Autonomous Lawnmower

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ECEN 404-904 Team 30

Project Summary

Problem Statement: *"You will start with a lawn mower shell, add motors to propel the wheels, microcontroller to control everything, comms to a wifi network where area to be covered and route will be entered, and a power mechanism (docking station or other)"*

- Use lawn mower body and reconfigure for our needs
  - Electric motors for wheel and blade
  - Solar and grid tied charging
  - Docking station
  - Navigate autonomously using various sensors
  - Receive user information about area to mow and scheduling through app

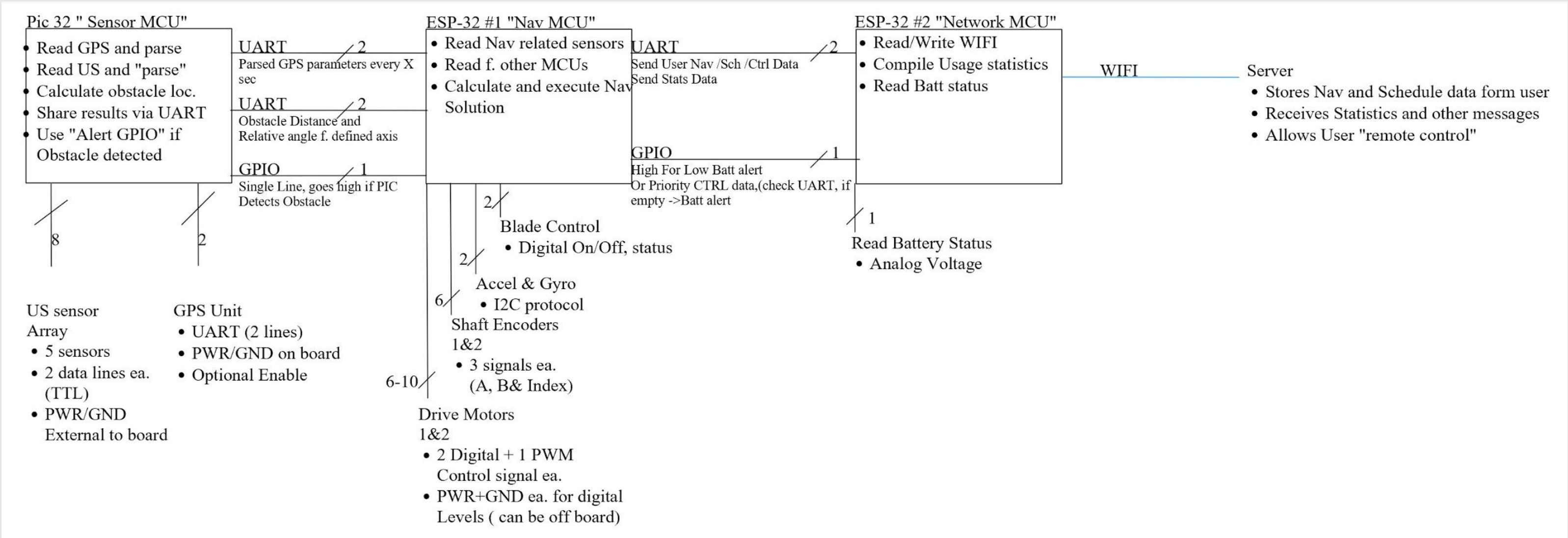
Problems and Solutions

Problems:

- Obstacle detection issues
  - Insufficient sensors
- PCB miss print
  - Damaged IC
  - Insufficient IO lines
- Lost design files
- Low budget

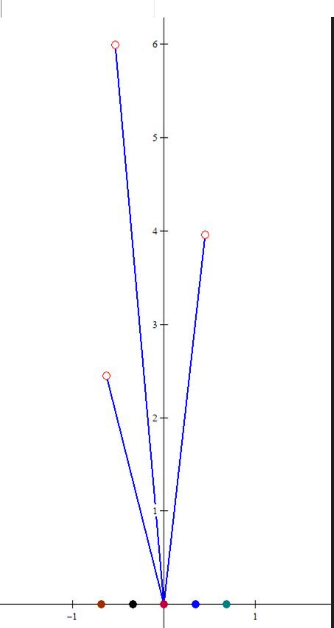
Solutions:

- Multi MCU approach
  - allows multiple team members to develop and test simultaneously
  - removes wait time for PCB respin
  - Includes all needed functionality
- Shifting responsibility
  - Max takes over obstacle detection from sensor subsystem
  - Jonathan takes over WIFI from MCU subsystem
  - Vincent begins disassembling mower body now, so that it’s integration ready when other subsystems are



MCU Subsystem

Quantities	Input Readings	Code output	validation data	difference	% Error
Distance	S1 = 61.2cm	61.18	61.18	0	0
Normal angle	S2 = 61.8cm	-75.6	-75.54	-0.06	0.079428
referance angle		83.349	83.29	0.059	0.070837
Adjacent distance		-15.72	-15.76	0.04	0.253807
Distance	S3 = 99cm	98.961	98.961	0	0
Normal angle	S5 = 100cm	88.414	88.397	0.017	0.019231
referance angle		81.75	81.734	0.016	0.019576
Adjacent distance		2.769	2.769	0	0
Distance	S1 = 150cm	149.95	149.95	0	0
Normal angle	S2=	-84.964	-84.949	-0.015	0.017658
referance angle	S3	78.554	78.539	0.015	0.019099
Adjacent distance	S4	-13.255	-13.255	0	0
	S5 = 153cm				
Distance	S1 = 61.2	98.729	98.729	0	0
Normal angle	S2 = 61.6	80.87	80.855	0.015	0.018552
referance angle	S3 = 100.0	89.29	89.274	0.016	0.017922
Adjacent distance	S4 = 99.0	15.893	15.893	0	0
	S5 = 98.7369				
Output data	**Note: all distances in cm**	**all angles in degrees.**			
Intermediate values	Normal angle is the angle a line drawn from the center of the mower to the obstacle makes with the baseline of the sensor array				
% Error	Reference is that obstacles left of center have a positive angle, and right of center a negtive angle, with 90deg for objects dead center				
	Distance is meassured perpendicular from sensor baseline to object				

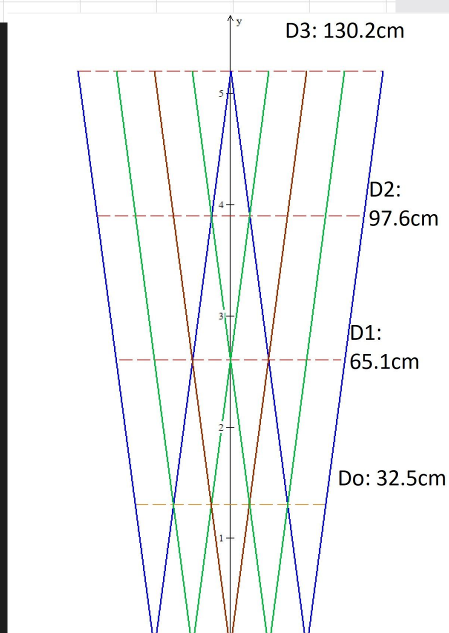


```
Object in region Do:
distance: 61.1835
angle: -75.6016
Dadj: -15.7237
refAngle: 83.3492


Object in region D1:
distance: 98.729
angle: 80.8704
Dadj: 15.8931
refAngle: 89.2904


Object in region D2:
distance: 98.729
angle: 80.8704
Dadj: 15.8931
refAngle: 89.2904


Object in region D3:
distance: 0
angle: 0
Dadj: 0
refAngle: 0
```



Status and Plans

- **Right Now**
  - Sensor array geometry determined
  - Front Facing Obstacle detection code 85% done, some cases tested
  - GPS function working and tested
- **Upcoming**
  - Finish & Implement obstacle detection on PIC-32
    - Detection Grouping
    - Area & point obstacle distinction
    - Transfer to PIC and validation in target
  - Side Facing obstacle detection function
    - easier than front facing, only 2 sensors
    - can reuse most of the code from front facing
  - Read Sensor array function
    - Pseudo code exists, as well as code from last semester
    - Need to integrate additional sensors
  - Clean Up code on PIC

GOAL: Begin integration in 3 weeks (2/24/2021)

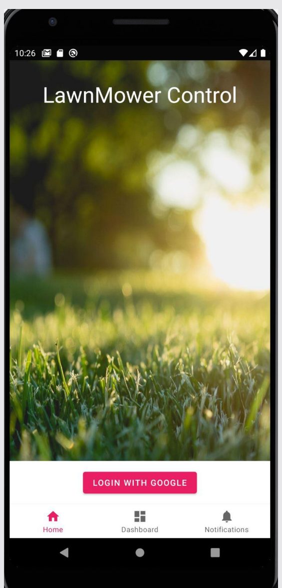
User Interface Update

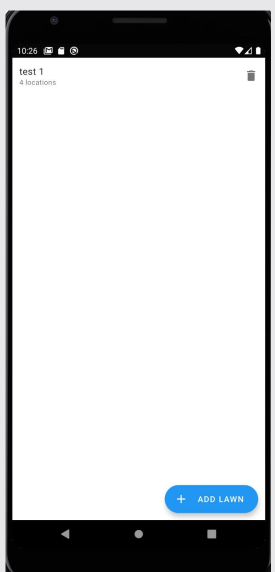
Android Application

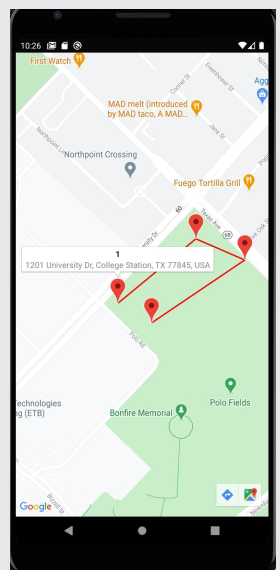
- Coded in Java through android studio
- Updates to server in realtime
- User can login through google account
    - **Access current location**
    - **Set markers for each corner of lawn**
    - **Custom lawns**
    - **Statistics**
    - **Schedule Information**

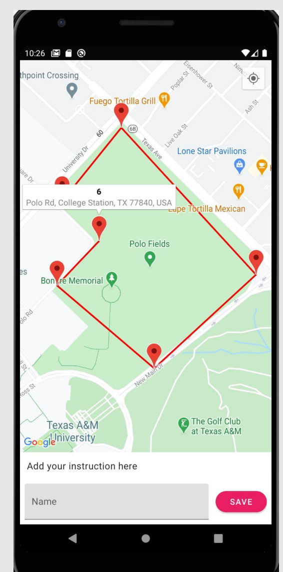
Problems-currently fixing

- Bugs
- Getting statistics and scheduling information to communicate with server









Server Update

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Google Firebase Realtime Database

- Latitude and Longitude from markers placed in app
- Scheduling times
- Statistics from sensors

API Keys

Name	Creation date	Restrictions	Key
Google Map SDK	Nov 21, 2020	None	AIzaSyBsW1...cNXQLJsSV8
Android key (auto created by Firebase)	Nov 21, 2020	None	AIzaSyAHc5...HtLqJpq91c
Browser key (auto created by Firebase)	Nov 21, 2020	None	AIzaSyAnLF...QMmaLOfTTE

OAuth 2.0 Client IDs

Name	Creation date	Type	Client ID
Web client 2	Nov 21, 2020	Web application	287950388755-ap9s...
Android client for lawnmower.app (auto created by Google Service)	Nov 21, 2020	Android	287950388755-ts34...
Web client (auto created by Google Service)	Nov 21, 2020	Web application	287950388755-p4lk...

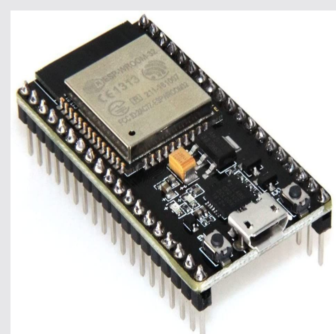
https://lawnmower-android-66b33.firebaseio.com/

- lawnmower-android-66b33
  - cfp1Uk5Vykbdgh44KVlkyFCyE4c2
    - test 1
      - 0
        - latitude: 30.625424945993725
        - longitude: -96.33683413267137
      - 1
        - latitude: 30.626864025619923
        - longitude: -96.33480872958899
      - 2
        - latitude: 30.626391739817688
        - longitude: -96.33353836834432
      - 3
        - latitude: 30.62498871714939
        - longitude: -96.33595872670413
    - test 2
      - 0
        - latitude: 30.626843541677534
        - longitude: -96.34311653673649
      - 1
        - latitude: 30.631599162036323
        - longitude: -96.33817322552204
      - 2
        - latitude: 30.627478541875483
        - longitude: -96.33362386375666
      - 3
        - latitude: 30.625203946705884
        - longitude: -96.33697159588337
      - 4
        - latitude: 30.62576481075448
        - longitude: -96.34019862860443

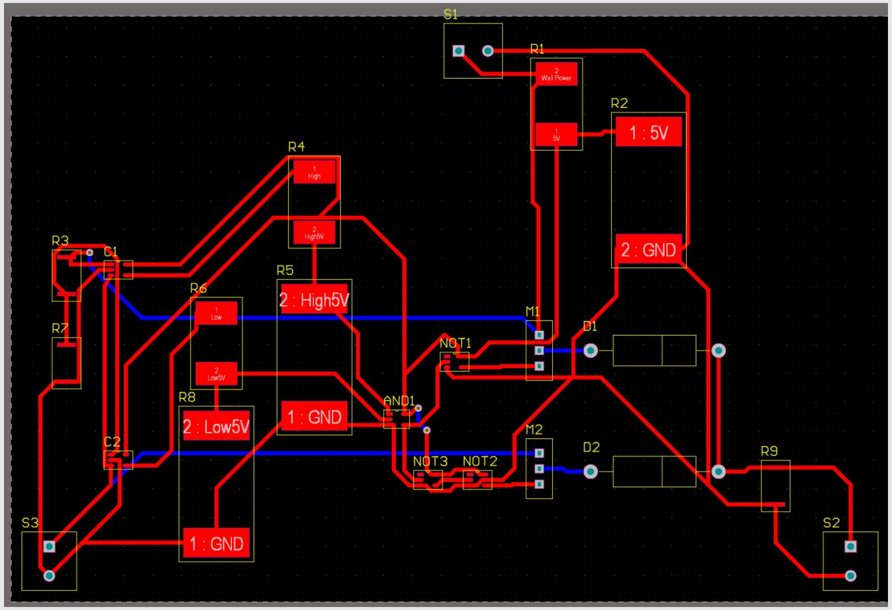
Database location: United States (us-central1)

Connecting Server to MC

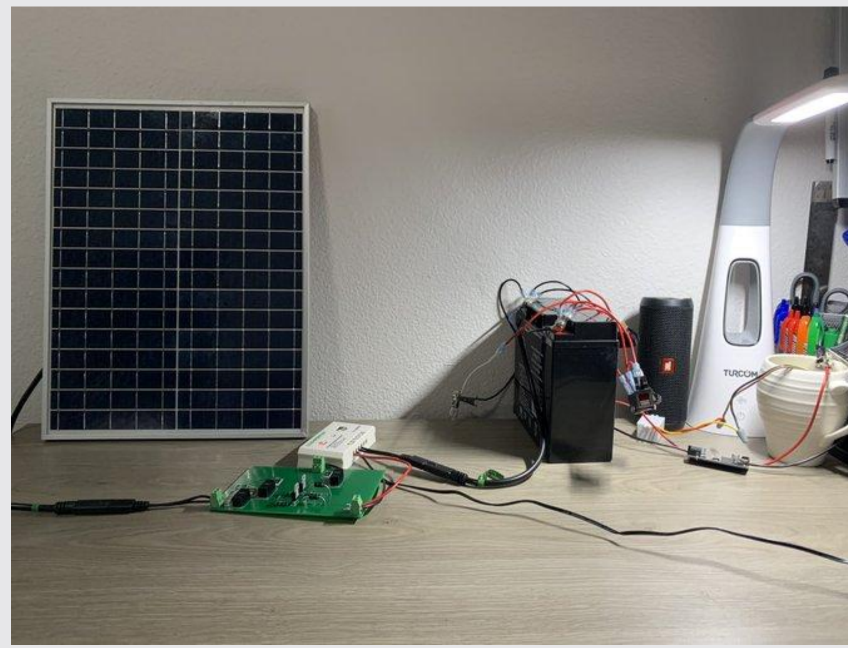
- ESP32
  - WiFi built in-creates own wireless network
  - Just received MC from Max
- Get server to be in same format as input for ESP32
- Will be a priority when bugs and application is fully ready for integration (ET: 1 week)



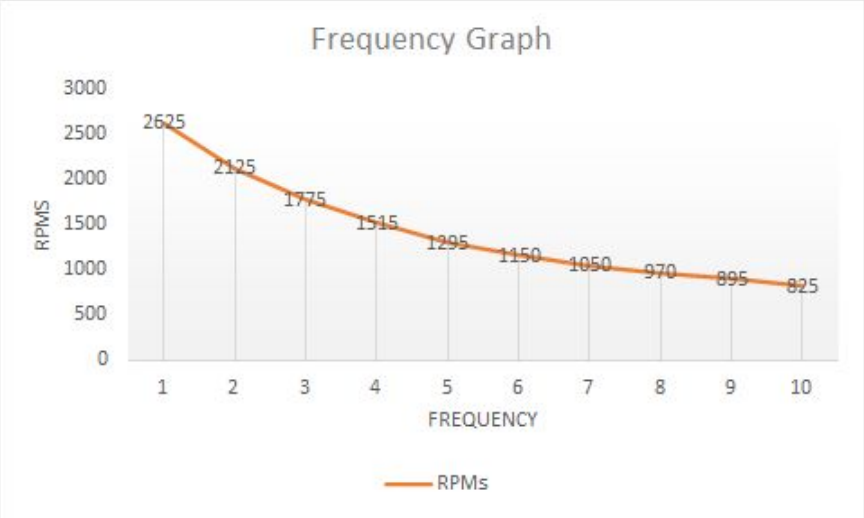
Power Supply Subsystem Status

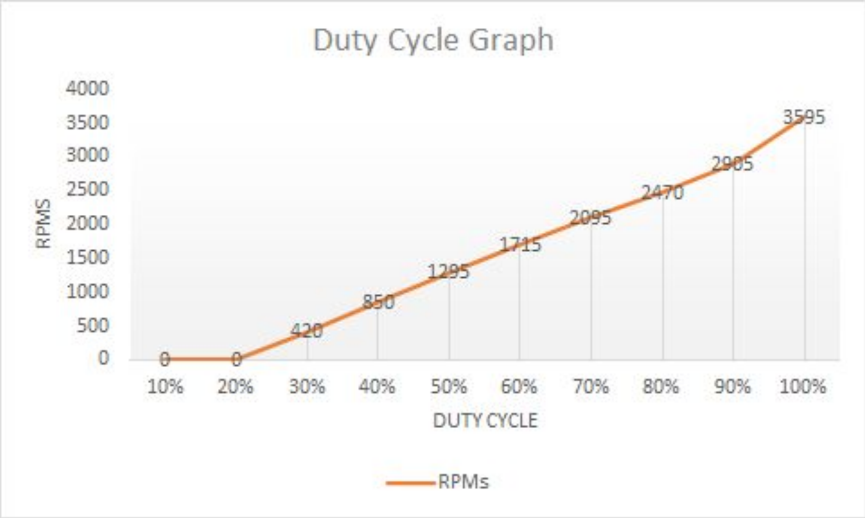


- Used car headlights to simulate the voltages, currents required
- Next Steps
  - Disassemble Lawn Mower
  - Docking Station Assembly



Motors Subsystem Status





IN1	IN2	ENA1	Output	RPM's
0	0	x	Break	N/A
1	1	x	Floating	N/A
1	0	PWM	Forward speed	450
0	1	PWM	Reverse speed	450
1	0	1	Full speed forward	3500
0	1	1	Full speed reverse	3500

The target speed of the mower is 4 mph. Assuming wheels have an 8-inch radius, and assuming weight of the mower affects speed by a factor of 2, the following calculations can be made:

$$\frac{4\,mi \times 2}{1\,hr} \times \frac{1\,hr}{60\,min} \times \frac{5{,}280\,ft}{1\,mi} \times \frac{12\,in}{1\,ft} \times \frac{1\,rev}{2\pi(8)\,in} = 168.07\,rev/min \approx 168\,rev/min$$

- Found relationship between duty cycle and frequency for RPMs using tachometer
- Created control signal table for motor driver
- Created plots for these relationships
- Given a desired speed and wheel size, a RPM was calculated
- This table shows the different inputs to the motor driver that output different motor speeds

Navigation Subsystem Update

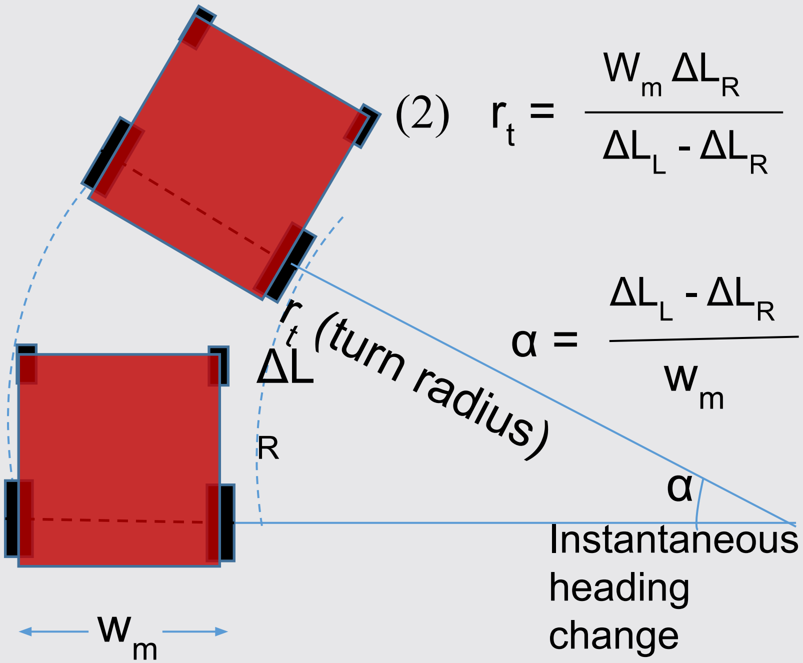
- Original design used GPS module for navigation measurements
- Testing over the holidays revealed that 10-ft GPS “wander” error is not accurate enough for an “unmanned blade on the run”
- New design uses individual left and right wheel shaft encoders as primary measurement
- Some new math was needed to translate the wheel encoder measurements to the correct position and heading of the mower (rigid body constraint)
- A new Matlab simulation movie will be presented here to demonstrate the recent changes

Wheel Encoder Navigation Calculations

Turning is initiated by the controller adjusting the relative speed of the right and left wheel motors

1. Compute delta distance each wheel moved (ΔL_L and ΔL_R) using wheel radius and shaft encoder change
2. Convert distances to turn radius and heading change in mower coordinates (rigid body)
3. Convert turn radius and heading change to {Δx, Δy} (changes in mower coordinates)
4. Convert mower coordinates to ground coordinates (heading rotation)

(1)



(2) $$r_t = \frac{W_m \Delta L_R}{\Delta L_L - \Delta L_R}$$

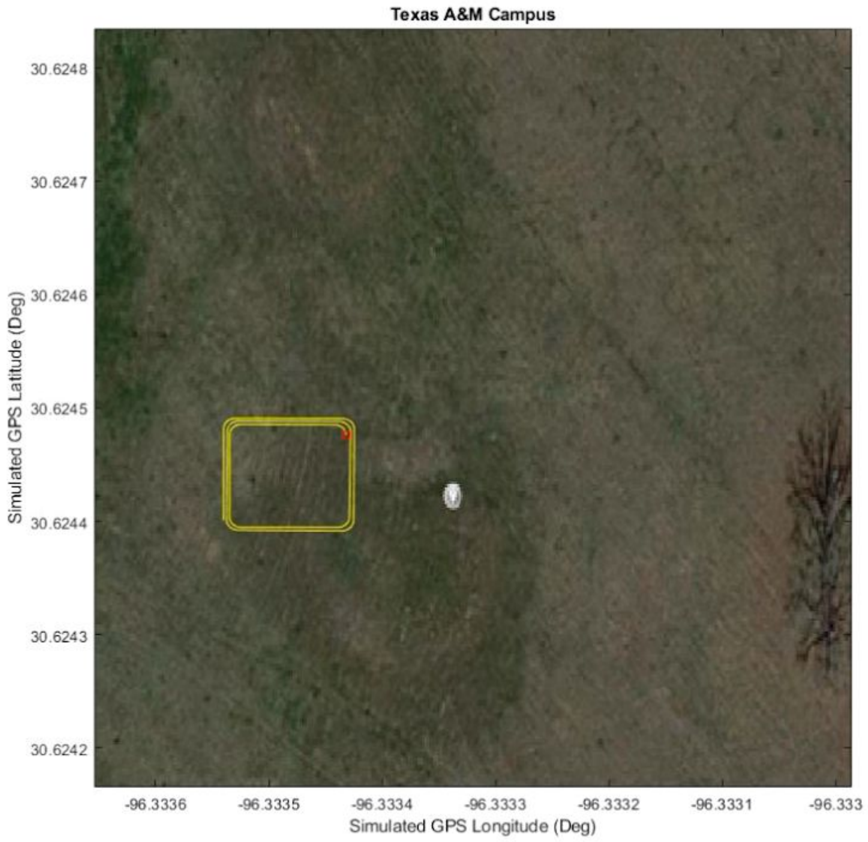
$$\alpha = \frac{\Delta L_L - \Delta L_R}{w_m}$$

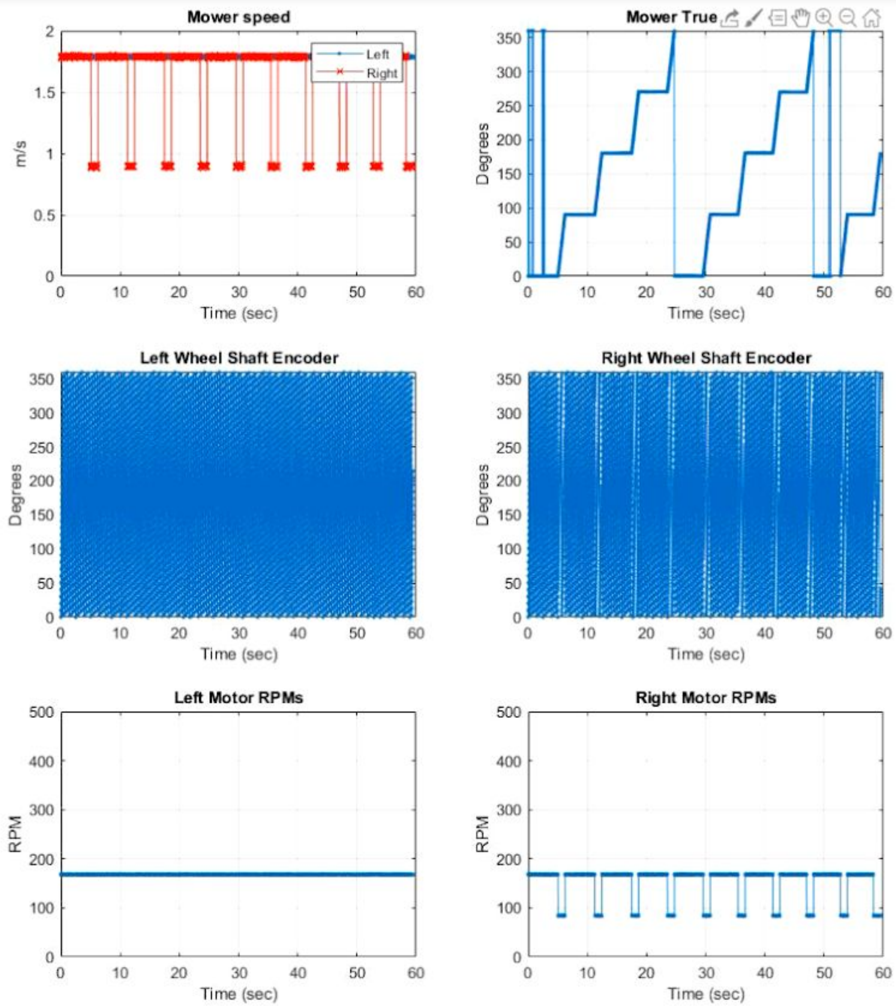
(3)
$$\Delta x = (w_m/2 + r_t)\,(1 - \cos\alpha)$$
$$\Delta y = (w_m/2 + r_t)\,\sin\alpha$$

(4) Rotate mower coordinates into ground coordinates using previous heading

$$\begin{bmatrix} x_g \\ y_g \end{bmatrix} = \begin{bmatrix} +\cos h & \sin h \\ -\sin h & \cos h \end{bmatrix} \begin{bmatrix} x_m \\ y_m \end{bmatrix}$$

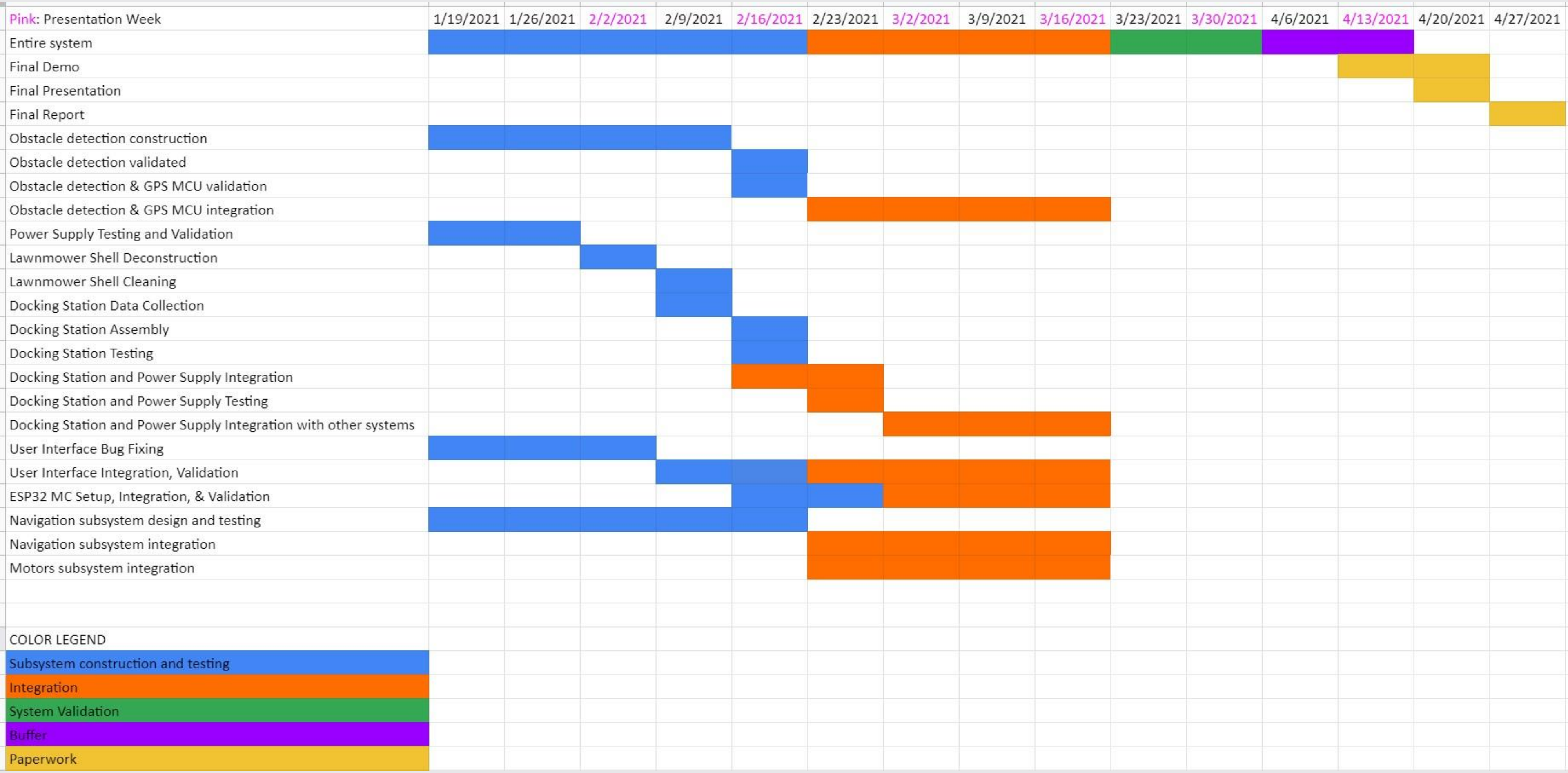
Simulation Updates Using Navigation Updates





Next step: Convert Simulation code to C for MCU to test on lawnmower

Schedule for the Semester



Validation Plan

Requirement title and heading, as found in the FSR	Abridged text of requirement (see FSR for full text)	Status
3.2.1 Functional/Performance requirements	Performance requirements for the compelates system	
3.2.1.1 Operational Stamina	The system shall mow grass continuously for no less than 1 hour in flat, obstacle free terrain	
3.2.1.2 Duty cycle	The system shall perform operations at least every 7 days.	
3.2.1.3 Obstacle Avoidance	The system shall avoid all obstacles that are harmful to the overall system, running over small obstacles that only impact blade sharpness or appearance is acceptable	
3.2.1.4 Navigation	The system shall use internal sensors to follow a spiral pattern within the boundaries outlined by the user	
3.2.1.5 Obstacle detection Range and Threshold	The system shall be aware of any obstacle in the hypothetical box extending forward from the front of the mower to 2M, as wide as the widest point of the mower	
3.2.2 Physical characteristics	Physical Requirements on the completed system	
3.2.2.1 Mass	The mowing unit shall not exceed a maximum weight of 70lbs	
3.2.2.2 Volume Envelope	The volume envelope of the Lawnmower shall be less than or equal to 30 inches in height, 25 inches in width, and 40 inches in length.	
3.2.2.3 Mounting	All components shall be mounted in a fashion to resist vibration incidental to lawnmowing, with service once every 6 months when used weekly	
3.2.3 Electrical Characteristics	Definitions of expected external inputs and outputs	
3.2.3.1 Inputs	The system shall not be damaged by any possible inputs or signals produced by the system, No user input shall result in the system engaging in unsafe or damaging operations	
3.2.3.1.1 Power Consumption	The power consumption of the lawnmower unit shall not exceed 200 Watts.	
3.2.3.1.2 Input Voltage Level	The input voltage level for the Lawnmower shall be 14.2 VDC to 14.4 VDC.	
3.2.3.1.3 External Commands	The Lawnmower system shall receive external commands from the User Interface via a WIFI connection. Details will be outlined in the ICD.	
3.2.3.2.1 Data Output	The mowing unit shall inform the user of problems and fault conditions through the UI app via WIFI.	
3.2.3.2.2 Diagnostic Output	The MCU shall include a hardware debugging port that may be interfaced to a computer for Diagnostics.	
3.2.3.3 Connectors	(Electrical) Connectors shall be resistant to vibration incidental in lawnmowing, with service no more than once per 6 months when used weekly	
3.2.3.4 Wiring	The wiring for signal and power interfaces shall be routed clear of any moving internal parts, and clear of all possible outside interference. And protected as appropriate	
3.2.4 Environmental Requirements	The Lawn mowing system shall operate in all environmental conditions that traditional residential lawn mowers operate and lawn care activities take place.	
3.2.4.1 Thermal	The Lawnmower shall operate in temperatures ranging from 40°F to 120°F.	
3.2.4.2 External Contamination	The Lawn mower shall be immune to dust and debris. The Lawn mower systems shall either be protected from, or insensitive to ingress of debriess 1mm or larger, as well as d	
3.2.4.3 Rain and extreme weather	The Lawn mower shall not operate in rain. It shall be able to withstand exposure to the elements when parked in the docking station.	
3.2.4.4 Humidity	The Lawnmower shall function temporarily in conditions of up to 100% humidity, but requires lower humidity or higher maintenance for long term storage and performance.	
3.2.4.5 Soil Moisture	The Lawn mower shall be able to operate on moist, but not wet solid, on level terrain.	
3.2.4.6 Distance from Router (WIFI connection dista	The Lawnmower shall be able to communicate with the network at the operating site from at least 100ft and through at least 1 wall of wood/drywall construction	
3.2.4.7 Sky clearance	The Lawnmower shall be able to operate with light to medium foliage overhead	
3.2.4.8 Vibration	The Lawnmower system shall operate without failure, under vibration incidental to lawn mowing for at least 6 months, when operated once weekly for 1 hour.	
3.2.5 Failure Propagation and protocols	No failure shall cause to mower to endanger bystanders	
3.2.5.1 Blade error	The lawnmower's user interface will notify the user if the blade is stuck on an obstacle. In this case the blade will shut down automatically	
3.2.5.2 Mower stuck	If the mower becomes stuck in terrain it shall power down, disabling the blade and alert the user.	
3.2.5.3 Lost Wifi connection	In cases where the WIFI connection to the user device is lost the mower will continue on its planned route and return to the rest position.	
3.2.5.4 Lost GPS connection	If the mower loses GPS connection it shall attempt to follow the planned route to the best ability.	
3.2.5.5 System Failure	In cases of system failure the mower shall alert the user through the UI, disable the main blade and return to the start position, if possible	
3.2.5.6 Critical System Failure	In Critical Failure cases, that is situations in which the MCU loses all ability to control the mower or it's subsystems the lawnmower blade will shut off.	

Legend	
Not Yet Validated	
Falied	
Passed	
Revised/adjusted	