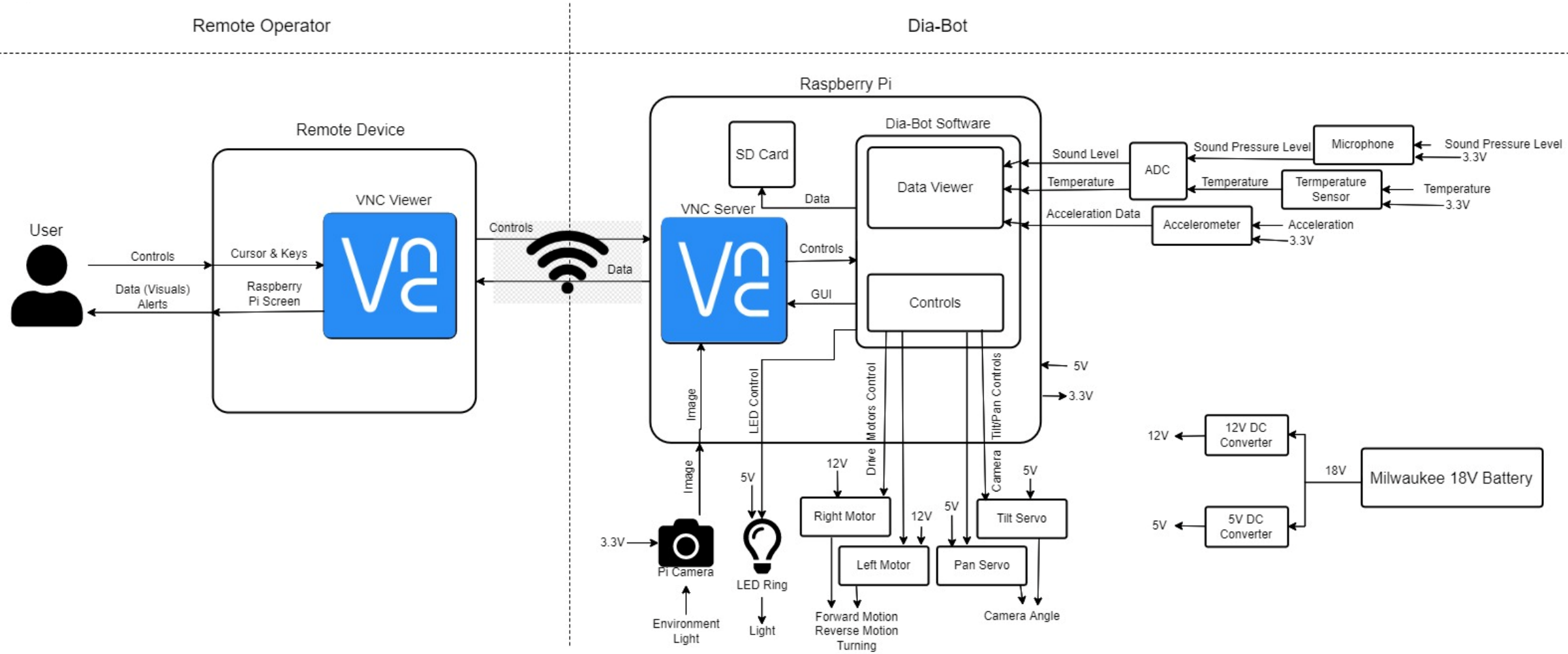


Complete CAD Model





Design Concept: System Architecture



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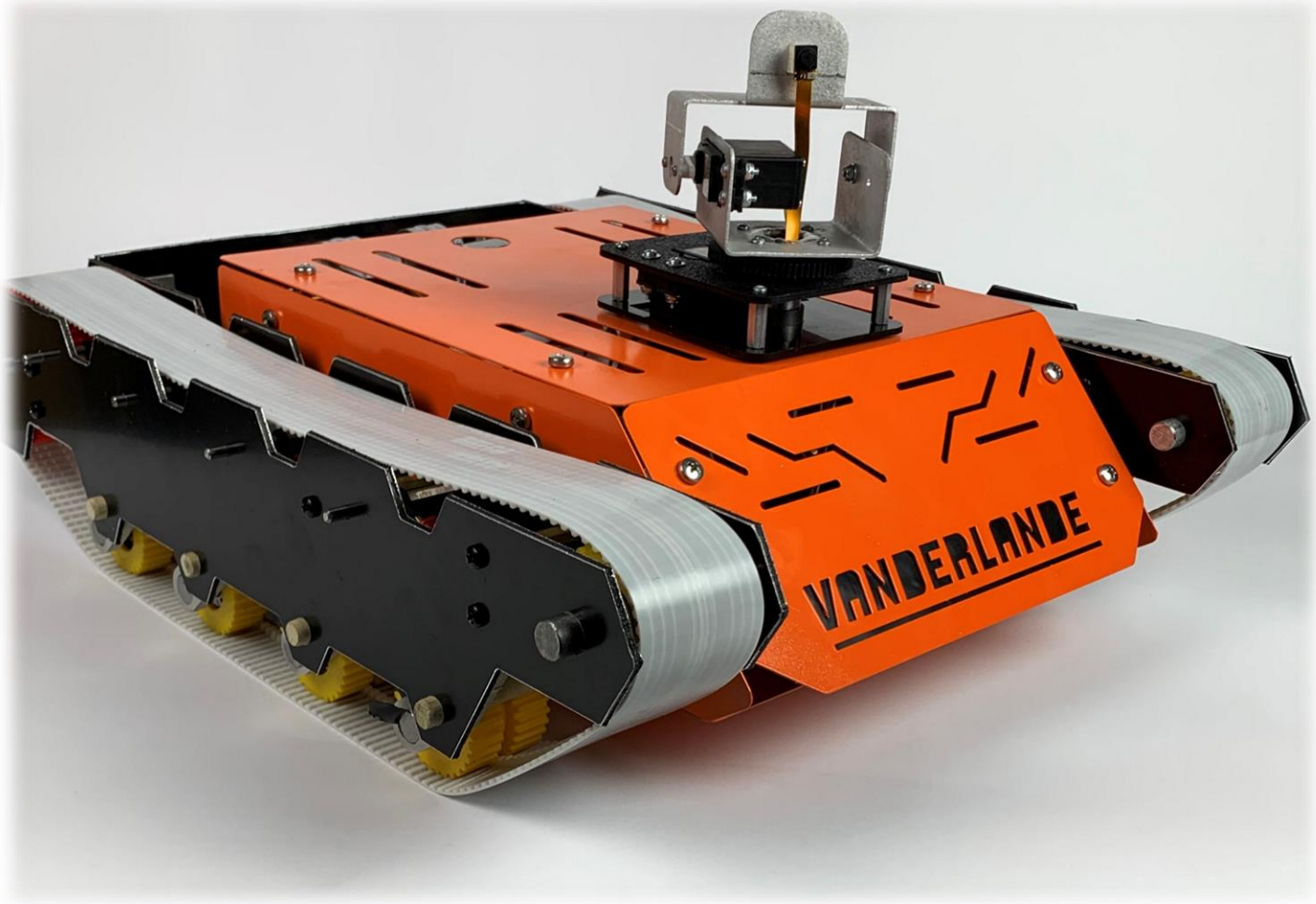
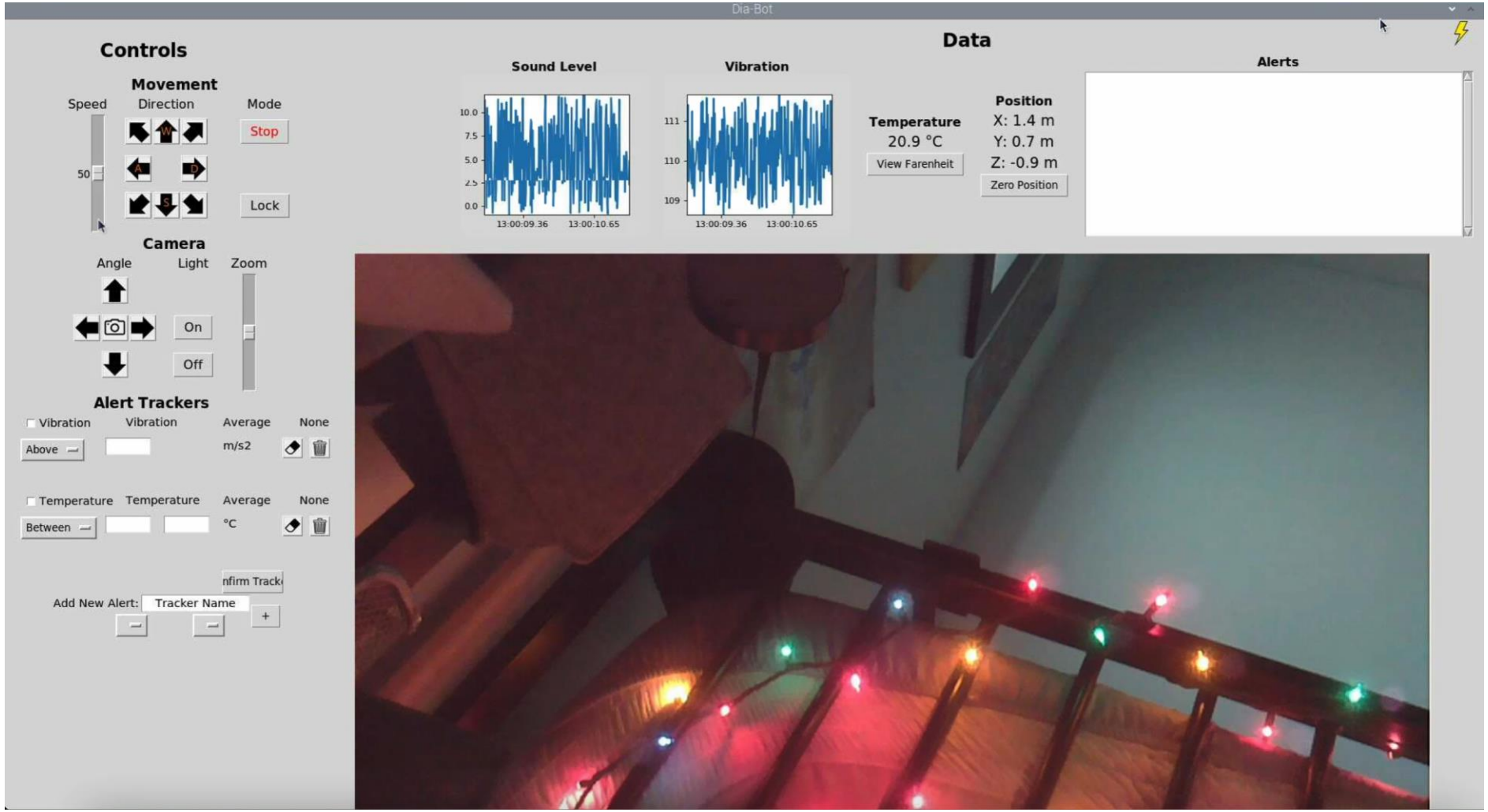
Prototyping Results

Mechanical: Full Assembly Demonstration

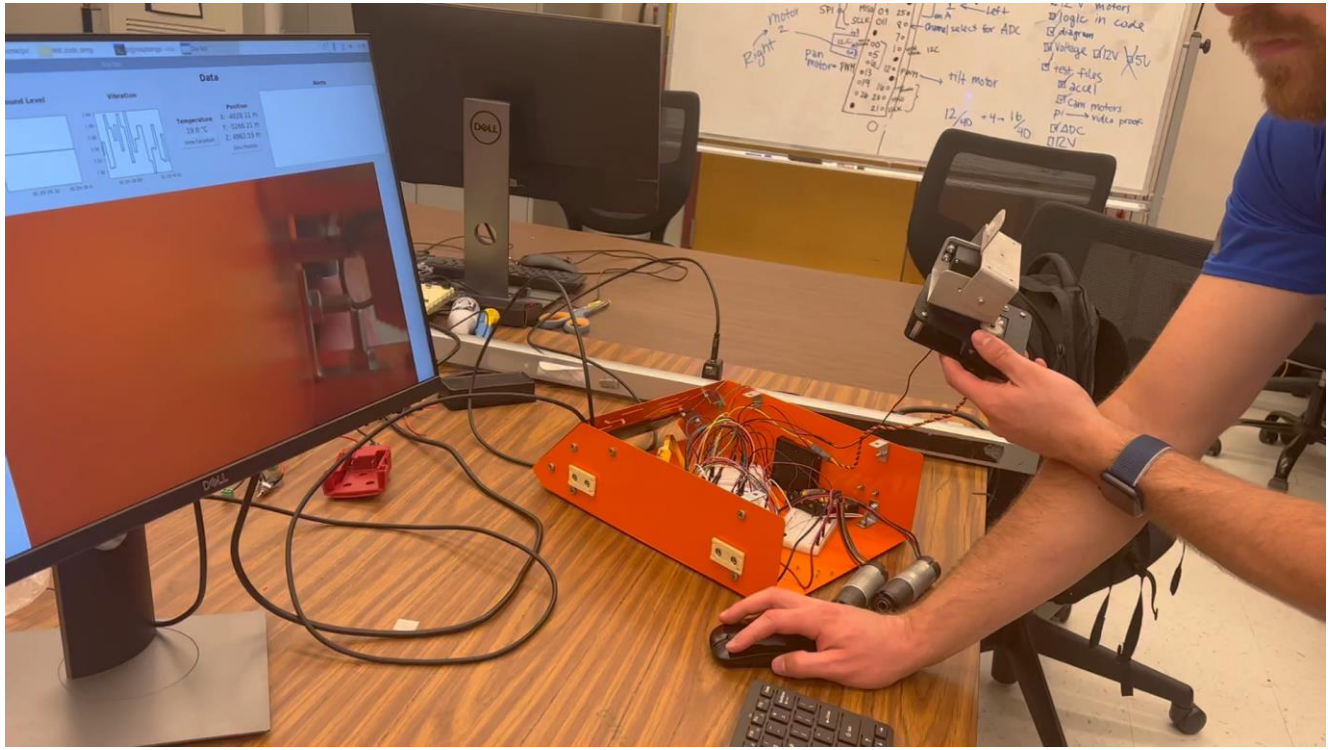


Electrical/Software: User Interface Demo



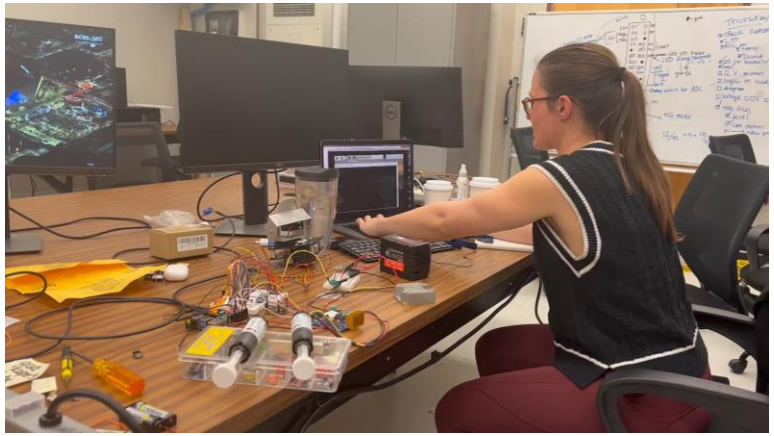
Testing by Demonstration

- Camera: Tilt, Pan, & Live Picture



- User Interface + DC Motor Interaction

- DC Motors



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Conclusions: Impact and Applications

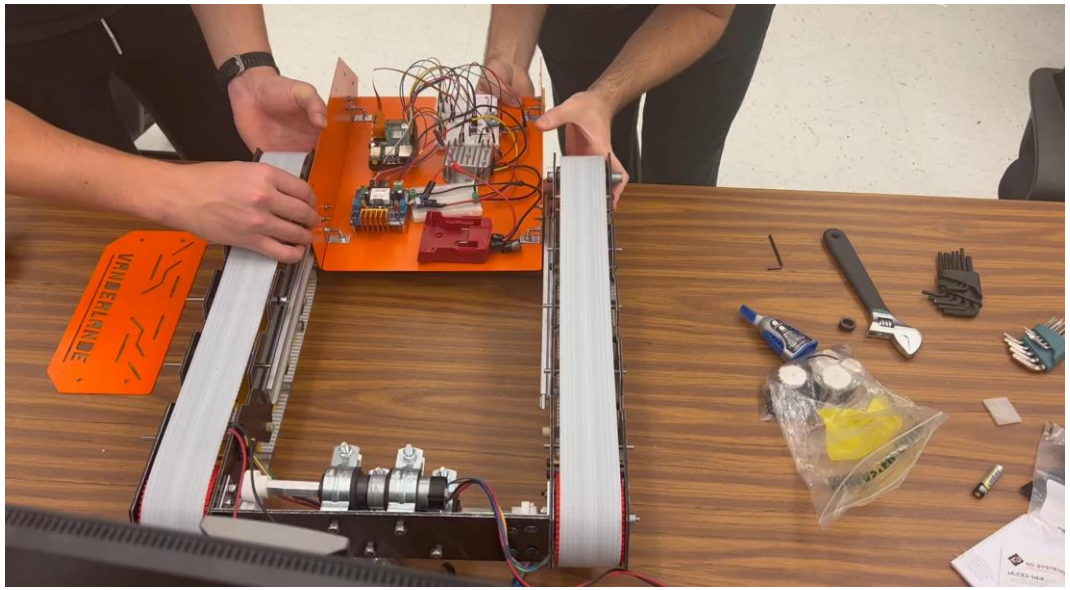
Diagnostic Robot: Modular Design

Overview

- Uniqueness the Dia-Bot comes from its **modular design and flexibility**
  - Individual components can be easily replaced or upgraded
  - Distinct from other robots designed for industrial applications
- Software interface allows users to choose applicable metrics
- Adaptable and economical

Modular Design Examples

- The drive chain can be completely changed out from tank treads to wheels
- The springs in the suspension system can be easily changed to accommodate weight changes
- Common battery pack (e.g. Milwaukee) allows for shorter downtimes

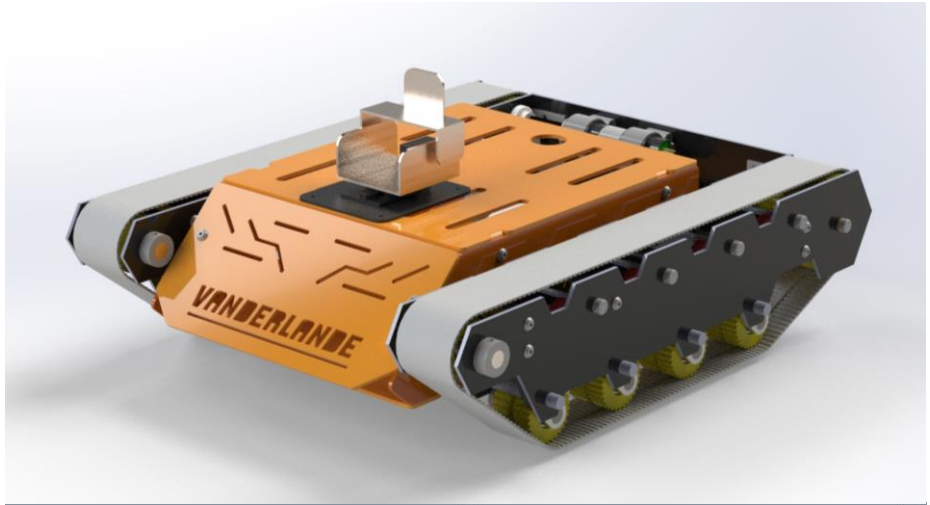


Final Results & Dia-Bot Application

- Physical Diagnostic Robot “Dia-Bot” concept validated
  - 520mm x 420mm x 265mm size
  - Navigate conveyor systems
  - Ability to remove treads to ride shuttles
  - Robust against system forces and vibrations

- Software written to interact with Dia-Bot:
  - Display live camera feed
  - Movement and camera controls
  - Data metric processing and visual display
  - Alert users when anomalies in data occur

- To be used by Vanderlande operators to collect visuals and data on their systems
  - Identify and fix errors more easily
  - Reduce installation time



Stretch Goals & Future Work

- Additional verification features
  - Semi or Fully **autonomous** driving and navigation
  - Swarm functionality with direct **communication between multiple bots**
  - **Computer vision** integration for visual problem detection
  - Train other **machine learning models** for additional patterns
- Investigate equipping the Dia-Bot with the ability to **automatically fix** certain common issues
- Use in an installed system*
  - Device testing
    - Detect real problems
  - Collect position data
    - Verify through demonstration
    - Improve system simulations

*Due to Vanderlande's client installation schedules, we were not able to test the Dia-Bot on a full racking system at this time.

Team Member Contributions

- **Andrew**
  - Prior Art Research, Attachment Design for Modular System, Body locking mechanism
- **Catherine**
  - Team Organizer, UI Design, Electrical Block Diagram, Embedded Building & Testing
- **Jason**
  - Motor Research for required Torque, RPM, and mounting, Social Impact Analysis
- **Hunter**
  - Design and Manufacturing of Chassis and Suspension System, Poster Design, CAD Renders
- **Connor**
  - Software and User Interface, Embedded Connection, Narrowed Project Scope, Editing
- **Douglas**
  - Design Concept Ideation- Function Tree/Morph Chart, Main Body Design

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Appendix

Prototyping Progress

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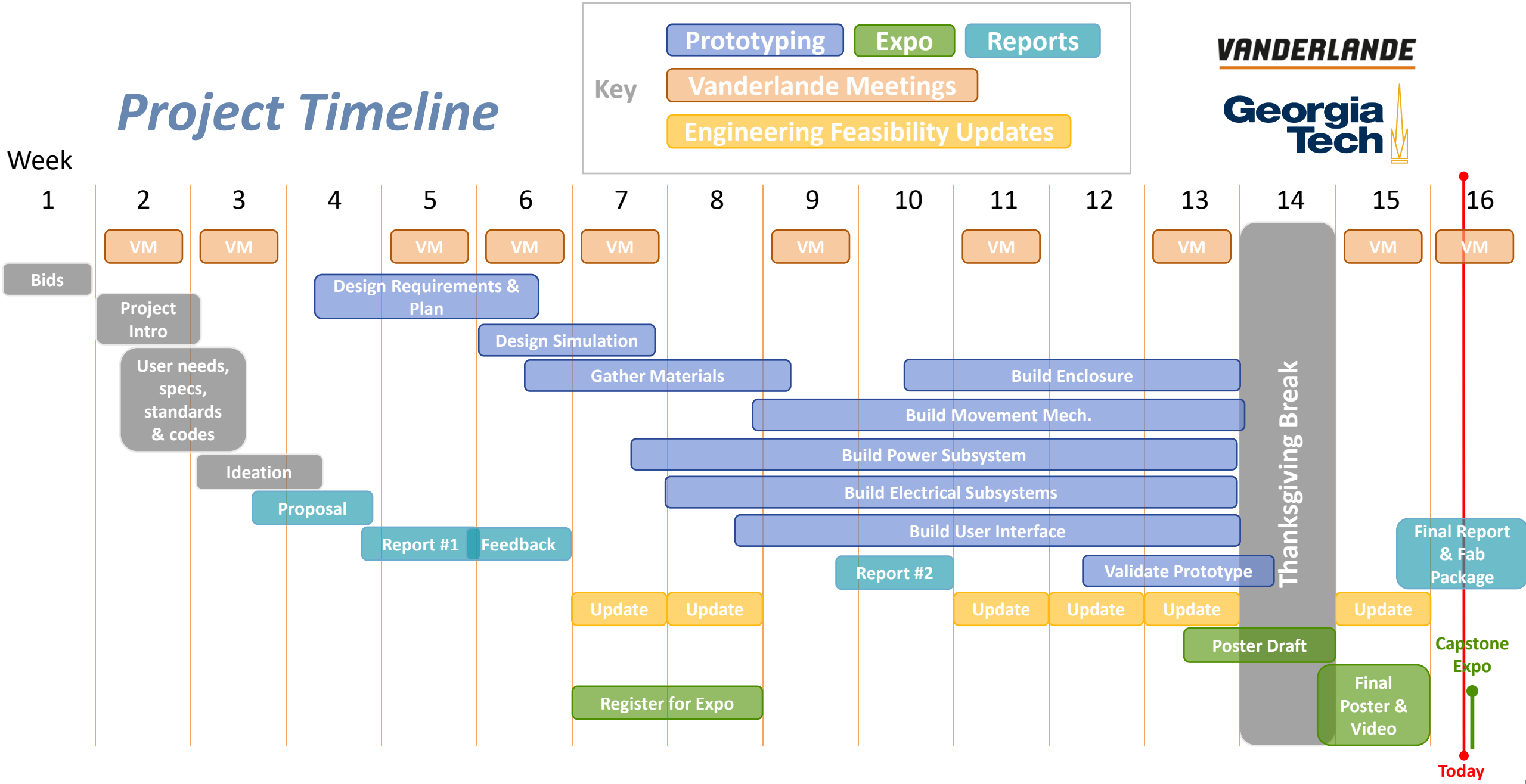
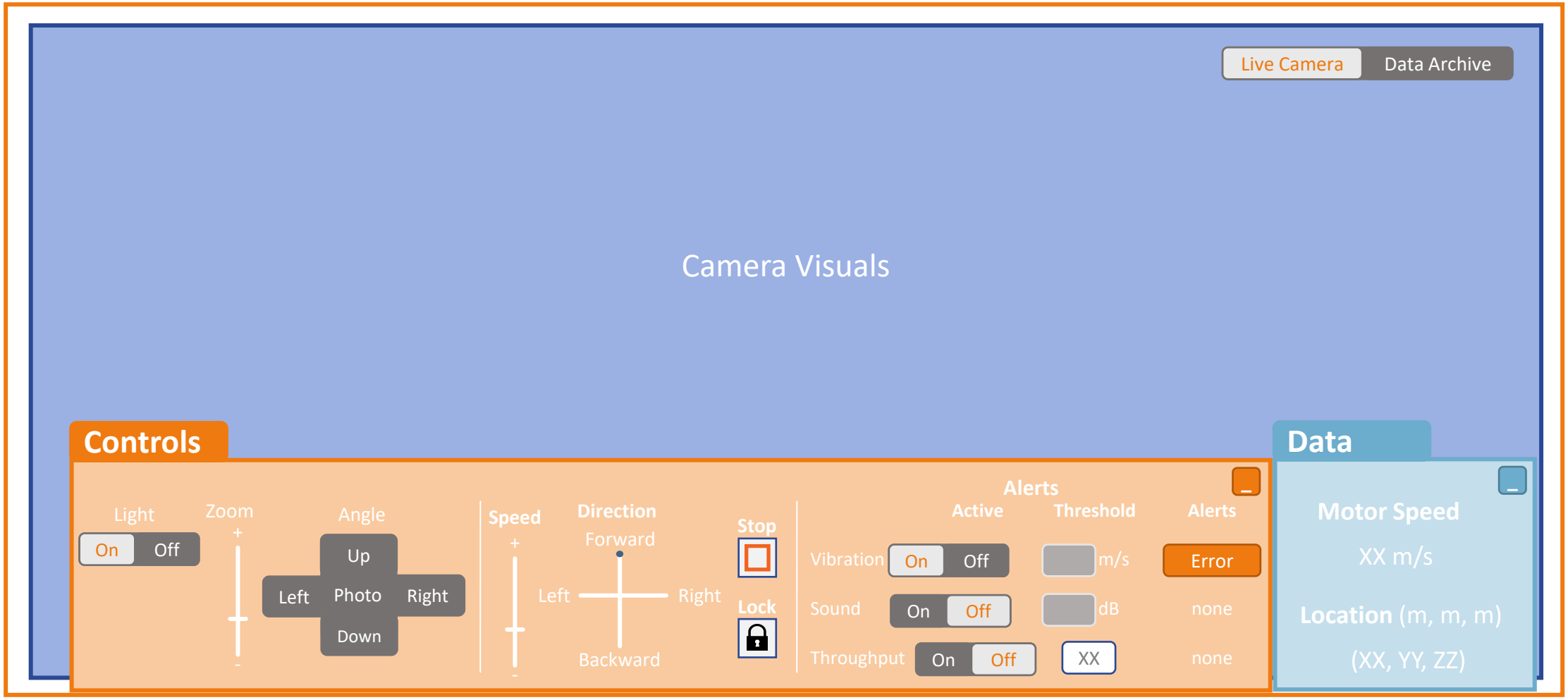
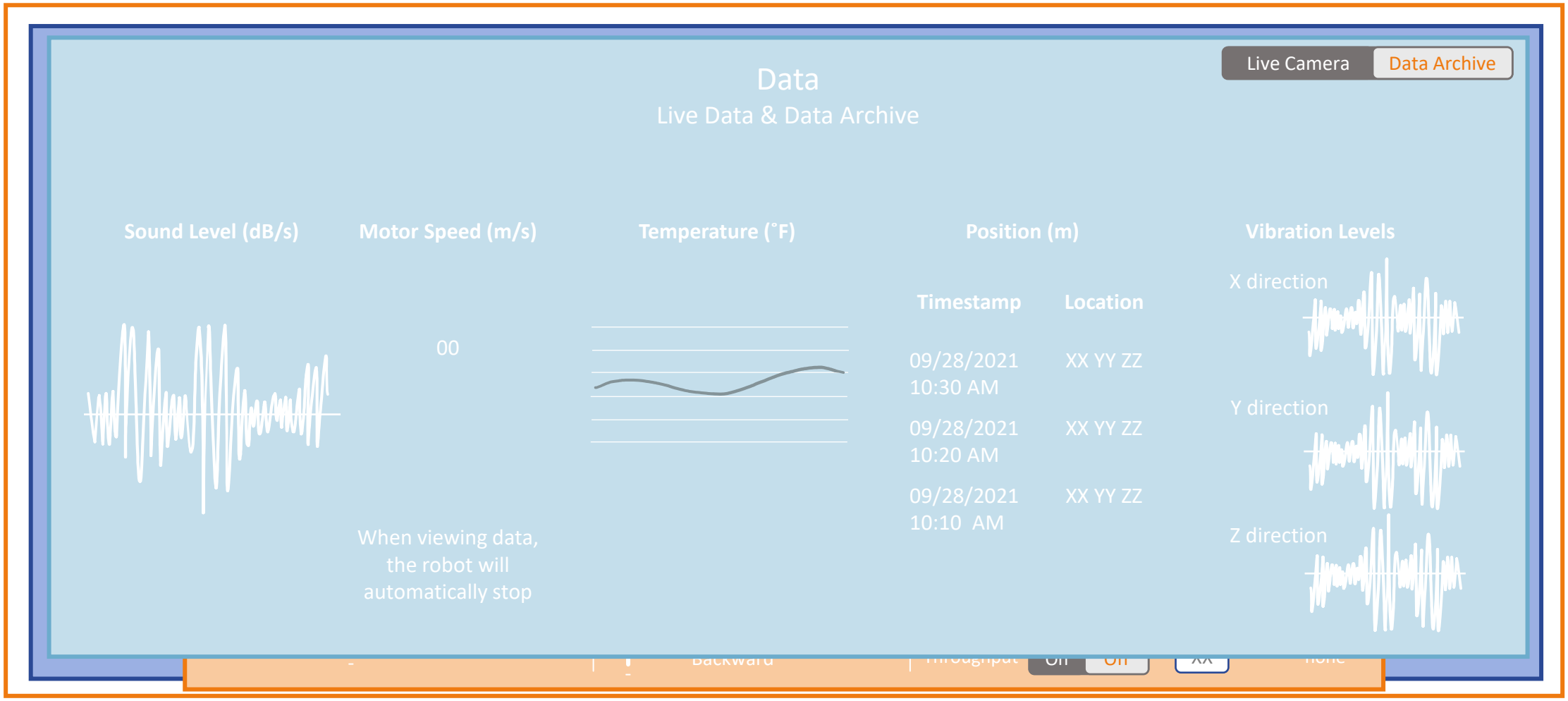
Project Timeline



Design Concept: User Interface (Alternate)



Design Concept: User Interface (Data View)



Design Concept: Morph Chart

Function Grouping	Function	Concept #1	Concept #2	Concept #3
Movement	Propulsion System	DC Motor Direct Drive	AC Motors	Servo Motors
	Retract/Extend Propulsion System	Servo Motors	Solenoids	
	Traverse Automated Warehousing System Features (Conveyors, Belts, Diverts, Merges, Inclines, etc.)	Tank Treads	Wheels	
	Suspension System	No Suspension	Shocks	Single Part
Protect Internal Components	Protect Internal Components	Roll Cage	Enclosed Sensor Box	

Recognize Errors	Audio Recognition	Microphone	Acoustic Pressure Sensor	
	Visual Recognition	Camera	Infared Scanner	
	Vibrational Recognition	Accelerometer	IMU	
	Temperature Recognition	Thermometer		
	Error Location Recognition	Integrate over accelerometer data	Beamforming	
Communication / User Interface	Control Movement and Sensors	Web Access with Keyboard Controls	Remote Control Center/Push Button Interface	VR Interface with Haptic Glove
	Wireless Communication Platform	Wifi	Bluetooth	
	Error Reporting / Logging	Sensor Threshold Limits	Archived Data	

Module View Pin Assignments

Module	Pin	Pi Pin or Intermediary
Microphone	V in	5V
	Data out	ADC in 1
	Ground	Gnd
Temperature Sensor	V in	5V
	Data out	ADC in 0
	Ground	Gnd
Camera Motor Tilt (HS-422 Servo)	Black wire	Gnd
	Red wire	5V
	Yellow wire	GPIO 12 (PWM)
Camera Motor Pan (HS-785 Sail Winch Servo)	Black wire	Gnd
	Red wire	5V
	Yellow wire	GPIO 13 (PWM)
Accelerometer	V in	3.3 V
	SDA	GPIO 3
	SCL	GPIO 2
	Ground	Gnd

Module	Pin	Pi Pin or Intermediary
LED Ring (NeoPixel Ring x12)	V in	5V (through a diode)
	Data In	GPIO 18 (PWM)
	Ground	Gnd
Camera	Camera Bus ribbon cable	Camera connection built into Pi
ADC: Analog to Digital Converter (MCP3002)	Pin 1: CS (Chip Select)	GPIO 8 (Chip Enable)
	Pin 2: Channel 0	Temp data out
	Pin 3: Channel 1	Mic data out
	Pin 4: Ground	Gnd
	Pin 5: Data In	GPIO 10 (MOSI)
	Pin 6: Data Out	GPIO 9 (MISO)
	Pin 7: Clock	GPIO 11 (CLK)
	Pin 8: V in	3.3 V

Module	Pin	Pi Pin or Intermediary
Dual H-Bridge	Motor A +	Right Motor + (red wire)
	Motor A -	Right Motor – (black wire)
	Motor B +	Left Motor + (red wire)
	Motor B -	Left Motor – (black wire)
	DC Motor +	12 V from DC Converter
	DC Motor -	Gnd
	Ground	Gnd
	In1	GPIO 23
	Enable A (ena)	GPIO 25
	In2	GPIO 24
	In3	GPIO 0
	Enable B (enb)	GPIO 5
	In4	GPIO 6
	5V, CSA, CSB	floating

Acceleration: SDA

Acceleration: SCL

LED Ring Data Line

Dual H-Bridge: in1

Dual H-Bridge: in2

ADC: Data In (pin 5)

ADC: Data Out (pin 6)

ADC: Clock (pin 7)

Dual H-Bridge: enA

ADC: CS (pin 1)

Dual H-Bridge: in3

Dual H-Bridge: in4

Dual H-Bridge: enB

Tilt Motor (PWM)

Pan Motor (PWM)

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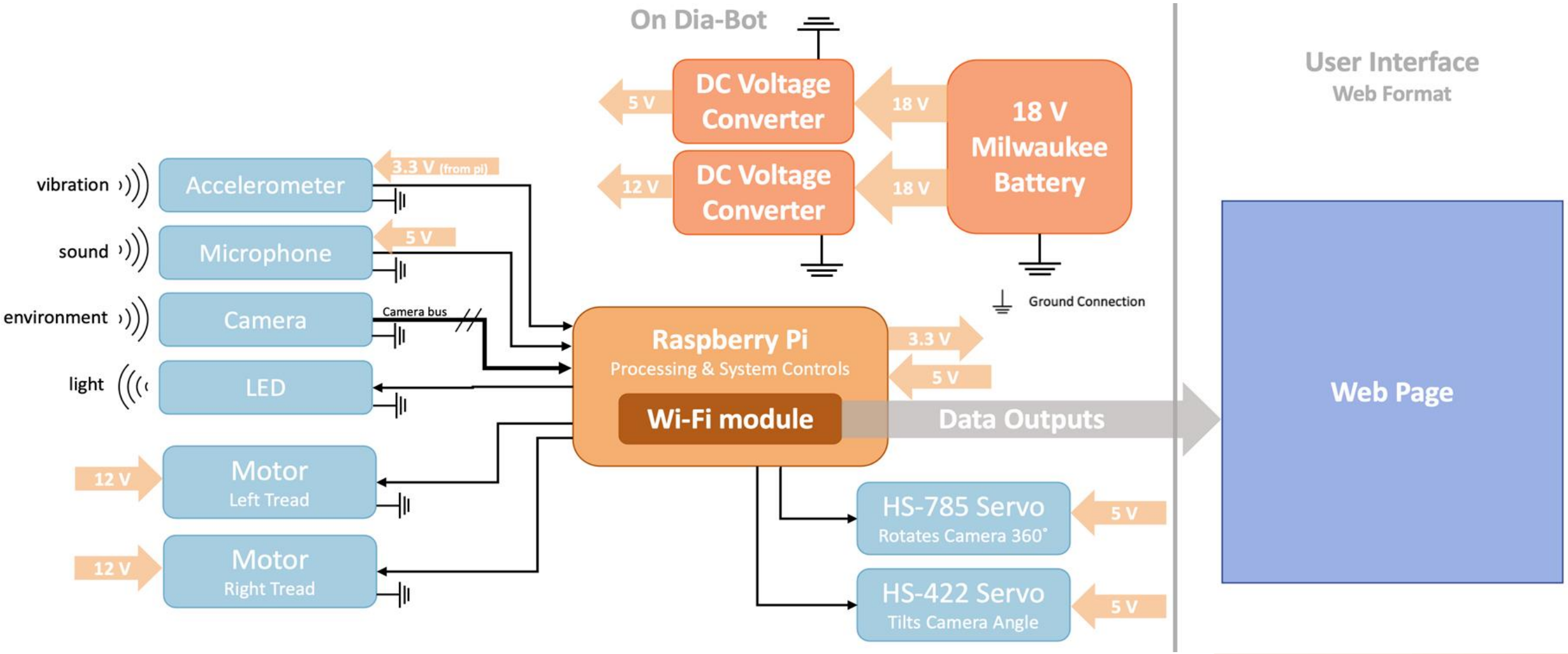
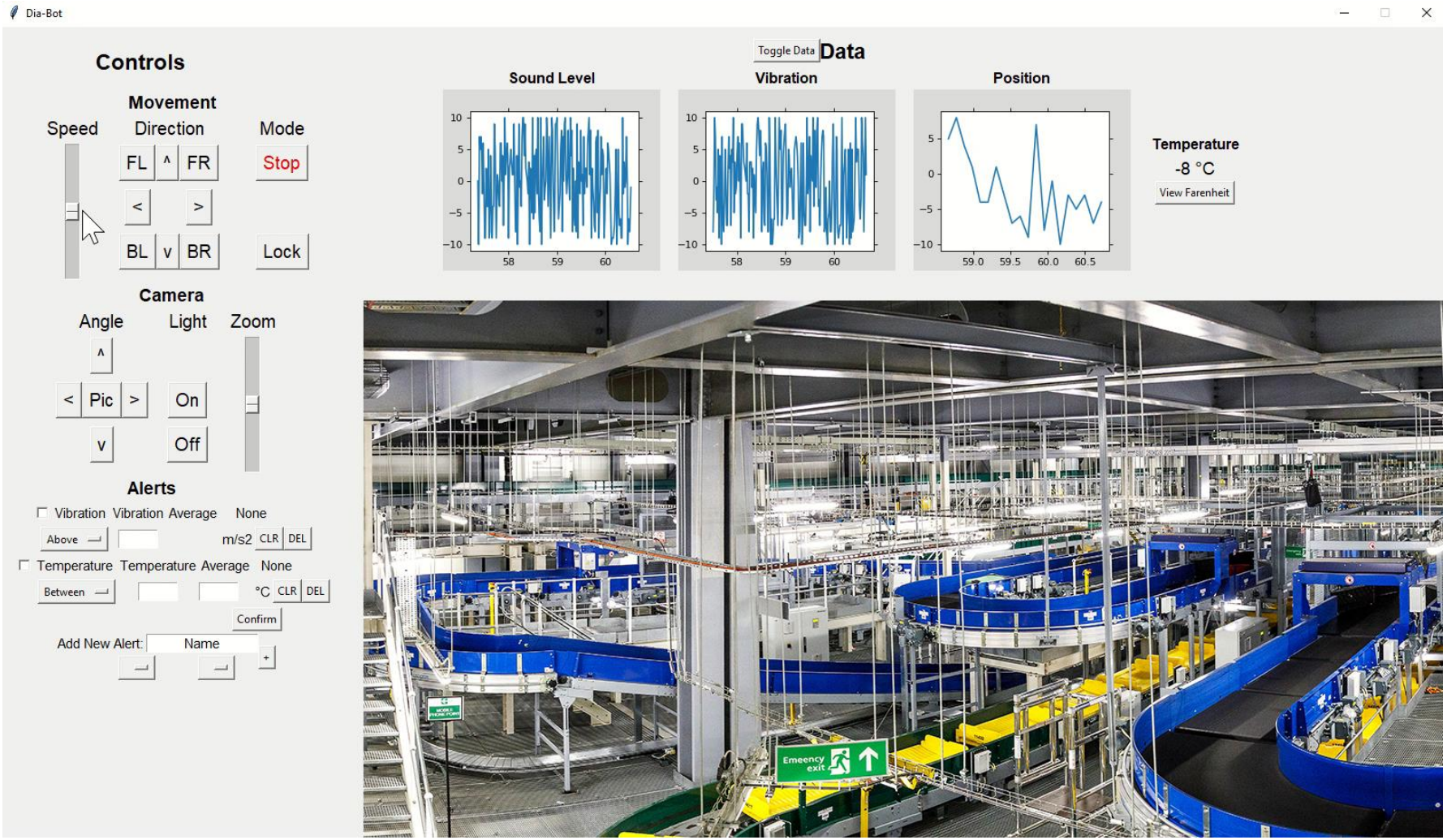
Georgia Tech

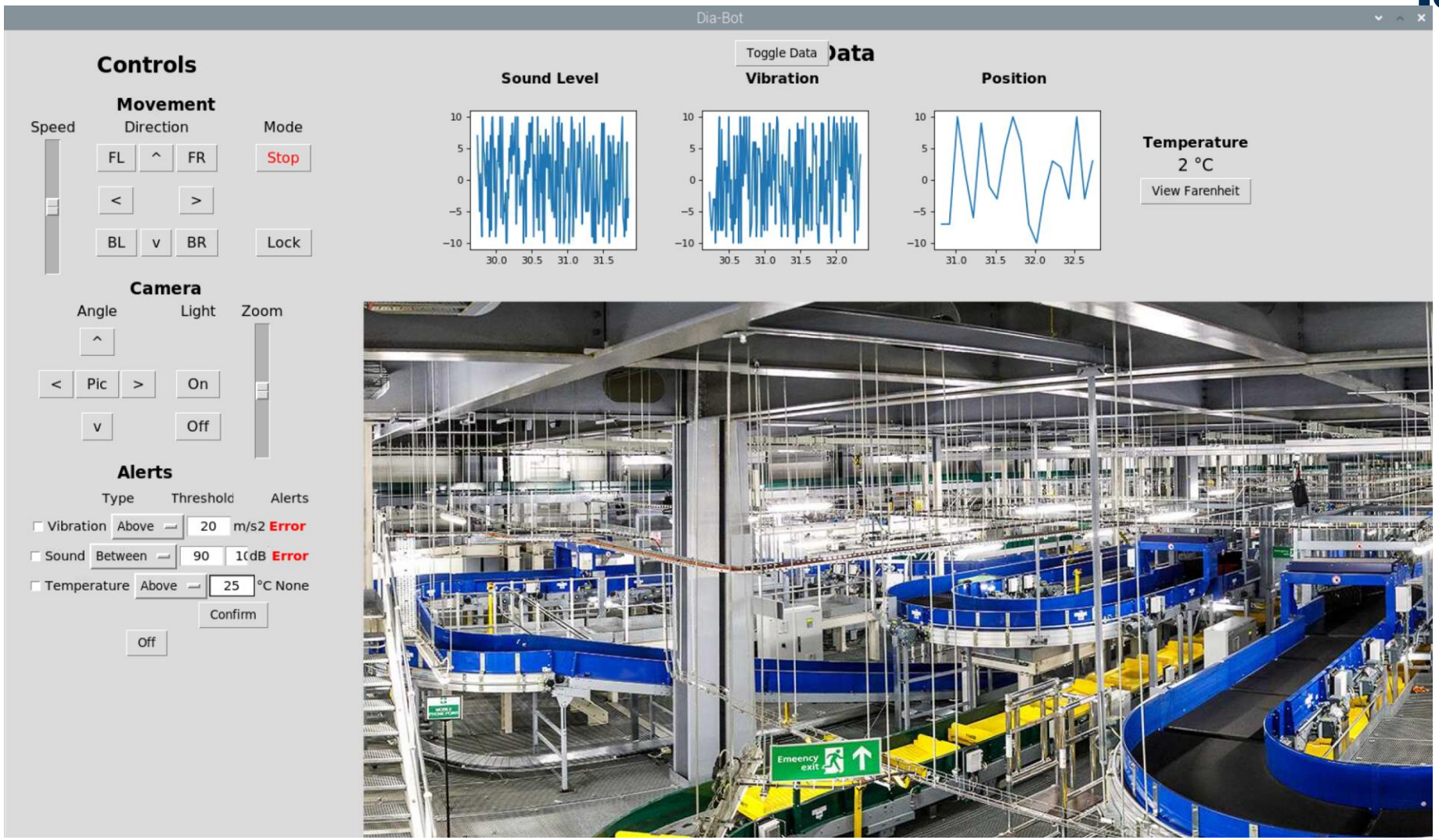
Design Concept: Electrical



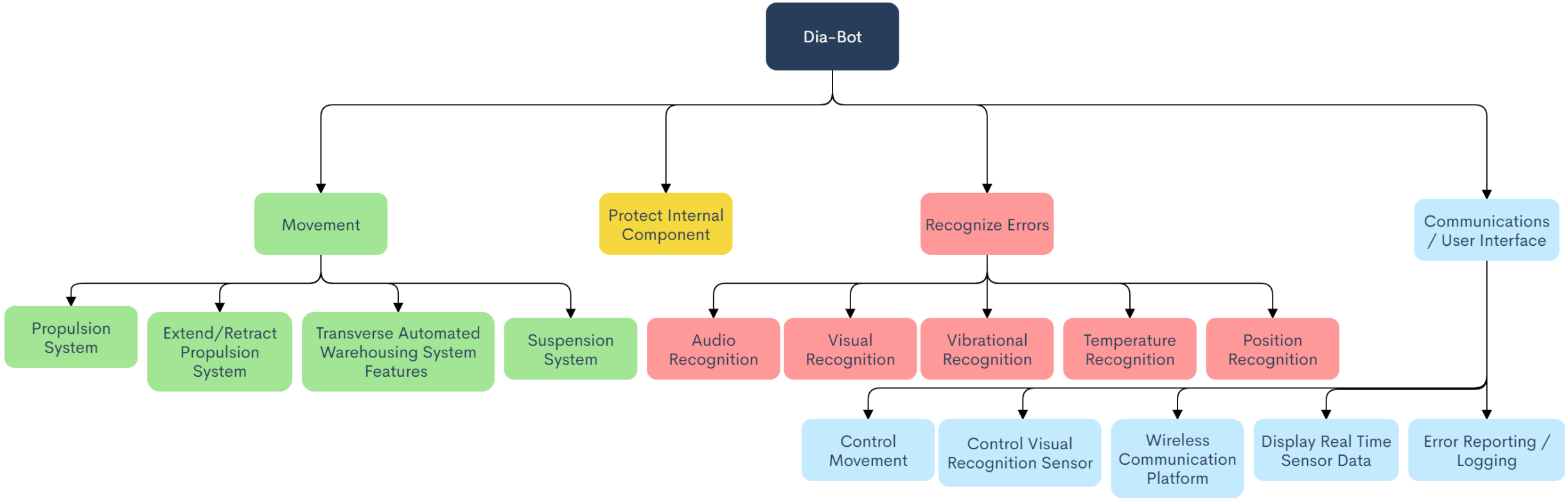
Prior UI Demo



(Old) User Interface



Previous Function Tree



Previous Design Concept: Electrical