ENGINEERING
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Autonomous Lawnmower

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ECEN 404-904 Team 30

Project Overview

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)" -*

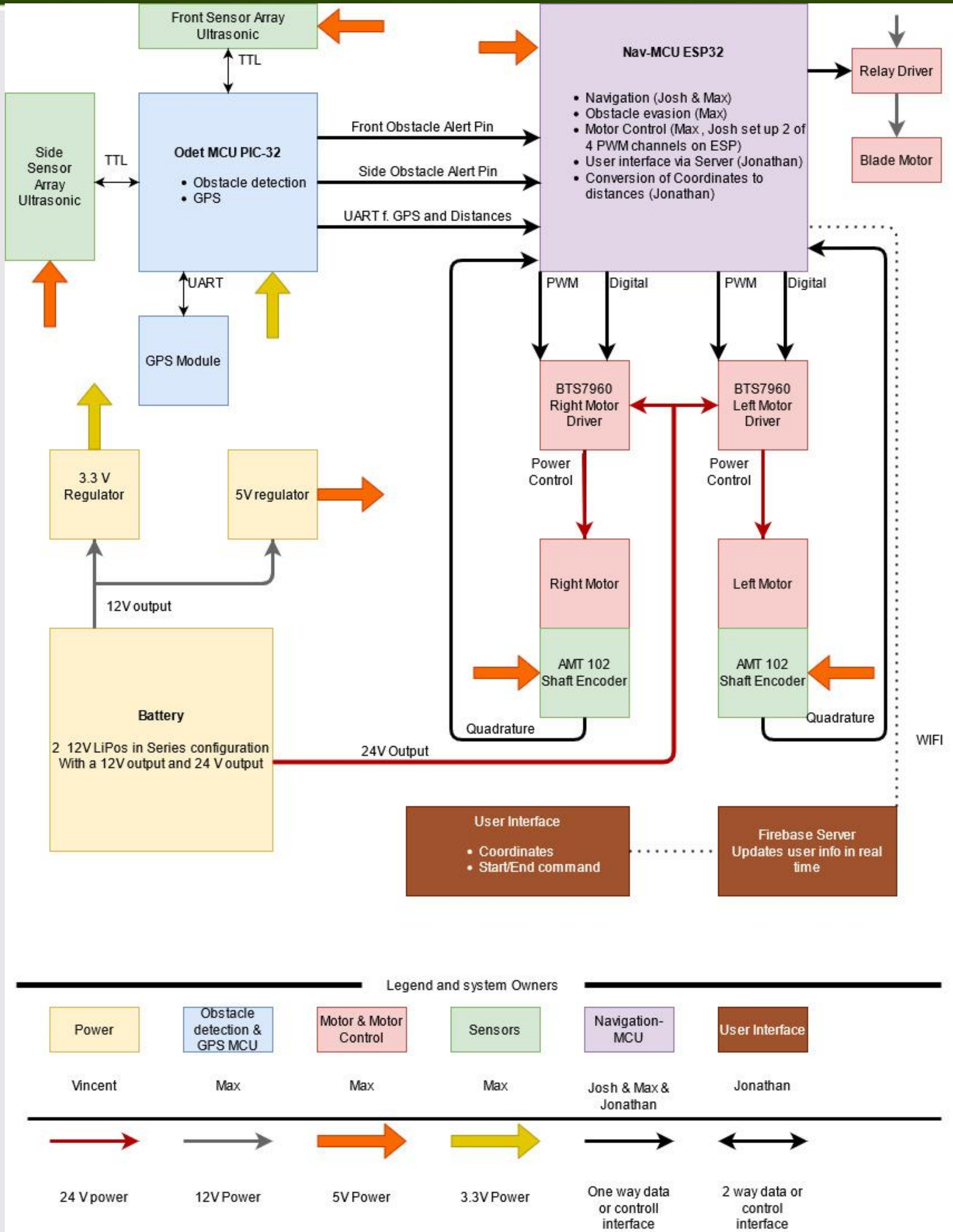
Sponsored by Prof Kalafatis

Solution approach : "We took a used lawn mower, stripped it of all its original parts, mounted motors, wheels, controllers, and sensors. We encountered many mechanical problems and had to rebuild large parts of the project in very short time, so sadly we did not get as far as we had hoped"

Subsystem Block Diagram

Subsystems:

- Power:
  - Provide Power to drive and blade motors
  - 3.3V & 5V power for sensors and microcontrollers
- User Interface
  - Accept Coordinates from user
  - Accept schedule information from user
  - Report Mower parameters to user
  - Allow user to start and stop through App
- Obstacle detection
  - Detect and alert mower to obstacles
- Navigation
  - Read Obstacle and user input
  - control drive and blade motors
  - read shaft encoders
- Motors
  - Drive and blade motors and control hardware
  - shaft encoder hardware
  - general mounting and mechanical work

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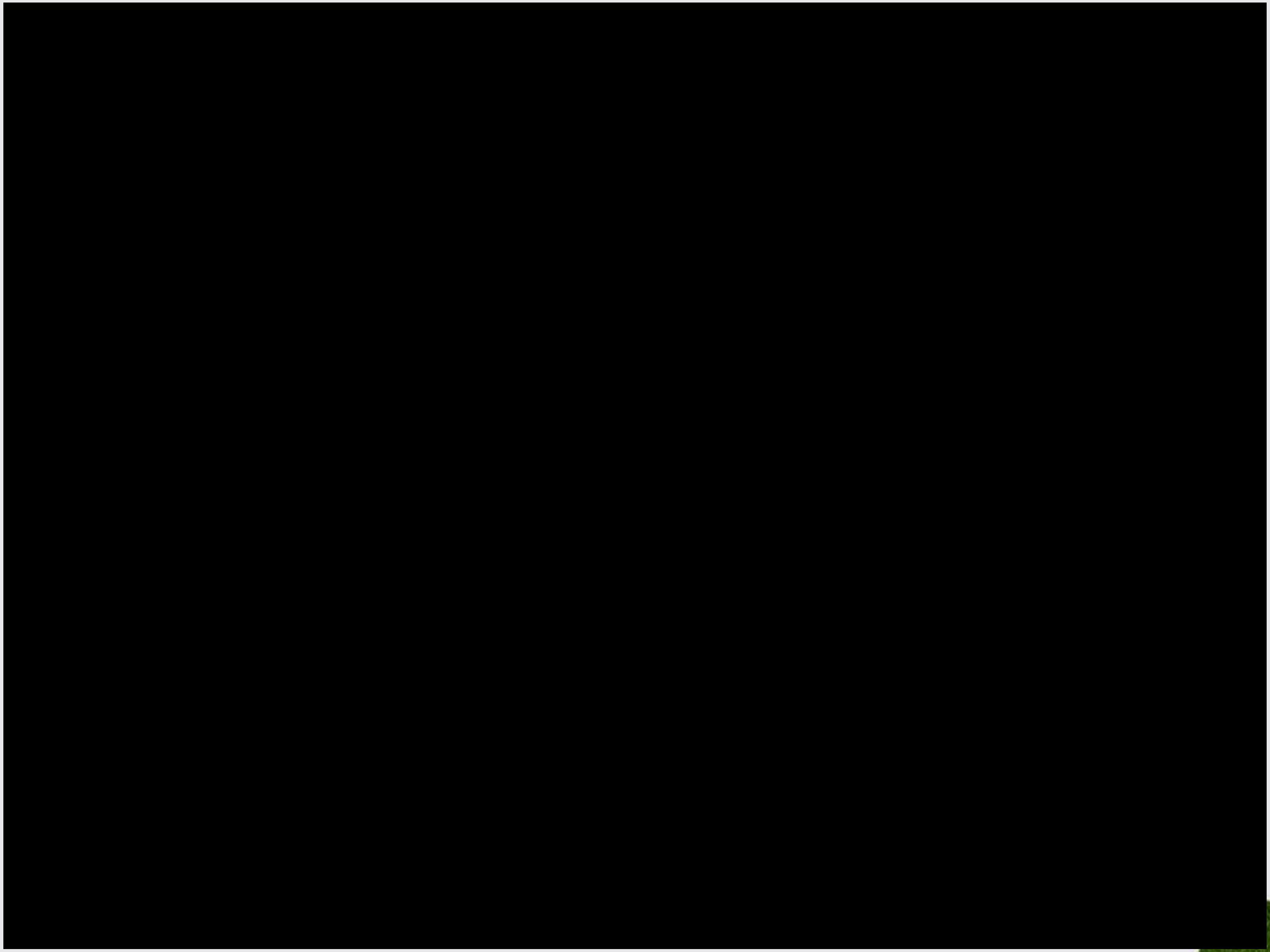

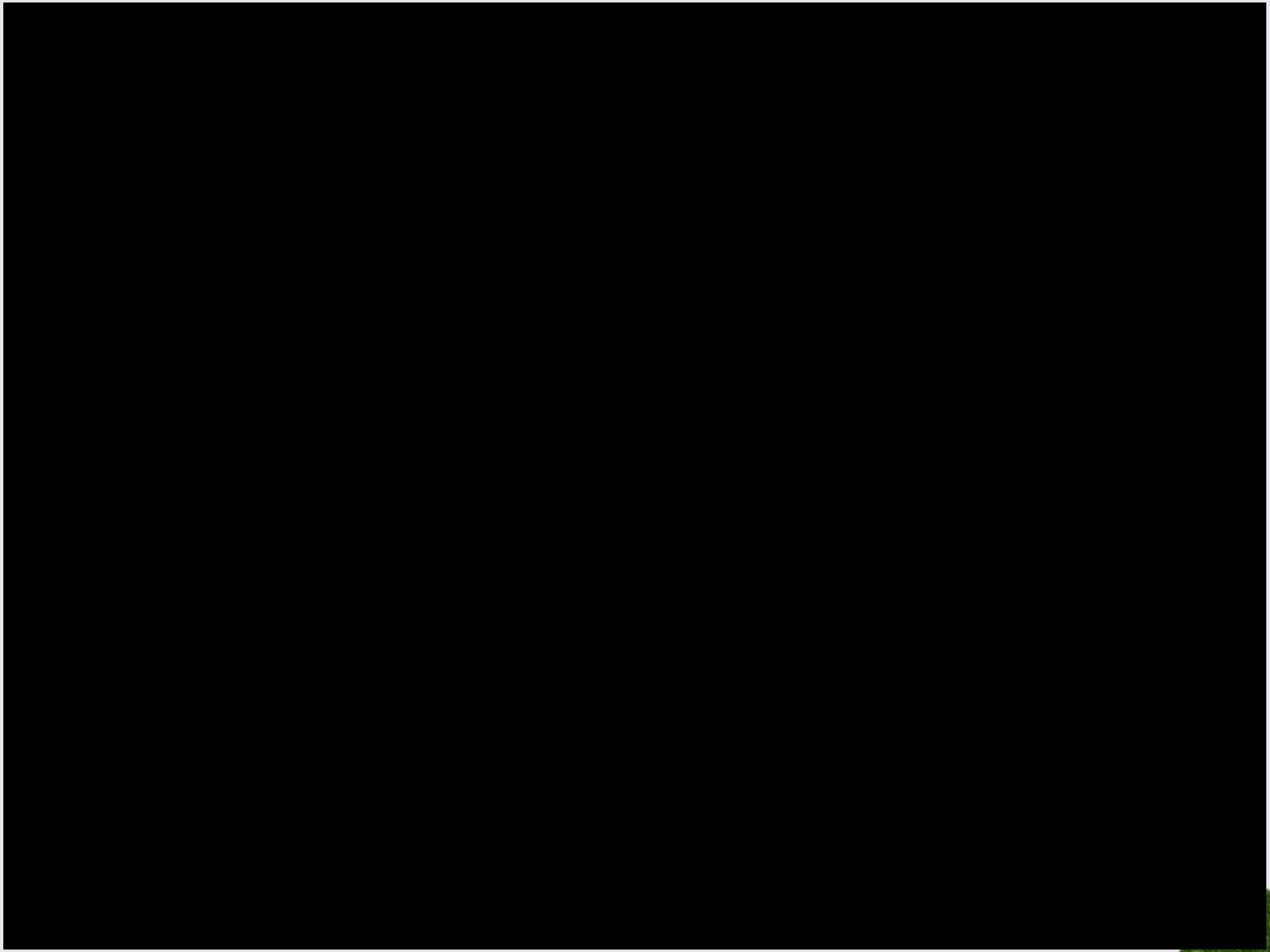

Validation Plan

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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	Comment
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	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	M. Lesser	
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	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	All	
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	V. McMasters M. Lesser	Sensor array validated to 3M on bench test, after operating on the for 2 weeks we experienced sensor failure on 2, and the maximum distance for any reading was ~ 90 cm
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	V. McMasters J. Samaniego	
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	V. McMasters J. Samaniego	
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	Given 2 weeks of testing, we expect with the system to operate for 6 months without any major maintenance.
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	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	V. McMasters	Changes to motors required a larger battery.
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	V. McMasters J. Samaniego	
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		All		ESP sends theoretical battery information to the server and phone application
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	V. McMasters J. Samaniego	Given 2 weeks of testing, we expect electrical connections to last for 6 months.
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	V. McMasters J. Samaniego	

Legend	
Not Yet Validated	
Falied	
Passed	
Data Being Recorded	
Modified/Conditional	

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	V. McMasters	Temperature Range Tested: 54°F-66°F and 72°F-82°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 dust.	see 3.2.4		All	V. McMasters	Unable to fully test, from operational tests system appears to sufficiently protected
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	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	V. McMasters	Humidity Range Tested: 41%-44%, 56%-71%
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		Unable to test on grass, due to motor/weight problems
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	J. Poulose	Was tested from within Max's apartment, which is approximately 100ft
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	M. Lesser	Mowing unit can operate without GPS
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	V. McMasters M. Lesser	Given 2 weeks of testing, we expect hardware connections to last for 6 months.
3.2.5 Failure Propagation and protocols	No failure shall cause to mower to endanger bystanders					
3.2.5.1 Blade error	The lawnmower 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		Jonathan Poulose	J. Poulose	Mowing unit can operate without WiFi
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	All	Mowing unit can operate without GPS
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	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	Mower shuts off all signals when MCU loses power

Legend	
Not Yet Validated	
Falied	
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Issues and problems

- Late Changes to Motors
- Late changes to Power system requirements
- Late changes to Navigation system
- Hardware failure for sensors on Circuit boards
- Mechanical complications with mounting

Lessons learned

- Test early, test often
- don’t have faith, validate
- ask for help
- Express clear expectations, and measure progress against them.
- Changing Canoes in the middle of a river is bad, but if you have to, do it before you take on too much water.

Conclusion

Our project came slightly short of the finish line, as we had to address a lot of issues at the very end. Given just marginally more time we believe we could have pulled it all together.

Nonetheless, we all learned a lot. And we're proud of the progress we've made.