Autonomous Lunar Vehicle Design

Purdue ENGR142

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Team 09

Project Overview

- Increases in light pollution and other radio frequencies has made looking through telescopes on Earth more difficult.
- Scientists are now looking to establish a radio antennae system on the far side of the moon that would allow the antennae to detect low level radio emissions from outer space.
- Our team's mission was to create an autonomous lunar vehicle (ALV) that would deliver these radio antennae.

Project Goals

The Autonomous Lunar Vehicle should have the capabilities to:

- ***Navigate*** to specific beacons (drop off locations)
- ***Deploy*** cargo accurately and in the correct orientation
- ***Dampen*** and minimize vibration of the cargo
- ***Detect*** and avoid unknown hazards
- ***Adapt*** as a system to based on new mission data

Technical Requirements

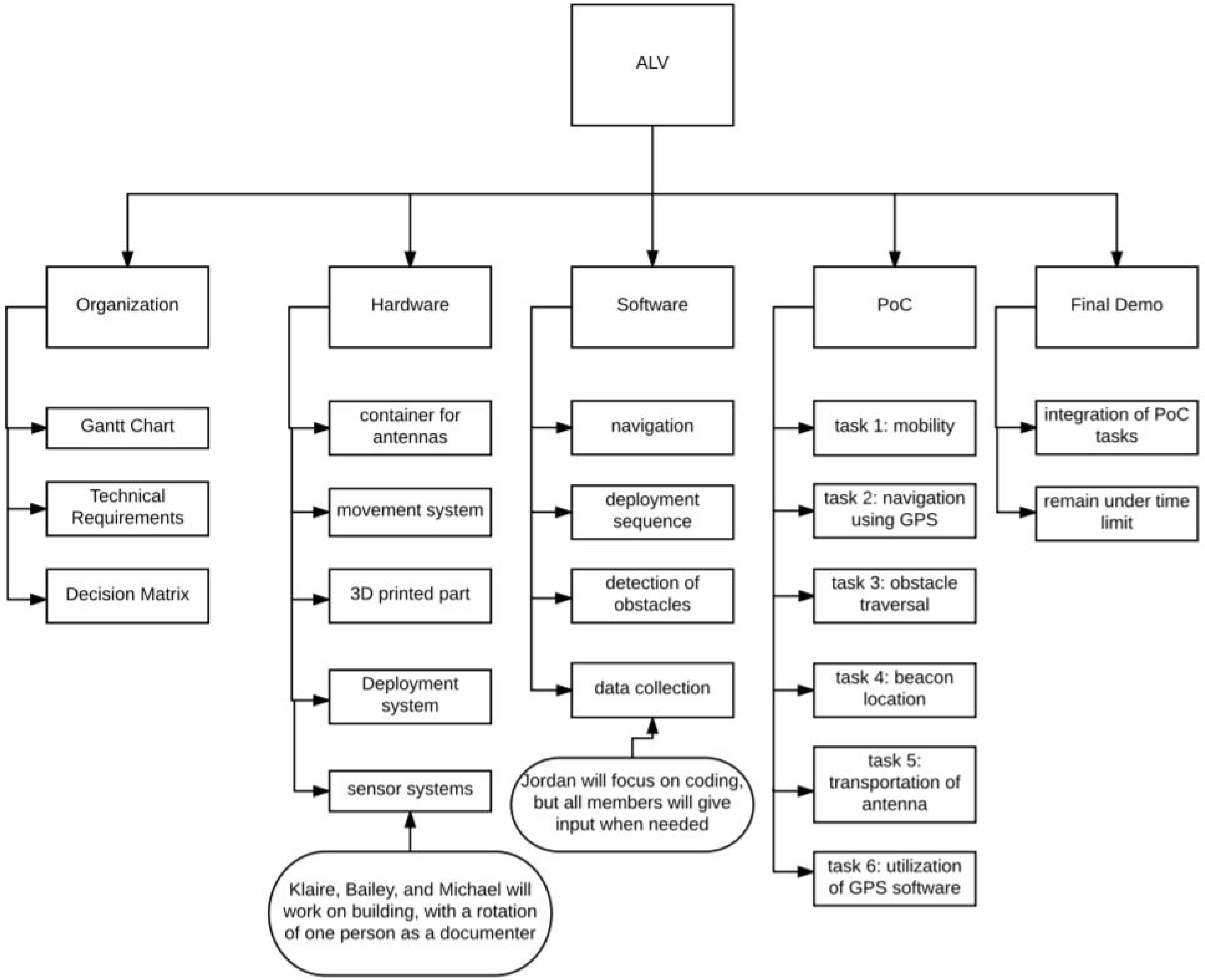
25 technical requirements were developed. A few key needs include:

Customer Need	Technical Need	Technical Requirement	Target Value
Turn Accurately	Robot can turn 90 degrees while deviating a max of x inches from the center point	Turn 90 degrees with a max deviation of the central point of the robot not deviating by more than 2 cm	Turn 90 degrees with a max deviation of 1cm
Move straight	Move with less than a specified degree of displacement from original path	Move with less than 20 degree displacement	Move with less than 5 degree displacement
Move to correct location	Move to coordinated location with specified precision	Move to coordinated location within 3 inches	Move to coordinated location within 2 inches
Move over small obstacles	Traverse obstacles of a certain height without interfering with structure	Traverse obstacles at least 1/2 inch in height without interfering with structure	Traverse obstacles at least 1 inch in height
Detect beacon	ALV needs to detect beacon from certain distance away from it	Detect beacon more than 3 inches away	Detect beacon more than 5 inches away
Transport antenna without exceeding average vibration level	Transport antennae without exceeding average vibration level	Transport antennae without exceeding average vibrations of 1.3m/s^2 (as measured by accelerometer inside of antennae)	Transport antennae without exceeding average vibrations of 1.0 m/s^2 (as measured by accelerometer inside of antennae)

Project Management

Tools Used:

- GANTT Chart
- Detailed Design Notebooks
- Weekly meetings



Hardware - Drive Train

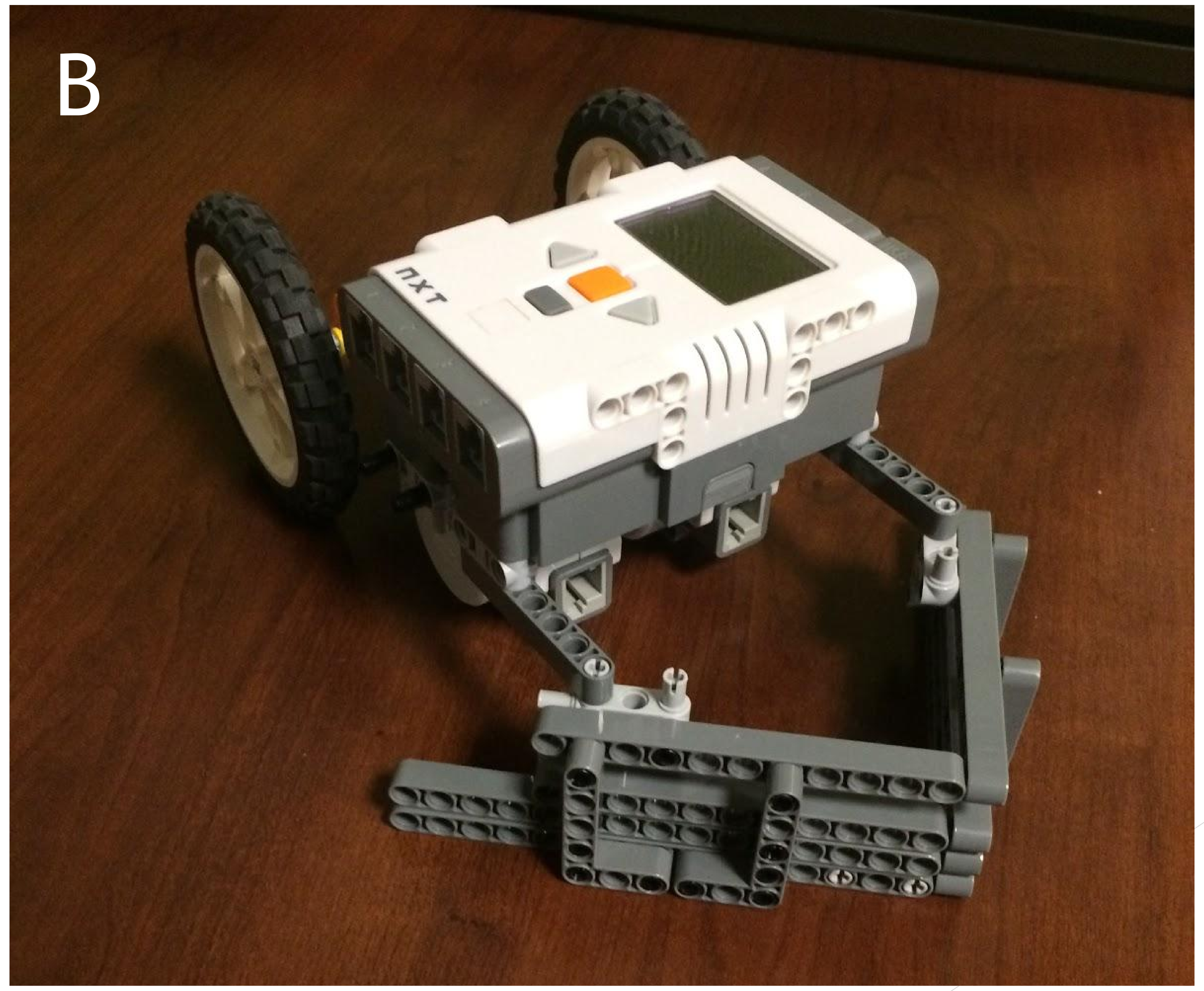
Specs Regarding Drive Train (weighted highest)

- Move Straight
- Turn accurately
- Turn with minimal deviation along axis

Three wheel design (A): **Unsuccessful**

Zero-Turn Mower Design (B): **Successful**

- Deviates **1 cm** for every forward foot
- Turns within ***2 degrees*** of orientation
- Axis deviates ***2 cm*** from initial position



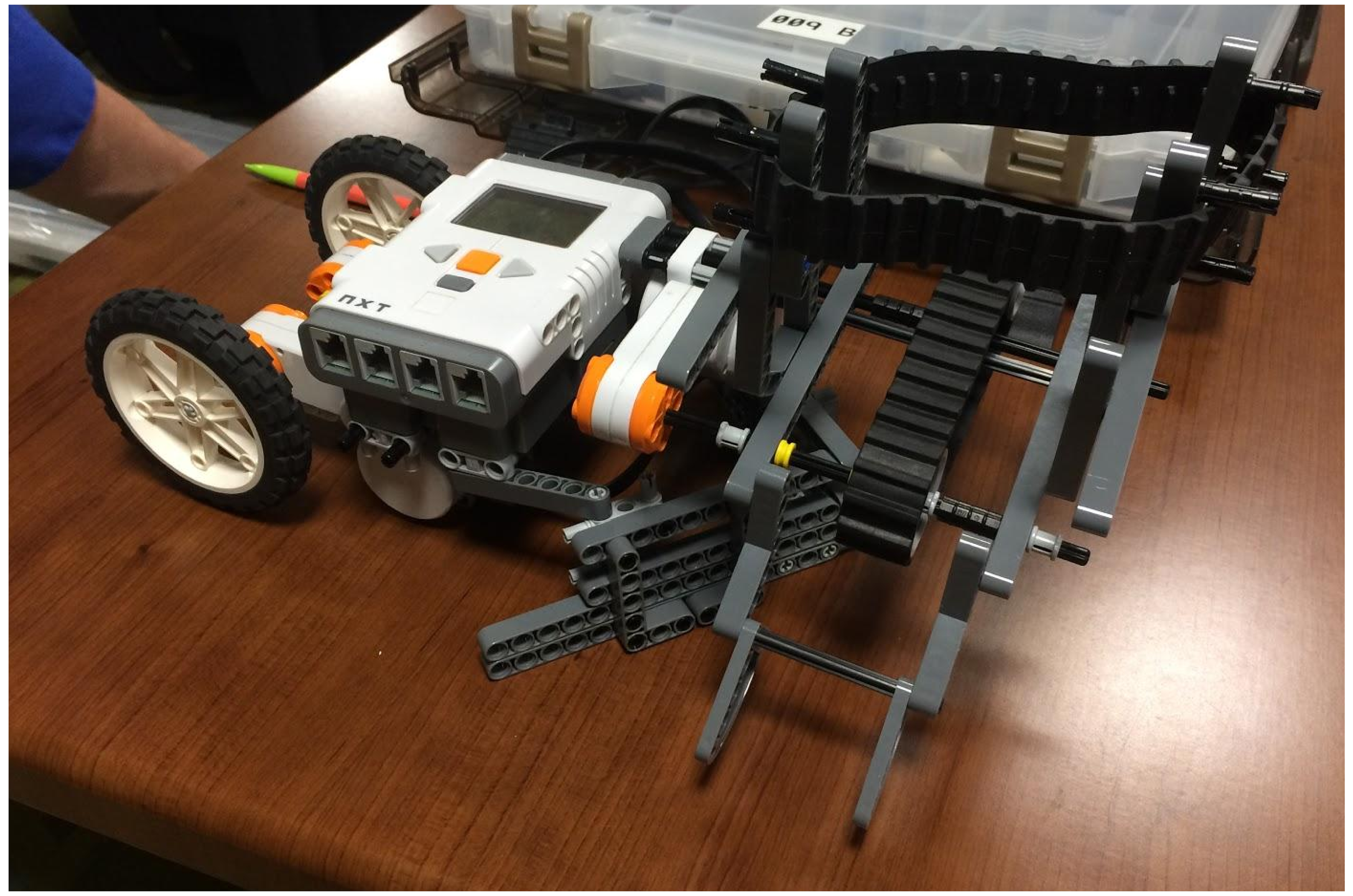
Hardware – Antenna Deployment

Two designs were attempted initially:

- **Conveyor belt above plow:**
  - Shifted the weight and increased the turn radius.

Conveyor belt above brick:

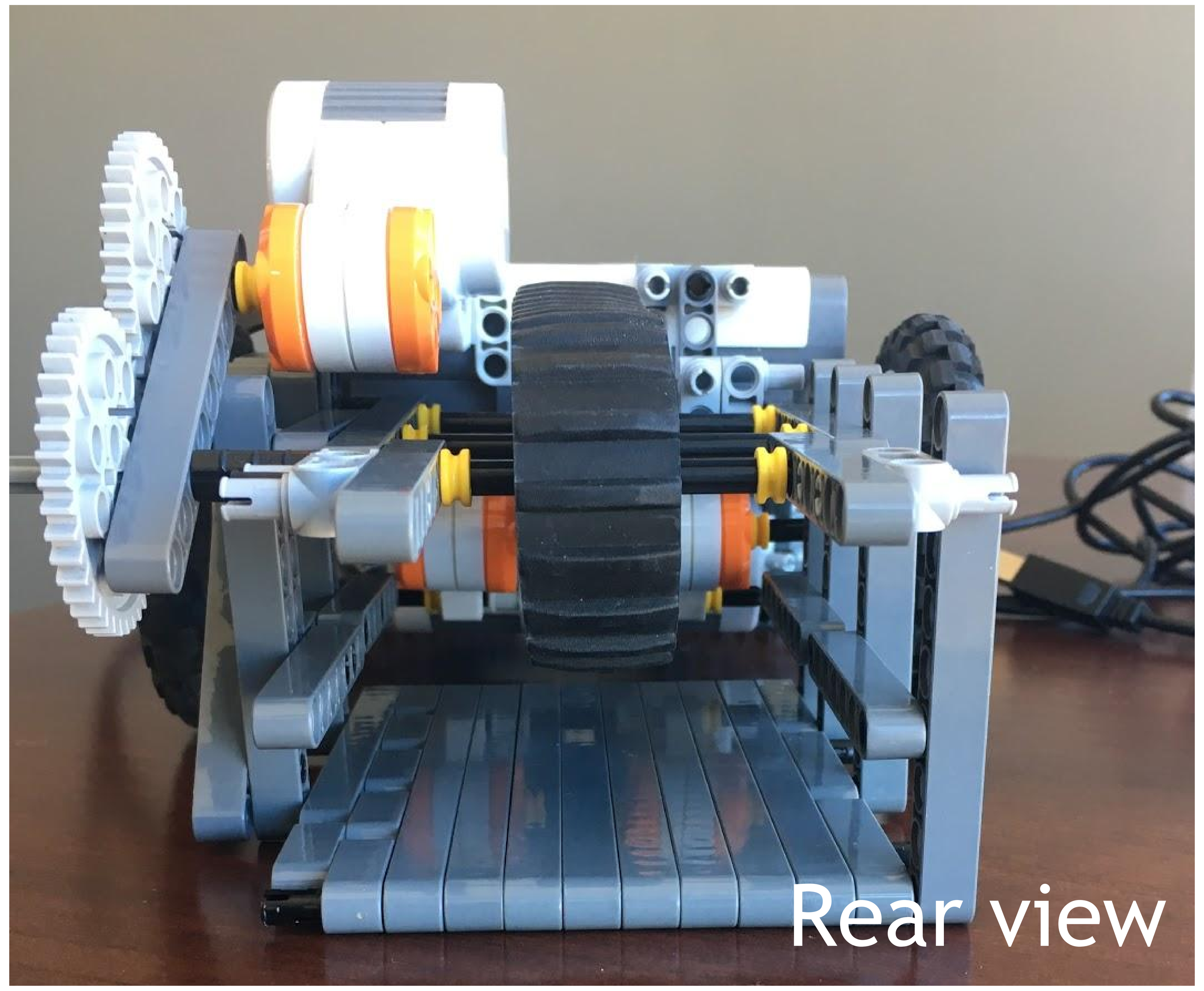
- Too far from the ground; needed a slide that took up too much space.

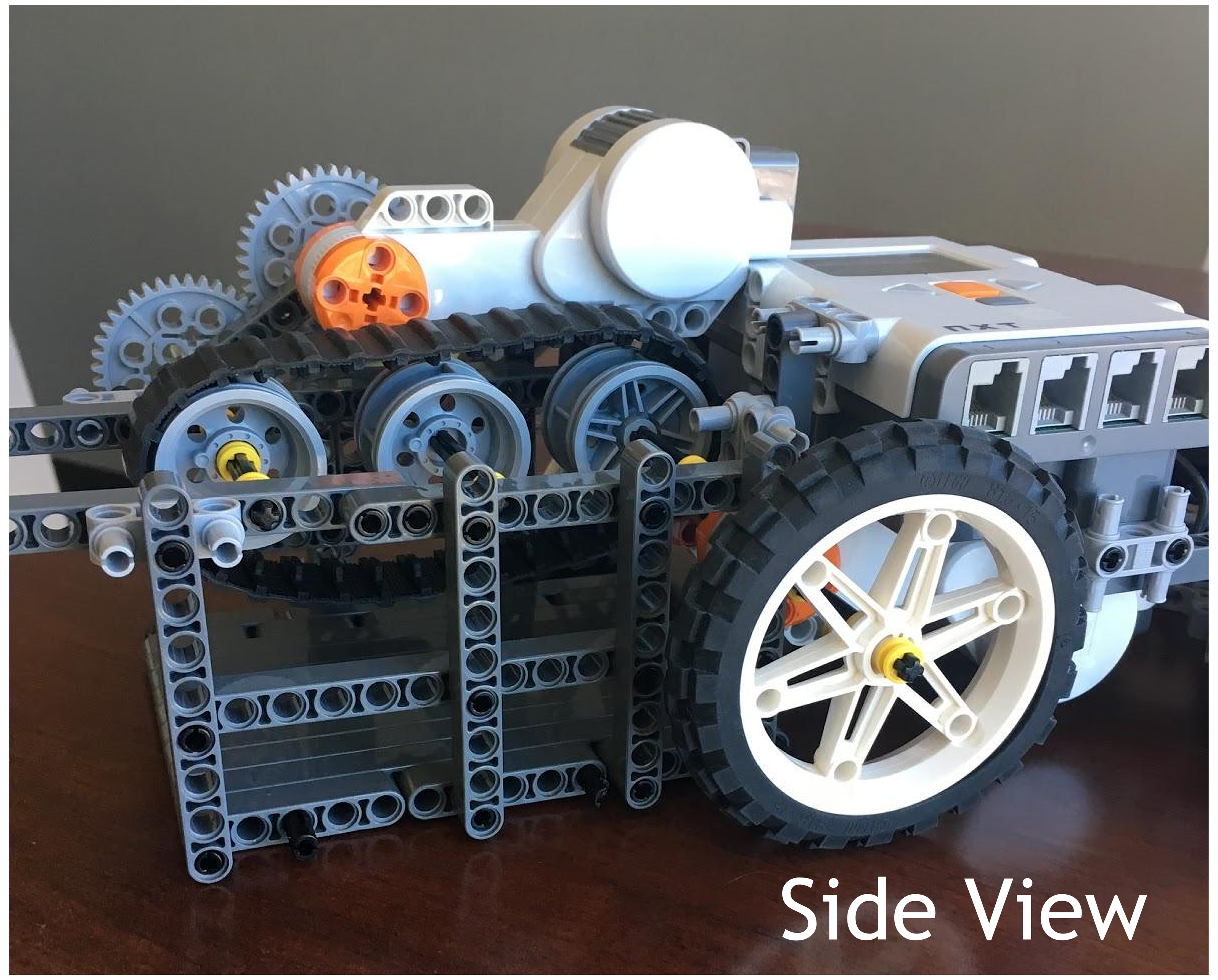


Hardware – Final Iteration

Final design: rear pulled sled

- Keeps weight centered
- Not a large drop between antenna and ground





Movement Accuracy Data

The data is a combination of drive train accuracy with an antenna deployment system added to the prototype.

Bin deployment is ranked lower than drive train accuracy.

Design	Deviation from Central Point on 90 degree Turn
Conveyor belt in front, wheels behind	7 cm
Conveyor belt on top, wheels behind	4 cm
Conveyor belt on top, wheels underneath brick (narrow)	3 cm
Conveyor belt on top, wheels underneath brick (wide)	1 cm
Conveyor belt on top, wheels underneath brick (wide)	2 cm

Sensor Testing Data

Data represents if deployment system can drop off antenna within allowable accelerations.

Design	Is force on antenna at a passing level?
Conveyor belt on top with two-piece slide	No
Conveyor belt on top with zig-zag (less steep) slide	No
Double conveyor belt slide	No
Sled on ground with conveyor belt above bed	Yes

Hardware Decision Matrix

Shortened matrix of key drive-train and deployment functions

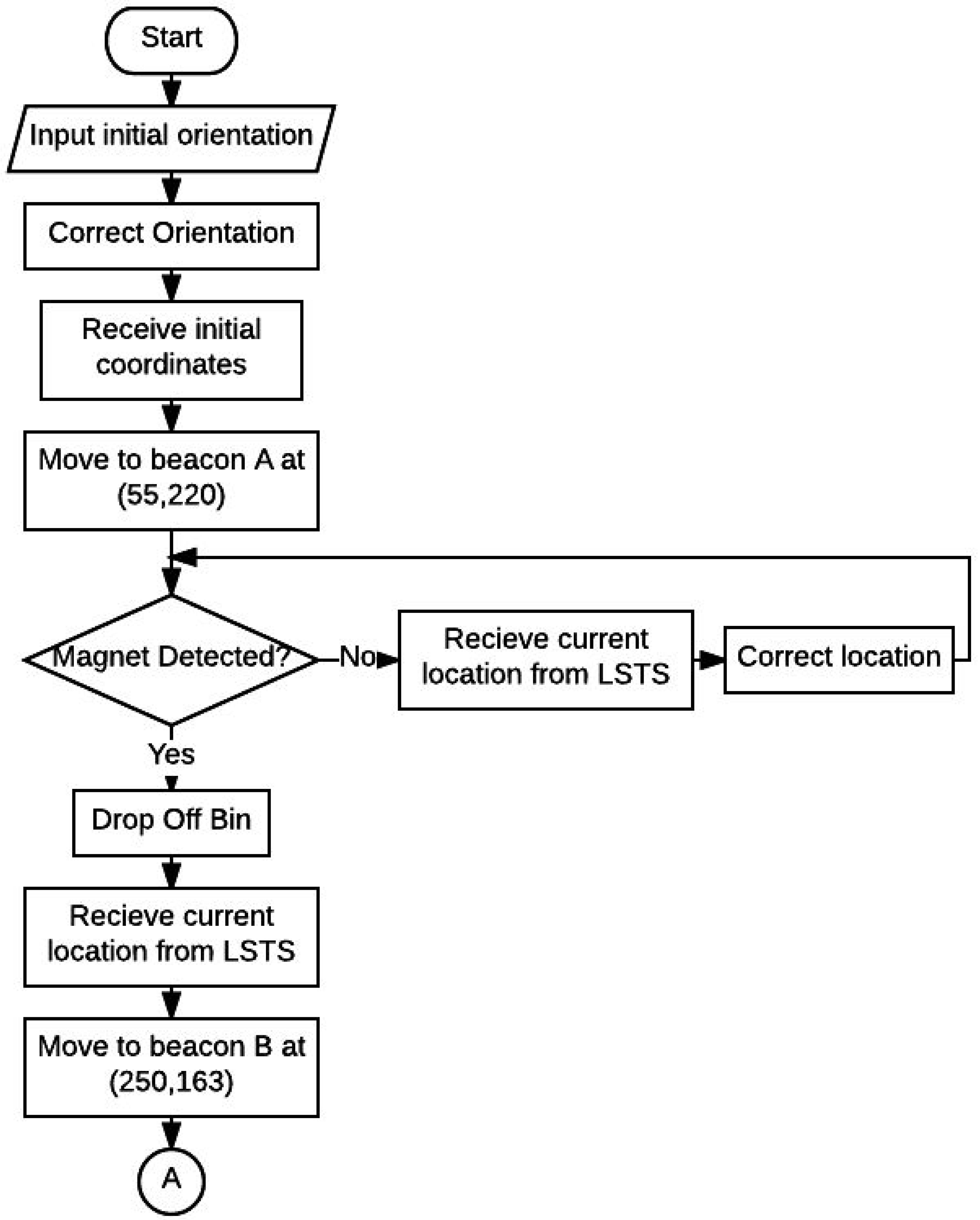
Consideration	Weight	Deployment System behind brick, wide-wheeled drive train	Deployment System above brick, wide-wheeled drive train	Deployment System above plow, narrow-wheeled drive train
Turns 90 degrees accurately	5	4	5	2
Minimal deviation from origin	5	4	5	2
Deploy bins with minimal vibration	3	5	1	3
	Totals	55	51	29

Software

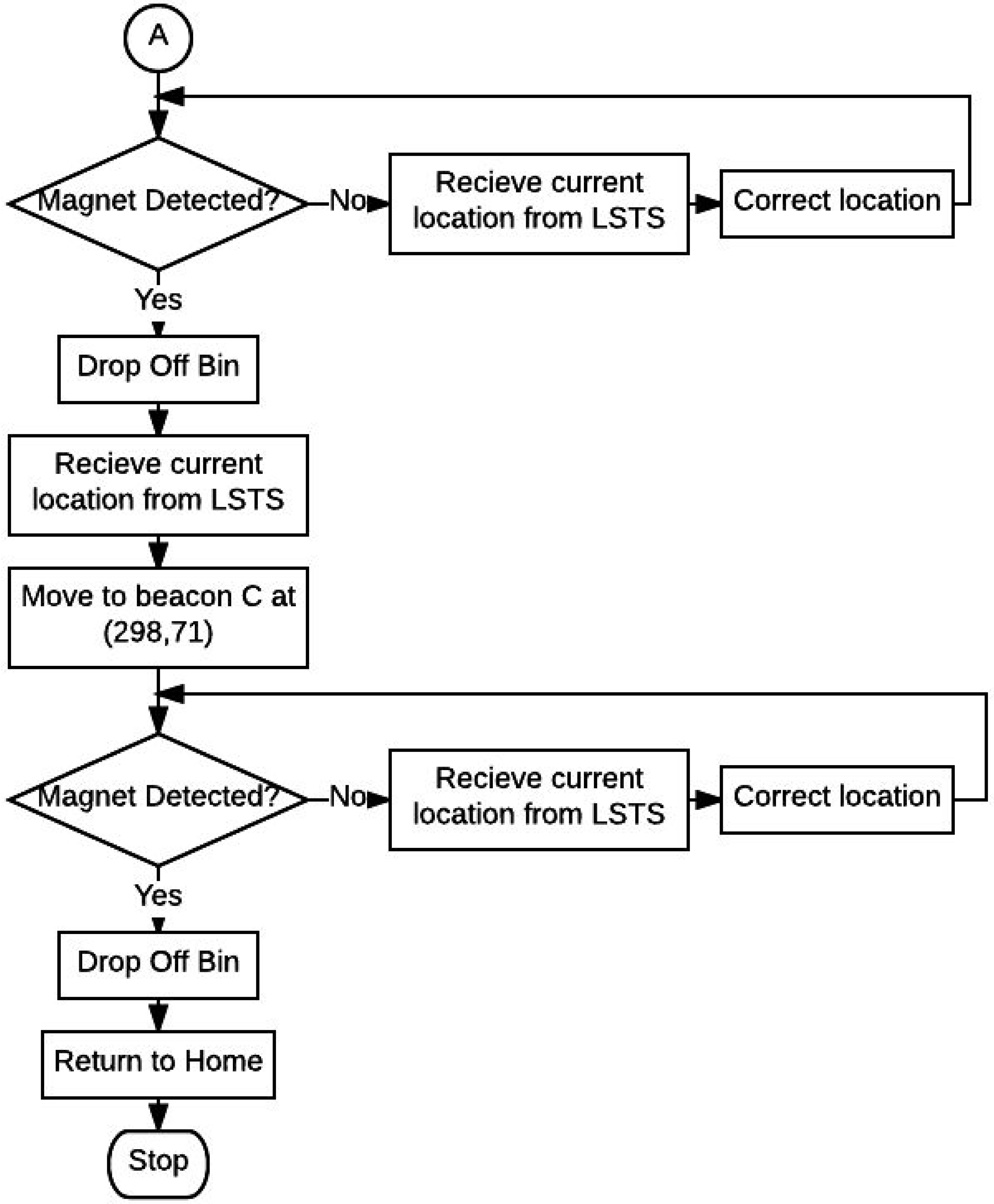
Three main beacon-finding mechanisms:

Consideration	Weight	LSTS	Magnetic Sensor	Mathematical Estimation
Consistency	4	3	4	4
Ease of Implementation	3	2	5	4
Accuracy	5	5	4	2
	Totals:	43	51	38

Software Diagrams



Software Diagrams



Unique Software Features

Friction Factors for turning and linear movement

- These were calibrated based on the surface the ALV was run on.

Used a combination of hard-coded locations and LSTS

- The robot would move to a set location but still check LSTS to account for deviations during turning and driving.

Calibrated magnet sensor

- The magnet sensor was calibrated to the initial reading and if the difference was greater than 10, a magnet was detected

Updated Orientation

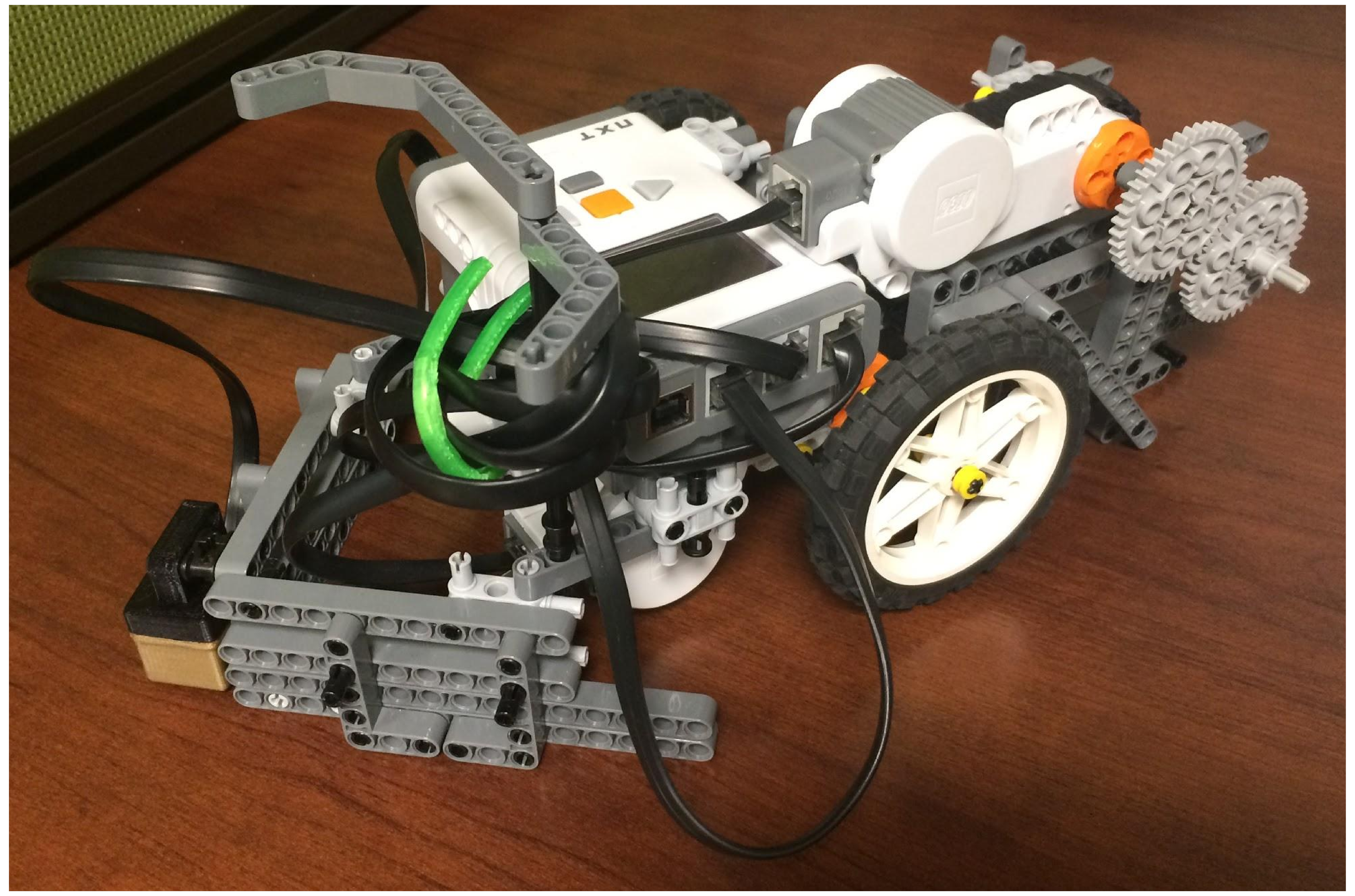
- The ALV would update its orientation after every turn

Goals vs. Performance

Customer Need	Target Goal	Performance	Ratio of Performance to Goal
Move over small obstacles	Traverse obstacles <= 1 inch in height	All small obstacles <= 3 inches pushed out of way	300 %
Move Straight	< 5-degree deviation	< 10-degree deviation	50 %
Turn precisely	< 10 degrees	< 5 degrees	200 %
Turn accurately	< 1 cm	2 cm	50 %
Safely deploy bins	Peak < 10 m/s^2 Average < 1 m/s^2	Peak 8.66 m/s^2 Average 0.3 m/s^2	115 % 333 %
Correctly detect current location	< 3 cm error	< 1 cm error	300 %
Can move to target location using LSTS	< 5 cm	Average on first try ~ 15 cm	33 %
Can detect a sensor	< 1 cm	0 cm (reference point directly above sensor)	∞ %

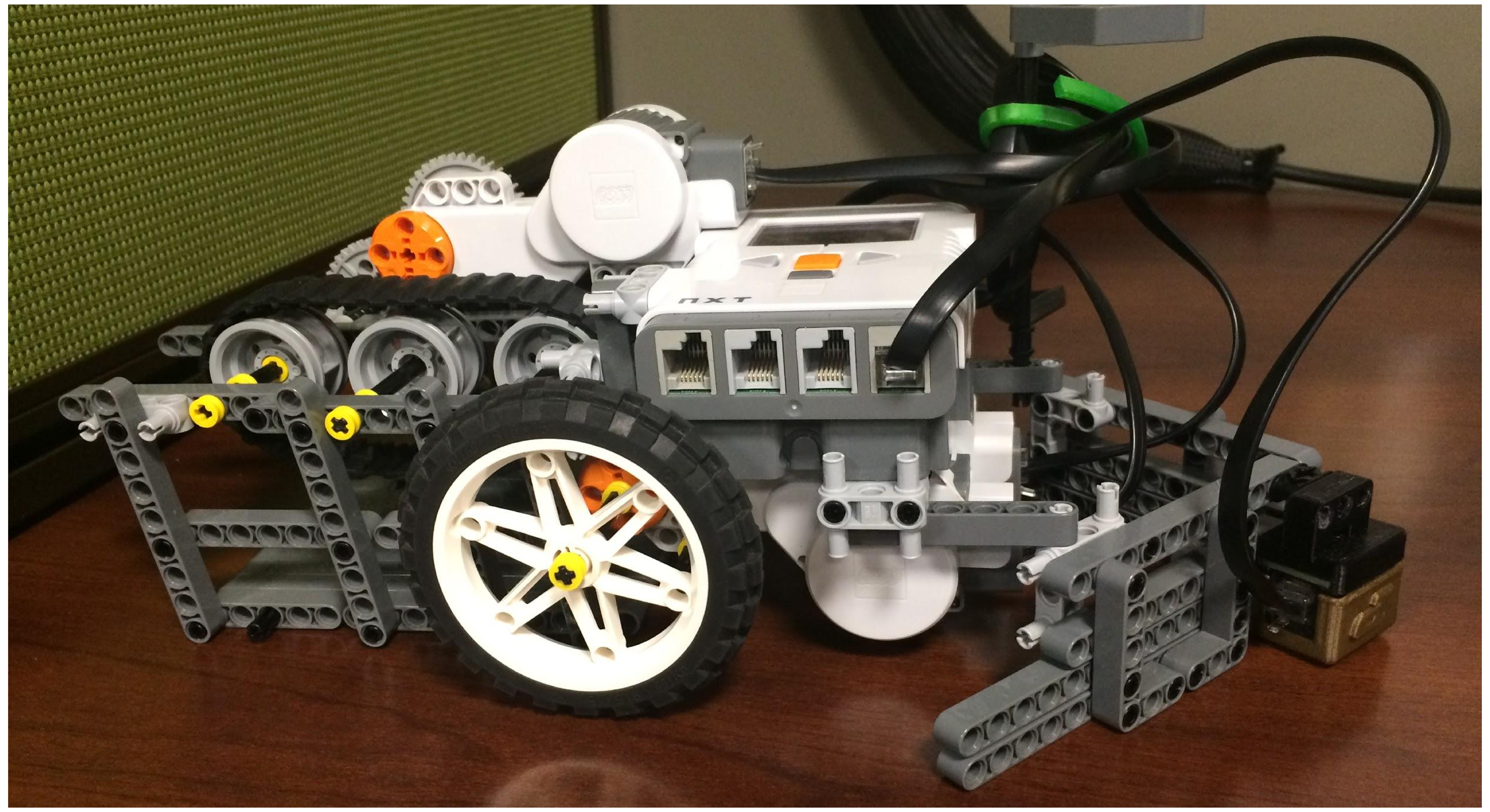
Pros of ALV

- Almost zero ***turn radius***
- ***Plow*** effectively moves debris
- ***Vibration*** of antenna is minimized
- Accurately determined ***location*** using LSTS
- Accurately detect ***deployment*** location



Cons of ALV

- Plow and deployment system create ***friction*** and make ALV extremely sensitive to small deviations in track
- Distance of wheels from motor creates ***stress*** on axle
- Small ***deviations*** in size of antenna affect deployment
- Could have been more compact



Conclusion

- ALV ran into walls due to lack of space
- The plow got caught up in the transitions from one piece of paper to another
- Delivery system failed due to lack of room to operate
- Motors ran at different speeds

Improvements

- More weight on left side caused ALV to drift left
  - Increase power of left motor to account for uneven weight distribution
- Antenna deployment system holds a maximum of three antenna
  - Increase capacity of antenna deployment system by shifting the frame
- ALV went too far north after point A
  - Account for difference between reference point for LSTS and the front point of the ALV
- Implement the algorithm created to account for the deviation of final angle from predicted angle

Questions?

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