ENGINEERING
TEXAS A&M UNIVERSITY

Autonomous Lawnmower

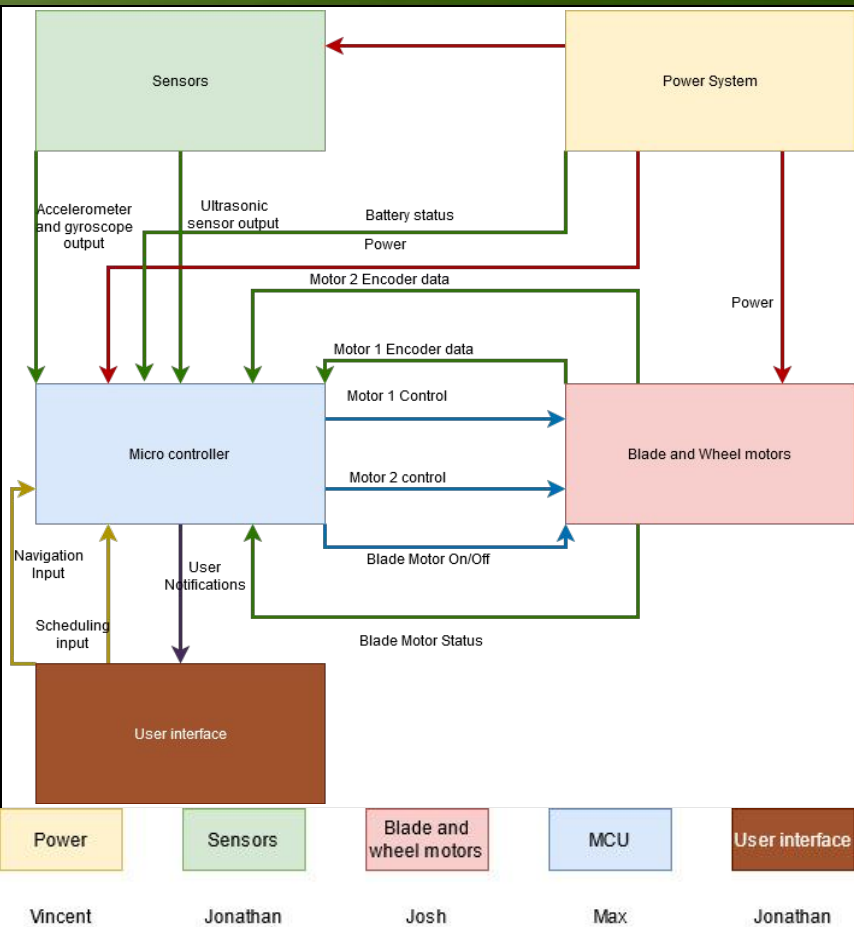
Max Lesser, Vincent McMasters,
Josh Samaniego, Jonathan Poulose
ECEN 404-904 Team 30

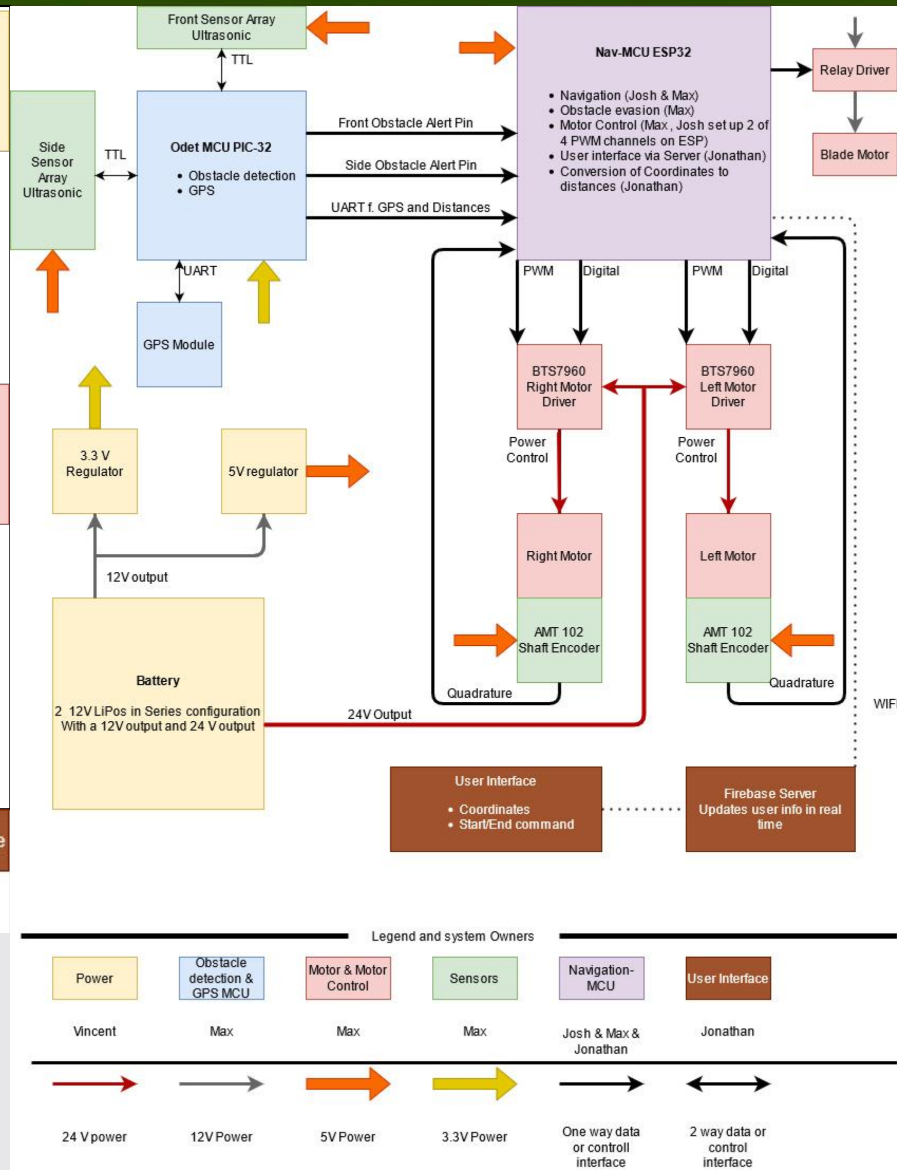
Project Summary

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)” -- Prof Kalafatis*

- 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

Sponsor/Subsystem Block Diagram





System Diagram at the start of 403 (left)
System Diagram as built (right)

Honest Self Assessment

Where we are now, and where we need to get by Demo time

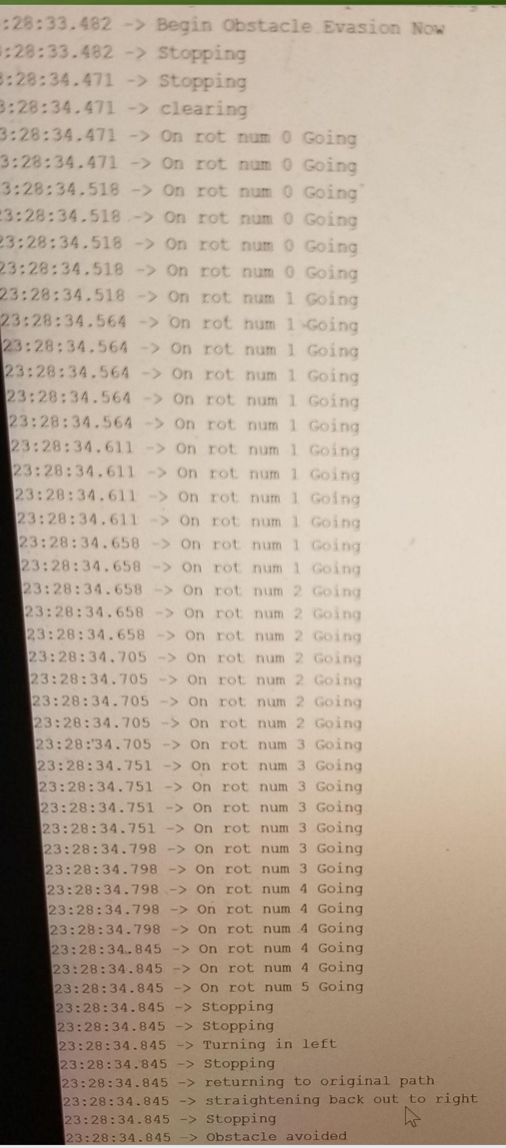
- We rebuilt the entire Motor and Nav subsystem in the last 2 weeks
  - New Motors
  - New H-bridges
  - New Code
  - New Power supply (needed for new motors)
  - Associated wiring and mounting hardware
  - Needs turing function fine tuned
  - Needs one more shaft bushing “Manufactured”
- Obstacle evasion code is ready once we can turn accurately
  - has been tested on the mower, but can’t validate until navigation works
- Obstacle detection is ready for testing
  - has been tested on mower, detects obstacles
- App is ready for testing with mower
- We may not be where we need to be, but I’ve worked tirelessly to get us here and I’m really proud of what I Accomplished over the last 2 weeks

It’ll be a long 6 days, but we’re now in a position to complete a viable project in time for demo

Obstacle Detection / GPS Subsystem

- Ultrasonic sensor array for the front determines Distance to obstacle and side of mower on which obstacle is located
  - Previous code calculated angle to obstacle, but sensor are not accurate enough for this to be useful
  - Sets an alert pin to notify Nav-MCU of obstacle within certain range
  - Transmits distance and approximate location via UART
- Ultrasonic array on the side of the mower determines if there is an obstacle on the side
  - Alert pin informs Nav-MCU of obstacle on the side and lets mower know when it’s safe to return to original path during obstacle evasion (see navigation slide)
- Reads Mowers GPS position
  - parses NEMA sentence
  - Sends relevant information to Nav-MCU via serial
- Tested on mower with Nav code, alerts the mower, and nav code takes evasive action. Not fully tested due to maneuvering difficulties (see nav slide)
- I have not been able to do much work on this system over the past month as I’ve been working on general integration and the motor and navigation subsystems

Obstacle Detection /Evasion Subsystem

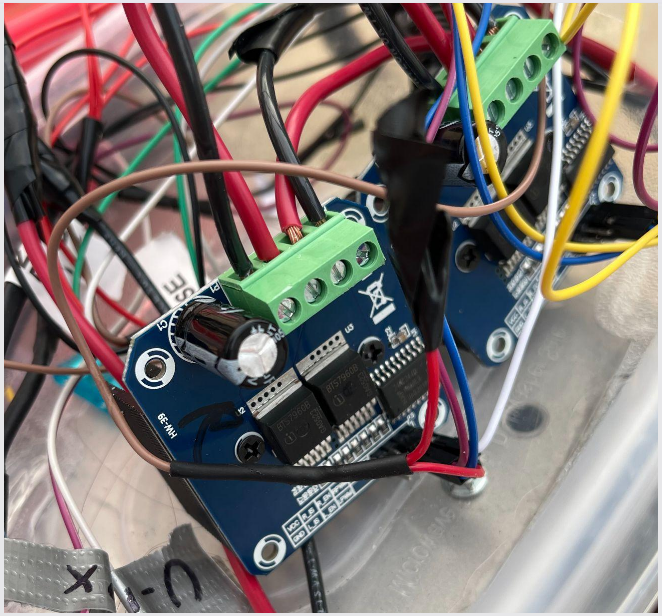


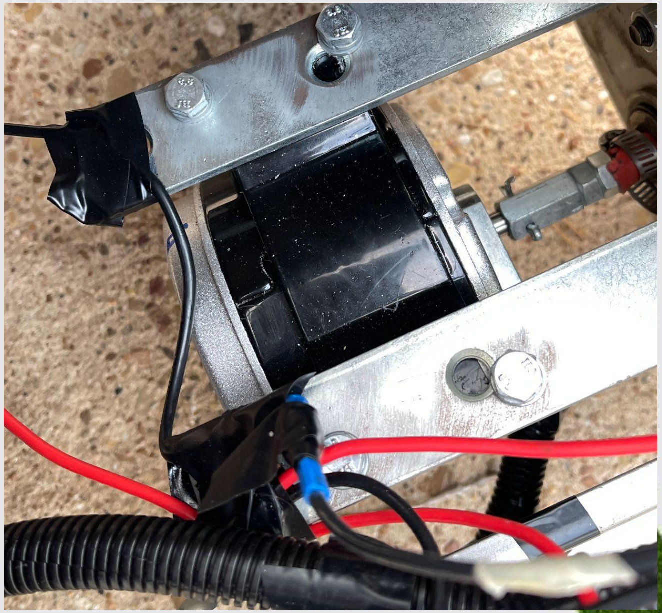
Obstacle Evasion

- Front array detects obstacle and alerts mower via alert pin
- Mower Stops
- Turns out of path until obstacle is no longer in sight of front array
- goes forward until it has cleared the obstacle
- straightened out on a path parallel to original path
- IF there is on object to the side, determined by side array, it moves forward until that object is cleared. afterwards/ otherwise it turns back into the original path
- and then straightens back out to be pointed in the same direction as it was when it first encountered the obstacle, to resume mowing
- Left code output was ran on mower, with PIC and ESP for simulated obstacle. Wheel movement was validated, and the mower took expected action. Ready for full test.

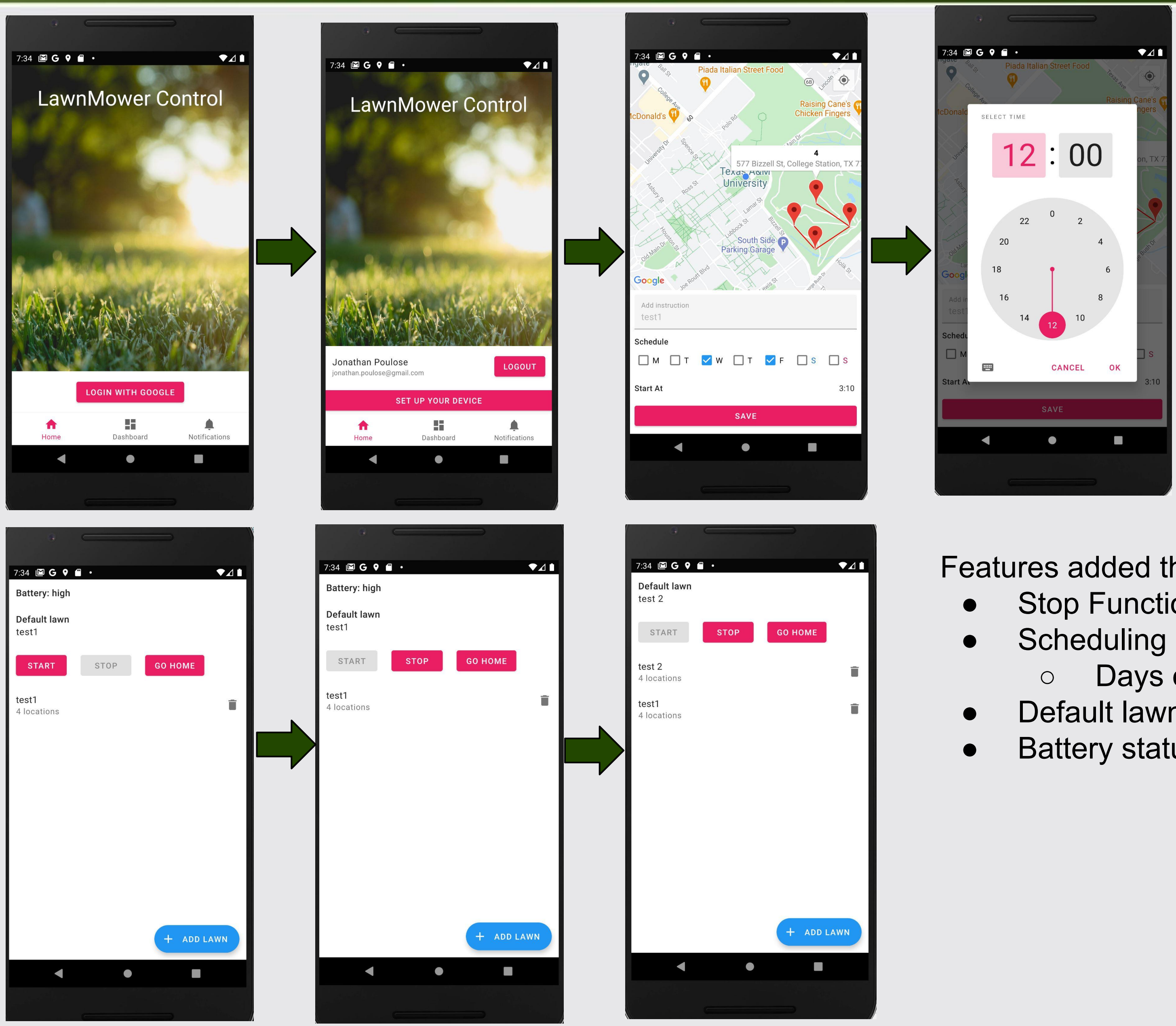
Motors Subsystem

- Old motors were connected and wired, but turned out to have insufficient torque
- upgraded to 250 W motors that allow us to drive and turn
- This entailed all new mounting hardware, wiring, control hardware and logic
- Needed special shaft coupling (bottom) and special “Shaft Bushing” (coming up)
- Motor and blade mount for blade drive, relay driver





User Interface Subsystem

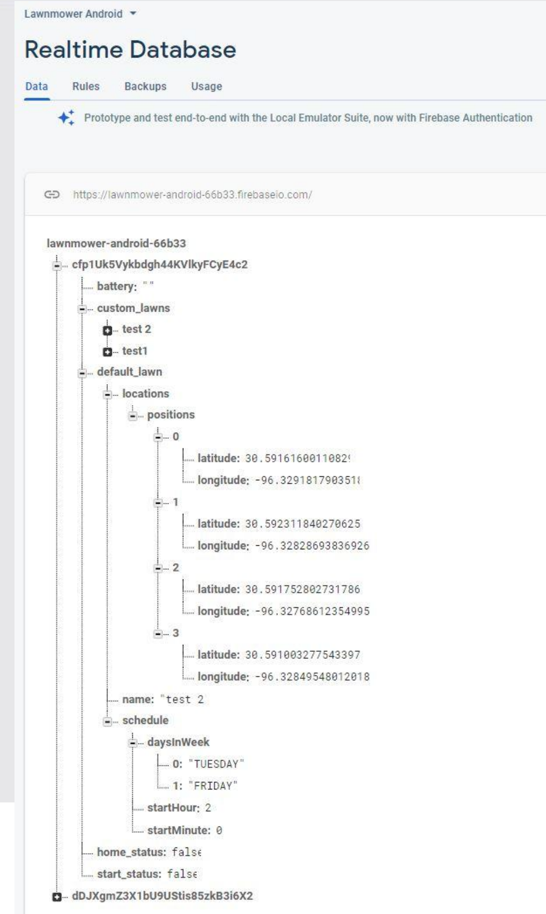


Features added this semester:

- Stop Function
- Scheduling ability
  - Days of the week/time
- Default lawn
- Battery status

Server/WiFi Subsystem

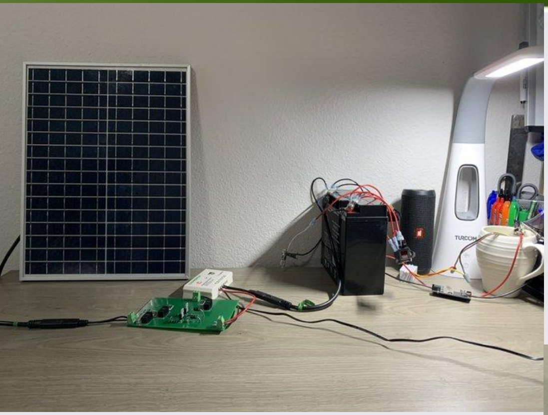
- WiFi MCU
  - Connects ESP32 to WiFi and checks Firebase
  - Gets start status/coordinates, sends battery information
- Combined WiFi MCU & Navigation MCU into one
  - Fixed restarting issue with Nav MCU
- Code added to combined .ino file
  - Calculate distances from the coordinates
  - Implemented start_status from server (start and stop) to old navigation code



Navigation Subsystem

- Due to my initial code having timing issues, Max helped program NAV code to have a functional mower
- This code utilizes the shaft encoders
- It also validates software control of variable PWM on both motors to go straight and turn
- The code can currently navigate the mower to go in a shrinking rectangle pattern until it reaches the middle, then stops
- Obstacle detection has been integrated but not tested, but we will test this for demo
- Turning accuracy needs improved

Docking Station/Power Supply Subsystem



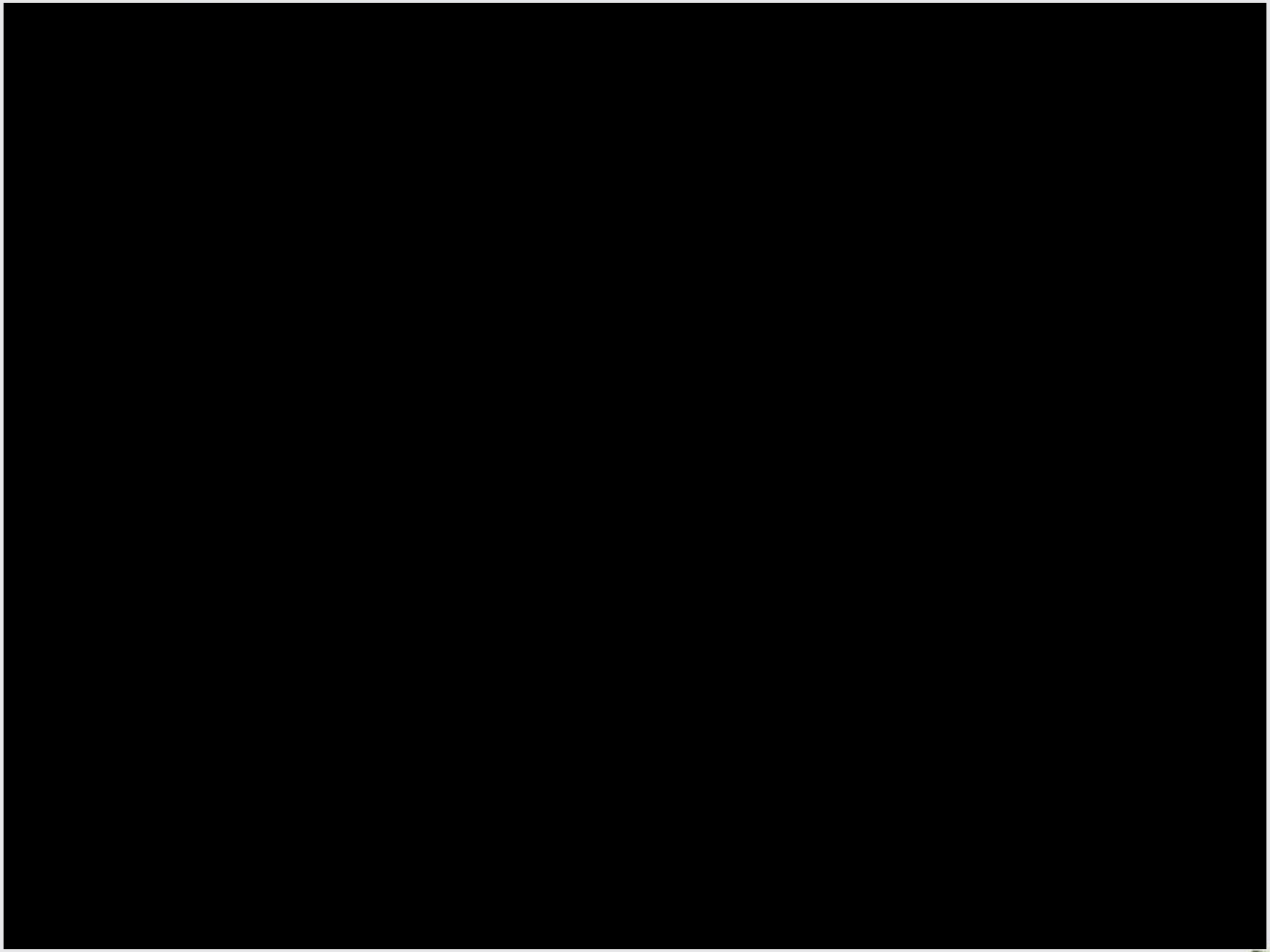
- Had to use different solar panel and charge controller than original planned with high power
- Parts mounted in box with holes for wiring
  - box protects electrical components from the elements

Mechanical Frustrations

Mechanical Challenges

- Stripping old mower
- Motor Mounts
  - old drive motors
  - new drive motors
  - blade motor
- Shaft coupler
- Shaft bushings (see left)
- Wheel adapters (Bottom right)
- Blade Mount and motor (Bottom Center)
- Front Mecanum Wheels

Video



Validation Plan

ENGINEERING
TEXAS A&M UNIVERSITY

Requirement title and heading, as found in the FSR	Abridged text of requirement (see FSR for full text)	Methodology	Status	Responsible team member	Validated By
3.2.1 Functional/Performance requirements	Performance requirements for the completed system				
3.2.2.1 Operational Stamina	The system shall mow grass continuously for no less than 1 hour in flat, obstacle free terrain	Time operation of system under normal conditions		All	
3.2.1.2 Duty cycle	The system shall perform operations at least every 7 days.	Validate Solar/grid charging rate against power consumption in above test		All	V. McMasters
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	Individual evaluation of obstacle detection and navigation function under realistic input. Full system validation in Realistic terrain		J. Samaniego & M. Lesser	
3.2.1.4 Navigation	The system shall use internal sensors to follow a spiral pattern within the boundaries outlined by the user	Simulation of Nav-code, Full system test under realistic conditions		J. Samaniego	
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	Individual test of Obstacle detection function, in final configuration		M. Lesser	
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	Weigh final system		All	M. Lesser
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.	Measure final system		All	M. Lesser
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	Test connection manually, not able to perform full test, will have to extrapolate results gained from other tests		All	M. Lesser
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	Provide mower with all possible input signals and observe performance		All	
3.2.3.1.1 Power Consumption	The power consumption of the lawnmower unit shall not exceed 200 Watts.	Measure battery discharge level after use		V. McMasters	
3.2.3.1.2 Input Voltage Level	The input voltage level for the Lawnmower shall be 14.2 VDC to 14.4 VDC.	Measure input voltage to battery from charging station		V. McMasters	
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.	Attempt to transmit Nav/Schedule commands from app and see if mower responds		J. Poulose	J. Poulose
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.	Generate Fault conditions on mower and see if reports to user		J. Poulose	
3.2.3.2.2 Diagnostic Output	The MCU shall include a hardware debugging port that may be interfaced to a computer for Diagnostics.	Physical validation of hardware access ports		M. Lesser	M. Lesser
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	Extrapolate from other physical trials		All	
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	Visual inspection of completed system		All	

Legend	
Not Yet Validated	
Falied	
Passed	
Data Being Recorded	

Validation Plan

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.	Test in as many environmental conditions as possible and extrapolate			
3.2.4.1 Thermal	The Lawnmower shall operate in temperatures ranging from 40°F to 120°F.	see 3.2.4		All	
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 dust.	see 3.2.4		All	
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.	see 3.2.4		All	
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.	see 3.2.4		All	
3.2.4.5 Soil Moisture	The Lawn mower shall be able to operate on moist, but not wet solid, on level terrain.	see 3.2.4		All	
3.2.4.6 Distance from Router (WIFI connection distance)	The Lawnmower shall be able to communicate with the network at the operating site from at least 100 ft and through at least 1 wall of wood/drywall construction	see if mower responds when specified distance from WIFI router		J. Poulose	
3.2.4.7 Sky clearance	The Lawnmower shall be able to operate with light to medium foliage overhead	test GPS unit in mounting configuration under specified overhead cover		M. Lesser	
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.	see 3.2.4		All	
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	Simulate stuck blade and validate mower sends error message and disabled blade drive		J. Samaniego & J. Poulose	
3.2.5.2 Mower stuck	If the mower becomes stuck in terrain it shall power down, disabling the blade and alert the user.	simulate/force mower to become stuck and monitor response		J. Samaniego & J. Poulose	
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.	disable WIFI router and monitor response		All	J. Poulose
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.	disable GPS module and monitor response		M. Lesser & J. Samaniego	
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	Simulate system failure, (f.e. by disconnecting sensors O.S.) and monitor response		All	
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.	Power down MCU during operation and monitor response		All	M. Lesser

Legend	
Not Yet Validated	
Falied	
Passed	
Data Being Recorded	

Gaps and Learning Hard Skills

- C/C++, Java coding skills
- PCB design in Altium
- Microcontroller programing
- Android Application design
- Online Database integration
- WiFi setup through Arduino
- Power Regulation
- Mechanical Integration and "Design"
- Motor Control and operation
- Wiring/Soldering

Gaps and Learning Soft Skills

- Part Selection
  - both online suppliers and local stores
- Creative Problem Solving
- Learning to trust intuition
  - Don’t be afraid to take the route that’s more work, cause you’ll end up doing it anyway
- Don’t make assumptions
- Improvisation
- Don’t be afraid to use third party input