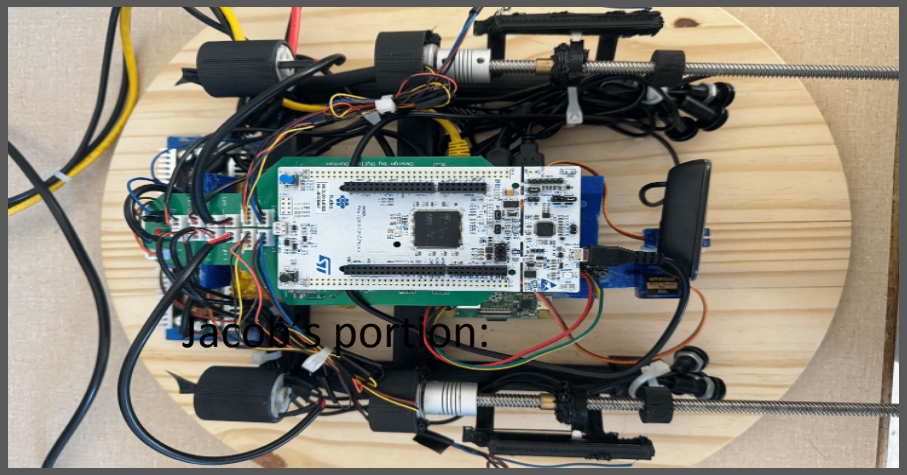
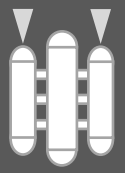
Submersible Drone for Hull Inspections



Dyllon Dunton (CE/EE)
Jacob Wildes (CE)
University of Maine Orono
Senior Project Final Presentation

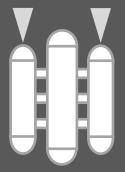
Contents



Introduction

What is the Submersible Drone? Why did we build it?

- Custom motor driving circuit
- Custom power supplies
- Custom operating software
- Lackluster commercially available options
- Options are expensive
- Jacob really likes water and boats



Commercially Available Options:

- Deep Trekker ROV (Starts at ~$12k)
- PowerVision ROV (~$1k)
- FFISH ROV (~$3k)

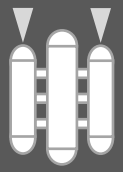
Deep Trekker ROV (courtesy of Deep Trekker)

PowerVision ROV (courtesy of Amazon)

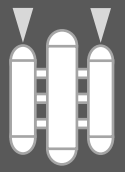
FFISH ROV (courtesy of Amazon)

Contract

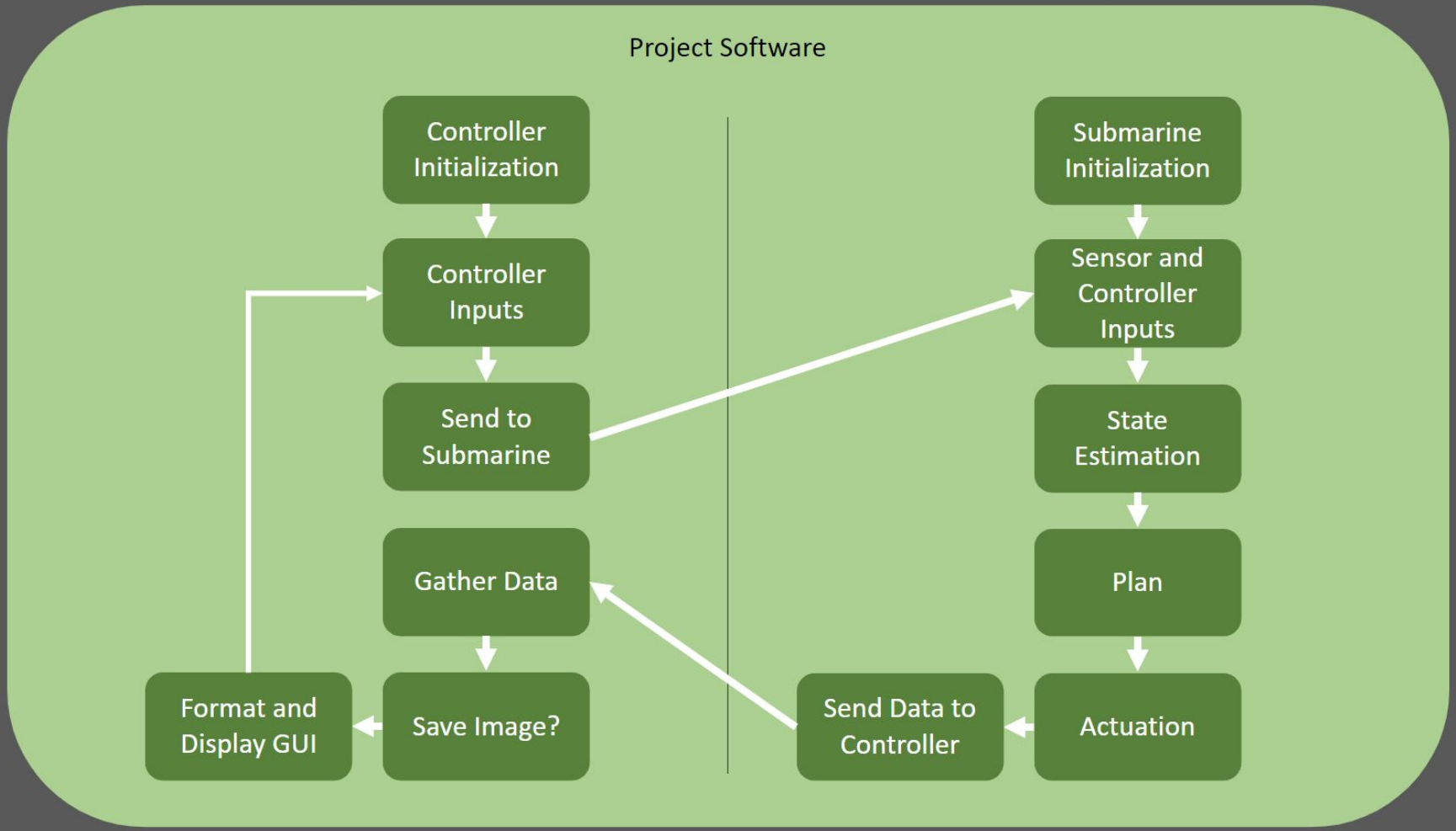
- Power Supply with output voltage of 12 V ± 5% at 1 A load current
- Recharge time of less than 4 hours
- Minimum one-hour long deployment time
- Custom PCB for the controller
- Minimum frame rate of 15 FPS



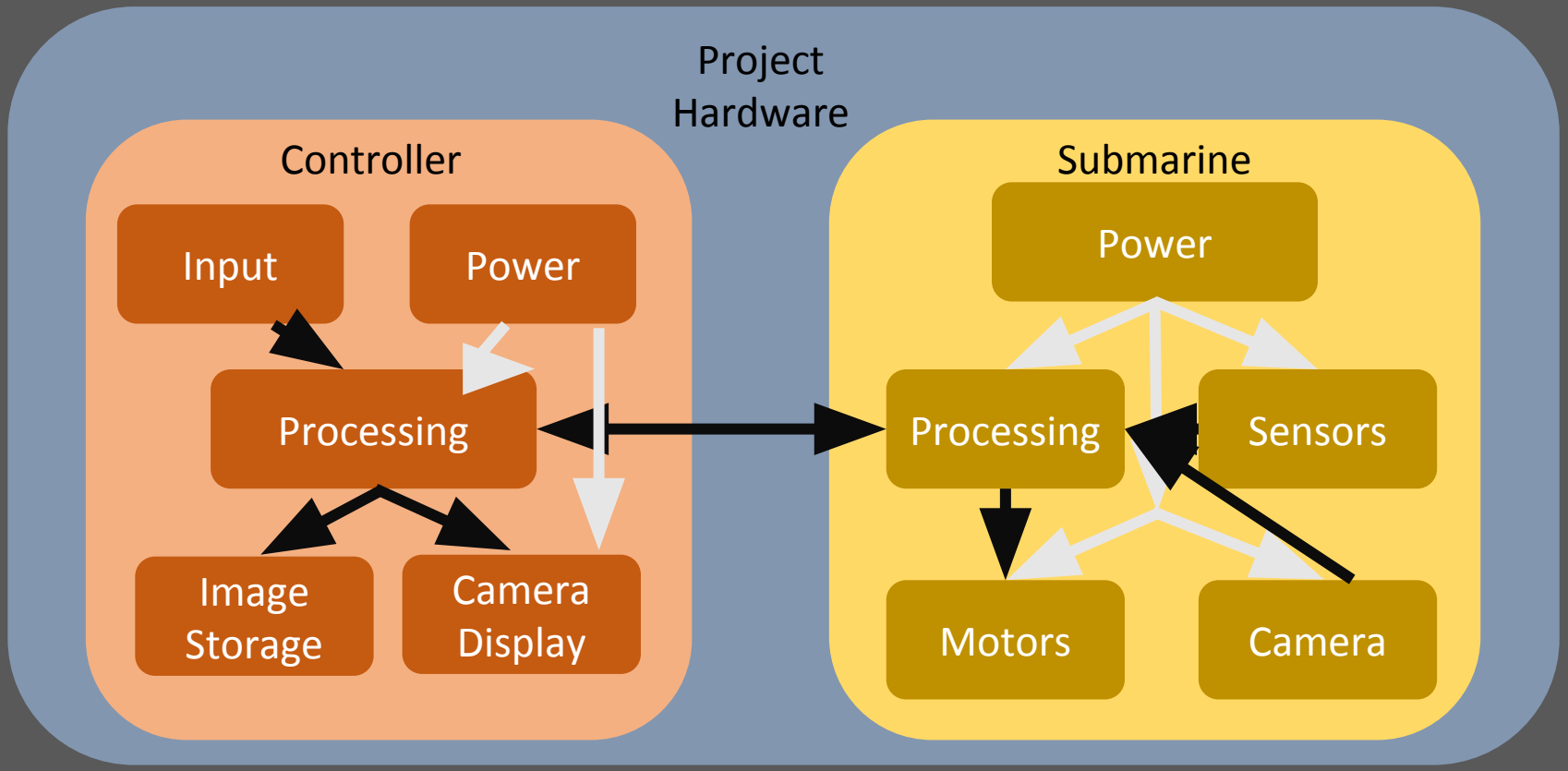
Overview



Block Diagram - Software

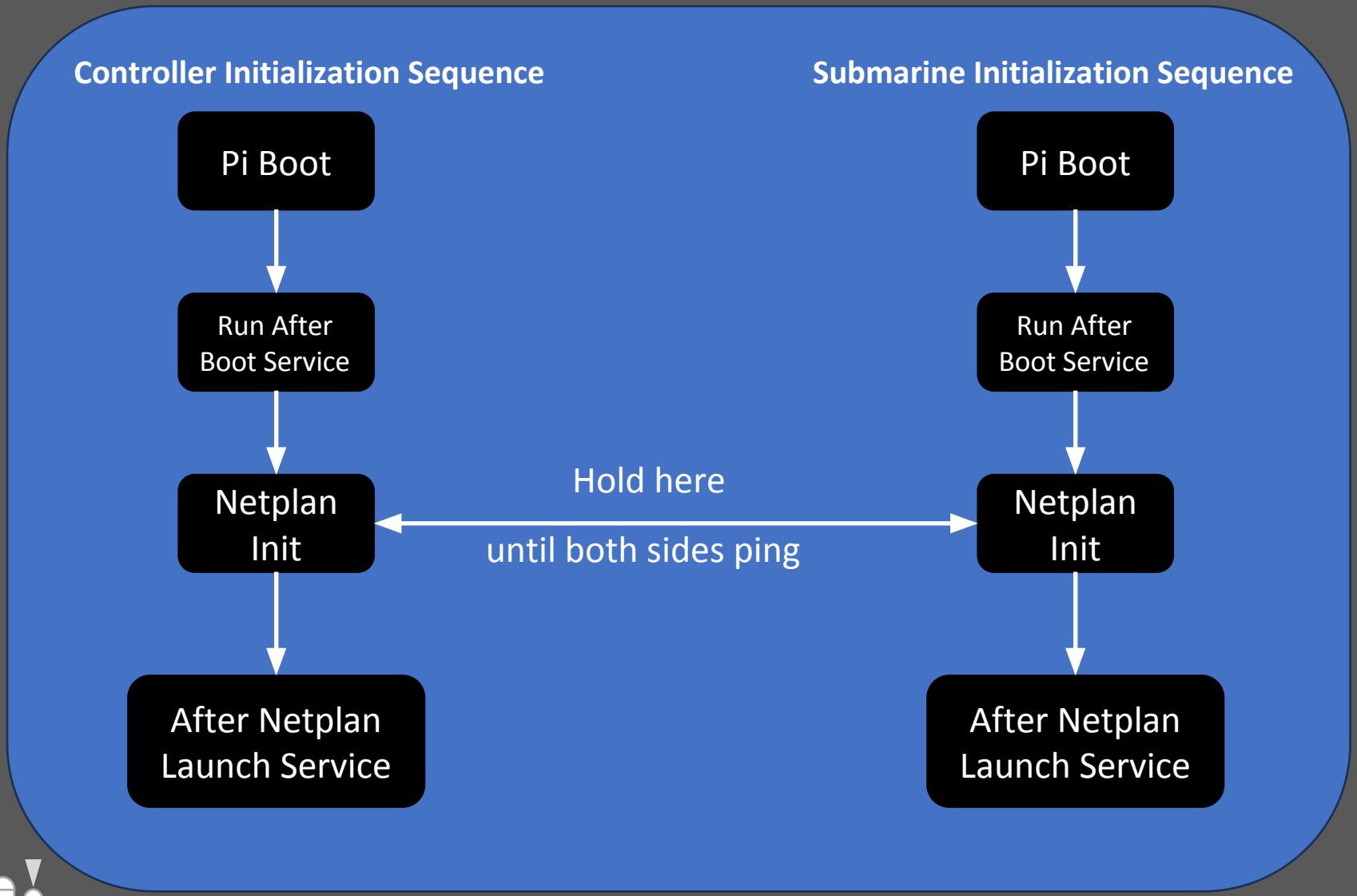


Block Diagram - Hardware

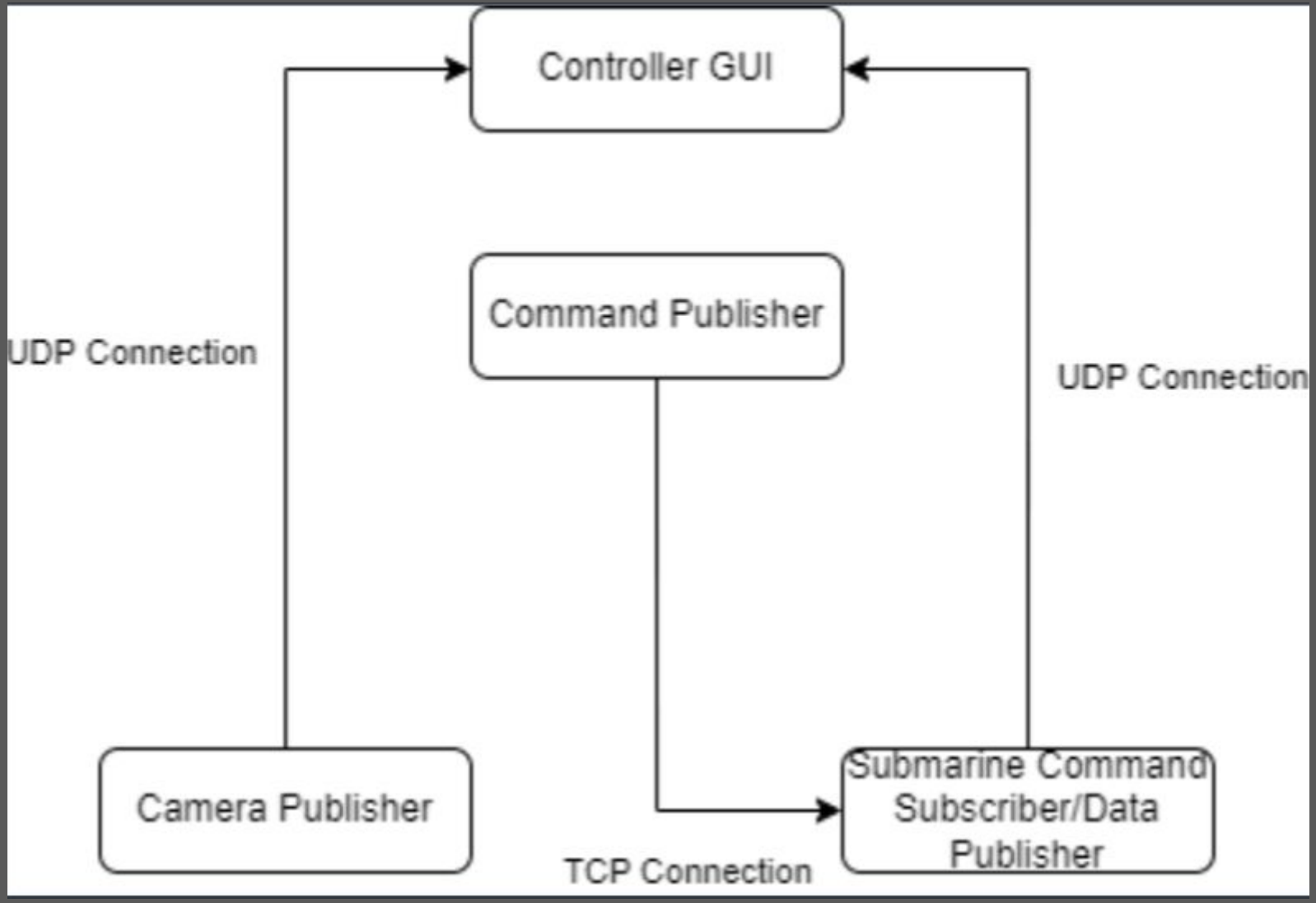


Details

Details – Initialization Sequence

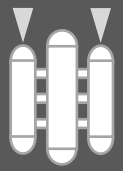


Details – ROS2 Network



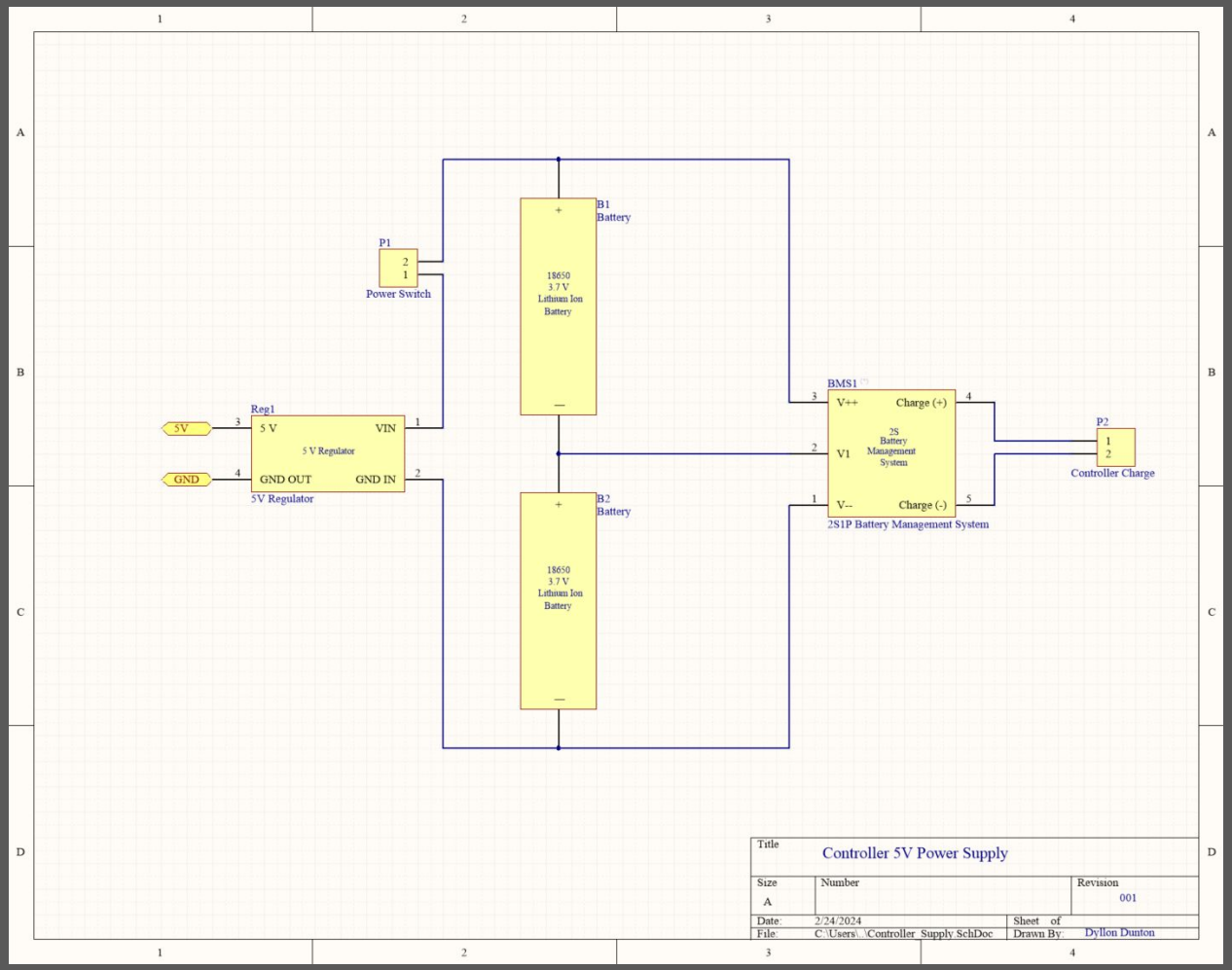
Details – Display GUI

- Display is made with Python and OpenCV
- The drawing happens on each frame



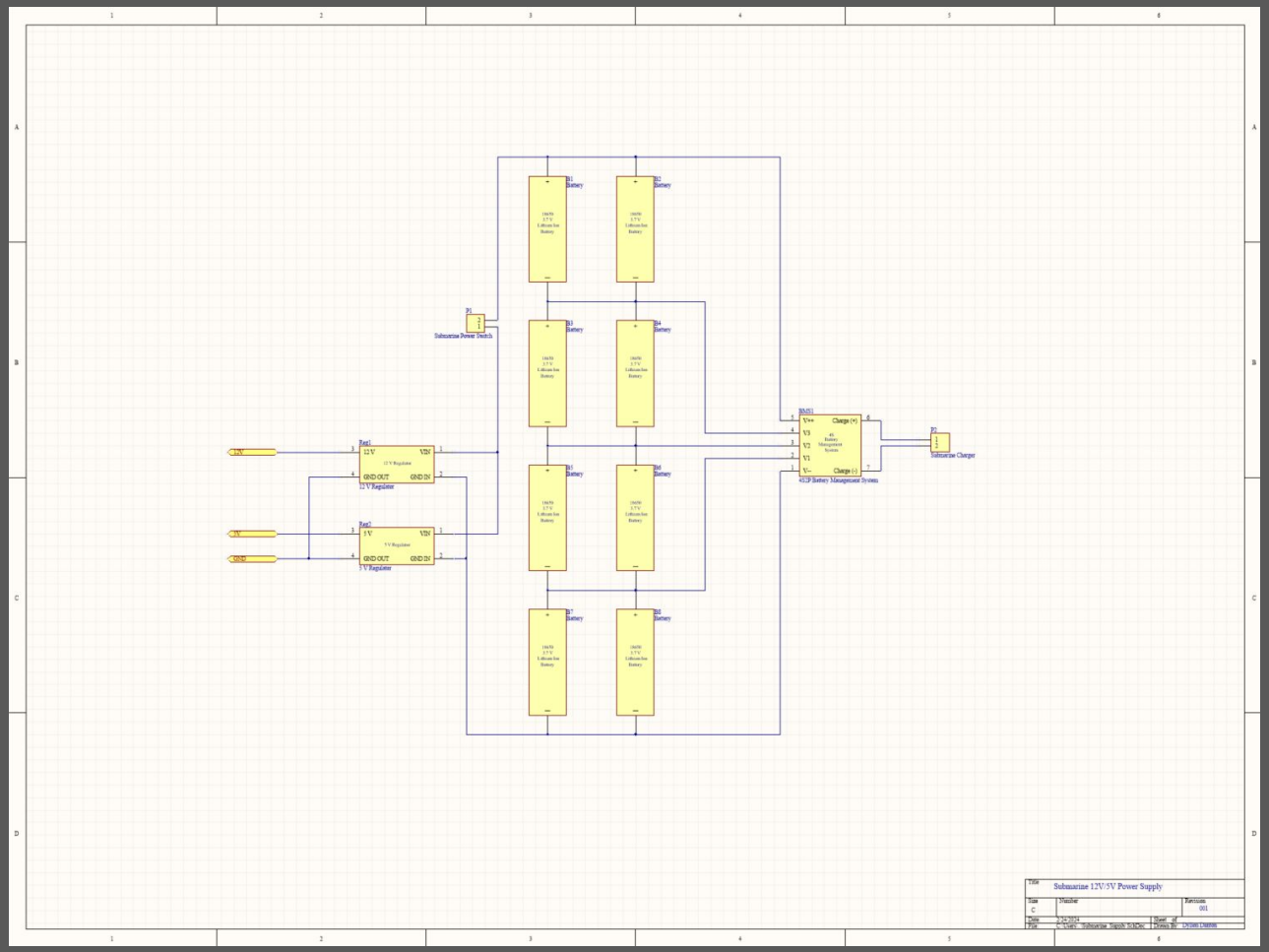
Details – Controller Power Supply

- 2 3.7 V ICR 18650 Li-Ion cells in series
  - Max Charge: 2.6 A
  - Max Discharge 3.9A
- Controller needed ~20 W supply
  - Achieved ~29 W
- 5 V voltage regulator as all systems on the controller need 5 V



Details – Submarine Power Supply

- 8 total 3.7 V ICR 18650 Li-ion cells
  - 4 pairs of parallel connected cells
- Submarine needed ~67 W
  - As designed, achieved ~115 W
- 5 V and 12 V regulator for various submarine power systems



Details – Motor Driver Circuit

- Can drive:
  - Two DC motors
  - One Stepper Motor
- Three of these circuits
- Takes input from STM32 L4R5Zi
- Outputs to Stepper/DC motors

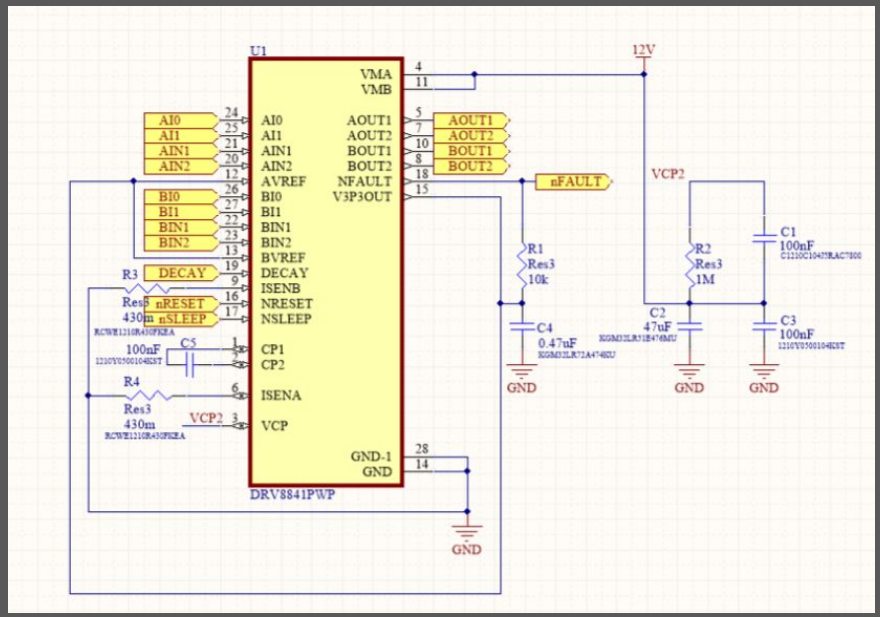


Table 4: DRV8841PWP Dual H-Bridge Component List

Component	Value	Purpose
C1	100 nF	Bypass
C2	47 μF	Bulk
C3	100 nF	Bypass
C4	470 nF	Bypass
C5	100 nF	Charge Pump
R1	10 kΩ	Pullup
R2	1 MΩ	Filtering
R3	430 mΩ	Current Limiting
R4	430 mΩ	Current Limiting

Details – Servo Motor Control

- Setup for SMRAZA S51 Servos
  - Clock Frequency: 120 MHz
  - PWM Frequency: 50 Hz
  - ARR: 2,399,999
- Parse Instruction
  - Get Duty Cycle from RPi command
  - Multiply by ARR to get CCR
  - Apply CCR to PWM signal control motor

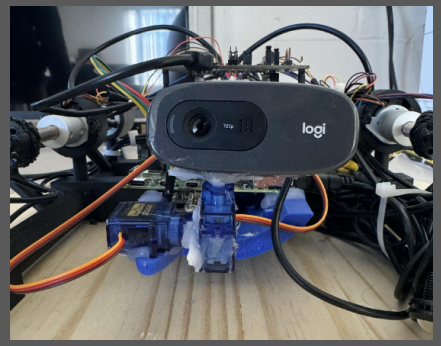
$$ARR = \frac{ClockFrequency}{PWMFrequency} - 1$$

$$DC = \frac{DC_{MAX} - DC_{MIN}}{2^8 - 1} * (8bitCommand) + DC_{MIN}$$

$$CCR = ARR * DC$$

Table 3: SMRAZA S51 Servo Motor Pins

Lead	Color	Pin
1	Red	5 V
2	Orange	Signal
3	Brown	GND



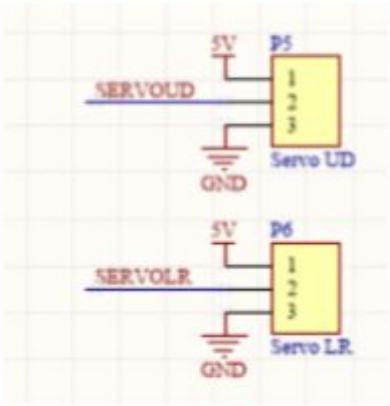
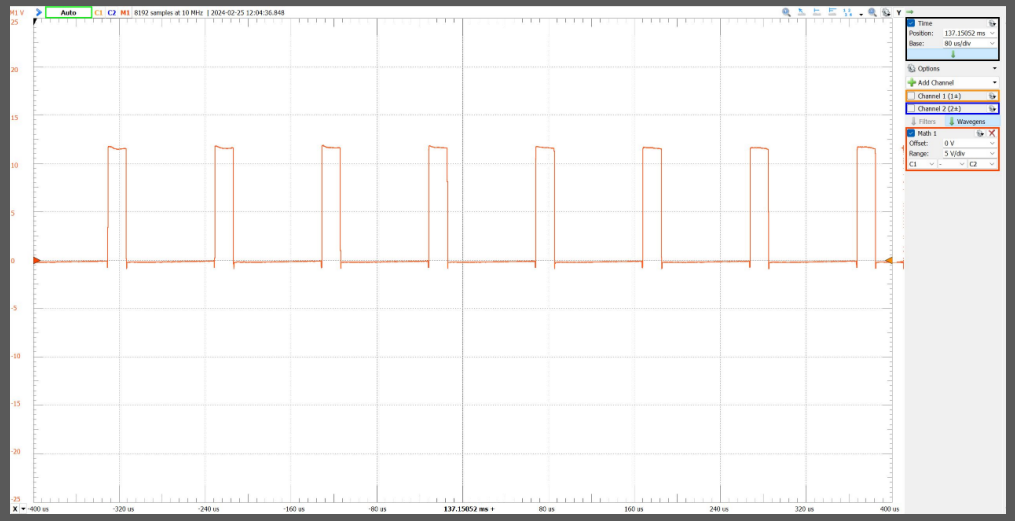


Figure 3: Servo Motor Connections.

Details – DC Motor Control

- Setup for Jameco 232022 DC Motor
  - Clock Frequency: 120 MHz
  - PWM Frequency: 10 kHz
  - ARR: 19,999
- Parse Instruction
  - Get turn and forward thrust from RPi
  - Split forward thrust into forward and backward components
  - Split turn thrust into left and right components
  - Mix components to calculate duty cycles for the two motors
  - Multiply the two DCs by the ARR to get the CCR and apply to the PWM signal



$$ARR = \frac{ClockFrequency}{PWMFrequency} - 1$$

$$Thrust_{dir} = \frac{DC_{MAX} - DC_{MIN}}{2^8 - 1} * (8bitCommand_{dir}) + DC_{MIN}$$

$$DC_{LeftMotor} = Thrust_{right} - Thrust_{left} + Thrust_{forward} - Thrust_{backward}$$

$$DC_{RightMotor} = Thrust_{left} - Thrust_{right} + Thrust_{forward} - Thrust_{backward}$$

$$CCR = ARR * DC$$

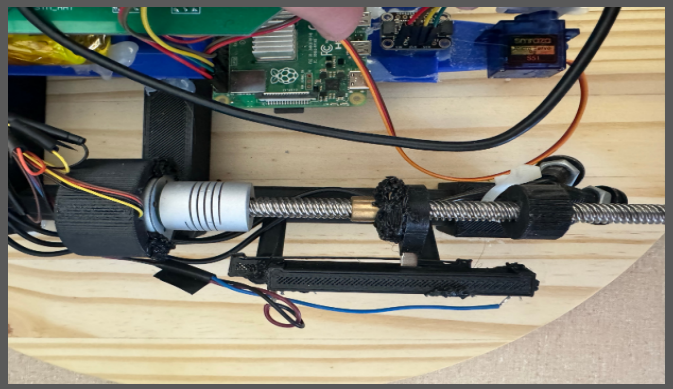
$$V_{avg} = V_{supply} * DC$$

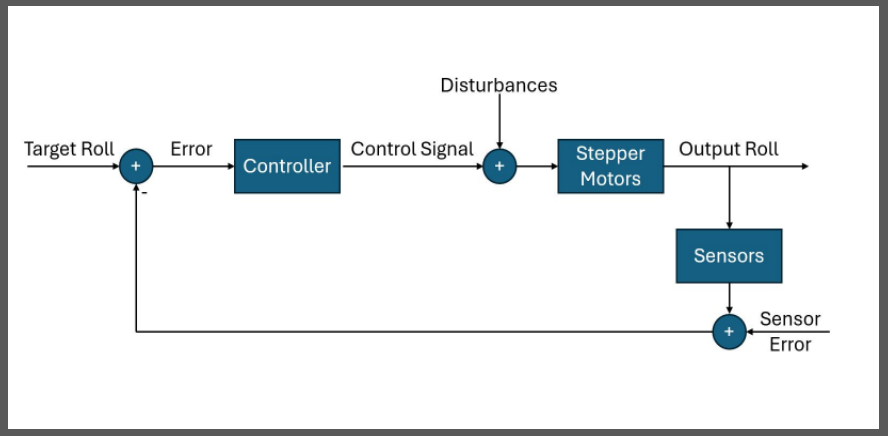
Details – Stepper Motor Control

- Setup for PM25L-075-035 Stepper Motor
  - Two motors
  - Eight GPIO pins
- Parse Instruction
  - Lookup table that holds steps and GPIO pin voltages
  - If up and can keep moving, step forward
  - If down and can keep moving, step down
  - Wrap step to be one to four
- Sensors
  - Linear variable resistors that measure ballast tank wall distance
  - Use ADC to convert to 8-bit value
  - Use this for bounding the ballast tank motion
- Passive Roll Correction using IMU

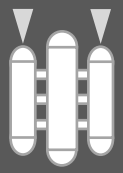
Table 6: Stepper Control Order

Pin	Color	Step 1	Step 2	Step 3	Step 4
1	BLACK	1	0	0	1
2	BROWN	0	1	1	0
3	ORANGE	1	1	0	0
4	YELLOW	0	0	1	1



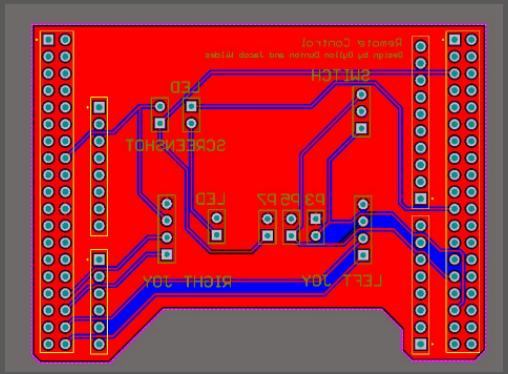


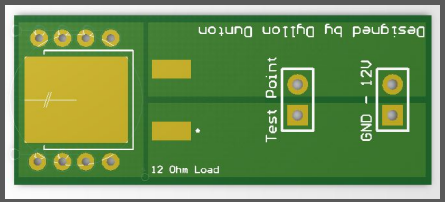
$$DigitalValue = \frac{255 * WyperVoltage}{3.3V}$$

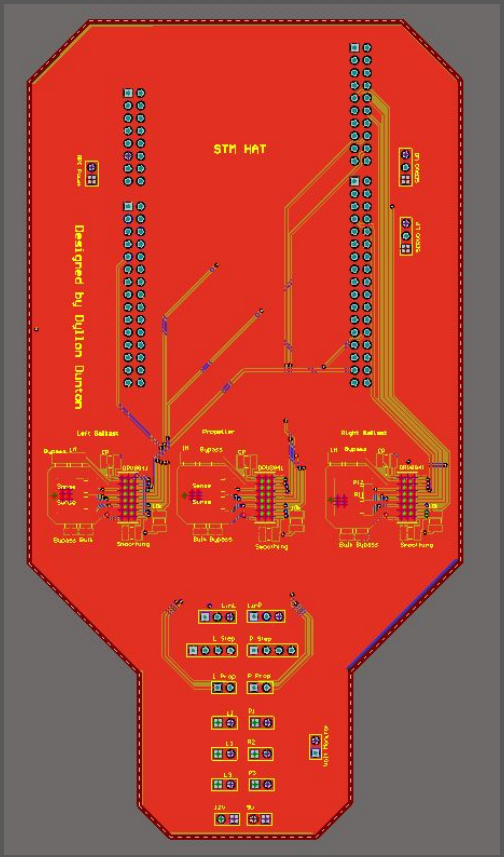


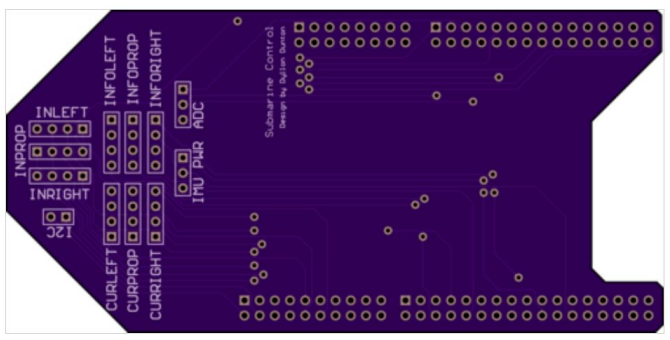
Details – PCB Design

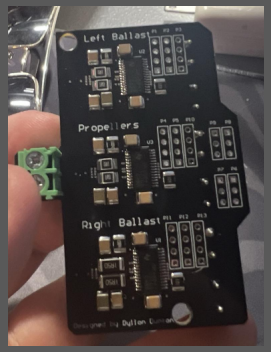
- Three final PCBs
  - Controller
  - Submarine
  - Test Load
- Out of service PCBs
  - Isolated H-Bridge
  - Isolated Submarine Connection







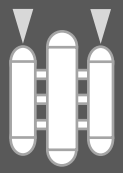




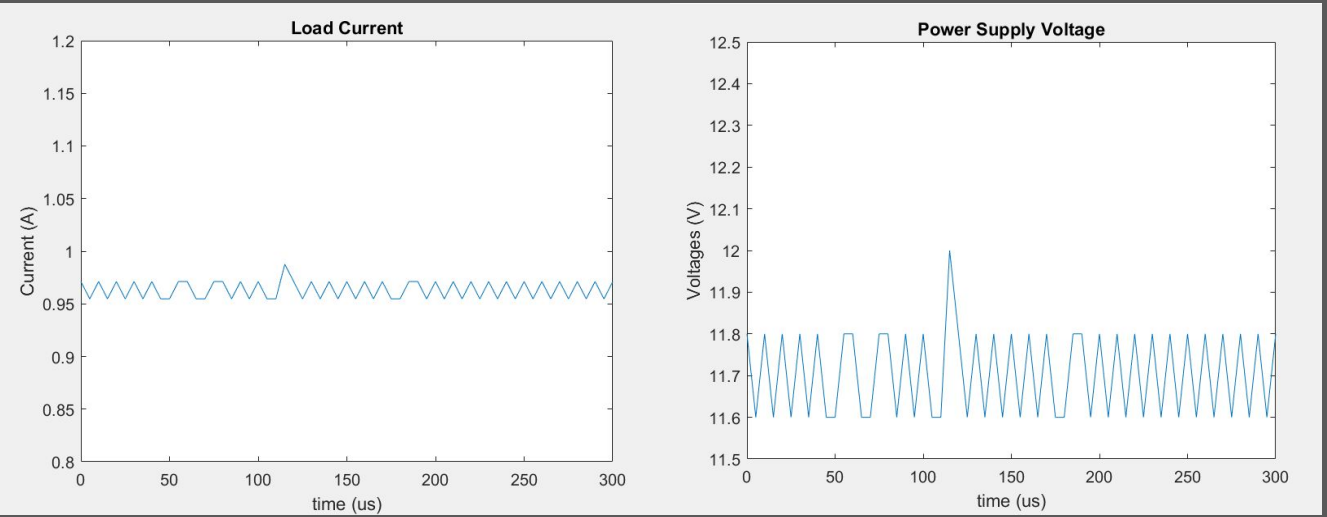
Results

Results

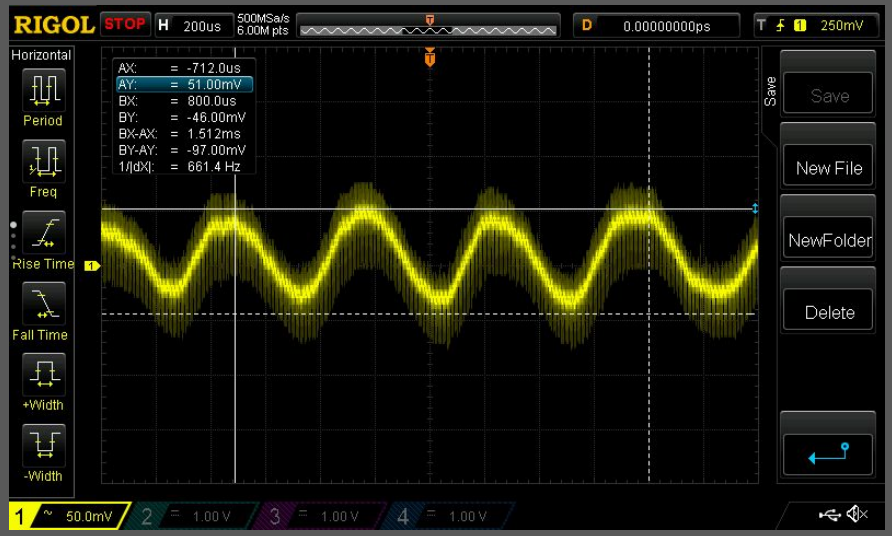
- **Power supply with output voltage of 12 V ± 5% with 100 mV ripple at 1 A load current**
- **Recharge time of less than 4 hours**
- **Minimum of one-hour deployment time**
- **Custom PCB for controller**
- **Minimum frame rate of 15 FPS**



Power supply with output voltage of 12 V ± 5% with 100 mV ripple at 1 A load current



Resistance: 12.15 Ohms
Load Current: 960 mA
Average Voltage: 11.7 V
-> 12V – 2.5%
Voltage ripple: 97 mV



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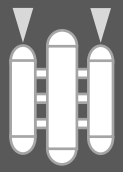
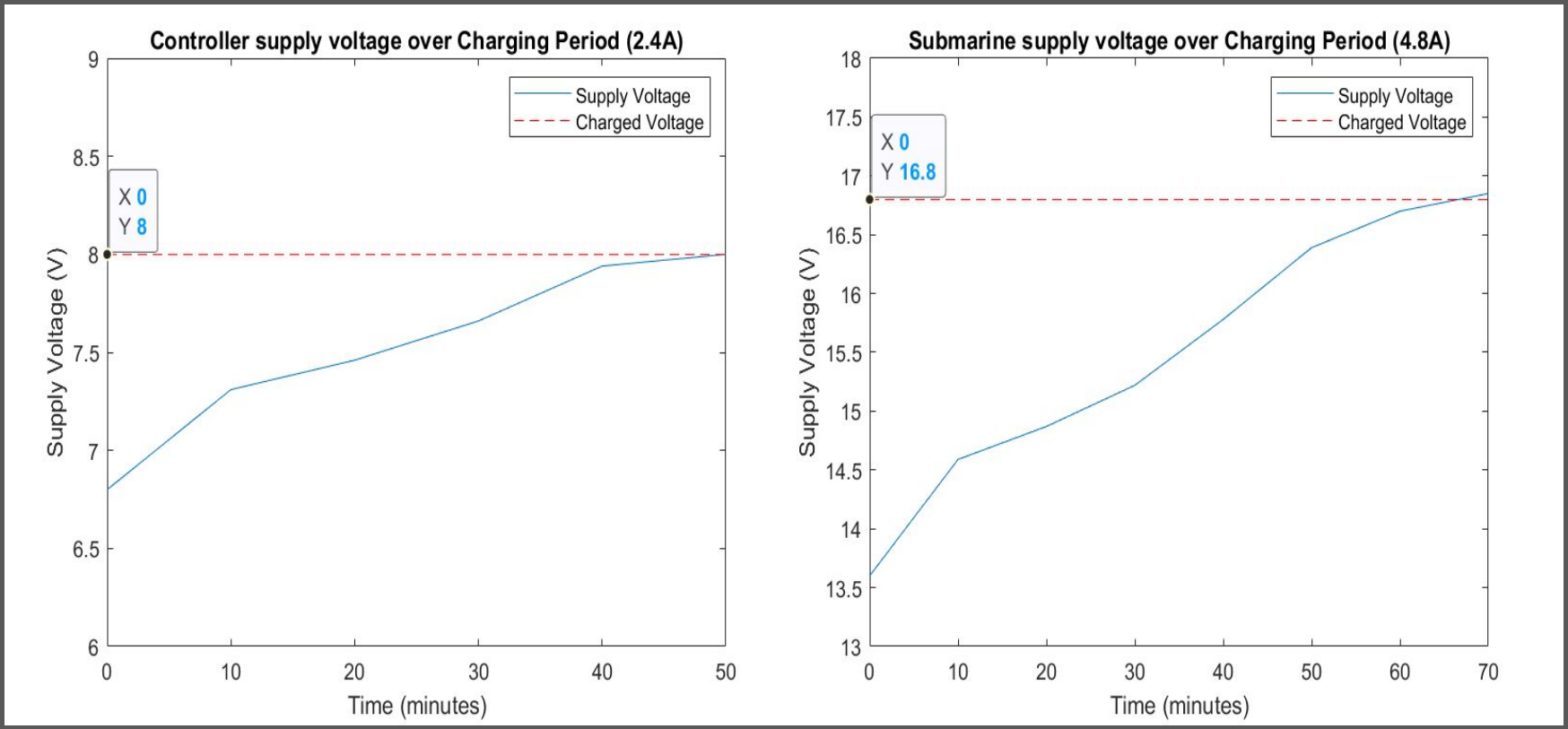


Recharge time of less than 4 hours



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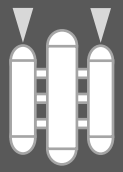
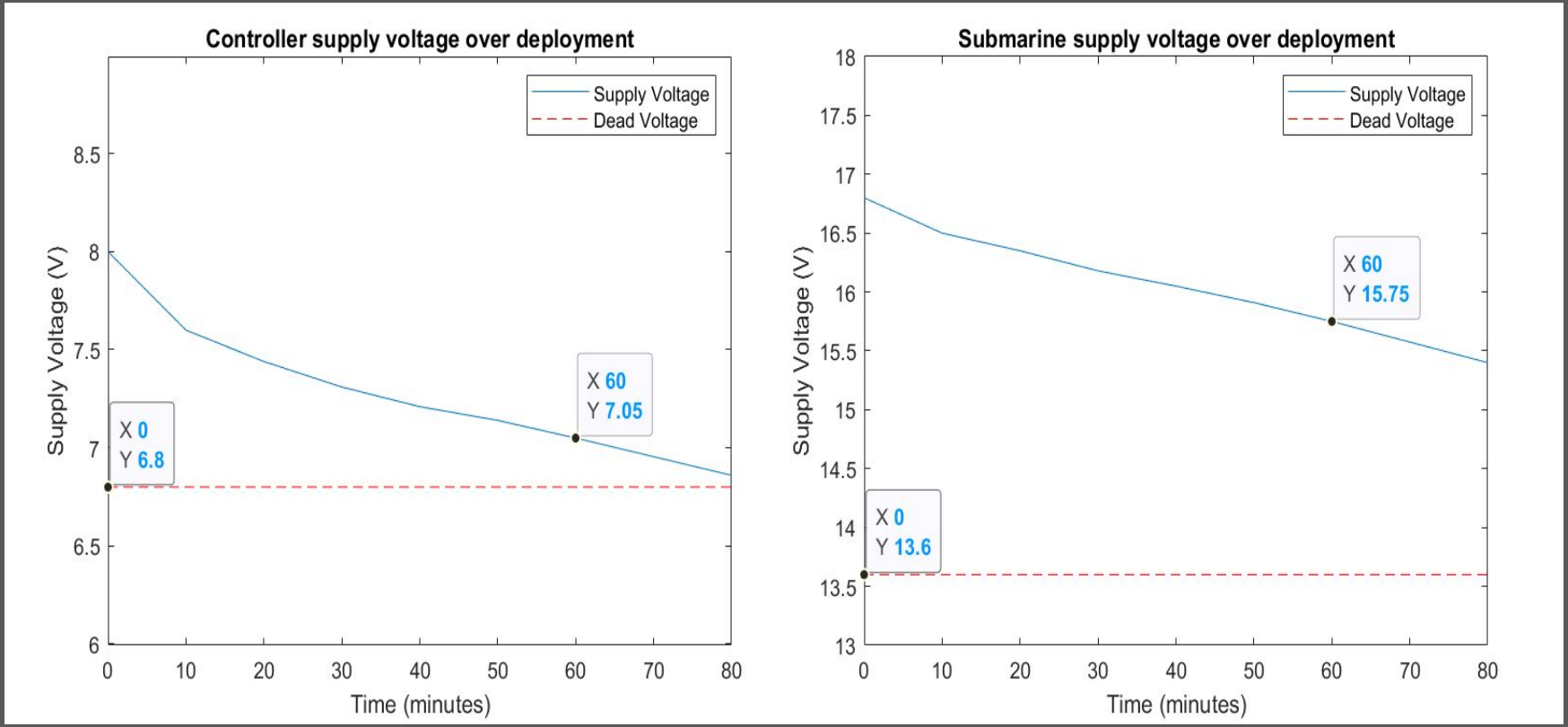


Minimum of one-hour deployment time



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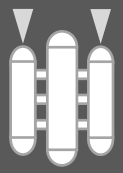
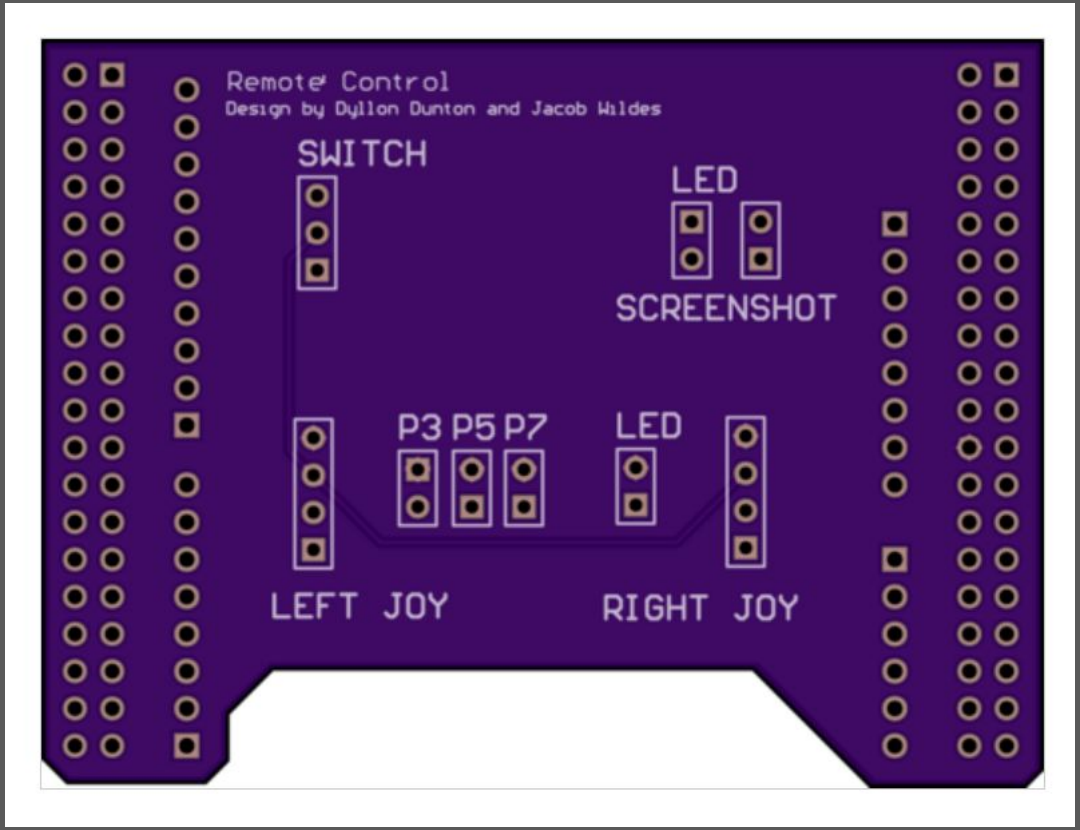


Custom PCB for controller



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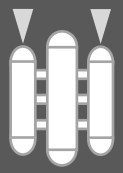
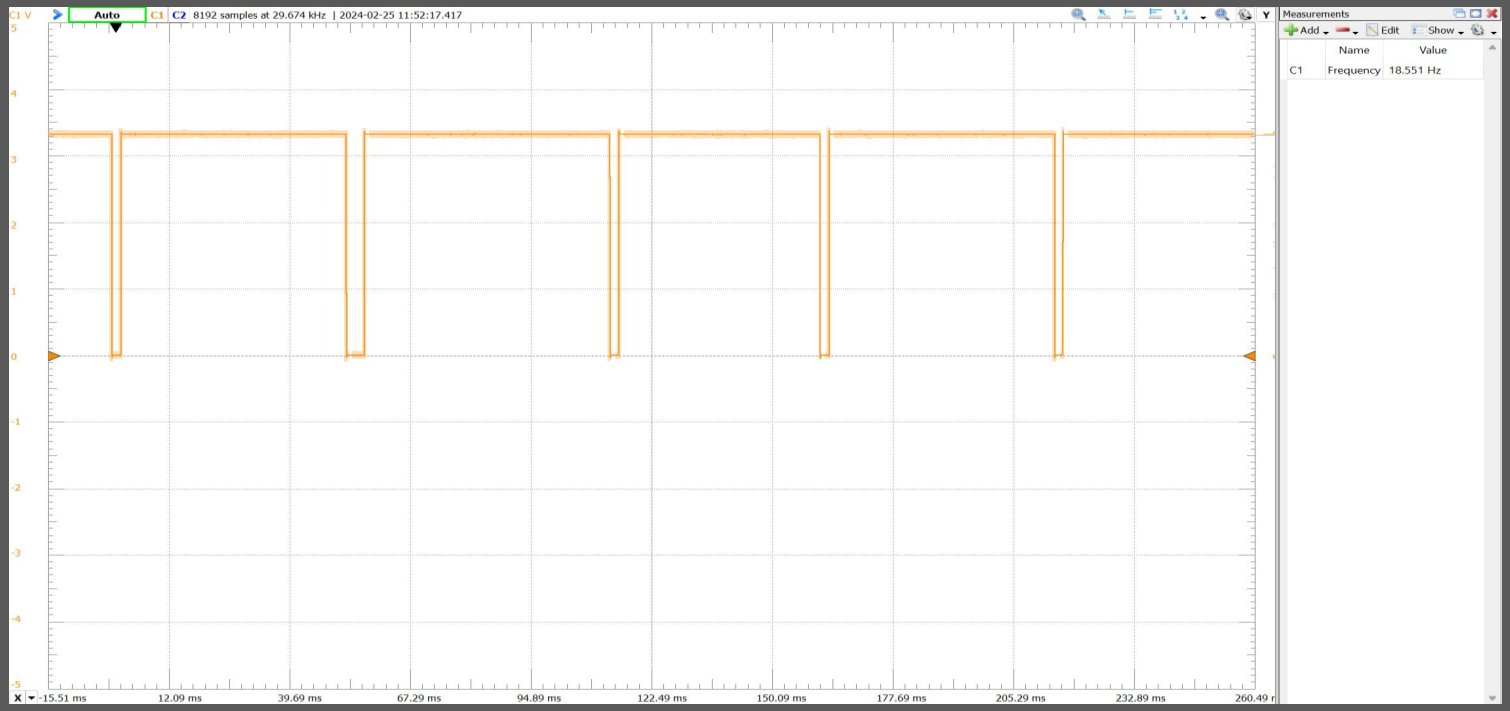


Minimum frame rate of 15 FPS



Frequency: 18.5 Hz

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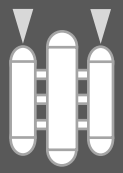
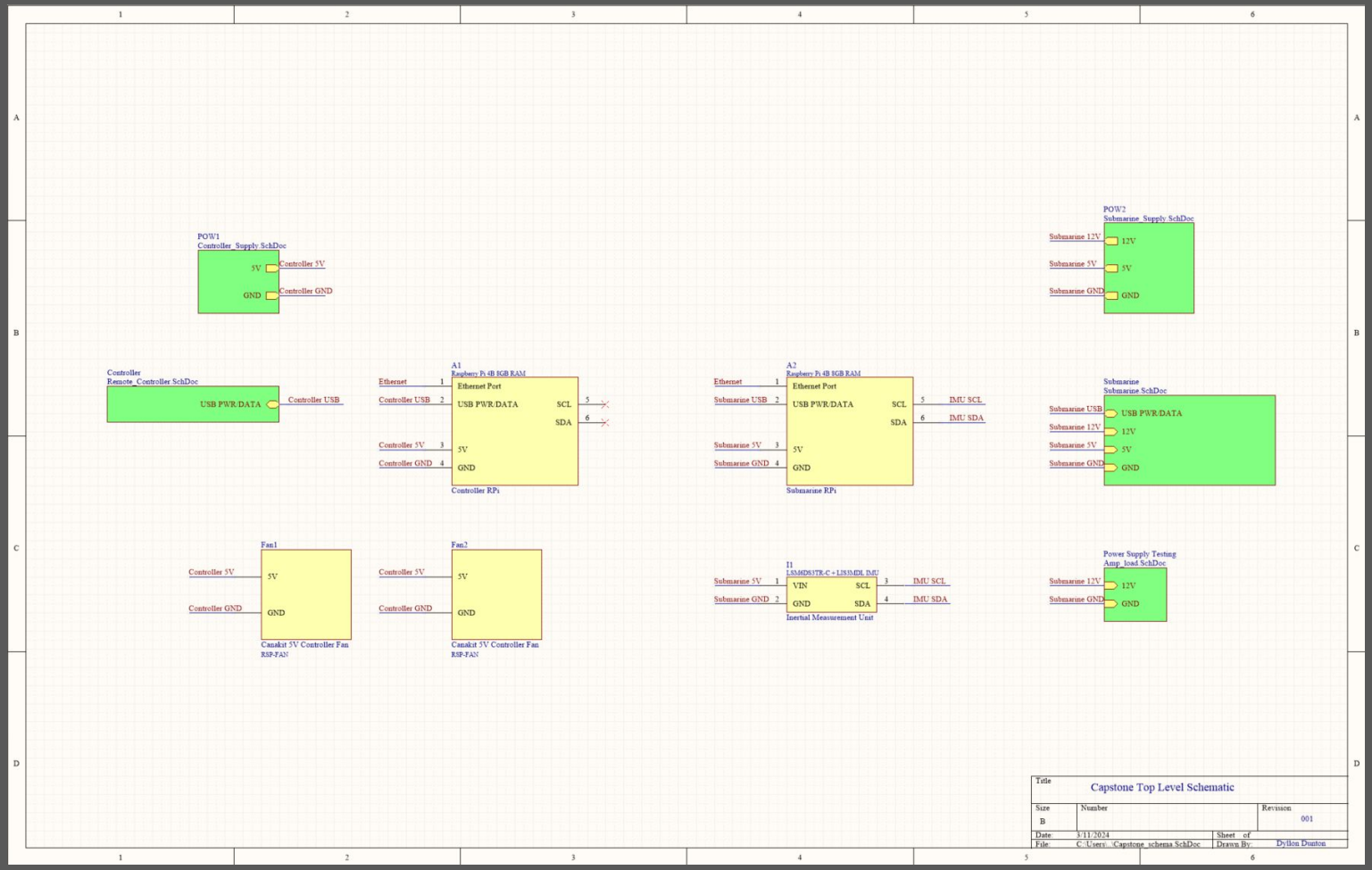
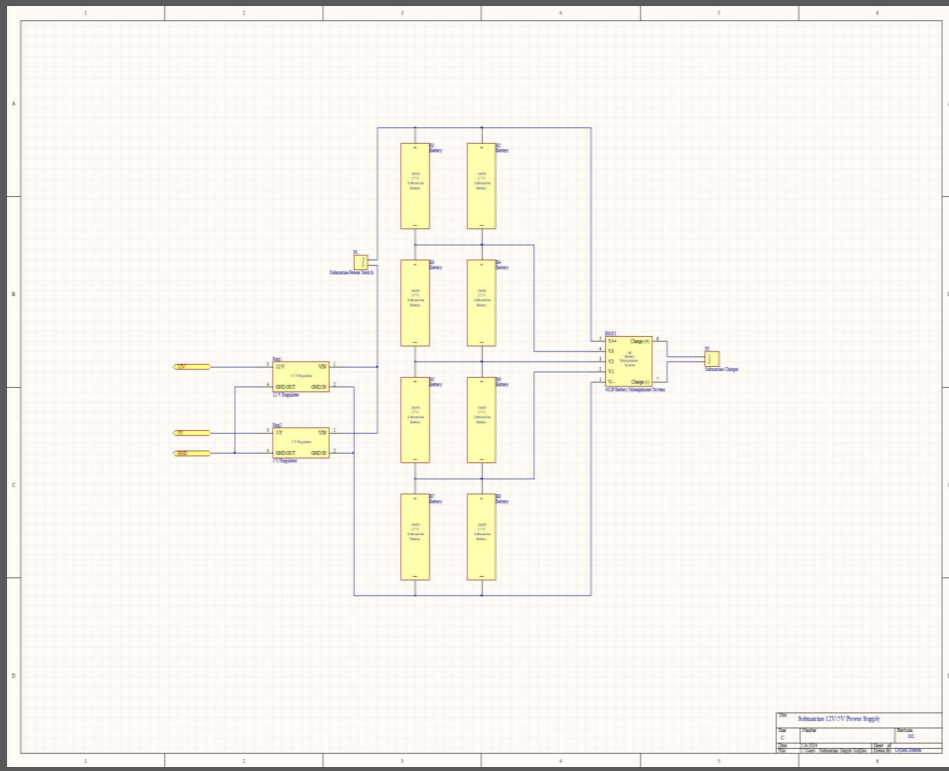
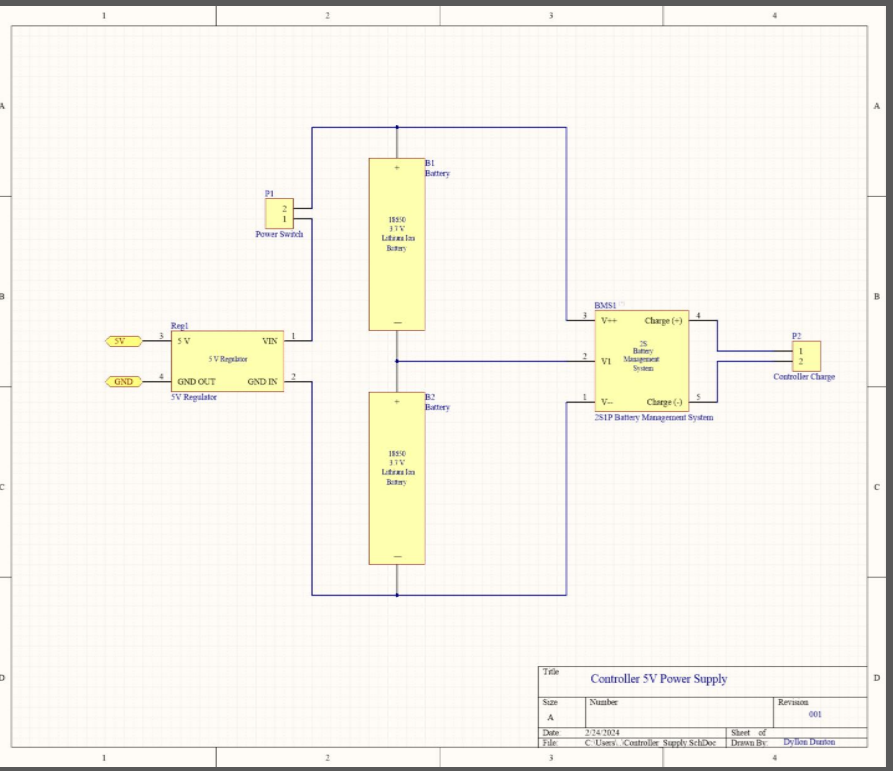


Schematics - Top

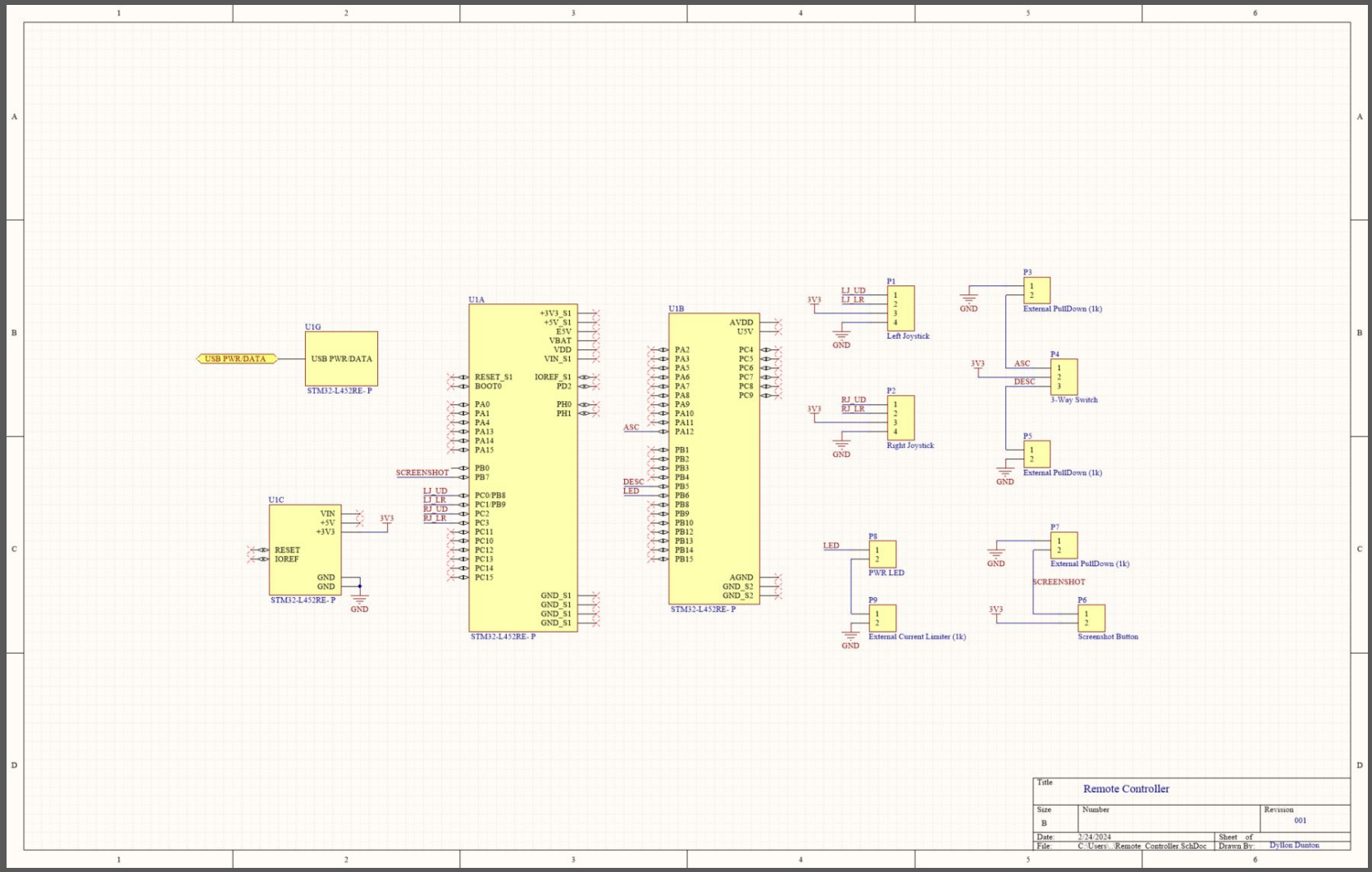


Schematics - Power Supplies

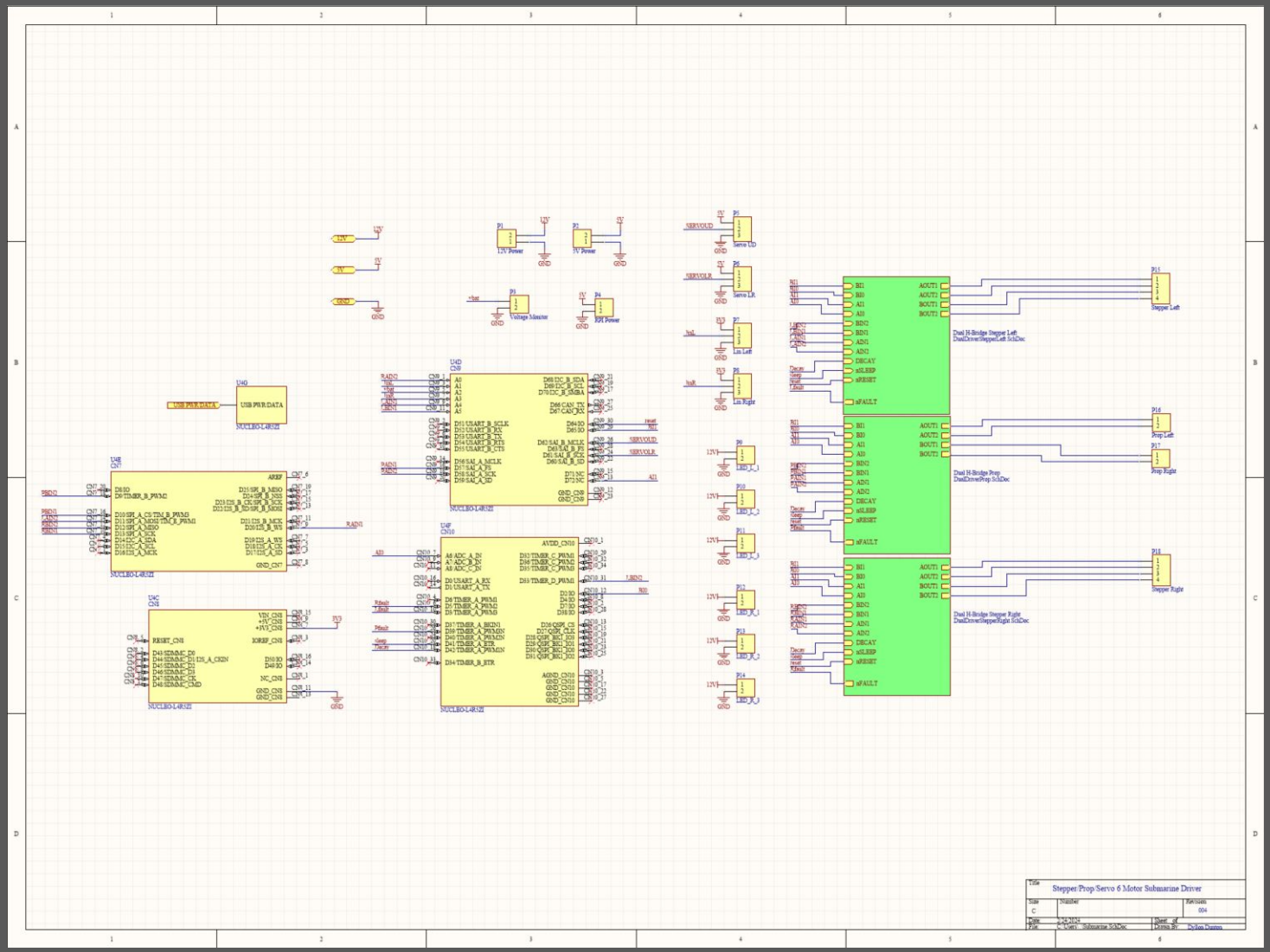




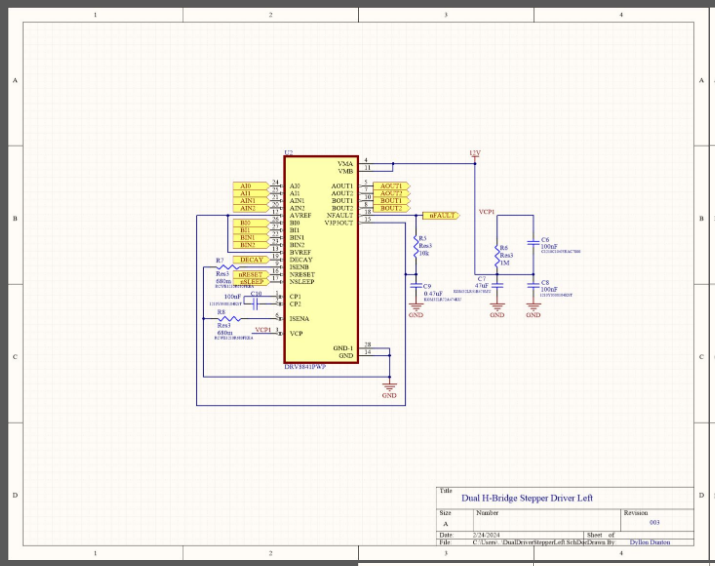
Schematics - Controller

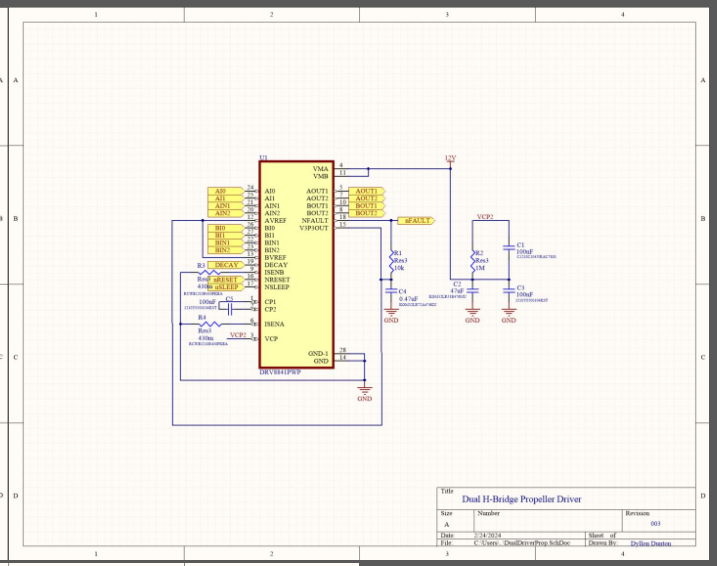


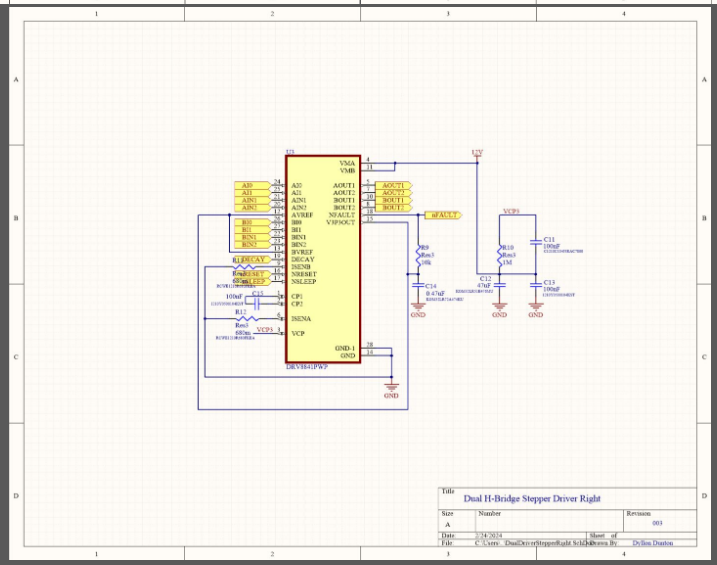
Schematics - Submarine



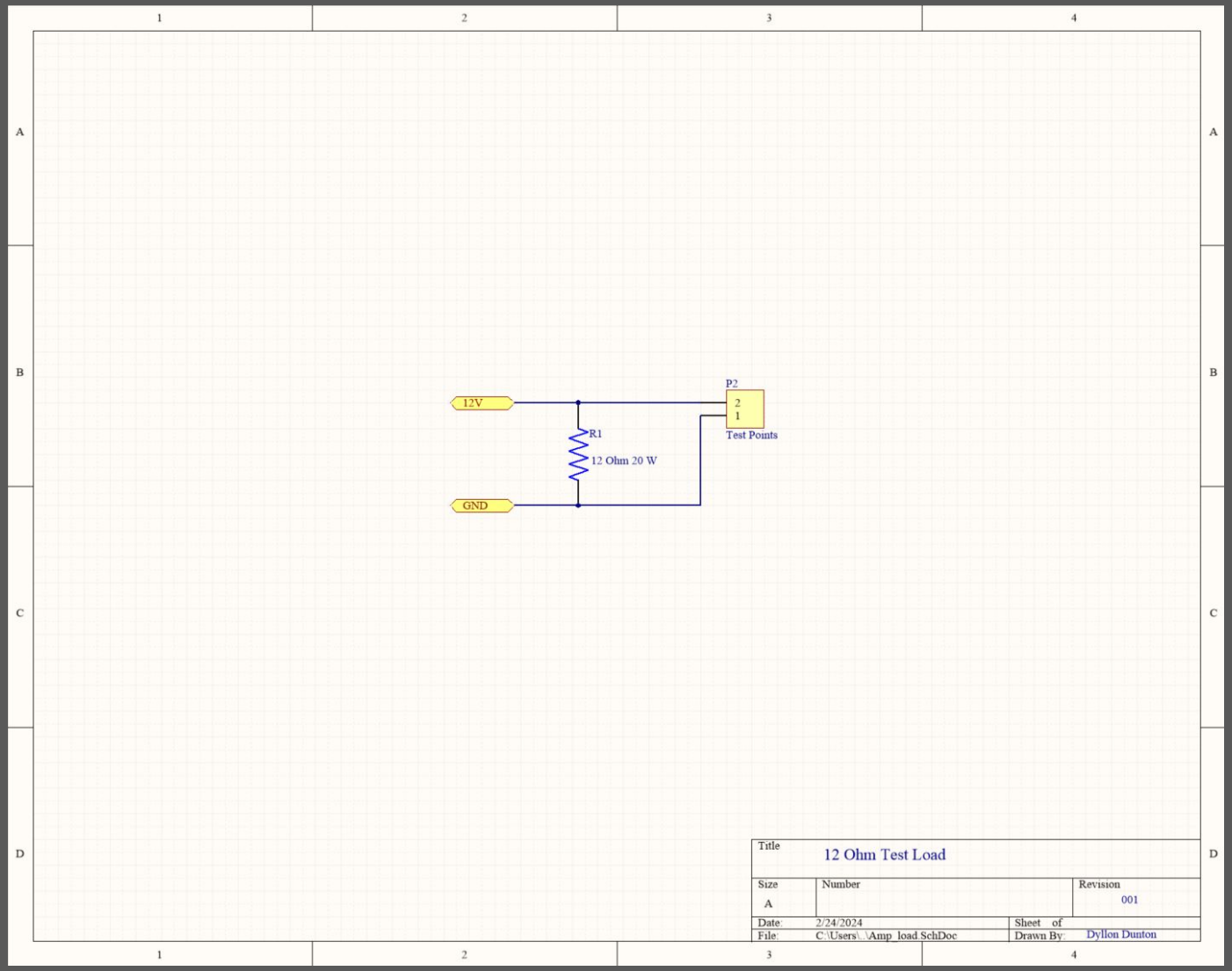
Schematics - Motor Drivers





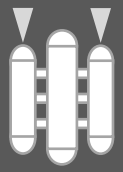


Schematics - Test Load



Advice

- Start as early as possible
- Take the PCB design class (EET414)
- Make good use of the Professors
- Don’t solder dev boards directly to a PCB, use headers (RIP 5 STM boards)
- Split code into different files early on
- Test code often so you know exactly where a bug is
- Use 3D printers for structures to make it look cleaner



Acknowledgements

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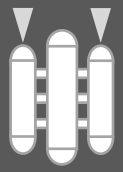
- Prof. Hummels
- Prof. Allen
- Prof. Weaver
- Sheaff
- Marc Michaud (for his easy bake oven)
- Will Poole (for his solder paste)



Questions?