Final Report

Group: L3-G7 (Tickle Me Pink)
By:
Miller Timlin (101115779)
Aryan Laxman Sirohi (101199497)
Basel Syed (101173816)

Introduction

This final report provides a comprehensive overview of the detailed System Testing and Customer Testing performed on our Snow Plowing Robot. The report provides Control Charts and Testing Results displaying our robots capabilities in a controlled and uncontrolled environment.

System Overview

The final version of our Robot leveraged the following hardware components:

- Analog Distance Sensor: This was primarily used for obstacle detection
- Line Follower Sensor (2): The sensors were used in parallel to provide accurate boundary detection information
- Wheel Encoder: These were used for determining distance traveled by the robot.

Our software approach for this robot was primarily through the use of interrupts.

Project Proposal Updates:

Appendix A contains an updated project proposal. The proposal remains mostly unchanged, with the only difference being the updated Cost section to include the updated Figures.

Control Charts:

The Control Charts provided in this section are used to illustrate the systems performance in fulfilling the base System Requirements. For this project, we will be providing Control Charts for the amount of distance out of the boundary the vehicle goes (Figure 1). We will also be providing a graph showing the speed the vehicle travels at (Figure 2) and finally the stopping distance when the vehicle detects an obstacle. Each Control Chart will illustrate 5 attempts at the test (Figure 3).

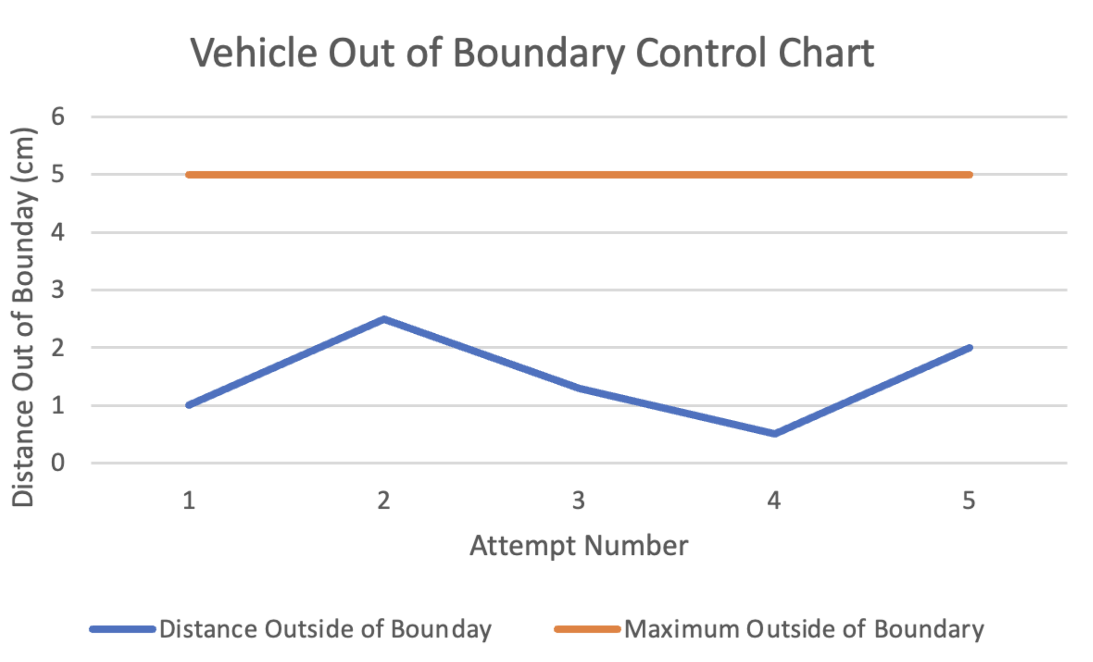

Image 1: Control Chart Showing Distance Sensors

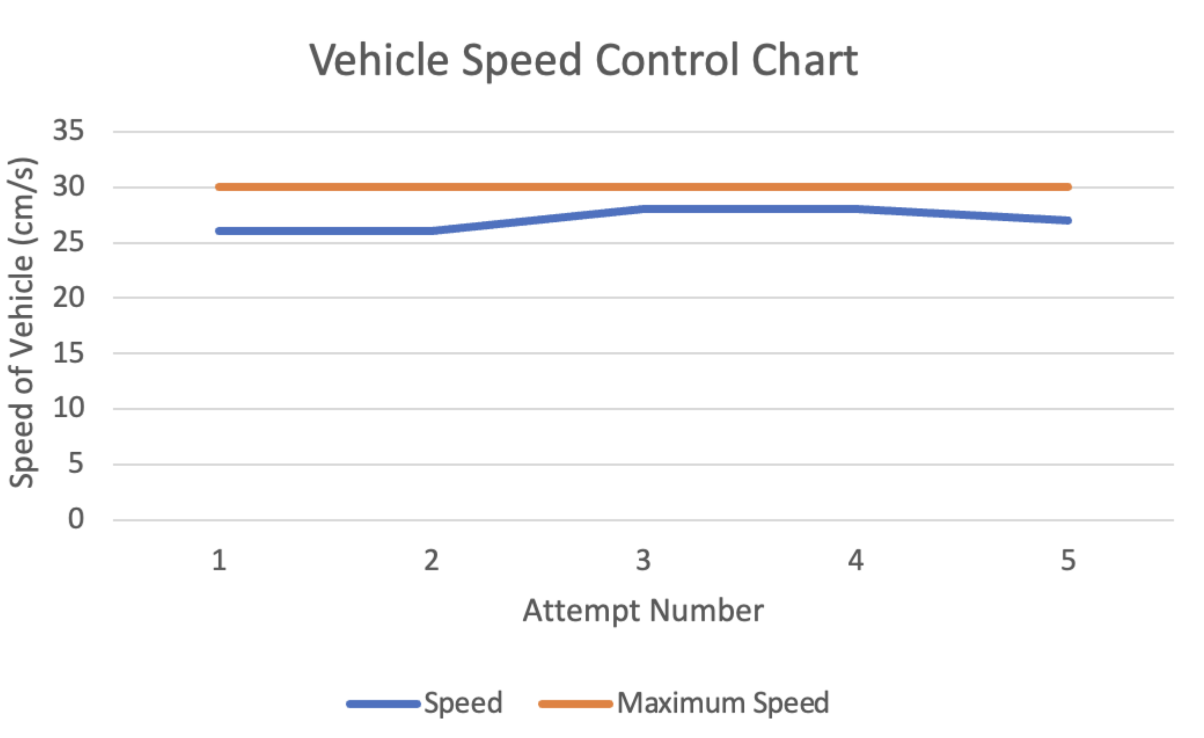

Image 2: Control Chart Showing Vehicle Speed

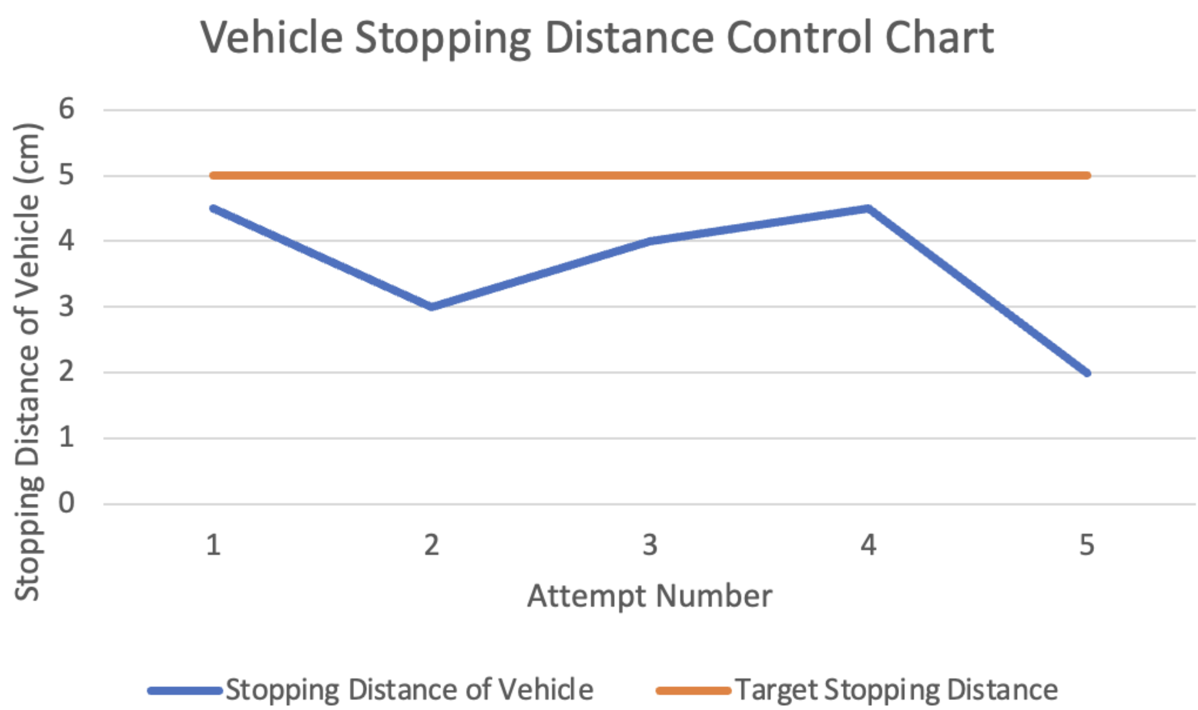

Image 3: Control Chart Showing Vehicle Stopping Distance

From this, we can see the vehicle consistently is able to over achieve the base requirements.

Testing Results:

System Testing (Lab 11):

During the System Testing we attempted to integrate all of our sensors together and observe their interoperability. This was where we encountered our first major issue as we discovered that our ultrasonic sensor was generating false positives due to interference from the motors. We attempted to mitigate this using physical isolation to reduce crosstalk between the wires however that was not useful as the issue persisted. Attempting to electrically isolate the sensor was also impractical as we required either electrically insulated wiring, a Low Pass Filter, or a separate power supply for the sensor.

Furthermore, we discovered that due to different surfaces that we tested the vehicle on, the wheel encoder values were highly variable and caused inconsistent 0-radius turns. We solved this issue through the use of debouncing as our encoders were triggering several times on a high signal whereas it should only trigger once on the rising edge. This solution allowed us to get a relatively consistent reading on our wheel encoders.

Customer Testing (Lab 12):

During the first run of our in-lab demo we had an issue at the beginning where we had to adjust the IR distance sensor. The robot also collided with the obstacles several times as it had several blindspots we failed to account for. It also left the arena once. It managed to clear 40 of the “snow” blocks

During the second run we had no issues with the IR distance sensor, however the robot still collided with obstacles due to the blind spot.   In this run, the robot did not leave the arena.   It managed to clear 32 of the “snow” blocks.

Trial #	Obstacles Hit	Obstacles Avoided	Boundary Avoided	Boundary Passed	Snow Cubes Cleared	Duration (minutes)
1	4	6	40	1	40	5:00
2	5	4	38	0	32	5:00

Github:

[SYSC-Courses/course-project-l3-group-7-tickle-me-pink: course-project-l3-group-7-tickle-me-pink created by GitHub Classroom]

<u>Appendix:</u>

Appendix A: Project Proposal

Project Proposal

Course: SYSC 4805 Fall 2023
Group: L3-7 (Tickle Me Pink)
By:
Miller Timlin (101115779)
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Basel Syed (101173816)

Project Charter:

Team name:

Tickle Me Pink

Overall Objective:

The primary objective of this project is to develop and optimize a small-scale prototype autonomous robot capable of clearing simulated snow in an indoor, controlled environment. In this simulation, snow will be simulated as small, lightweight wooden blocks. The robot will be limited to only driving in an arena delimited by black painter's tape. Using a suite of onboard sensors, the robot must be able to proficiently navigate the arena, identify the black painter's tape and understand its workable area, and be able to differentiate between snow and potential obstacles and hazards. It must also be able to adapt to constantly changing environments, including environments with moving obstacles and multiple robots performing the same operation. With this project, we not only aim for the robot to be able to clean snow successfully, but to also do so without any impedance, and embodies robustness, reliability, and efficiency in robots' performance. In the final iteration of this project, our vision is to see the robot operating uninterrupted in the most diverse and challenging conditions. The goal of this project is to design, develop, and test an embedded system in order to solve a practical problem.

Overall Deliverables:

- Project Proposal (Due October 20th)
- Progress Report (Due November 17th)
- Final Report (Due December 8th)
- In-Lab Demonstration (December 5th)
- In-Lecture Presentation (December 7th)

Scope

Requirements:

1. Robot must not exceed dimensions (Width x Length x Height) of 226 x 262 x 150 mm
2. Robot must begin operation from a corner of the area
3. Robot must be able to detect boundaries of area marked by painter’s tape using a line sensor so that Robot’s wheels dot not go outside the boundary by more than 5cm
4. Robot must not exceed a speed of 30 cm/s
5. Robot must clear “snow” from area of approximately 6m^2 within 5 minutes
6. Robot must be able to complete the task autonomously such that it requires no human intervention after being started
7. Robot must be able to detect and avoid collision with static and dynamic obstacles

Deliverables:

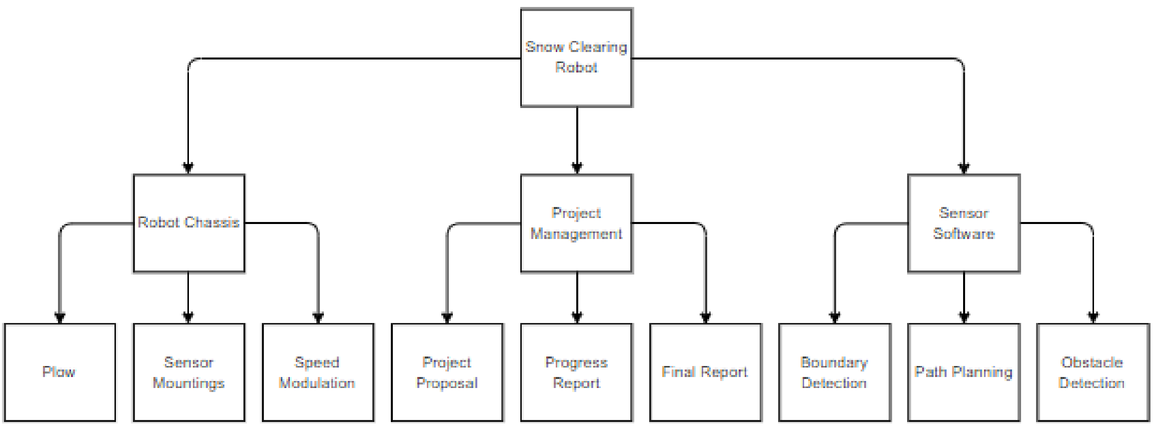

Image 1: WBS Outlining all Project Deliverables

Testing plan:

1. Plow Design:

   The Robot will be measured manually to ensure it does not exceed the specified dimensions with the plow attached. A significant amount of simulated snow will be laid out along a path. The robot, with the plow attached, will move along the path collecting as much snow as possible.
   Pass: The Robot does not exceed (Width x Length x Height) of 226 x 262 x 150 mm and collects at least 75% of the simulated snow

2. Sensor Mountings:

   Sensor Mountings will be tested concurrently with Boundary Detection, Path Planning, and Obstacle Detection as those tests all require the sensors and their mountings
   Pass: Boundary Detection, Path Planning, and Obstacle Detection tests pass

3. Speed Modulation:
   The Robot will be set along a path and the wheel encoders will measure and collect its maximum speed
   Pass: the maximum speed does not exceed 30cm/s

4. Boundary Detection:
   Set up a small scale model of the Arena and allow the robot to navigate through it, while ensuring the wheels do not pass more than 5cm outside the boundary. One possible way to test this is to set up 2 lines; one marking the actual boundary, and another marking 5cm outside the border. It may be important that this other line does not trigger the boundary detection, as it could confuse the robot.
   Pass: Robot navigates entire area without passing more than 5cm over the boundary line

5. Obstacle Detection:
   Using the same small scale model of the Arena, the Robot will be allowed to navigate freely throughout it. This time, physical obstructions will be introduced and the robot will be expected to avoid them. Dynamic obstructions (such as other robots) will be simulated by moving a cardboard box around the arena manually.
   Pass: Robot navigates within the Arena without colliding with static or dynamic obstacles

6. Path Planning:
   The Robot is supposed to clear as much snow as possible from the given area/Arena. Therefore it must be able to navigate obstacles in the area while still clearing snow from around them. This will be tested by using the same small scale of the Arena and allowing the robot to navigate freely throughout it.
   Pass: The robot is able to stay within the borders of the Arena, while not only avoiding but navigating around obstacles to ensure area coverage. The Robot must cover at least 75% of the area, do be determined visually.

Schedule

Activities:

Table 1: Activity Assignment per work session

Work Session	Member	Activity
Lab 6 (October 17th) ● Project Proposal	Aryan	Project Proposal: Overall Objective, Schedule Network Diagram
	Basel	Project Proposal: Gantt Chart, Responsibility Assignment Matrix
	Miller	Project Proposal: Requirements, Deliverables, Testing, Activities, Cost Baseline Figure
Lab 7 (October 31st) ● Development	Aryan	Speed Modulation
	Basel	Sensor Mountings
	Miller	Plow Design
Lab 8 (November 7th) ● Development	Aryan	Boundary Detection
	Basel	Obstacle Detection
	Miller	Path Planning
Lab 9 (November 14th) ● Progress Report	Aryan	Progress Report: State diagram, Sequence Diagram
	Basel	Progress Report: Project Proposal Updates, Planned Value Analysis Figure, Watchdog timer demonstration
	Miller	Progress Report: System Architecture, Working code in Github Repository
Lab 10 (November 21th) ● Testing and Debugging	Aryan	Boundary Detection Testing and Debugging
	Basel	Obstacle Detection Testing and Debugging
	Miller	Path Planning Testing and Debugging
Lab 11 (November 28th) ● Final Report	Aryan	Final Report and presentation preparation: Control Charts
	Basel	Final Report and presentation preparation: Results of system testing
	Miller	Final Report and presentation preparation: Updating project proposal and Github documentation

Lab 12 (December 5th) • Demonstration	Aryan	Demonstration
	Basel	
	Miller	

Schedule Network Diagram

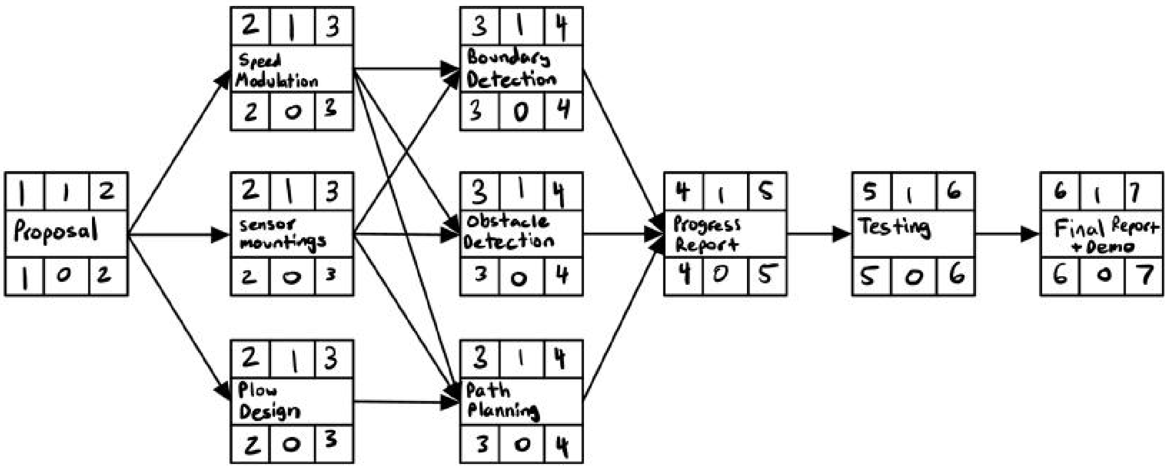

Image 2: Schedule Network Diagram

Gantt Chart

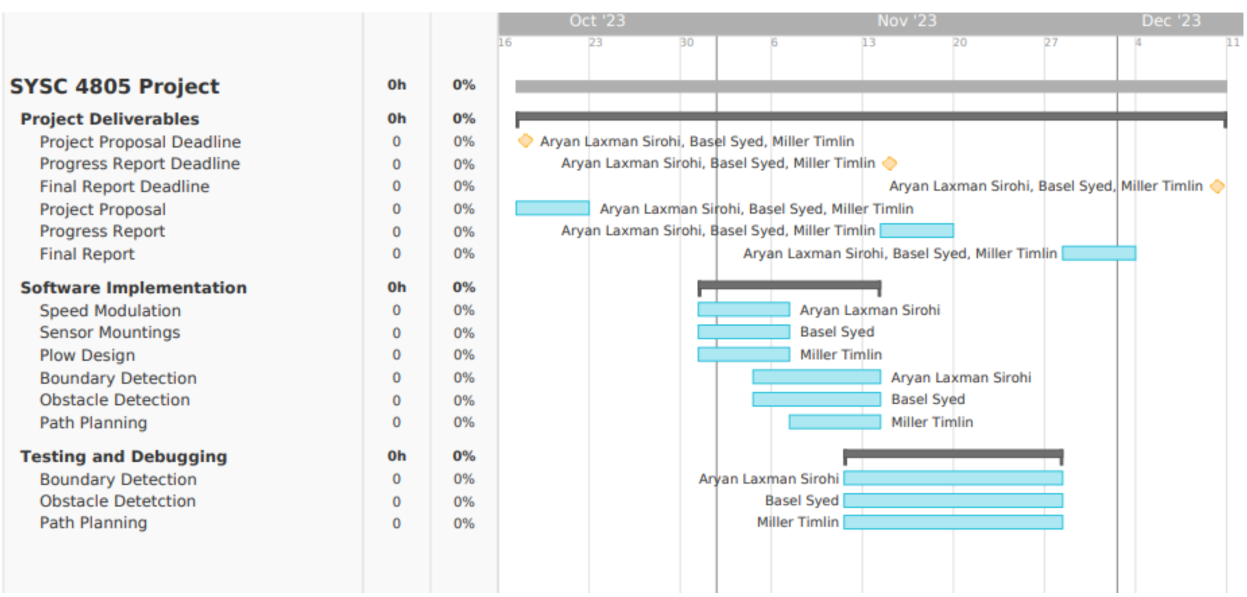

Image 3: Gantt Chart

Cost

Baseline Cost Figure:

Table 2: Cost Breakdown

Item	**Cost**
Lab Kit	$500
Aryan work hours	4hrs*5 lab sessions*$50/hour = $1000
Basel work hours	4hrs*5 lab sessions*$50/hour = $1000
Miller work hours	4hrs*5 lab sessions*$50/hour = $1000
Total:	$3500

Table 3: Cost-Activity Breakdown

Activity		Estimated Time	Cost
A. Software Implementation	A1. Speed Modulation	5 hours	$250
	A2. Sensor Mounting	5 hours	$250
	A3. Plow Design	5 hours	$250
	A4. Boundary Detection	5 hours	$250
	A5. Obstacle Detection	5 hours	$250
	A6. Path Planning	5 hours	$250
B. Testing and Debugging	B1. Boundary Detection Testing	5 hours	$250
	B2. Obstacle Detection Testing	5 hours	$250
	B3. Path Planning	5 hours	$250
C. Project Deliverables	C1. Project Proposal	5 hours	$250
	C2. Progress Report	5 hours	$250
	C3. Final Report	5 hours	$250

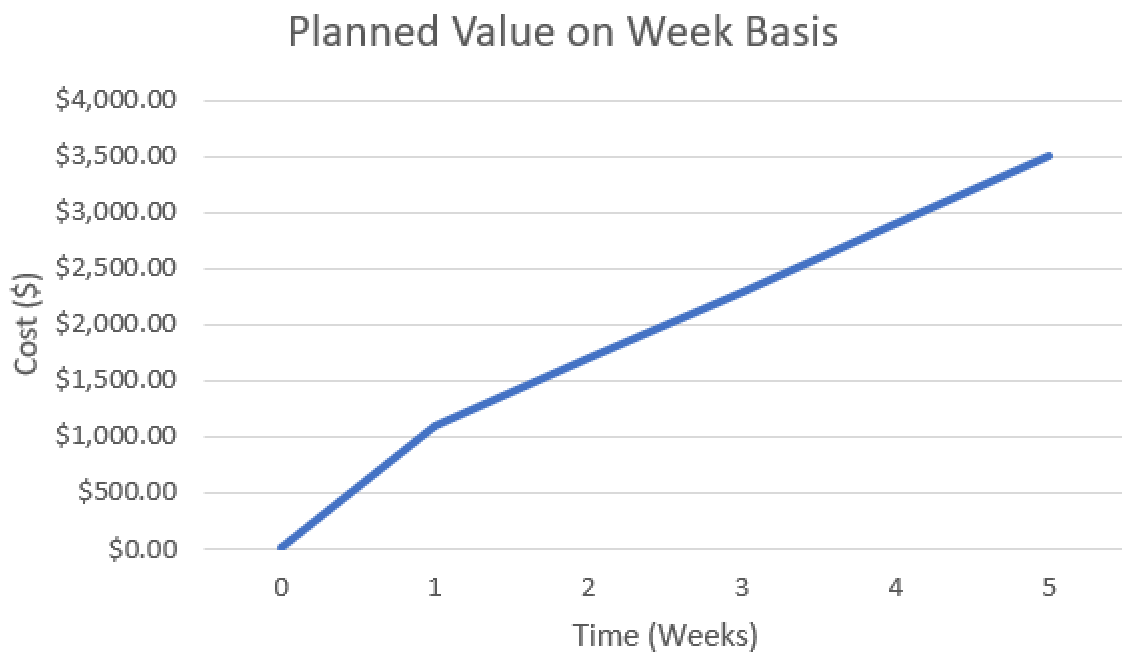

Image 4: Planned Value vs Time Graph

Final Cost Figures:

The following was the actual cost of implementing the project. There was a much higher cost than was initially expected. This was mainly due to an underestimation on the weekly hours required to implement the project. Originally we had estimated to only need 12 hours per week, however we found that we needed much more (roughly around 20). Image 5 and 6 depict these details.

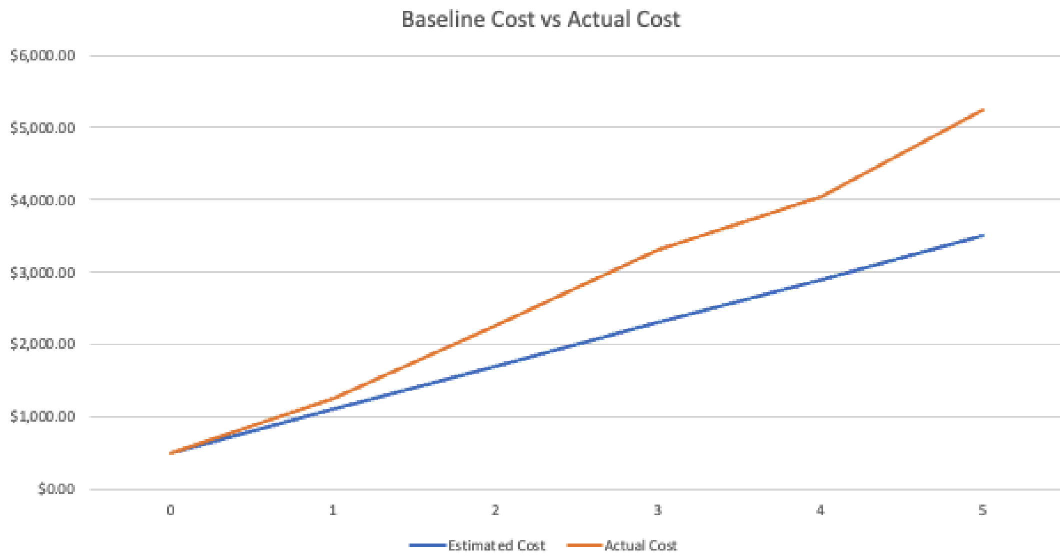

Image 5: Baseline Cost vs Actual Cost

Week	Estimated Hours	Actual Hours	Cost
0	0	0	0
1	12	15	15 x 50 = 750
2	12	20	2250
3	12	21	3300
4	12	15	4050
5	12	24	5250

Image 6: Baseline Hours vs Actual Hours

Human Resources

Responsibility Assignment Matrix:

Table 4: Responsibility Assignment Matrix

Activity		**Aryan**	**Basel**	**Miller**
Proposal	**Overall Objective**	R	A	
	Schedule Network Diagram	R		A
	Gannt Chart		R	A

	Responsibility Assignment Matrix	A	R	
	Requirements		A	R
	Deliverables		A	R
	Testing	A		R
	Activities	A		R
	Cost Baseline Figure		A	R
Speed Modulation		R	A	
Sensor Mountings			R	A
Plow Design		A		R
Boundary Detection		R	A	
Obstacle Detection			R	A
Path Planning				R
Progress Report	**Project Proposal Updates**	A	R	
	System Architecture		A	R
	Statechart of overall system	R		A
	Sequence diagrams	R	A	
	Watchdog timer demonstration		R	A
	Planned Value Analysis figure	A	R	
	Working code in Github repository		A	R
Boundary Detection Testing and Debugging		R	A	
Obstacle Detection Testing and Debugging			R	A
Path Planning Testing and Debugging		A		R
Final Report	**Updated Project Proposal document**		A	R

	Control Charts	R		A
	Results of system testing	A	R	
	Complete Github repository		A	R

R = Responsible, A = Approver