Group 4 CDR: Final Presentation
Laser Integrated Navigation & Kinematics

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Meet the Team

Jeremy Goodenough
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Brian Corchuelo
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Dylan Farnsworth
EE

Santiago Castro
CPE

Motivation and Background

- Navigation using only a 2D map can be difficult
  - You can confuse your position and direction very easily on a 2D map

- True scale, size, and distance of terrain can be misleading from the ground
  - Larger objects are hard to gauge

- Once you DO find yourself on a map, it may be impossible to locate another target
  - Target can be defined as any other point of interest, like mountain, hill, building, ect

Motivation and Background Continued

- Navigation using only a 2D map can be difficult
  - You can confuse your position and direction very easily on a 2D map
  - L.I.N.K. finds YOU on the map, and shows where you are looking

- True scale, size, and distance of terrain can be misleading from the ground
  - Larger objects are hard to gauge
  - L.I.N.K. shows you how far away objects really are on a map

- Once you DO find yourself on a map, it may be impossible to locate another target
  - Target can be defined as any other point of interest, like mountain, hill, building, ect
  - L.I.N.K. will show you those targets on the map, giving their exact location

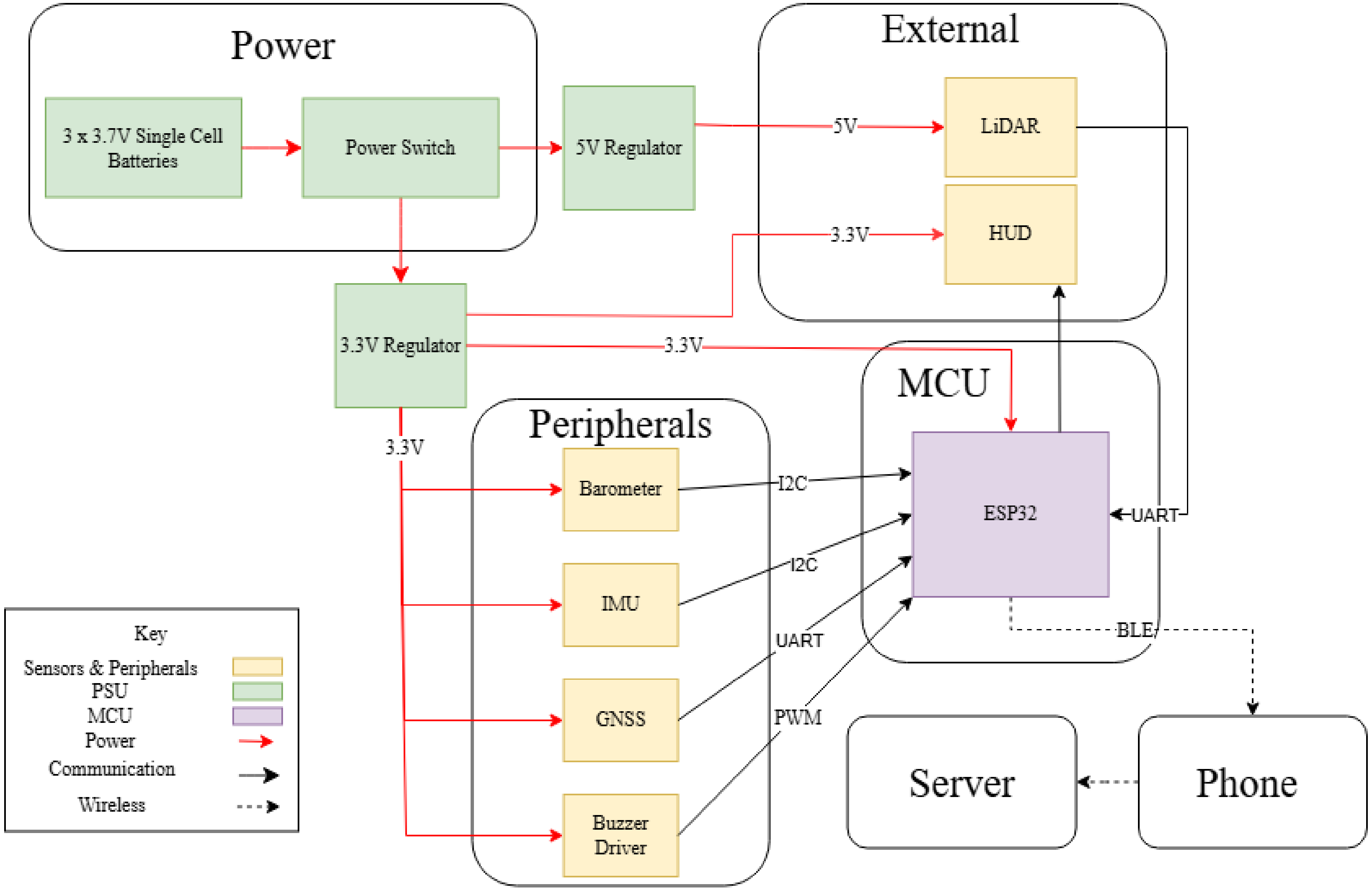
Goals and Objectives

- Enhanced observation experience
  - Custom designed, high magnification, optical binoculars to view any distant targets
  - Integrated heads-up display within binoculars, to see live information of targets
- Seamless navigation experience
  - Sensor suite obtains user position, as well as distance and position data of target
  - Obtained sensor data live updates to integrated HUD, and to companion website
- Portability and versatility
  - Lightweight, battery operated, and UV resistance packaging
  - Partial offline capabilities, the integrated HUD always works regardless of internet connection

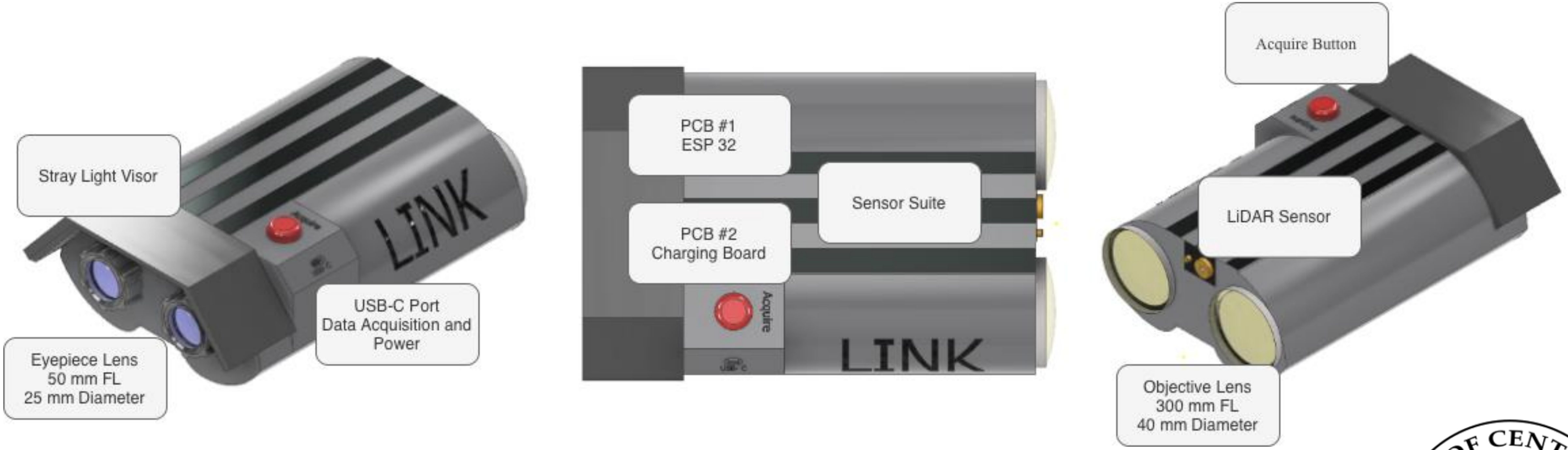
System Specifications

Parameter	Value	Description
Optical Stacks		
Magnification	6×	Minimum angular magnification required for target observation.
Apparent Field-of-View	20°	Angular field visible to the user through the binocular optical system.
H.U.D. Latency	≤50 ms	From sensor suite data collection to range calculation to display latency
Target Mapping		
Mapping Range	200 m	The pinging subsystem can measure any target within 200 meters.
Mapping Error	±10 m	When considering the error from the LiDAR, IMU, and data processing, the targeted ping shall not exceed a 10 meter error radius from the true target.
Website Latency	≤1.5 s	Time from ping command to companion website ping indicator display shall not exceed 1.5 seconds.
Packaging		
Size	200 mm × 200 mm × 100 mm	Maximum allowable package envelope for device portability.
System Weight	<2000 g	Target total device mass shall not exceed 1500 grams.
Power Draw	≤3.32 W	Device operating at full power shall not draw more than 3.32 W.

Hardware Block Diagram



L.I.N.K. Enclosure 3D Render



Peripheral Devices

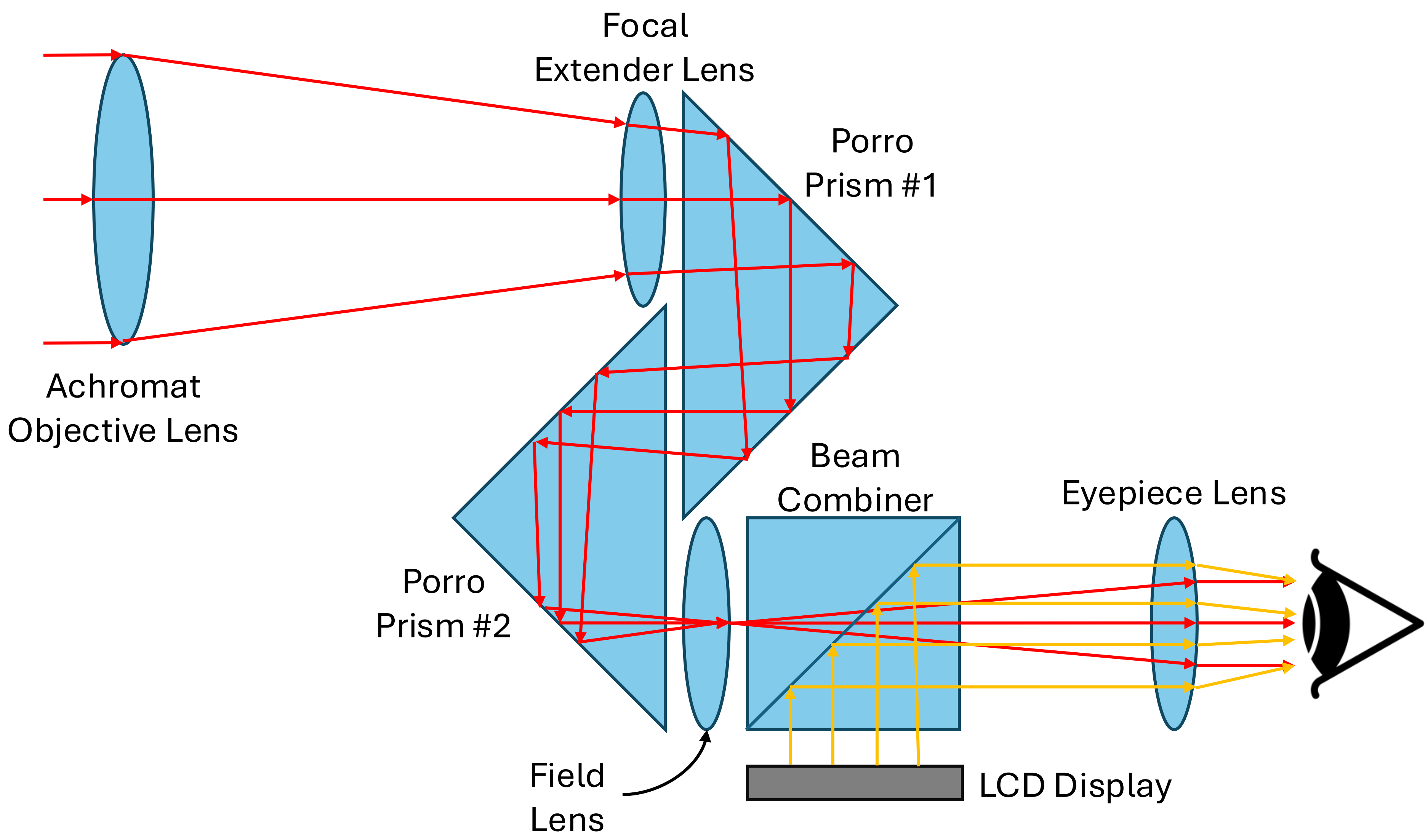
Navigation Sensors

- GNSS Receiver for user latitude/longitude
- IMU class sensor for heading/orientation
- BMP280 barometer for pressure/altitude

Range and user feedback

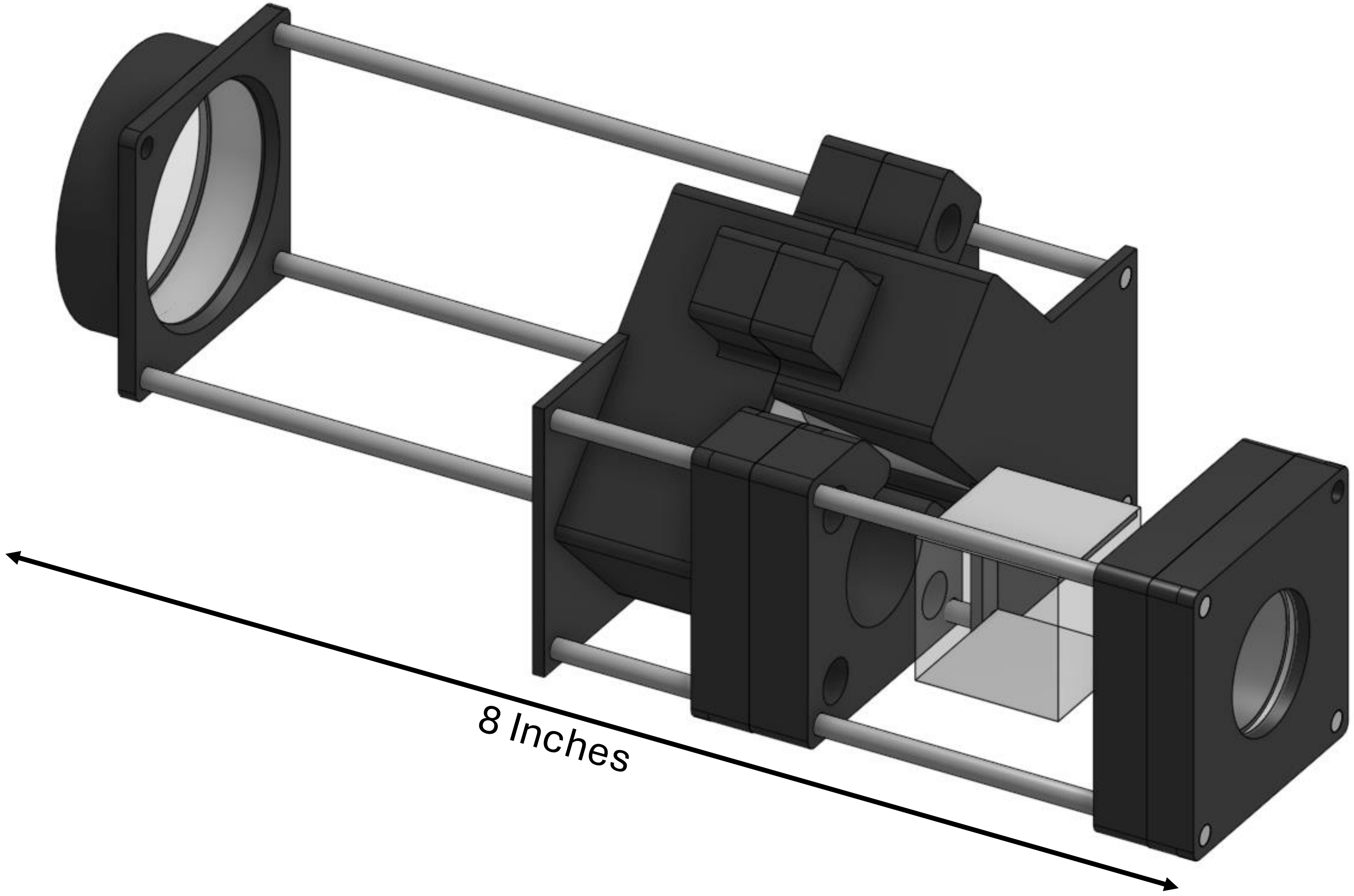
- PTYS – 12x class LiDAR module of UART
- TFT HUD Display over SPI
- Button and buzzer boards for user action/feedback

Optical Hardware Design



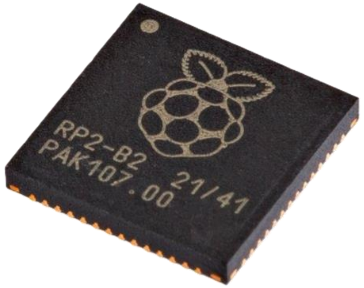
Sponsor-Supported Optical Components
Achromat objective lens
Eyepiece lens
Focal extender
Field lens
Porro prisms
Beam splitter
Optics subtotal

Opto-Mechanic Hardware



Microcontroller

- Low-power operation for a battery powered binocular system
- Enough GPIO and serial buses for GNSS, LiDAR, barometer, TFT display, button, and buzzer
- Built-in wireless communication so the binocular can send waypoint data to the phone
- Interrupt / timer support for responsive user input and sensor sampling



Microcontroller Selection

General comparison of the three MCU platforms considered before the final part selection.

MCU Platform	Main Strength	Main Tradeoff
ESP32	Built-in Wi-Fi/BLE, dual-core MCU, SPI/I^{2}C/UART/GPIO, strong Arduino + ESP-IDF support	Higher idle power than ultra-low-power MCUs
STM32	Excellent timers, ADC, DMA, and professional embedded ecosystem	Most options need a separate wireless module
RP2040	Very low cost, easy debugging, strong PIO timing features	No built-in Wi-Fi/BLE in base chip

Voltage Regulator Selection

Model	LTC3113	TPSM863253	LTC3539	TPS61088	LM2596S
Brand	Analog Devices (Linear Technology)	Texas Instruments	Analog Devices (Linear Technology)	Texas Instruments	Texas Instruments
Input Voltage (V)	5.5	11.1	11.1	5.5	11.1
Output Voltage (V)	3.3	3.3	5.0	5.0	3.3 or 5.0
Output Current (A)	0.9	3.0	0.6	10.0	3.0
Price ($)	12.44	2.88	8.27	2.74	6.18
Type	Buck-boost	Buck	Boost	Boost	Buck

Thermal Design

5V Regulator:

Parameters	
$V_{out\ (V)}$	5.0
I_{out} (A)	0.45
P_{out} (W)	2.25
Efficiency η	92
P_{loss} (W)	0.196

Thermal	
$T_{Ambient\ (°C)}$	38
$T_{Junc\ (°C)}$	48.4 < 150
Margin to 150 °C (°C)	101.6

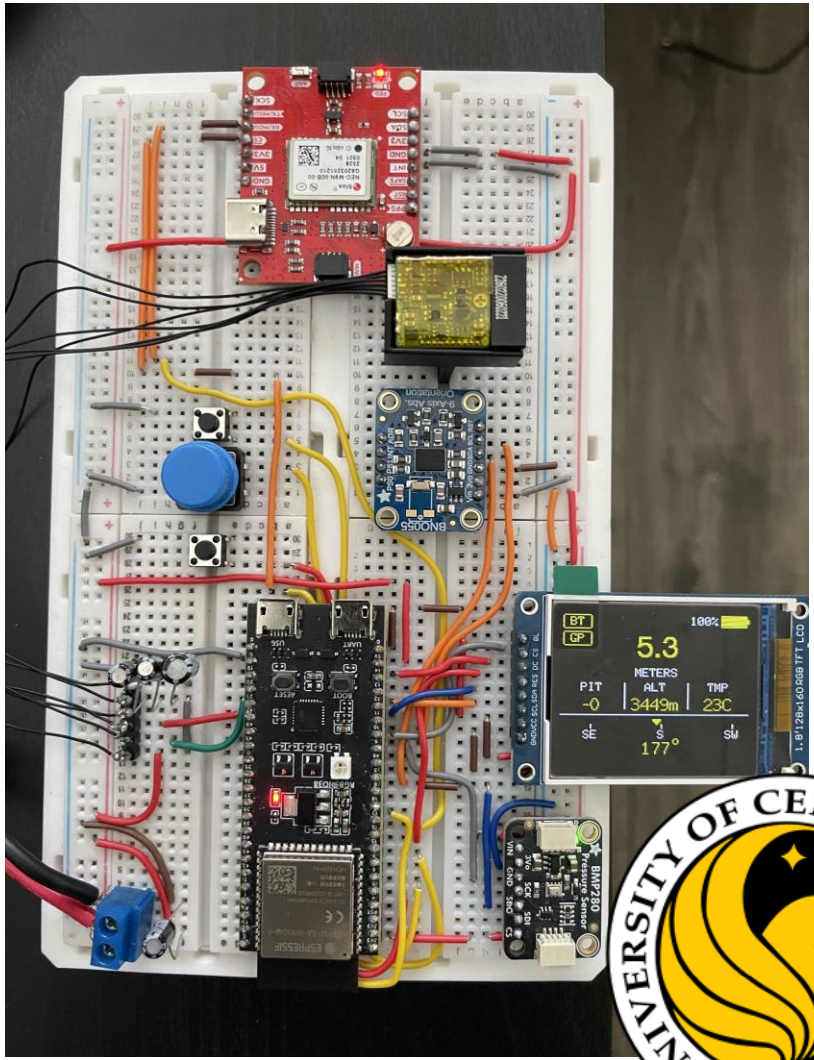
3.3V Regulator:

Parameters	
$V_{out\ (V)}$	3.3
I_{out} (A)	0.776
P_{out} (W)	2.561
Efficiency η	92
P_{loss} (W)	0.223

Thermal	
$T_{Ambient\ (°C)}$	38
$T_{Junc\ (°C)}$	49.8 < 150
Margin to 150 °C (°C)	100.2

Prototype / Dev Board Components

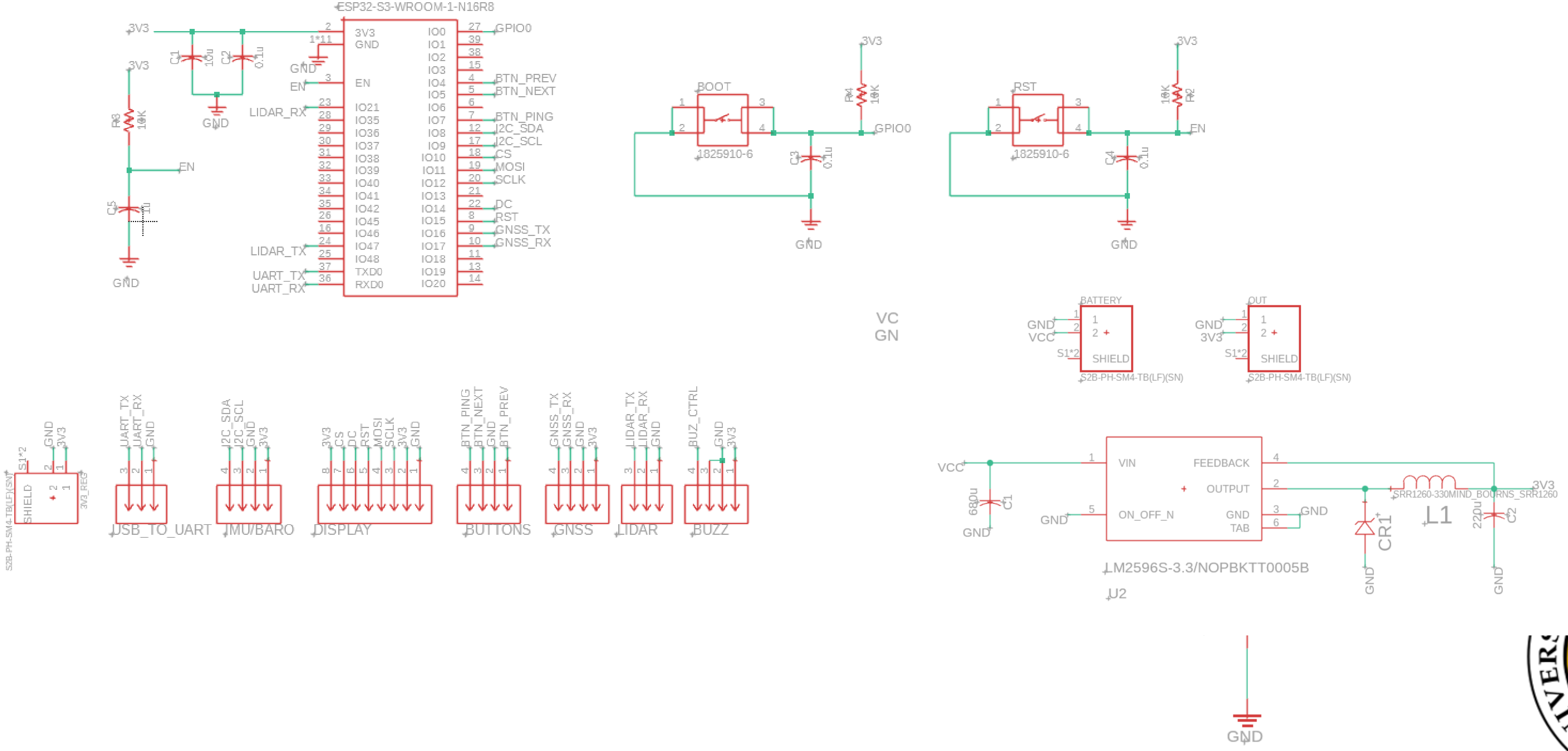
Prototype / Dev Hardware Used	Use in Prototype
ESP32-S3 DevKitC-1	Firmware bring-up before custom MCU PCB
Adafruit IMU breakout	Heading/orientation testing
Adafruit barometer breakout	Pressure/altitude testing
SparkFun NEO-M9N GNSS	Latitude/longitude prototype testing
PTYS-12X LiDAR module	Distance/range measurement
SPI TFT display module	HUD display prototype



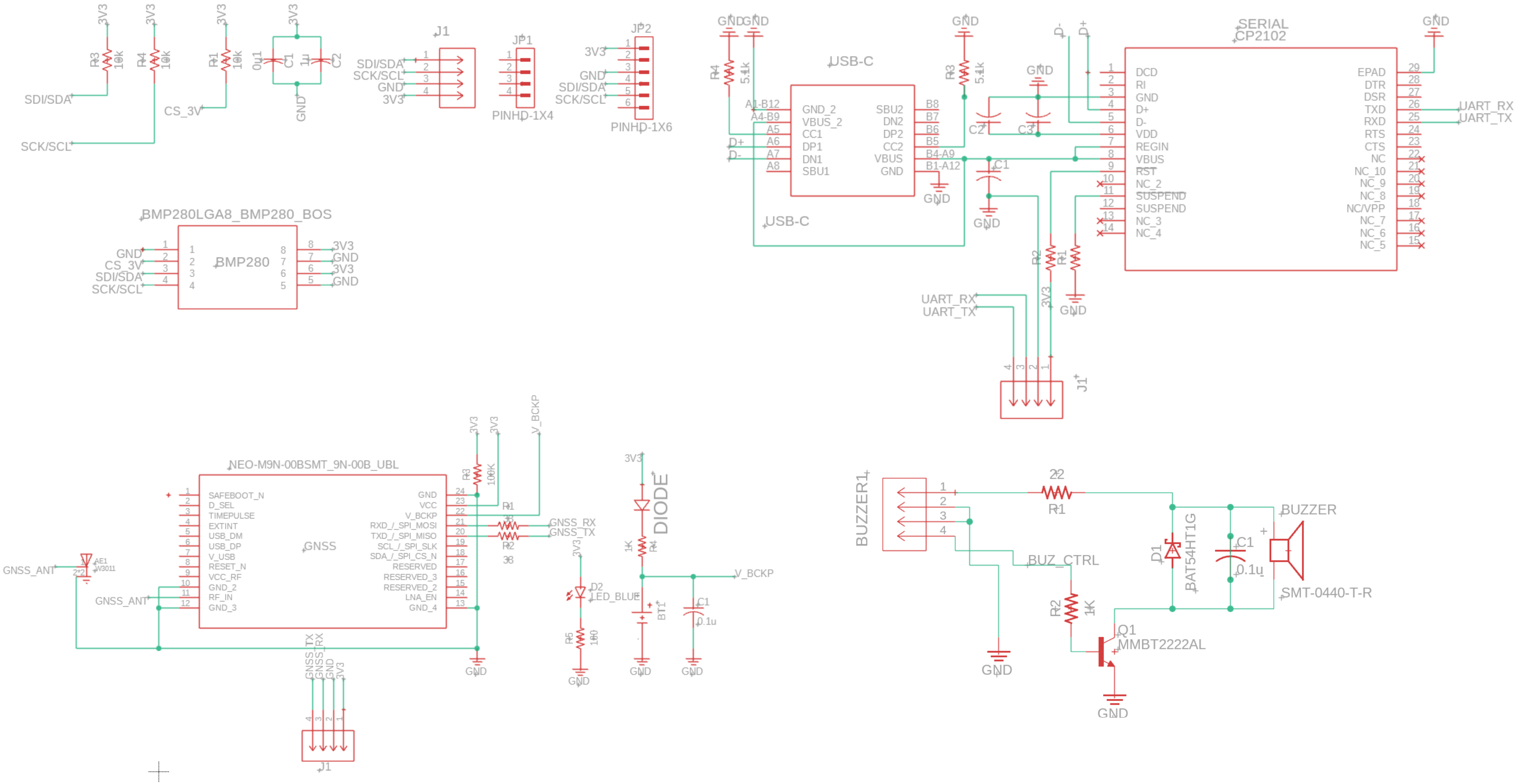
Final Hardware Design

- After much iteration and componant integration- a final design has been reached- following closely to the initial design render:

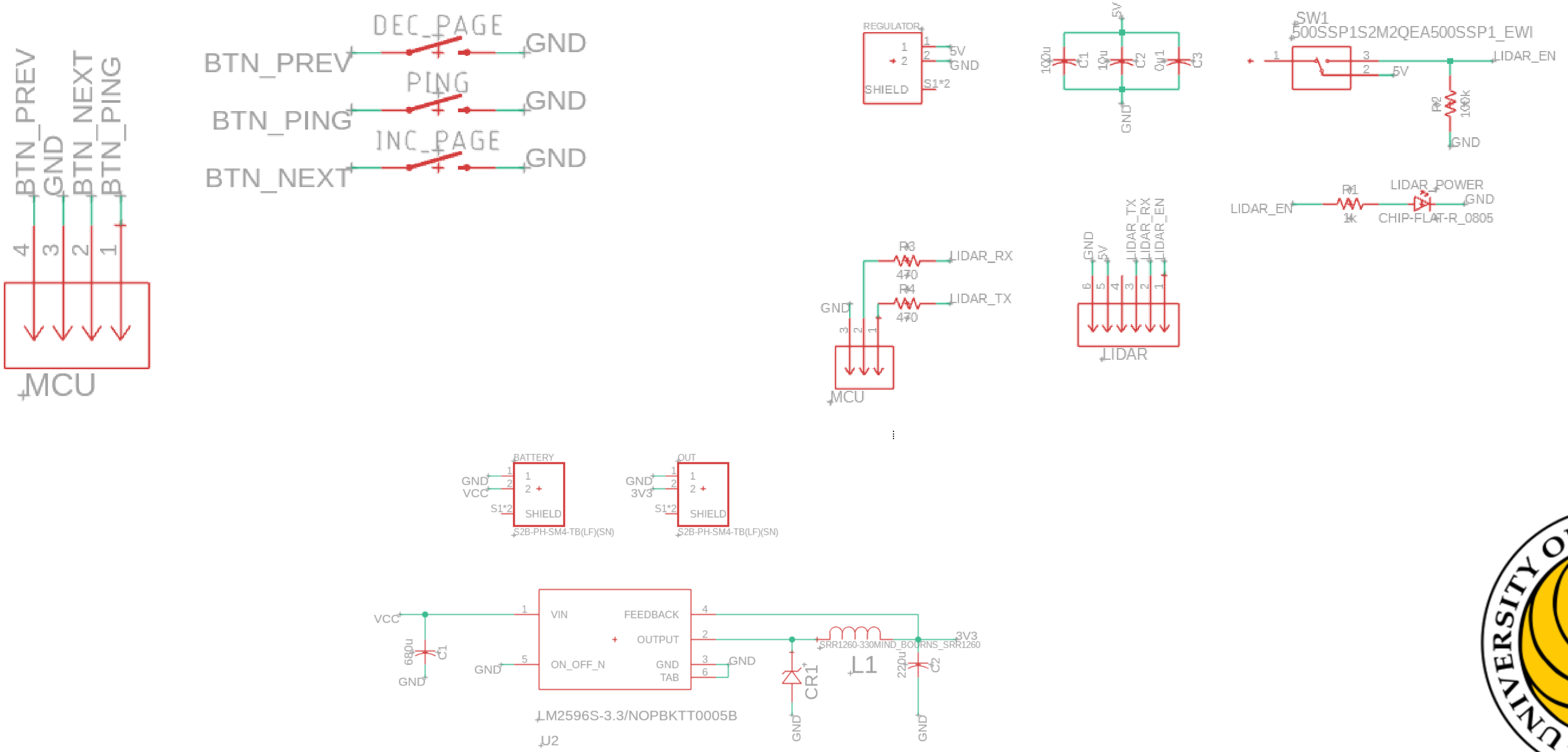
Overall Schematic



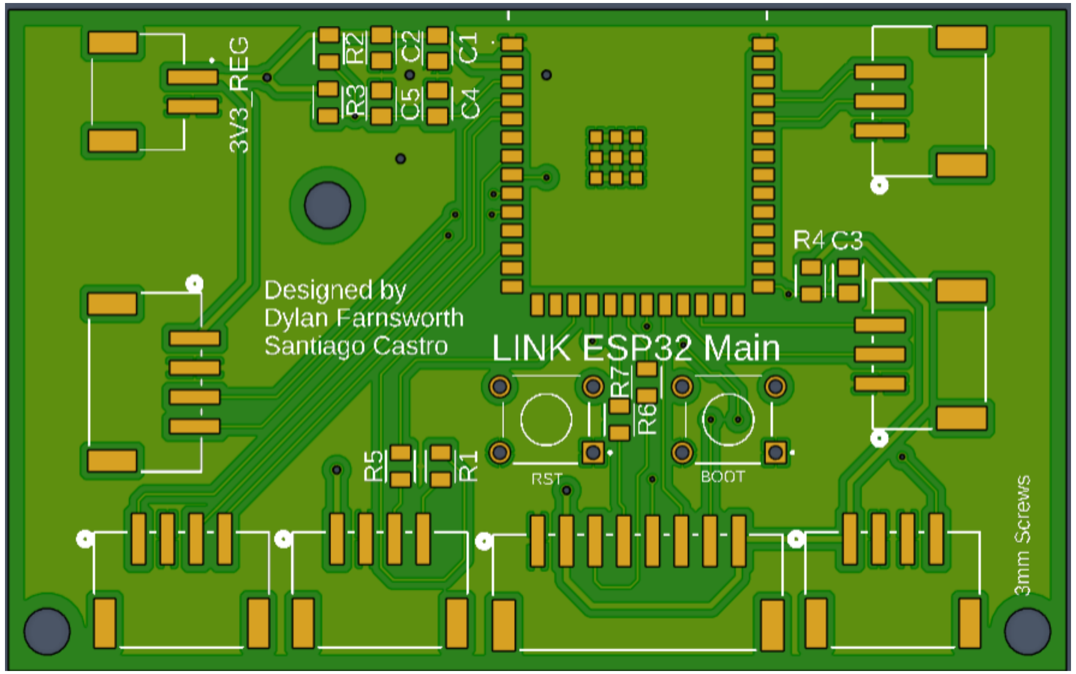
Peripheral Schematics



Connector & Regulator Schematics



PCB Design – ESP32 Board



11 PCBs Designed:

- BMP280, button, buzzer, display, GNSS, LiDAR interface, MCU, power switch, 3.3 V regulator, 5 V regulator, and USB-serial.

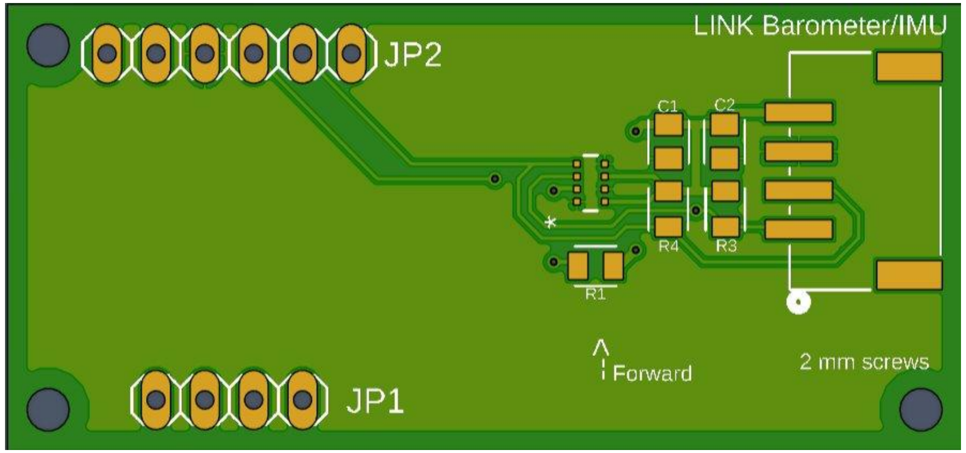
MCU Board:

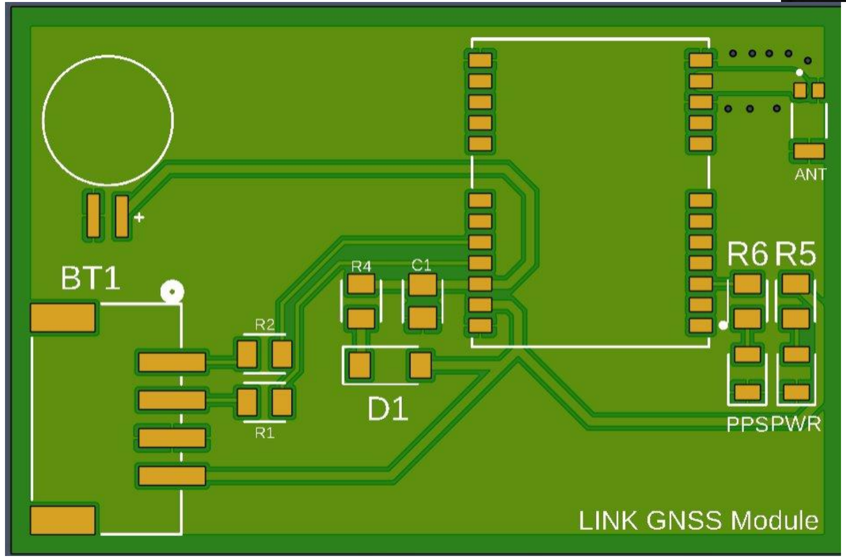
- ESP32-S3 WROOM-2 module, labeled JST ports, display/button/sensors connections, and programming/debug interface

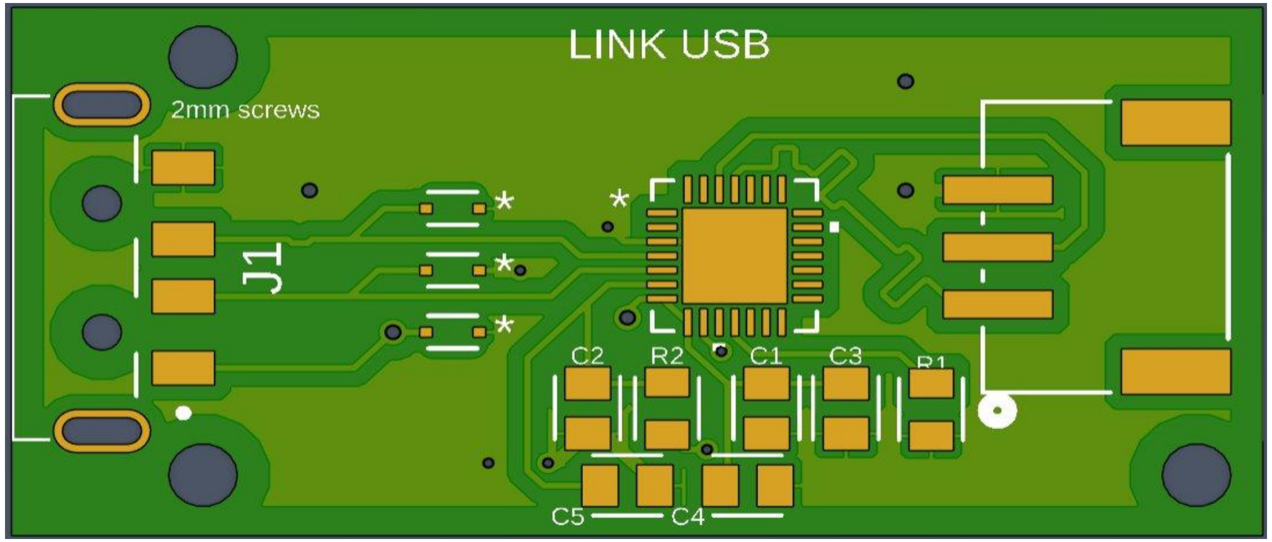
Power Arc:

- Power Switch Board, 3.3V or 5V Regulator Boards separate from noisy/high-current power from logic

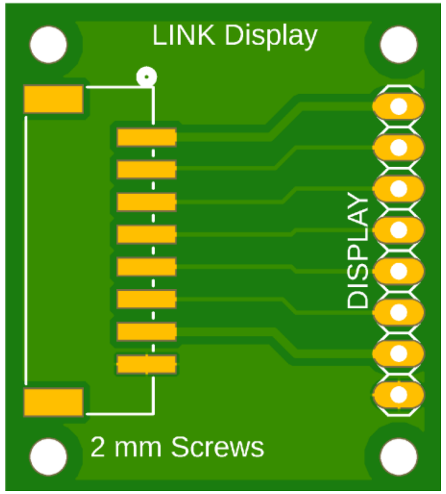
PCBs- Peripheral Boards

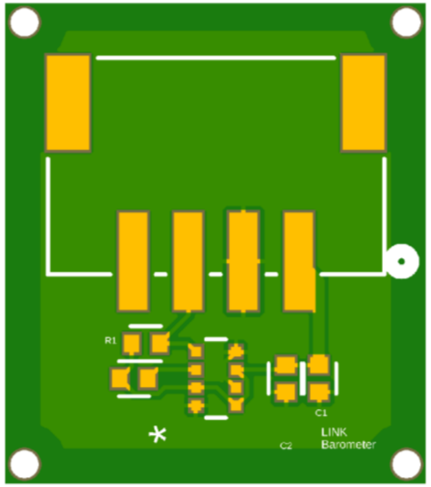


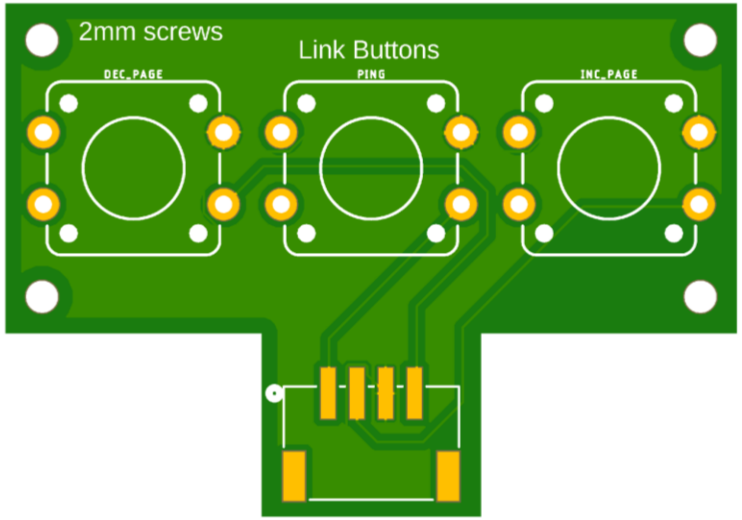


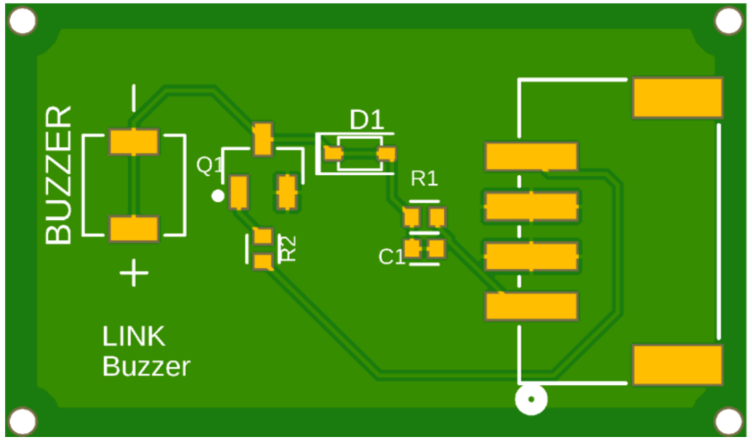


PCBs- Peripheral Boards

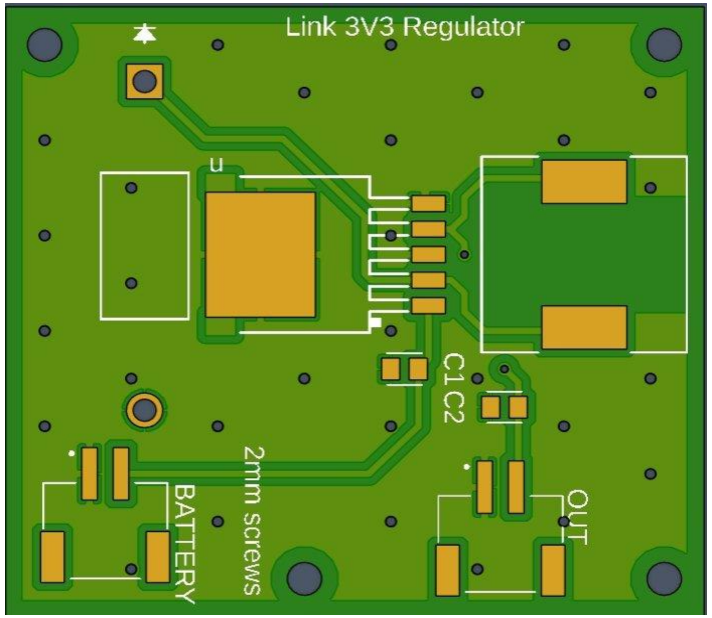


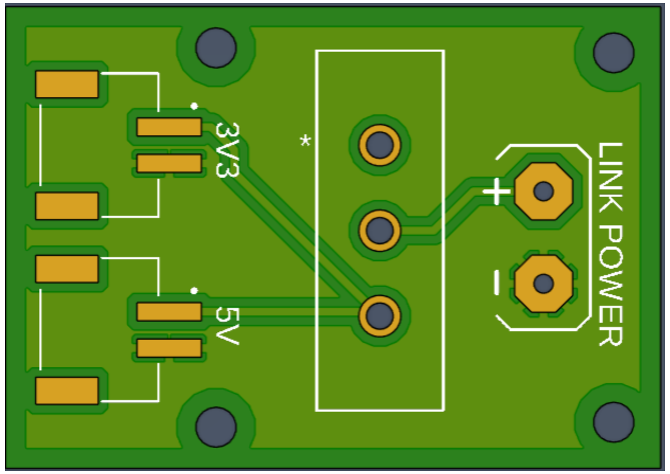






PCB Design – Power Architecture Boards





3V3 Regulator: LM2576S – 3.3/NOPB

- Steps down the voltage from 11.1V to 3.3V for the rest of the peripherals

5V Regulator: LM2576S – 5.0NOPB

- Steps down the voltage from 11.1V to 5V for the LiDAR module

Battery: 3 x Lithium-ion 18650 3.7V 2500 mAh

- Three 18650s are arranged in series providing 11.1V input voltage to both the 3.3V and 5V regulators

Power PCB

- Incorporates two JST connectors that interface with both regulators
- Master power switch enables/disables entire system from a single point

Software Comparison: Webstack

What the website needs:

- Runs on a phone without app-store deployment
- Shows user position and saved target pins on a map
- Receives waypoint payloads from the ESP32 over BLE
- Stores data locally if the server/internet is unavailable
- Syncs saved pins to a small backend for logging and later viewing

Option	Main Idea	Pros	Cons
Native Mobile App	Phone app built for Android/iOS	Best hardware access Polished mobile feel	More setup and deployment Harder to maintain cross-platform
Traditional Web App	Website loaded from browser	Simple to host Easy to update	Weak offline behavior Less app-like on phone
PWA + REST API	Installable web app with backend API	Offline capable Easy phone install Works well with React + BLE	Browser support must be checked Needs HTTPS for deployment

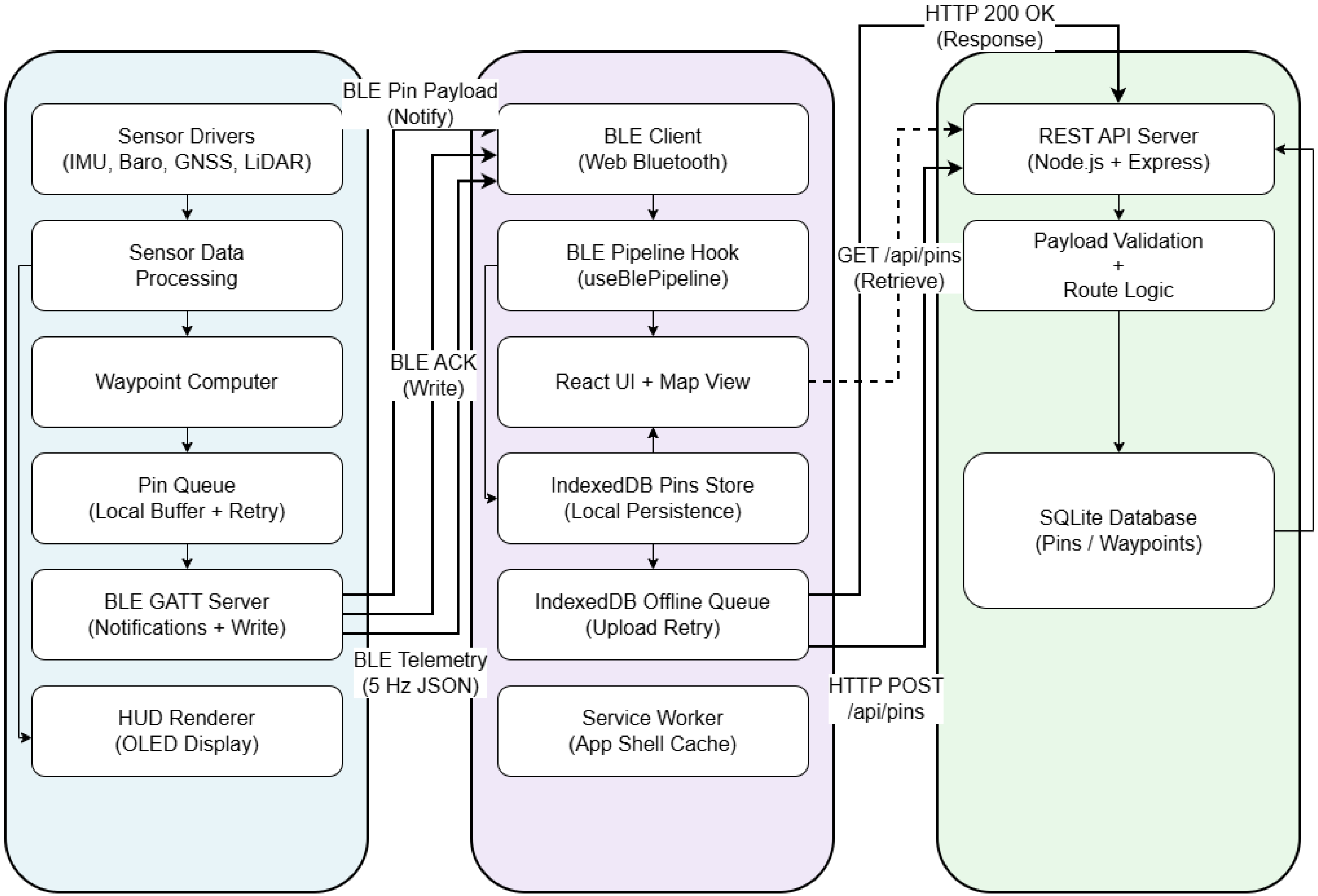
Software Comparison: Firmware

What the embedded software needs:

- Bring up sensors and the TFT display quickly during PCB testing
- Read UART, I^{2}C, SPI, GPIO, and button inputs reliably
- Package GNSS, LiDAR, barometer, and heading data into waypoint messages
- Keep the local HUD responsive even if the phone is disconnected
- Support BLE transfer

Option	Main Idea	Pros	Cons
Arduino / C++	C++ firmware using Arduino-style libraries	Fastest bring-up Large ESP32 library support Easy sensor/display testing	Less low-level control than ESP-IDF
ESP-IDF	Official Espressif SDK with FreeRTOS support	Best control of BLE and tasks Professional ESP32 workflow	More setup time More complex debugging
MicroPython	Python running on the MCU	Very fast prototyping Readable scripts	Slower runtime Less ideal for final sensor + display timing

Software Flow Chart



Software Design: ESP32 Firmware

Firmware responsibilities:

- Initialize ESP32-S3 hardware, sensor buses, BLE service, and SPI TFT HUD
- Poll GNSS position, LiDAR range, barometer altitude, heading/orientation, battery status, and button input
- Update the local TFT HUD with the most important live information
- On user capture, build a waypoint payload with observer location, target estimate, range, bearing, and module status
- Send live telemetry and captured pins over BLE; receive ACKs and calibration data from the phone app
- Keep a simple resend/queue behavior so pins are not lost during a temporary phone disconnect

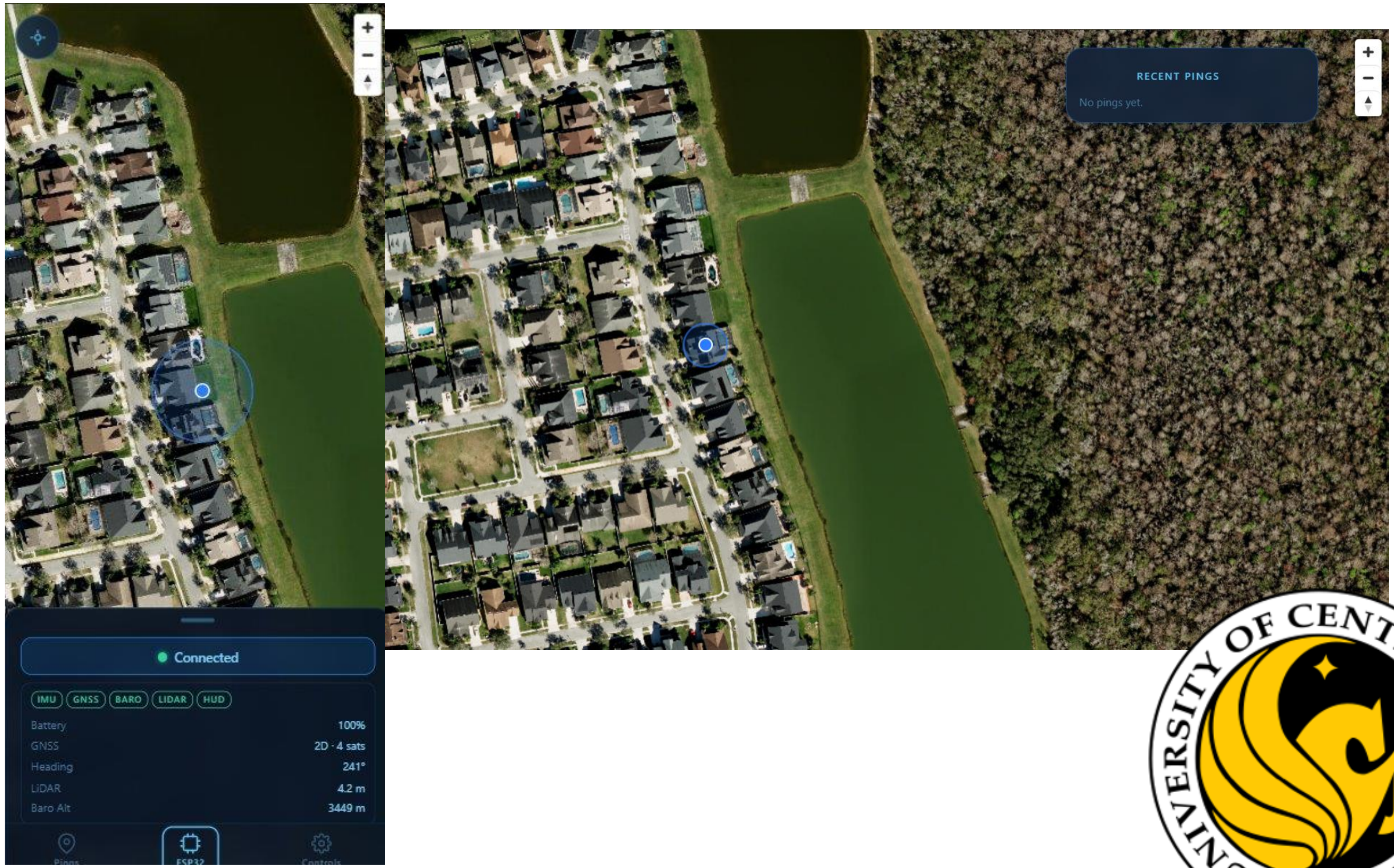
Firmware Area	Data In	Output
Sensor Layer	GNSS, LiDAR, BMP280, IMU/button	Cleaned readings + module health
HUD Layer	Latest sensor values and capture state	TFT display update + buzzer feedback
BLE Layer	Telemetry and waypoint payloads	Phone transfer + ACK handling
Capture Logic	Button press + current measurements	Target pin payload

Software Design: Web App

Application behavior:

- Phone connects to the binocular over Web Bluetooth and listens for telemetry/pin payloads
- Map view shows current user/binocular position and the newest target pings
- Satellite and street map views can be switched depending on the test environment
- Pins are saved in IndexedDB first, so the app still works with poor service
- When the server is reachable, the app POSTs pins to/api/pins and receives confirmation
- After a successful server upload, the phone sends an ACK back to the ESP32 over BLE

Current web app map view



Budget + Sponsor

Updated prototype/dev-board items reflect the hardware actually used for bring-up; sponsor-supported optics are kept separate.

Electrical Hardware	Description	Qty	Budget
ESP32-S3 DevKitC-1	Firmware bring-up before custom MCU PCB	1	$10.00
Adafruit IMU breakout	Heading/orientation testing	1	$22.00
Adafruit barometer breakout	Pressure/altitude testing	1	$10.00
SparkFun NEO-M9N GNSS	Latitude/longitude prototype testing	1	$80.00
PTYS-12X LiDAR module	Distance/range measurement	1	$100.00
SPI TFT display module	HUD display prototype	1	$20.00
Jumpers, JST leads, mounts	Bench wiring and test harness	1	$15.00
Custom PCB fabrication/order	Finalization of board for projects	1	$262.00
Digi-Key PCB components order	Finalization of board for projects	1	$210.31
Electronics Subtotal			**$729.00**

Optical Hardware	Price	Qty	Budget
Achromat objective lens	$181.00	2	$362.00
Eyepiece lens	$43.10	2	$86.20
Focal extender	$44.25	2	$88.50
Field lens	$40.50	2	$81.00
Porro prisms	$18.75	4	$75.00
Beam splitter	$389.00	1	$389.00
Optics Subtotal			**$1,081.70**

Sponsored optics highlighted Yellow, thanks to Edmund Optics

Grand Total	**$804.00**
Out of Pocket Total	**$1810.70**

Work Distribution

Responsibility	Primary	Secondary
PCB Design & Assembly	Dylan Farnsworth	Santiago Castro
Optical Design	Jeremy Goodenough	Brian Santiago
Photonic Design	Brian Corchuelo	Jeremy Goodenough
Optomechanical Design	Brian Corchuelo	N/A
Software Design	Santiago Castro	N/A

Progress and Plan of Completion

- Current Progress:
  - PCB’s ready and ordered
  - Full mechanical housing design in progress
  - Pinging system and website software fully functional
- Future Milestones:
  - Test and verify PCB functionality (*Week 6*)
  - Complete and 3D print mechanical housing (*Week 7-8*)
  - Prepare for Midterm Demo (*Week 9-10*)
  - Showcase/Final Demo (*Week 12)*

Questions?

- CREOL Group 4: L.I.N.K.
- Please ask us any questions you have!
- Thanks!

Jeremy Goodenough
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