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Group 10 Final Presentation

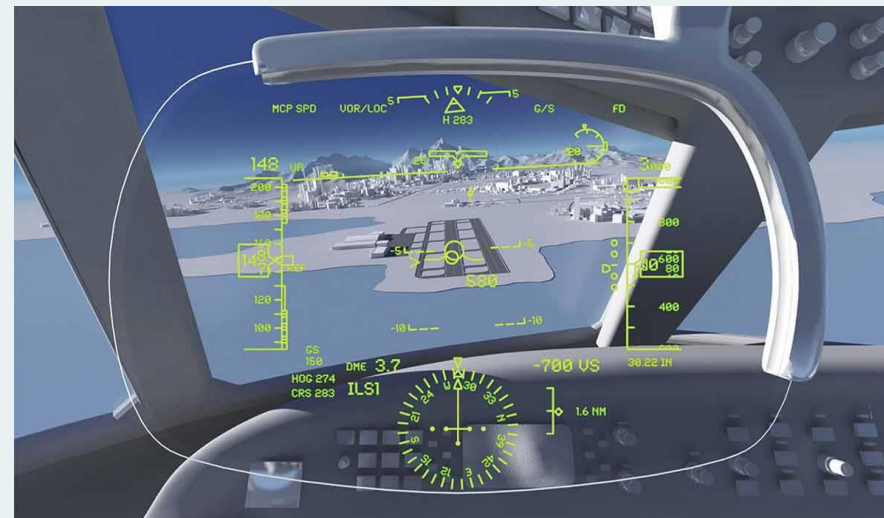
P.E.G.A.S.U.S. (Pilot Enhanced Guidance and Augmented Sight Utility System)



Motivation & Background



- Heads-Up Displays are a tool utilized in vehicle situational awareness across a myriad of industries. In aviation, commercial and military cockpit environments have HUD compatibilities. Civilian HUDs for general aviation are not commonplace.



***Motivation & Background



- The P.E.G.A.S.U.S. Heads-Up Display seeks to increase pilot situational awareness, while remaining a compact and affordable solution for the general aviator.



Goals & Objectives - Goals

Basic Goals:

- Develop a portable standalone Heads-Up-Display (HUD) for aircraft.
- Display essential flight data in a Graphical User Interface.
- The system be visible in various lighting conditions and portable.

Advanced Goals:

- System will contain an adaptive lighting system for comfortable visibility in all settings.



Goals & Objectives – Basic Objectives



Basic Objectives:

- House all optical components and sensors in an optomechanical housing.
- Implement an Inertial Measurement Unit (IMU) to calculate three-dimensional attitude data and compass heading data.
- Implement an altimeter for altitude data reading.
- Incorporate one microcontroller unit (MCU) designated to real-time sensor reading.
- Implement a dedicated MCU for data formatting and GUI display control.
- The GUI will display attitude (orientation in space) data, altitude, and compass heading.
- Display brightness visible through polarized and unpolarized lenses.



Goals & Objectives – Advanced Objectives



Advanced Objectives:

- System displays data for >80% of total flight time with restart technology if an unexpected shut off occurs.
- Correct for system aberrations and distortion specifically localized within target eye box area.

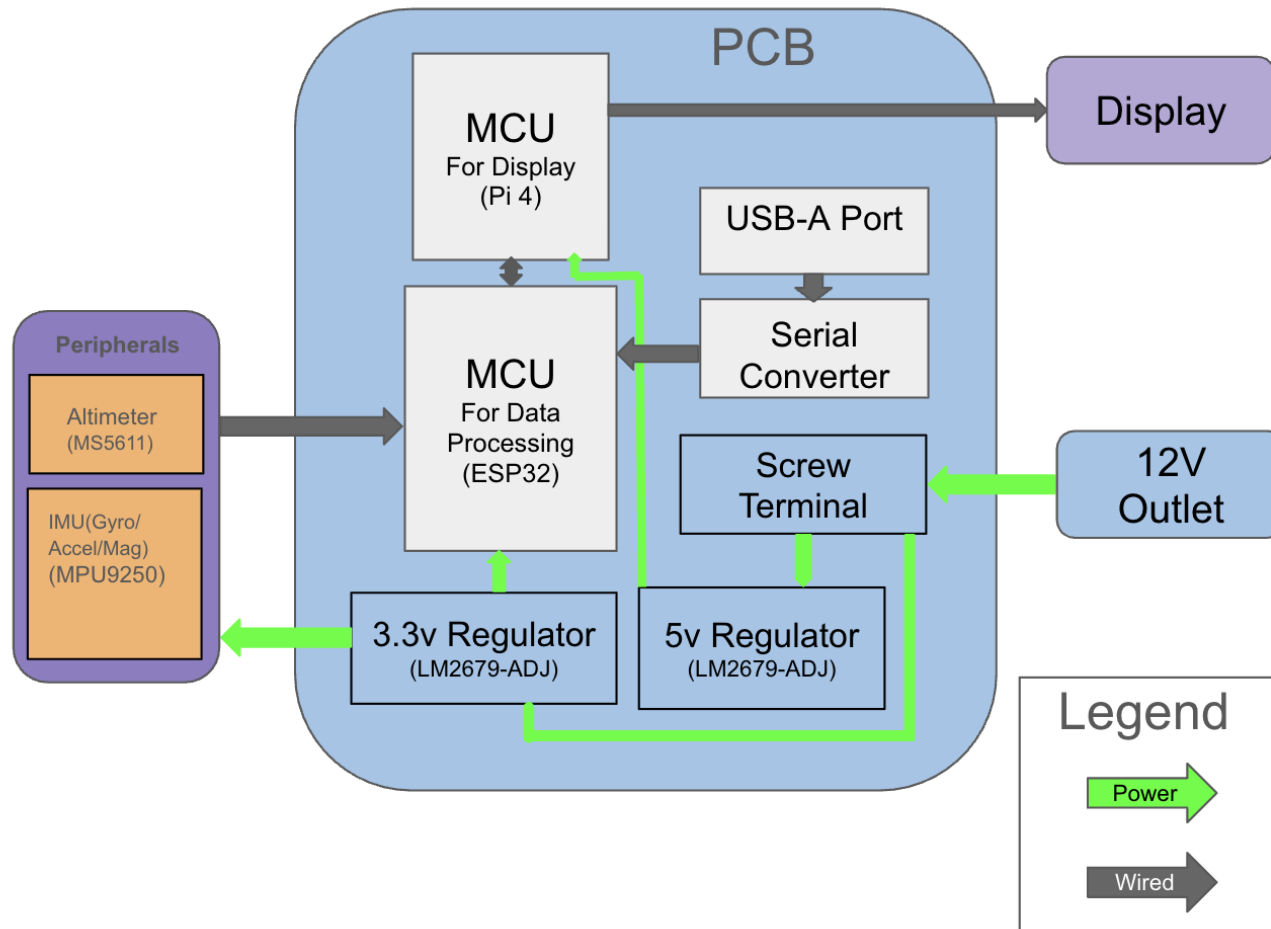


Engineering Specifications



Parameter	Specification	Description	Priority
Accuracy	~90%	Ensures data is accurately displayed to pilot	High
Total System Power Consumption	<21W	Critical for aircraft electrical load margin	Med
GUI Display Brightness	>750 nits	Ensures HUD visibility in cockpit daylight	High
System Boot Time	< 1 minute	Pilot needs minimal delay at startup	High
Attitude Measurement, Processing and Display Time	<200ms	Ensures prompt reading to ensure accurate display of data	Med
IMU Polling Rate	>9.9 Hz	Smooth sensor readings	Med
GUI Refresh Rate	> 30 FPS	Ensures a responsive GUI	Med
Total System Weight (including housing)	<11 lbs	Keeps system portable and minimizes aircraft load	High
Horizontal Field of View Overlay*	>39°	Provides useful HUD coverage	Low

Hardware Diagram





Hardware Comparison & Selection - MCU

- Pi4 + ESP32 had the highest learnability and development speed with acceptable clock speed and high graphics rendering leading to this being selected for our MCU combination
- STM32 has less community support and the most difficulty developing on hence why combinations with it were not selected

Factor	Pi4 + ESP32	Pi4 + STM32	ESP32 + STM32
Graphics	Highest	Highest	Lowest
Clock Speed	Low	High	Highest
Latency	Medium	Low	Lowest
Learnability	Highest	Low	Lowest
Feasibility	Highest	Low	Lowest



Hardware Comparison & Selection – Altimeter



Part	Pressure	Altitude Capability	Accuracy	Noise/ Vol Consumption	Cost
BMP-390	300 -1200hPa	-500m - 9000m	±0.5hPa	Very Low	Very Low
MS5611	10 -1200hPa	-1000m - 11000m	±1.5hPa	Moderate	Moderate
LPS22HB	260 - 1260hPa	-1000m - 10000m	± 0.1hPa	Low	Low

- The MS5611 has the best all around capabilities for our project
- They are similar enough that the the easy to solder package makes it the clear choice.





Hardware Comparison & Selection – IMU

Part	Axes	Noise/ Vol Consumption	Difficulty of Typical Use	Power Systems	Cost
BMI270	6-axis(Accel + Gyro)	Very Good	Easy	Modern Low	Low
LSM9DS1	9-axis(Accel + Gyro + Mag)	Good	Easy	Modern Low	Very Low
MPU9250	9-axis(Accel + Gyro + Mag)	Moderate	Moderate	Low Power Systems	Low

- The IMU needs to have 9 axes
- The more easily solderable package makes the MPU-9250 our choice



Hardware Comparison & Selection – Power Consumption / Communication Protocol



Part	Voltage	Current	Communication Protocol
ESP-32	3.3V	500mA	I2C Compatible
Raspberry Pi4	5V	3A	I2C Compatible
MPU9250	3.3V	4mA	I2C Compatible
MS5611	3.3V	5mA	I2C Compatible

- Low power system outside of the Raspberry Pi
- Only require a 3.3V and 5V regulator
- All I2C Compatible



Hardware Comparison & Selection - Regulator



Part	Type	Good for	Vin Range	Iout Max	Downsides
LM-2679-ADJ	Buck	5V and 3.3V	5 - 40V	5A	Complex design
LMR33640	Buck	5V	1.8 - 36V	4A	Unreliable part
TLV767	LDO	3.3V	2.5 - 16V	1A	Unreliable part

- The LM-2679-ADJ can be used for both
- The only difference is its component values





Hardware Comparison & Selection – Display

Part	Brightness	Driver Board / No Driver Board	Type of Display	Cost	Resolutio n
NHD-3.5- HDMI-HR- RSXP	950 Nits	No Driver Board	TFT LCD	Inexpensive (<\$120)	640 x 480
SY049LDM02	1500 Nits	Driver Board	Micro-OLED	Expensive (\$500+ for whole system with tariffs)	1920 x 1080



Hardware Comparison & Selection – Polarizer



Part	Polarization	Ease of Integration	Surface area of polarizing element	Cost
$\lambda/4$ Polarizing Film	Circular	More complex, have to design housing	High	Inexpensive (\$20) for a 11x8.5" segment of film
$\lambda/4$ Waveplate	Circular	Comes with existing housing	Low and cost prohibitive	Expensive (\$500+ for small diameter plates)



Hardware Selection: Petzval Relay Projection System

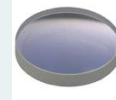
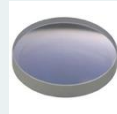
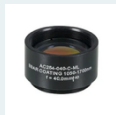
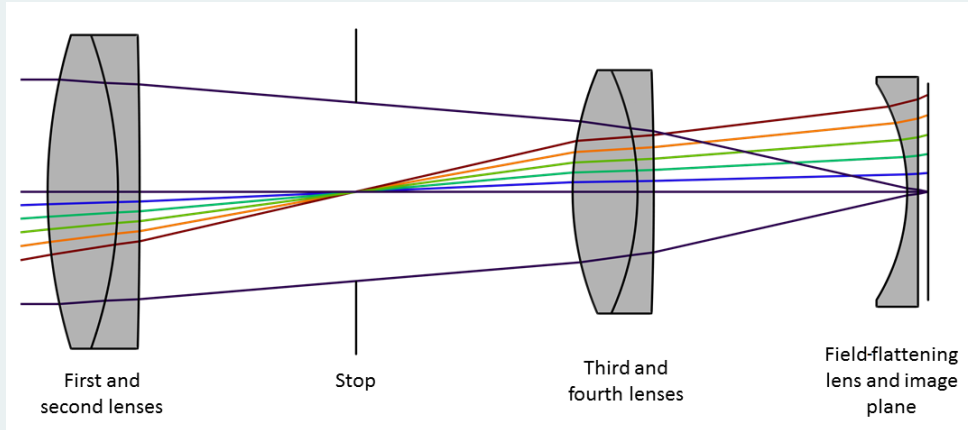
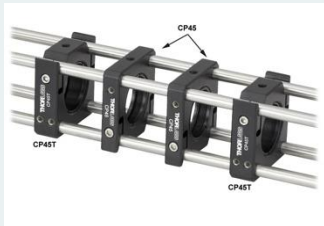
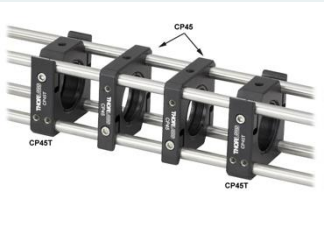
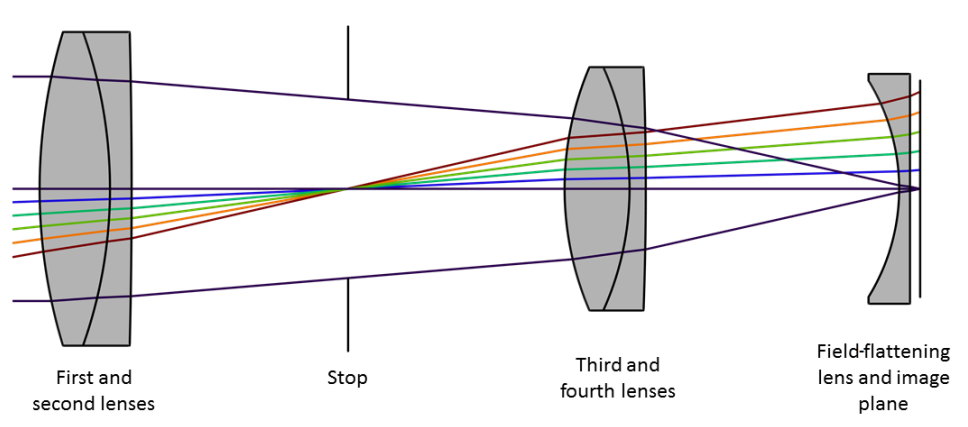


Diagram and Schematic of Petzval Relay System

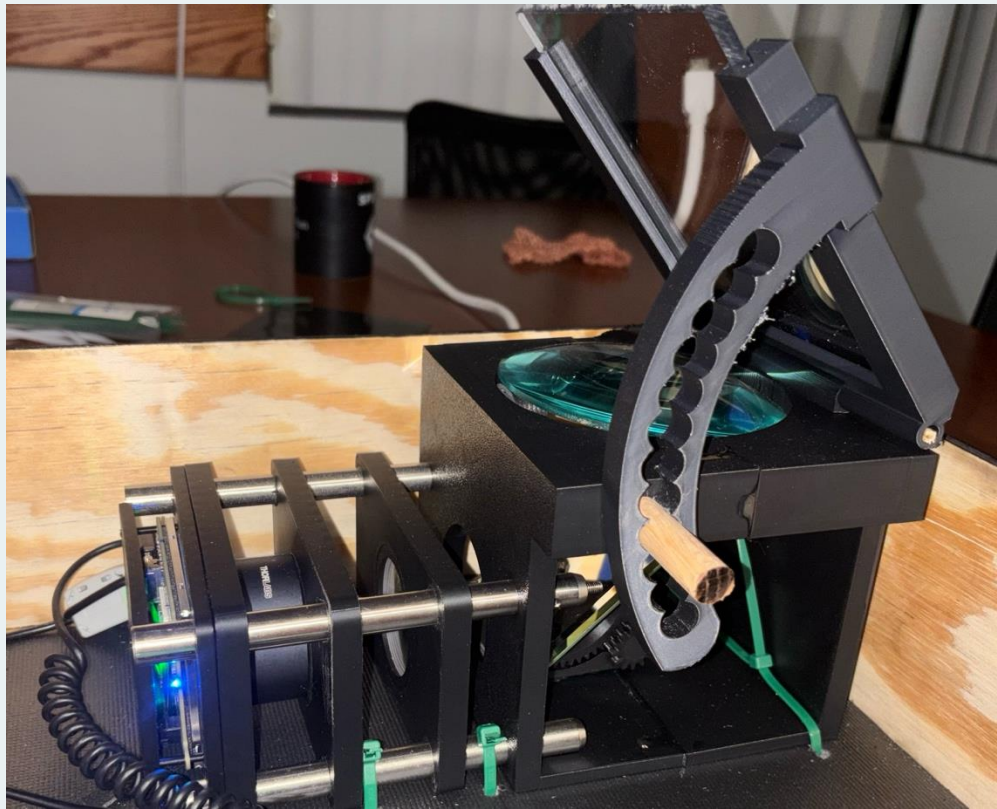
PEGASUS V1 Petzval Relay System + Polarizer



Hardware Selection: Petzval Relay Projection System



Hardware Selection: Projection and Optical Combination



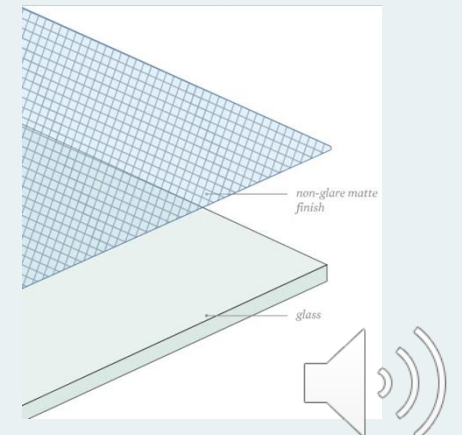
Hardware Selection: Optical Combination



We selected a high-transmission 40/60 Dielectric Optical Combiner Glass for the heads-up display.

The optical combiner assists in the elimination of “ghost images” as well as providing a projection medium for our final image.

In addition, the combiner also allows for physical mounting of any add-ons such as self-dimming elements.





Software Comparison & Selection – ESP32 Programming Languages

- C has the highest processing speed and due to the developer's familiarity with the language, this was the best option for the ESP32 programming language
- Python is too slow for our purposes
- C++ is overly complicated for sensor reading

Language	Speed	Stability	Ease of Use
Python (MicroPython)	Lowest	Lowest	Highest
C++	High	Highest	High
C	Highest	High	Lowest





Software Comparison & Selection – GUI Framework

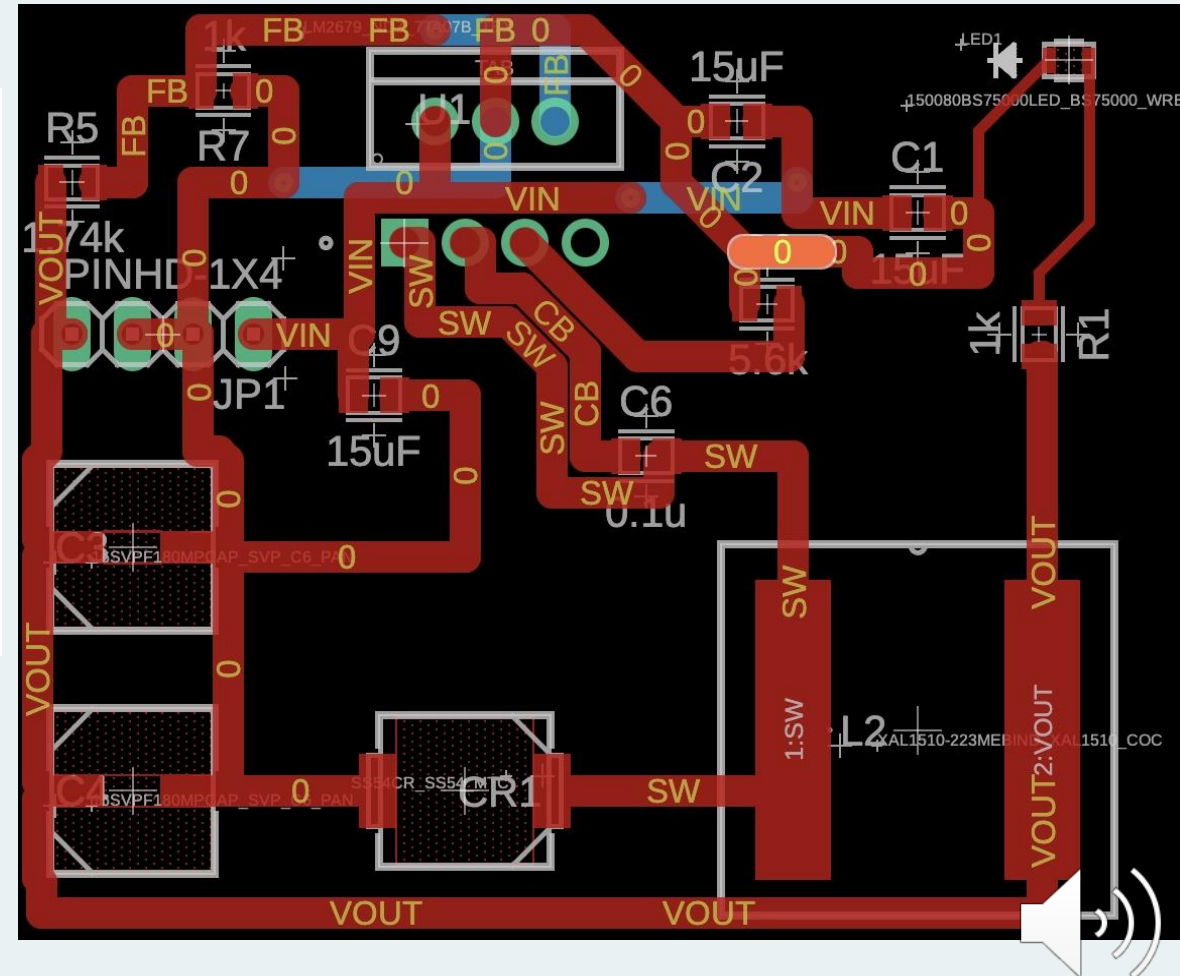
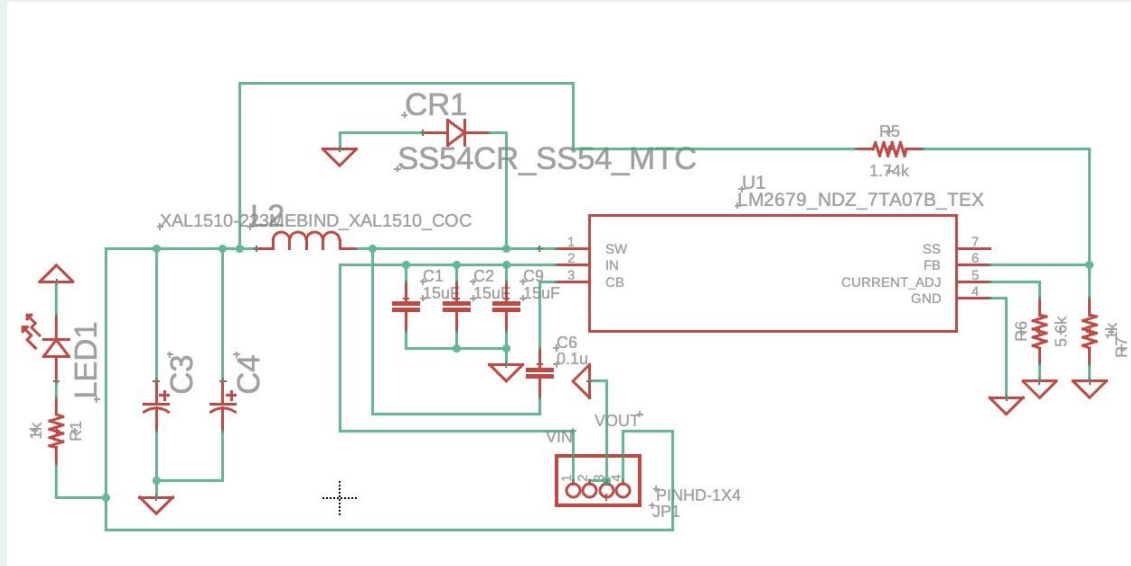
- C++ & Qt offer the widest variety and support of graphics rendering while maintaining a high speed
- Python & PyQt are too slow
- C & SDL2 offer too little graphics rendering support

Language & Framework	Ease of Use	Resource Usage	Speed	Boot Time
C++ & Qt	High	Low	High	Low
Python & PyQt	Highest	Highest	Highest	Highest
C & SDL2	Lowest	Lowest	Highest	Lowest



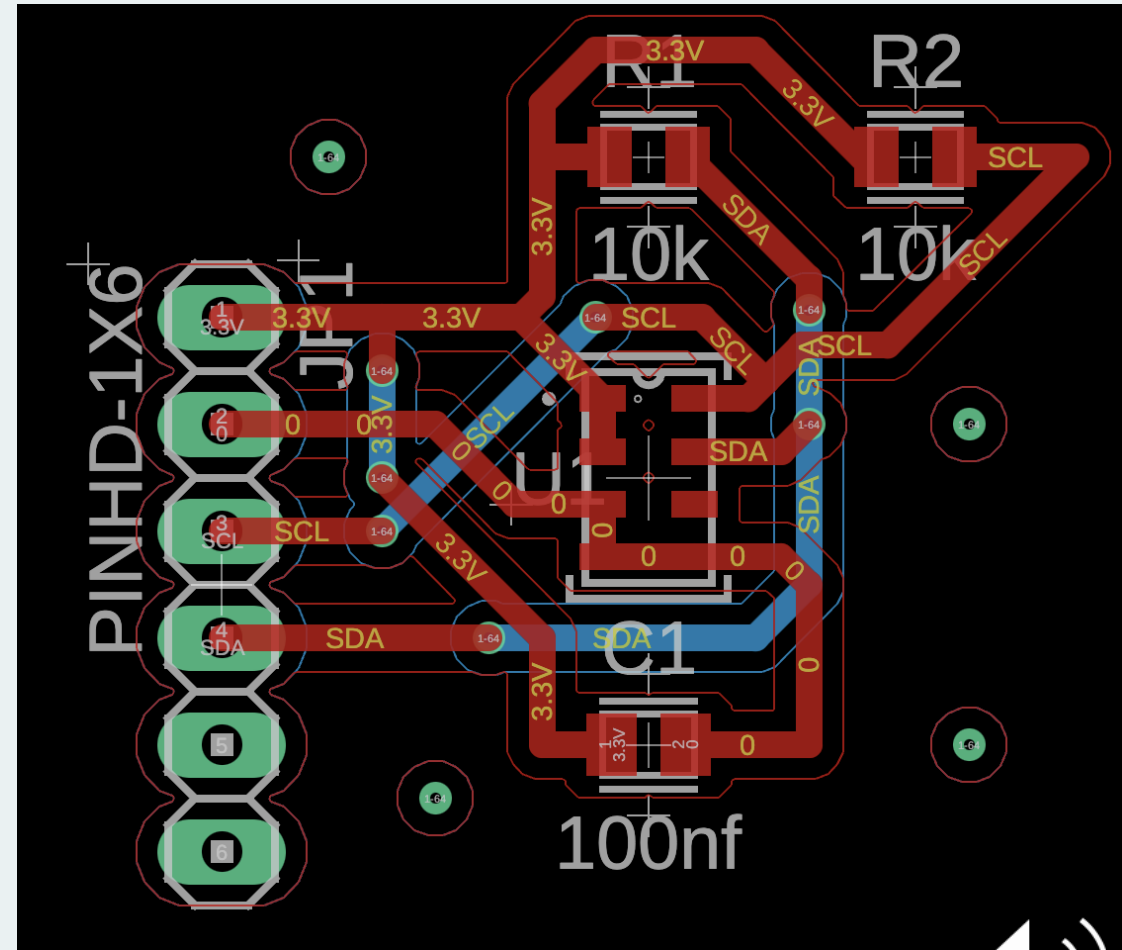
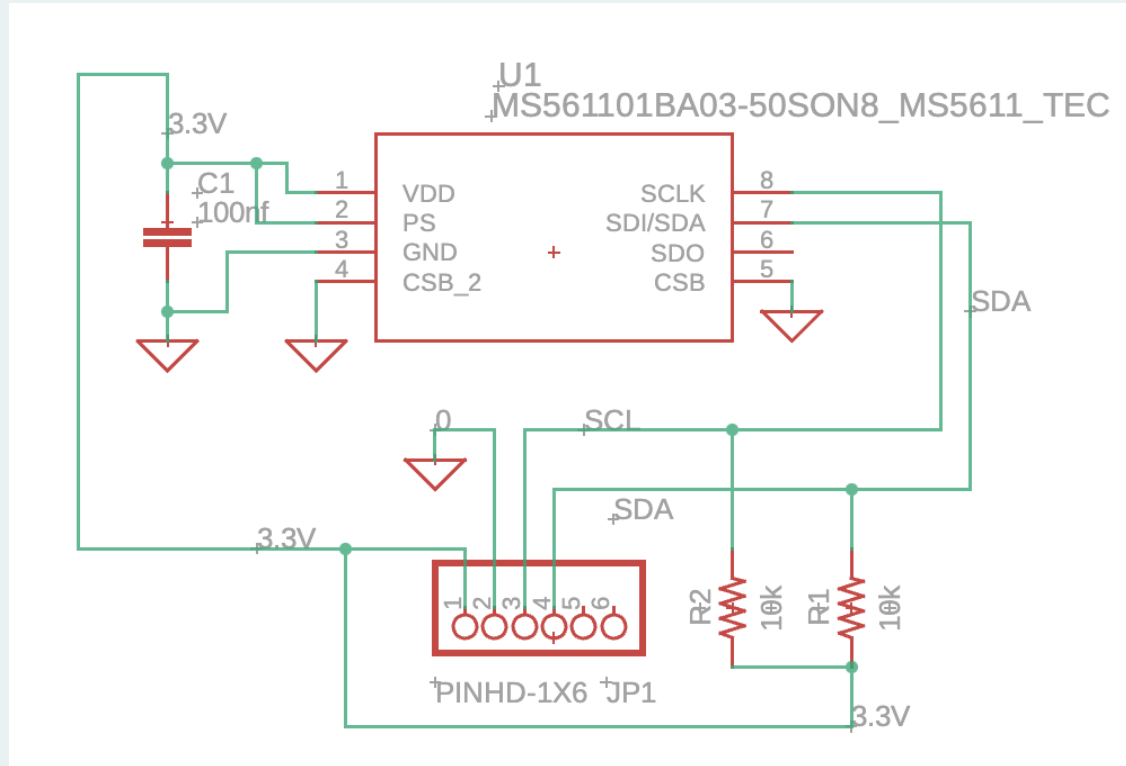


PCB Design - Regulator

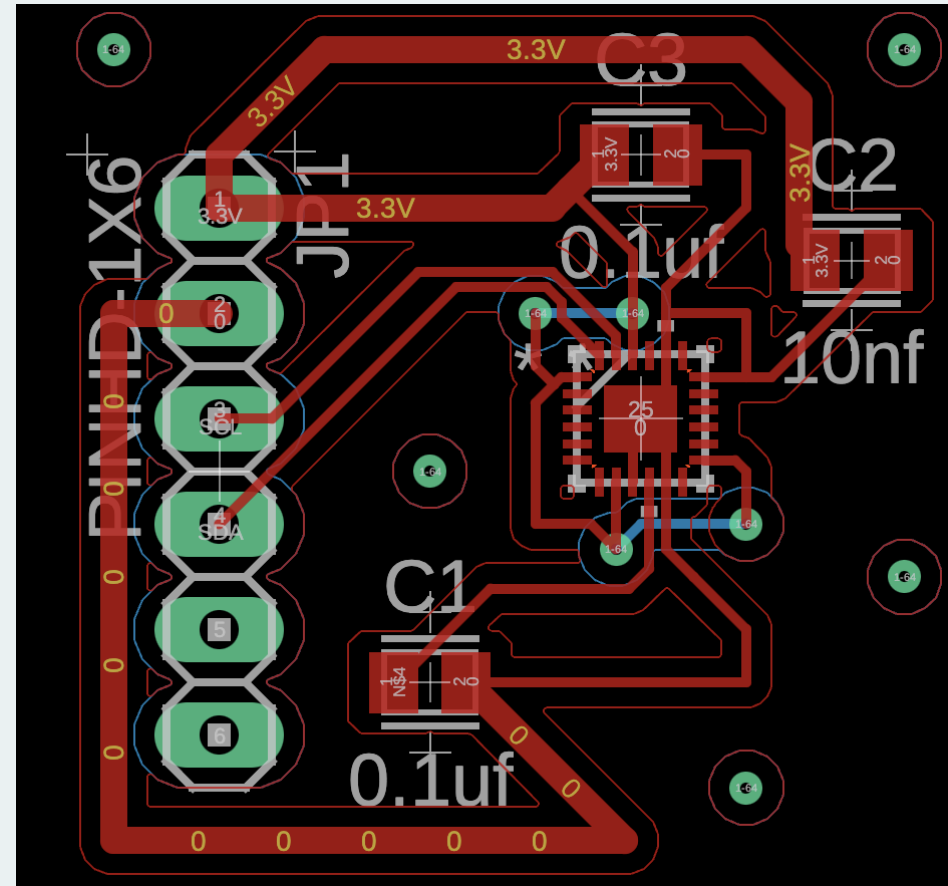
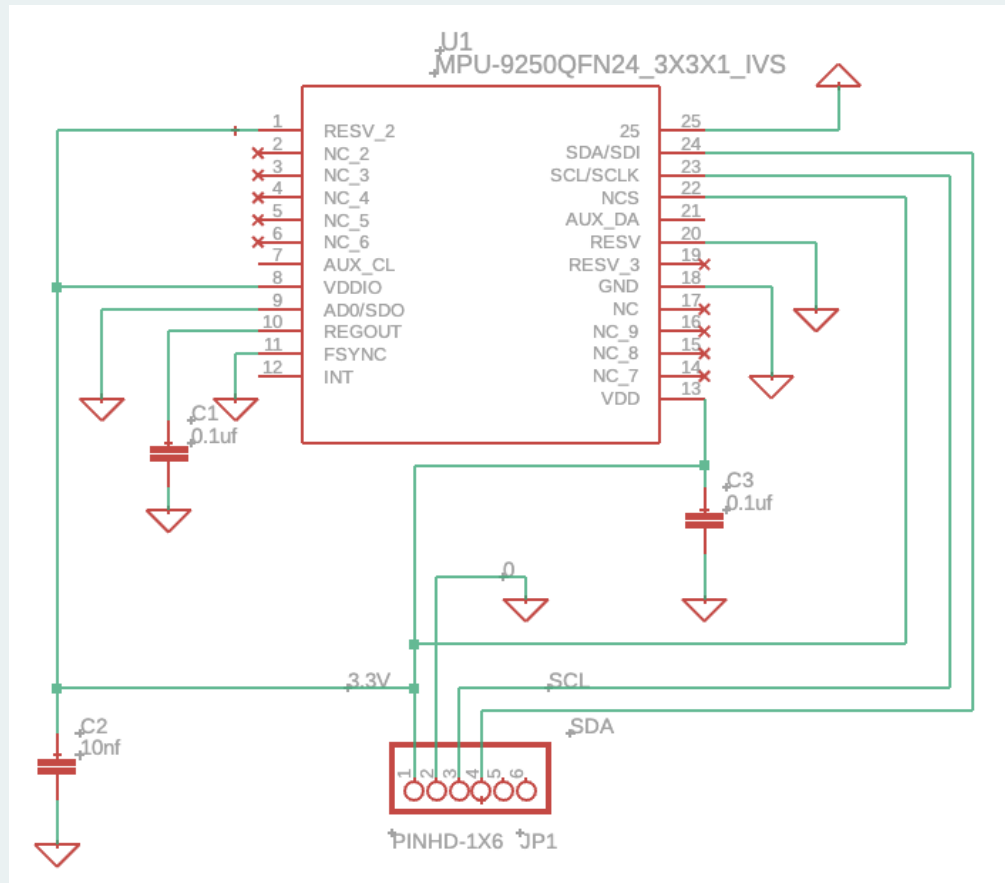




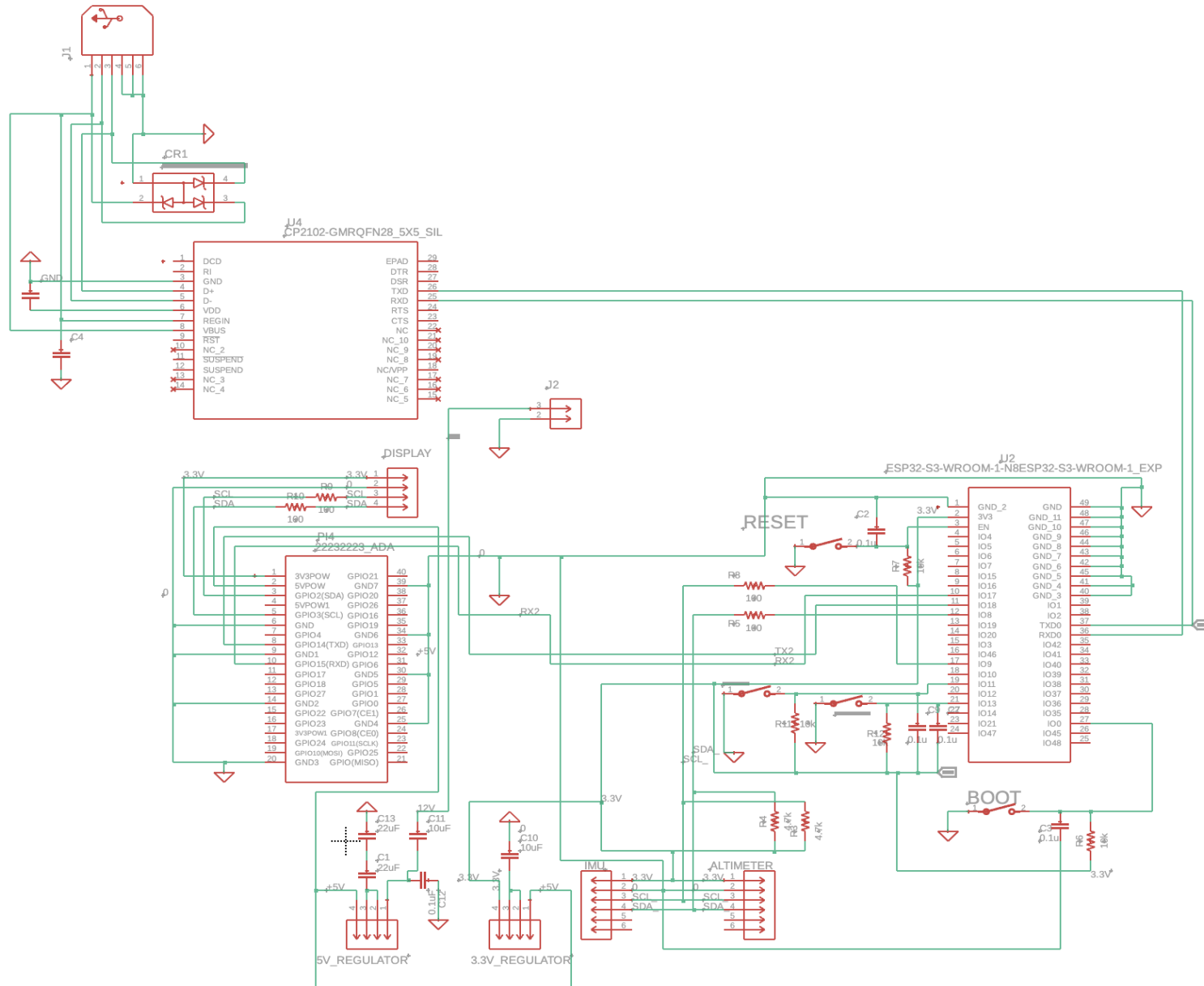
PCB Design-Altimeter

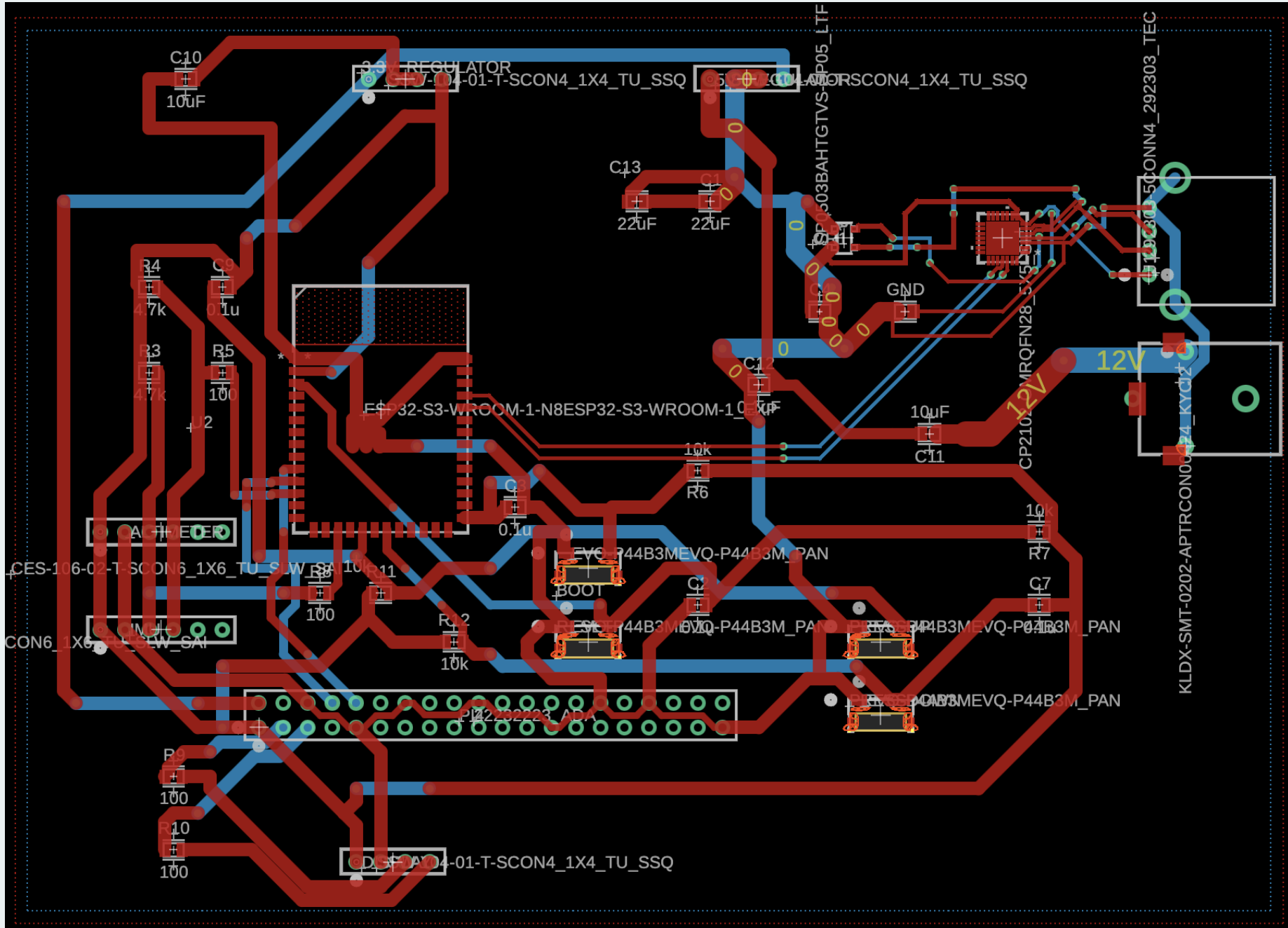


PCB Design - IMU

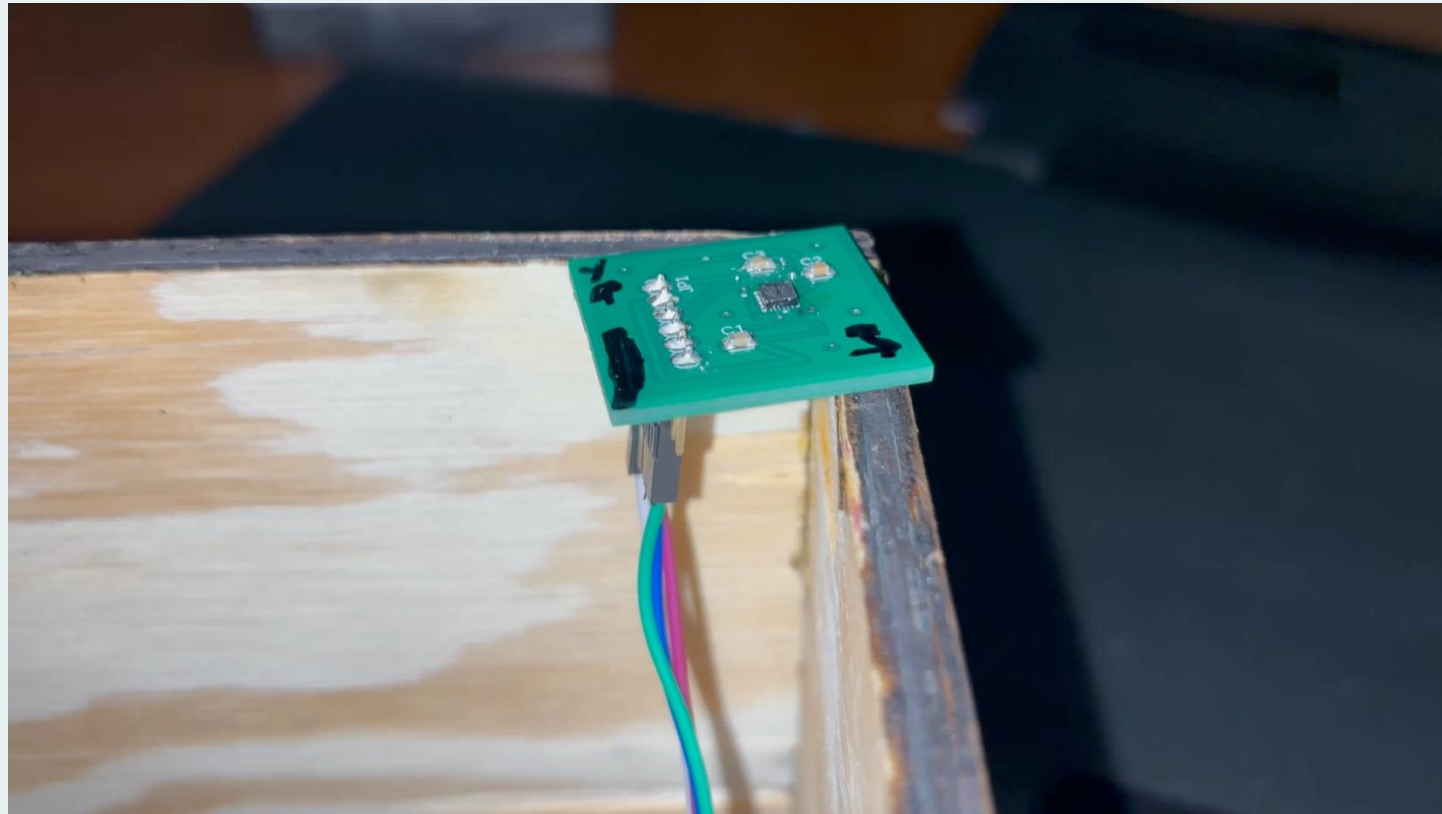


PCB Design - Main PCB



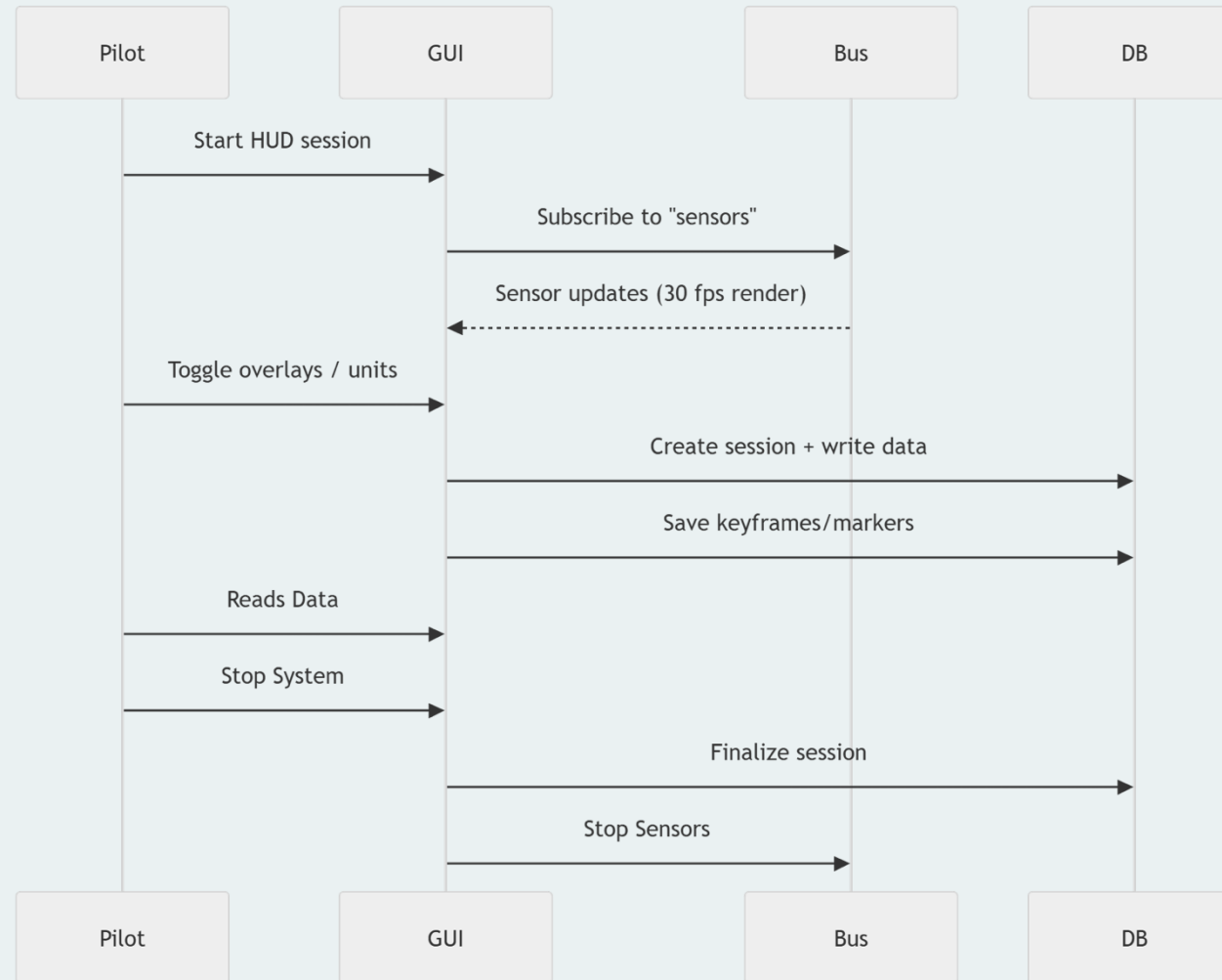


V1 Final System – PCB / Sensors



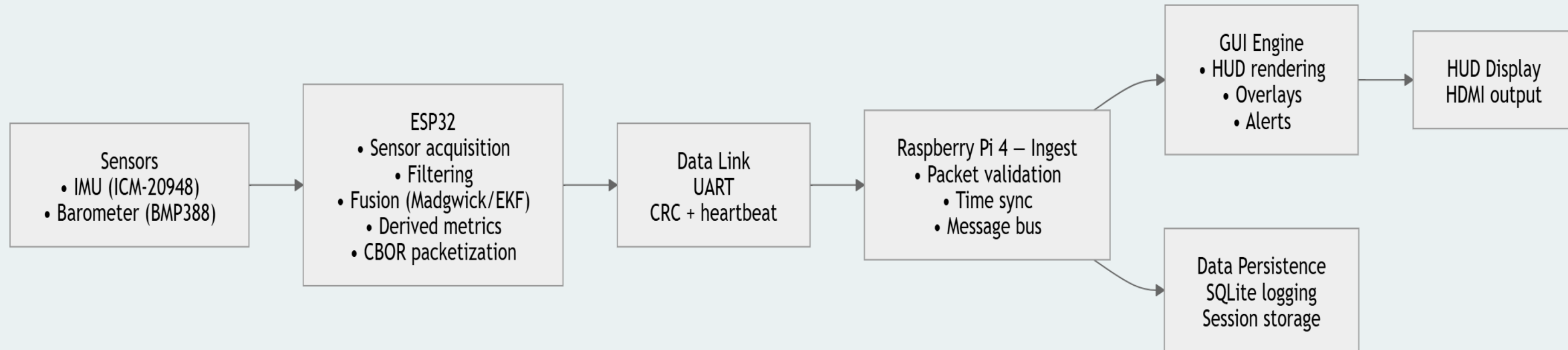


Software Design – Use Case Diagram



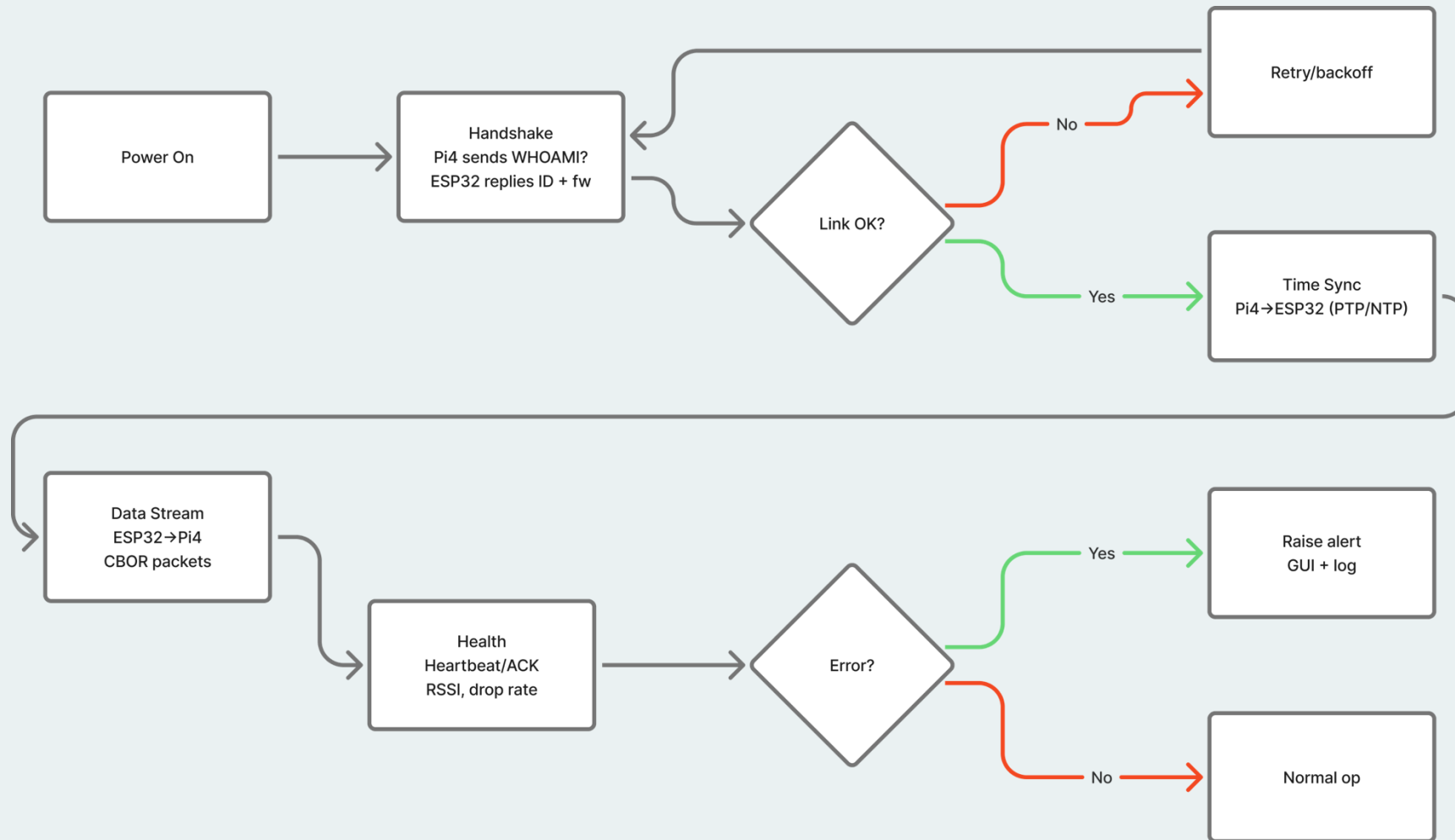


Software Design – System Flow

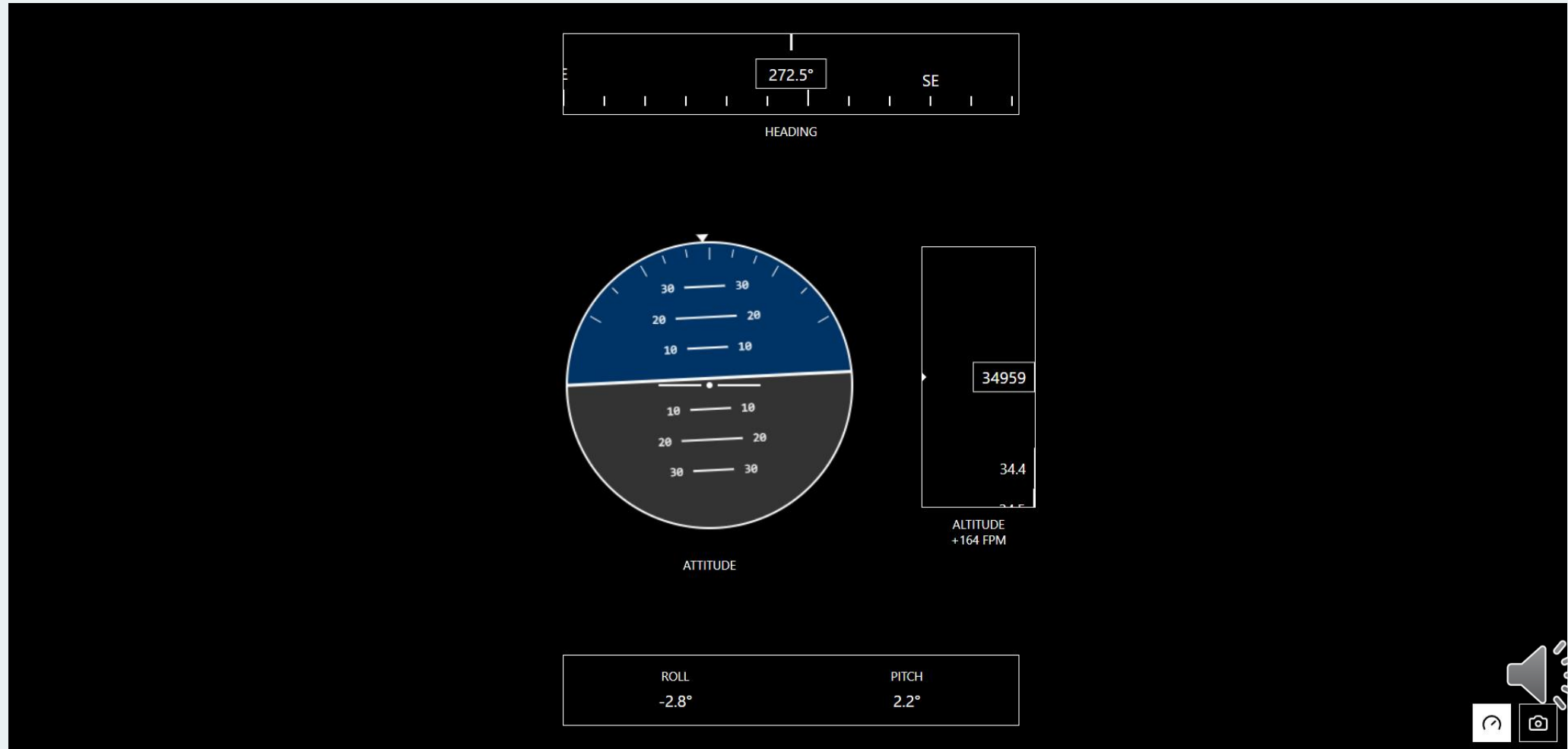




Software Design – MCU Integration



Software Design – UI Spec



Early Prototyping

- Successfully built a benchtop basic projection prototype utilizing:
 - Raspberry Pi4 for peripheral integration / GUI
 - Quarter Waveplate Polarizer
 - Projection Magnification lens System
 - Reflective Optics for Packaging Constraints
 - Breadboard for electrical integration



Early Prototyping



Test Display Screen outputting sample imagery for our setup



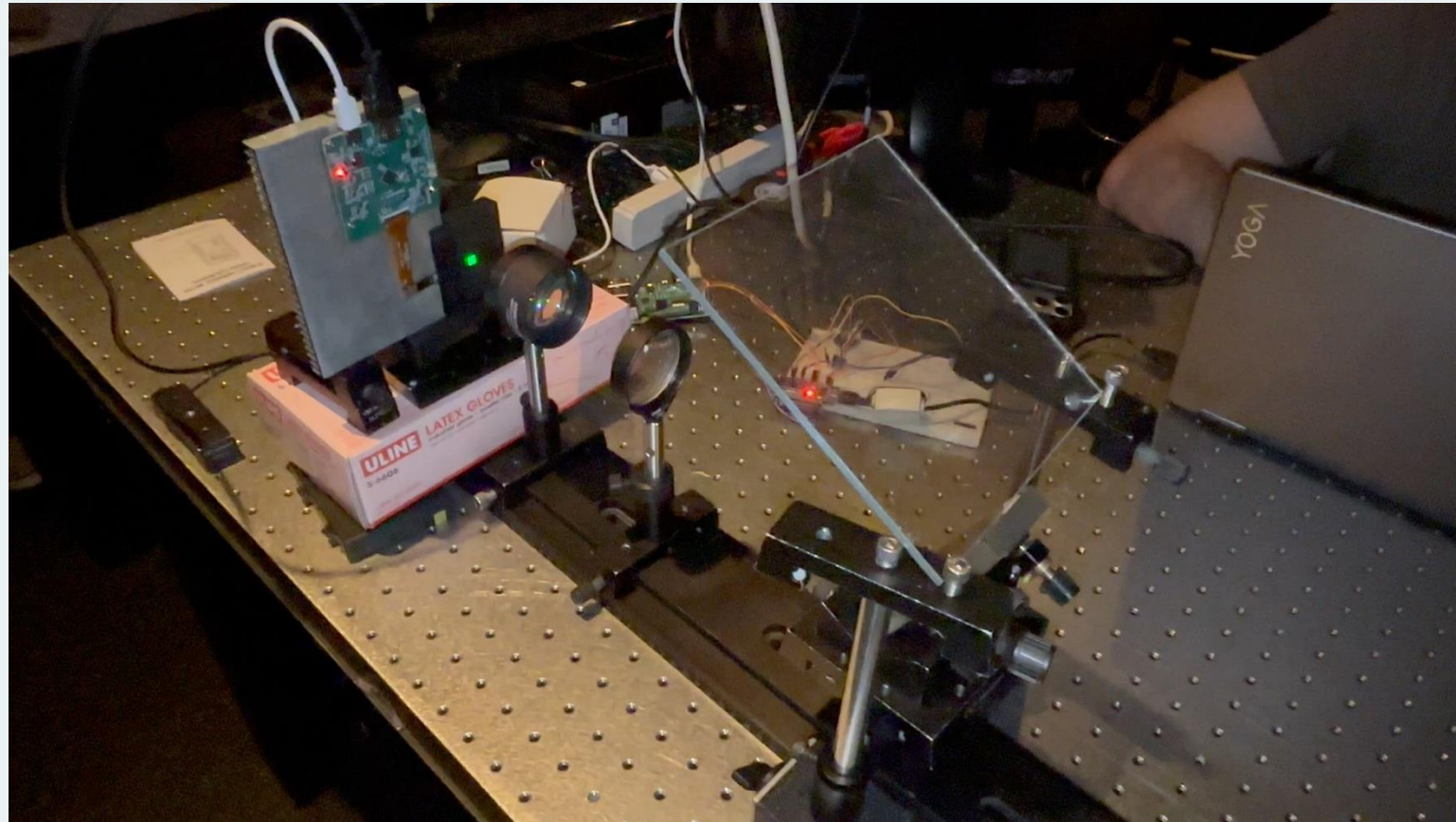
Optical Test Setup with display



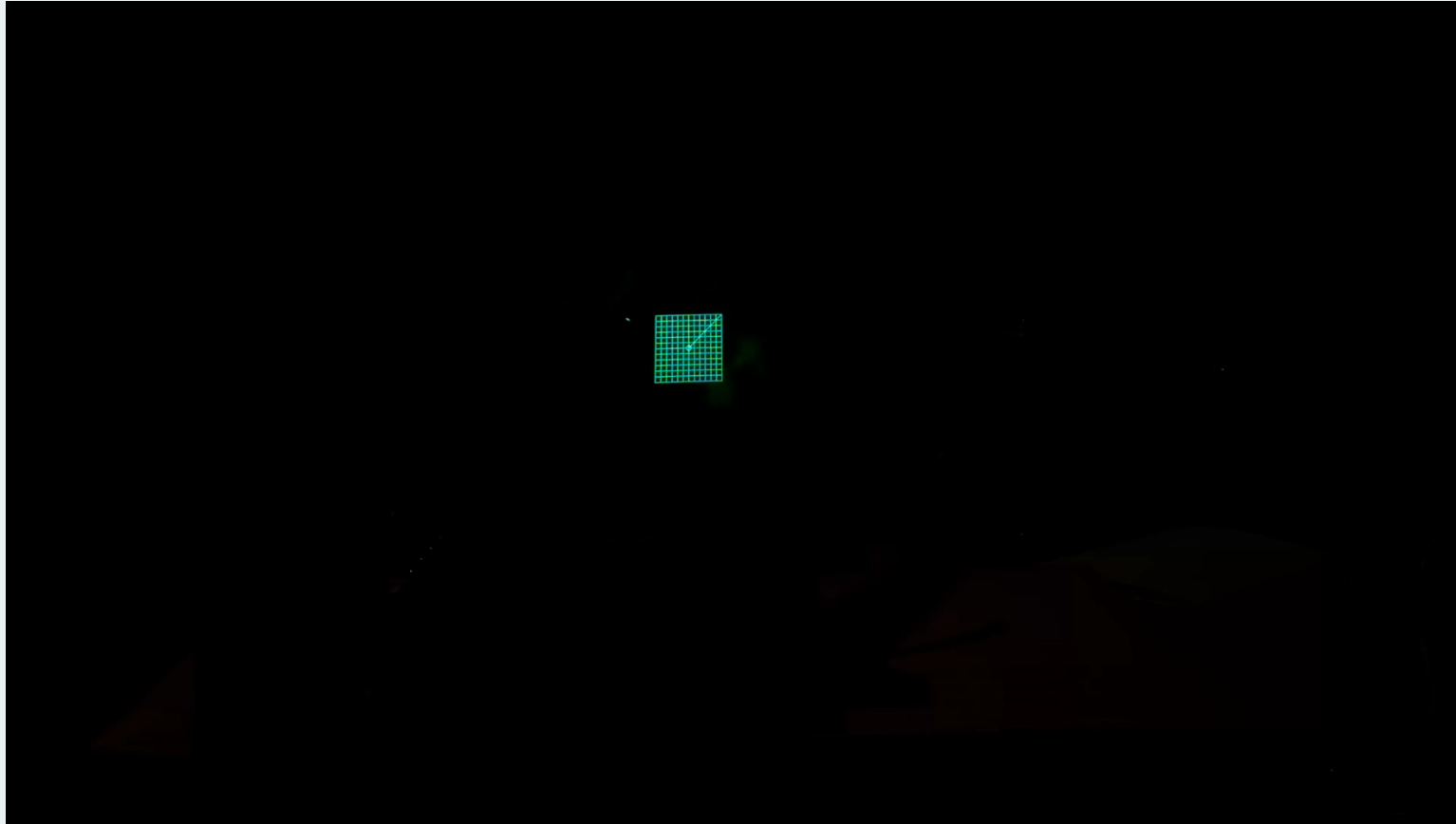
Test setup complete with optics and display integration



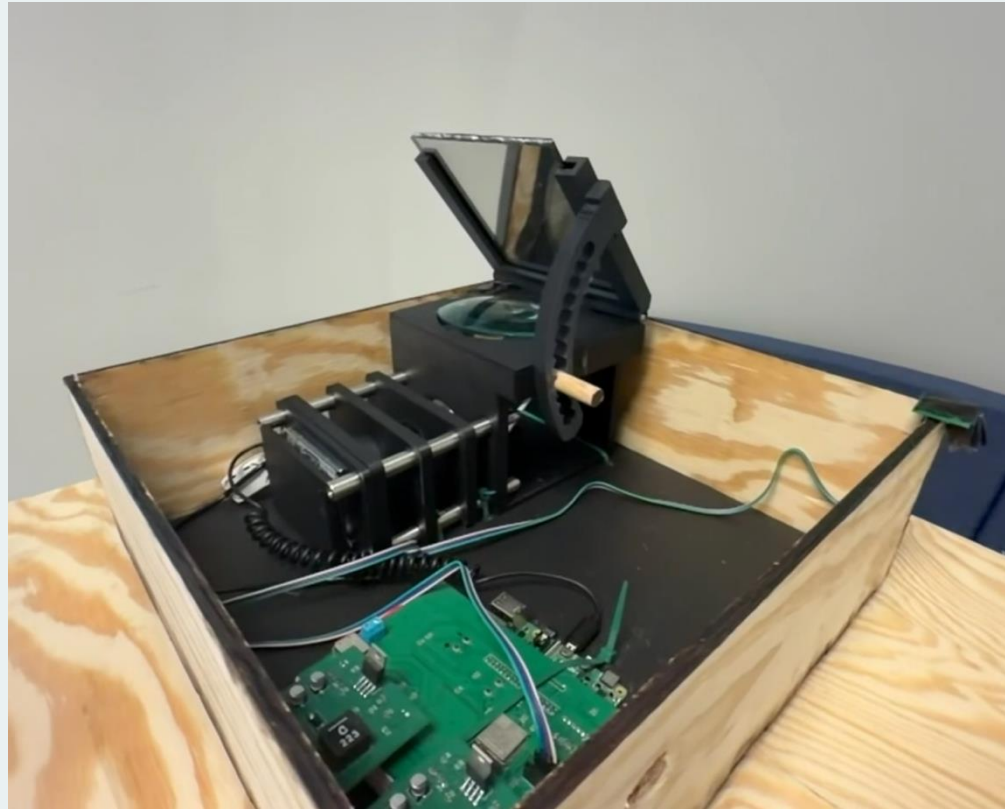
Benchtop System Prototypig



Test Pattern on Benchtop System



***Designed Product (P.E.G.A.S.U.S. V1)



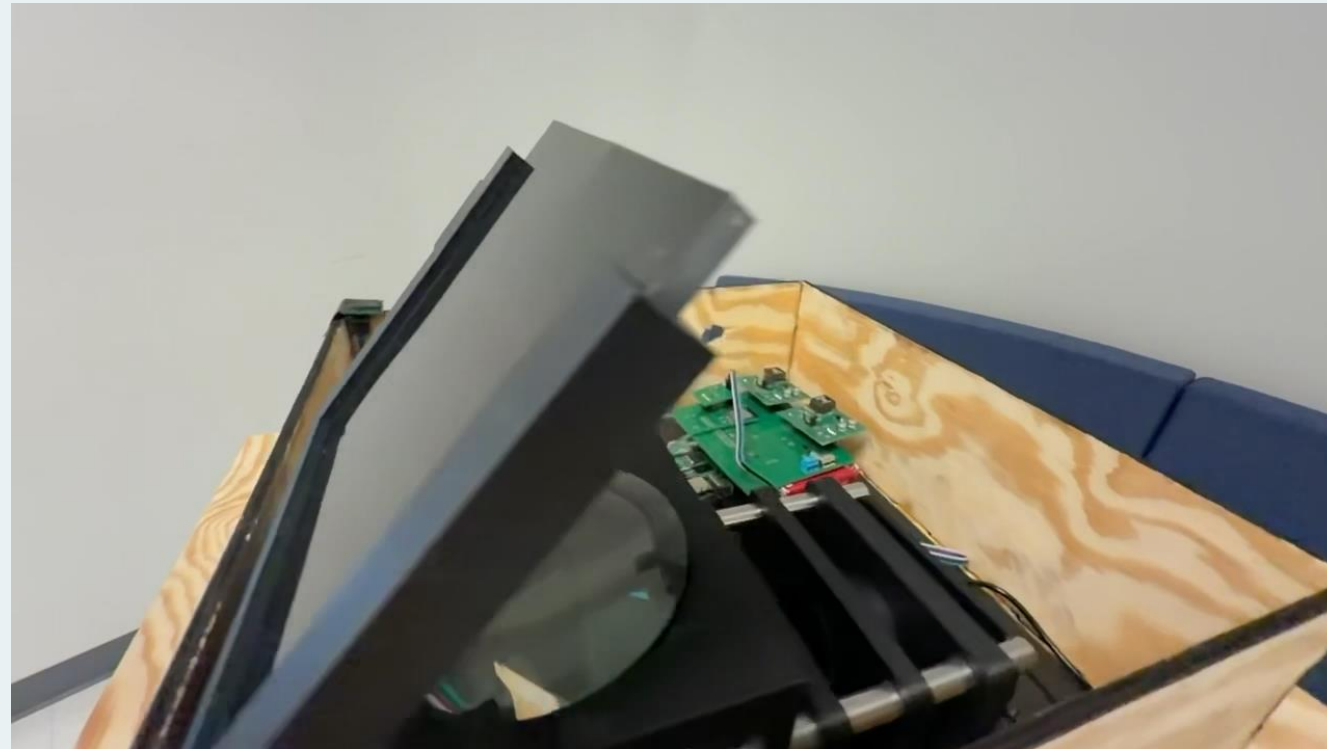
Final housing with PCB and optical systems fully integrated



Final GUI overlaid on to pilots FOV with accurate data



V1 Final System: Internal Components



Optical Hardware Difficulties Faced



Issue Faced	Solution
Optomechanical Housings and Mounts	Designed optomechanics and utilized additive fabrication techniques (3d printing) to iterate upon mechanical housings
Optical Alignment Challenges	Utilized the optical rail cage system in order to ensure optical axis consistency as well as ease of alignment.
HUD Brightness Improvements	Introduced Optical Attenuation Film to combiner in order to increase GUI contrast
Polarization Cost Improvement	Incorporated cost-effective Circular Polarizing $\lambda/4$ film instead of having to buy a costly $\lambda/4$ waveplate

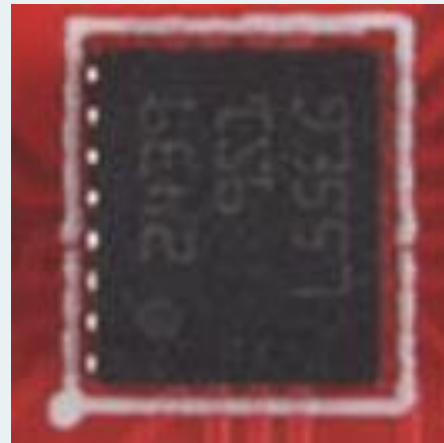
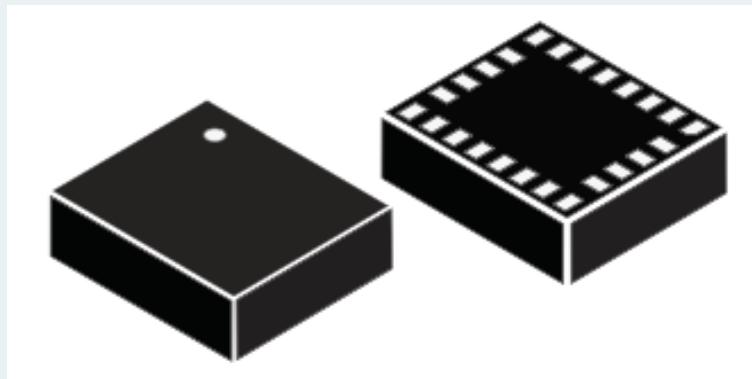


Electrical Hardware Difficulties Faced



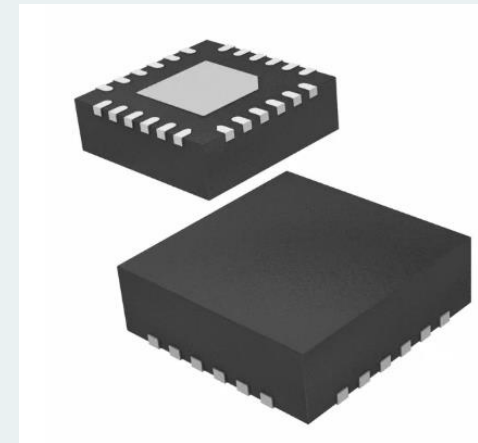
- Solderable sensors
 - Picking the correct package
 - Making sure there are no shorts

No Side Pins



LSM9DS1

Side Pins



MPU9250





Software Difficulties Faced

Issue Faced	Solution
Magnetometer Distortion & Unstable Heading - Magnetic interference and sensor noise caused inconsistent heading readings.	Used a Mahony sensor fusion filter with calibration and correction logic to stabilize heading.
IMU Bias & Drift - Gyroscope and accelerometer biases caused orientation drift over time.	Applied multi-axis calibration to compute and correct sensor offsets.





Administrative Content - BOM

#	Item / Part No.	Qty	Unit Price (USD)	Line Total (USD)
1	Raspberry Pi 4 Model B (4 GB)	1	\$55.00	\$55.00
2	Adafruit Feather ESP32-S3 (STEMMA QT)	1	\$19.95	\$19.95
3	MS5611 Chip	1	\$11.95	\$11.95
4	MPU9250 9-DoF IMU	1	\$15.95	\$15.95
5	Quectel L76K	1	\$9.90	\$9.90
6	25mm Ceramic Patch Antenna	1	\$4.19	\$4.19
7	32GB SDHC Flash MEM CARD	1	\$6.98	\$6.98
8	Arducam IMX-219 Wide-FOV Pi Camera (IMX219, 160°)	1	\$12.09	\$12.09
9	LM2679-ADJ	2	\$8.76	\$17.52
10	6 Pin Male Header	3	\$0.36	\$1.08
11	6 Pin Female Header	3	\$0.31	\$0.93
12	4 Pin Male Header	1	\$0.34	\$0.34
13	4 Pin Female Header	1	\$0.17	\$0.17
14	0805 100k ohm Resistor	2	\$0.10	\$0.20
15	0805 24.9k ohm Resistor	1	\$0.10	\$0.10
16	0805 500k ohm Resistor	1	\$0.10	\$0.10

17	0805 160k ohm Resistor	1	\$0.10	\$0.10
18	0805 4.7k ohm Resistor	4	\$0.10	\$0.40
19	Ceramic X7R 100nF Capacitors	4	\$0.10	\$0.40
20	Ceramic X7R 220nF Capacitors	1	\$0.10	\$0.10
21	Ceramic X7R 1uF Capacitors	4	\$0.08	\$0.32
22	Ceramic X7R 10uF Capacitors	2	\$0.08	\$0.16
23	Ceramic X7R 22F Capacitors	6	\$0.08	\$0.48
24	Ceramic X7R 0.1uF Capacitors	3	\$0.08	\$0.24
25	Ceramic X7R 2.2uF Capacitors	1	\$0.08	\$0.08
26	Ferrite Bead 600ohm 100mHz	1	\$0.10	\$0.10
27	8uH Inductor	1	\$1.23	\$1.23
28	OLED Display	1	\$139	\$139
29	Multi-Order Quarter Waveplate	1	\$17	\$17
30	Collimating Lens	1	\$113	\$113
31	Reflective Mirror	1	\$25	\$25
32	OAP Mirror	1	\$185	\$185
33	Magnifying Lens	1	\$56	\$56
34	Photochromic Film	1	\$40.50	\$40.50
35	Optical Combiner	1	\$100	\$100
36		Total:		862.04

Administrative Content – Work Distribution



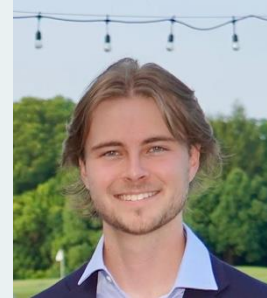
Computer Engineering	Responsibilities
Luke Anderson	Software Design and Implementation
	MCU Selection and Implementation
	Website Design and Management
	Project Lead
Electrical Engineer	
Frank Murphy	PCB/PSU Design
	Hardware Component Selection
Optics Engineer	
Ethan Dill	Optical Design
	Component Alignment
	Optical Component Integration



Future Changes

- Utilize GPS module instead of magnetometer for improved heading
- Implement an overlaid navigation feature to allow pilots to navigate using this system
- Head / eye tracking for dynamic eye box





Thank You!



Questions?