PhotoLock

Tying photo integrity to a specific device

Team 4

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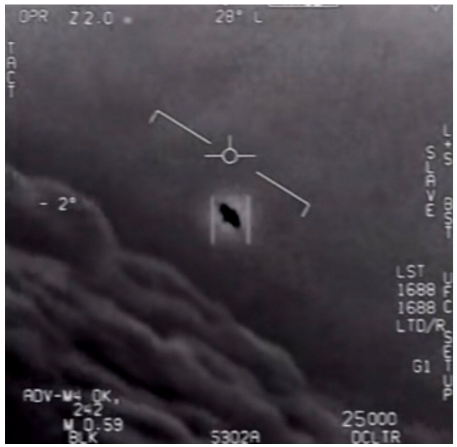
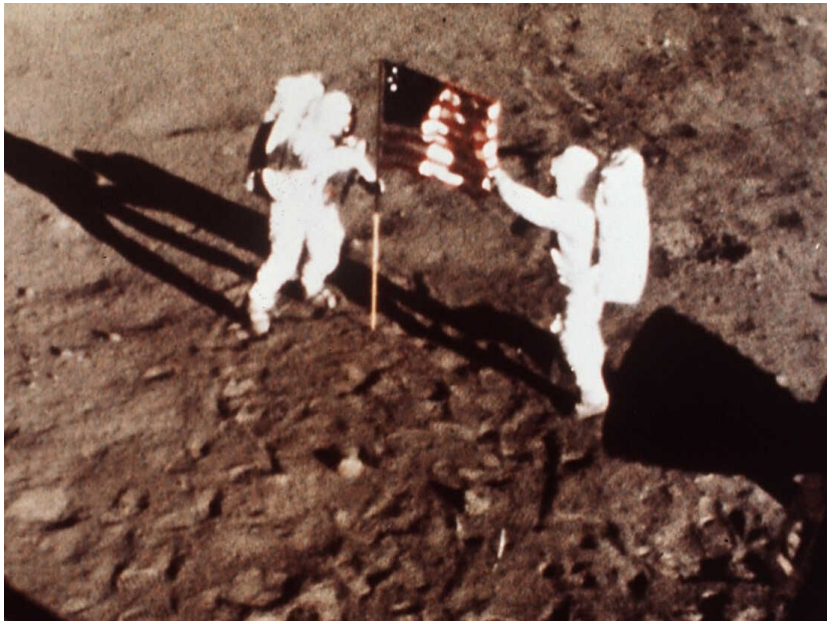
Problem Statement

Images, which once were viewed as a source of undeniable proof, have now become targets of societal manipulation. Most of the population utilizes online platforms such as Twitter and Google for news where images are posted daily; Twitter alone has over 500 million active users. The negative impact of altered or AI generated images on society includes body dysmorphia, political disruption, and proliferation of conspiracy theories.



Conspiracy theories

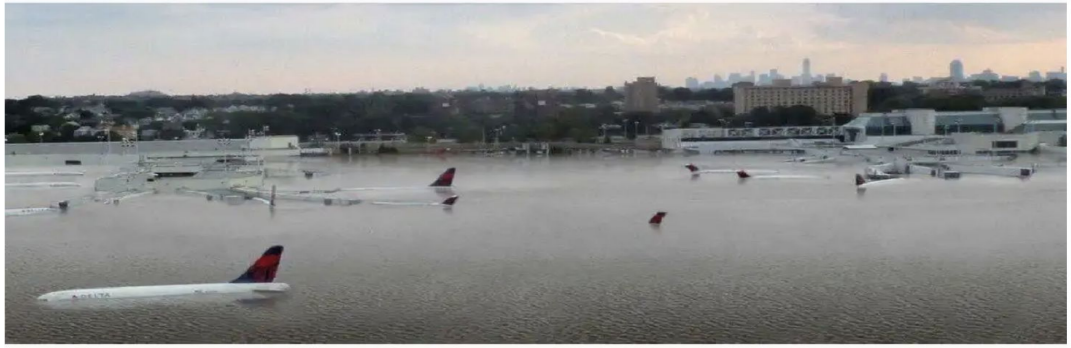


Problem Statement

Modified weather events

Political disruption and disinformation

Photoshop



Faked: planes underwater in Houston

Problem Statement

Law Enforcement, Intelligence Agencies

Justice system

Real-time world events on Social Media

Insurance claims

Updated Solution Overview

Push Button

Camera

Date: April, 6th 2023
Time: 4:12 PM
Location: Concord, Massachusetts
Signature: JLCI9J12SZJ6H3NI9KV2

Cloud
- HTTPS Endpoint
- File Storage
- Verification

Custom Application For Image Storage

Image & Metadata

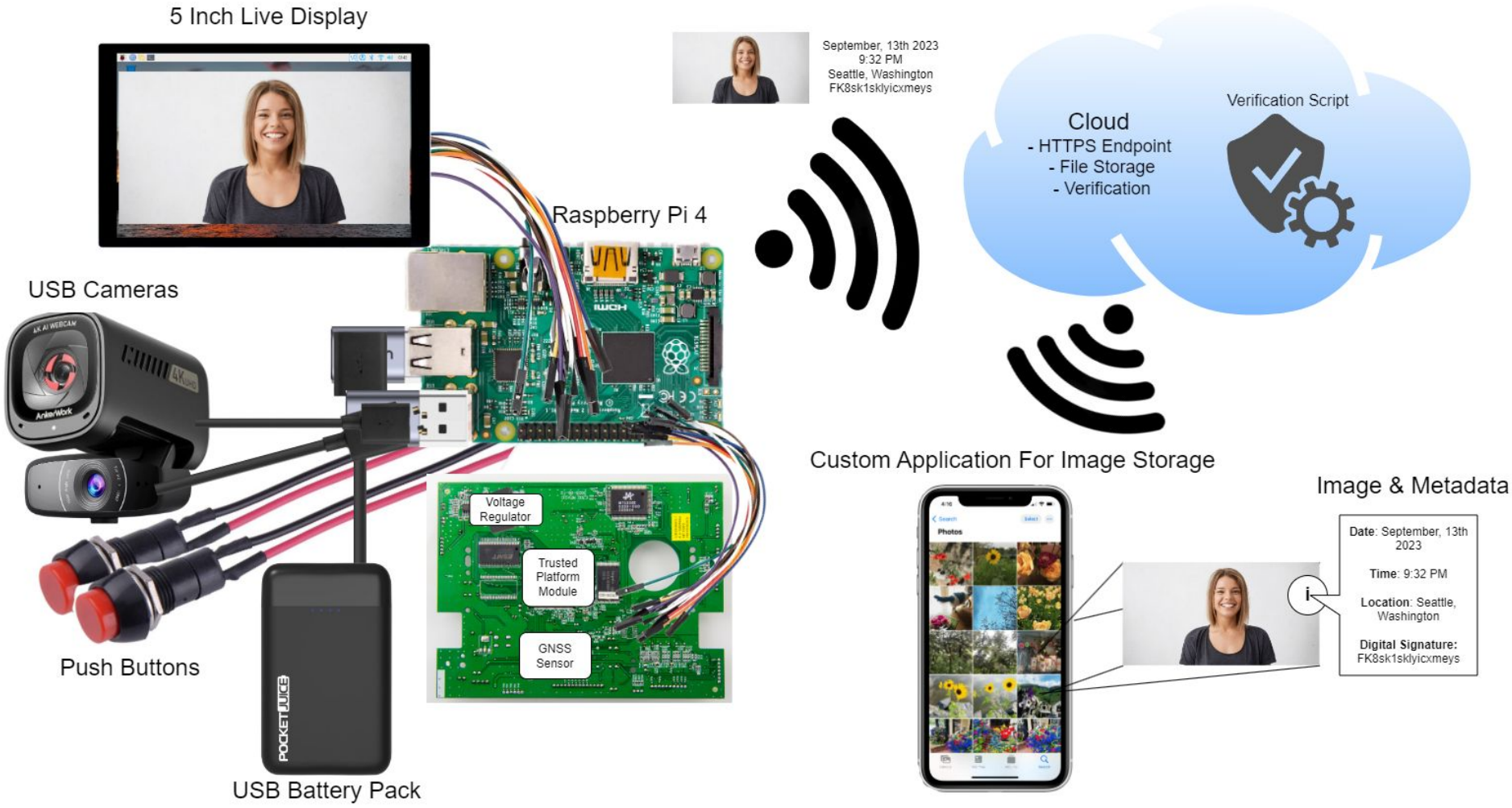
Date: April, 6th 2023

Time: 4:12 PM

Location: Concord, Massachusetts

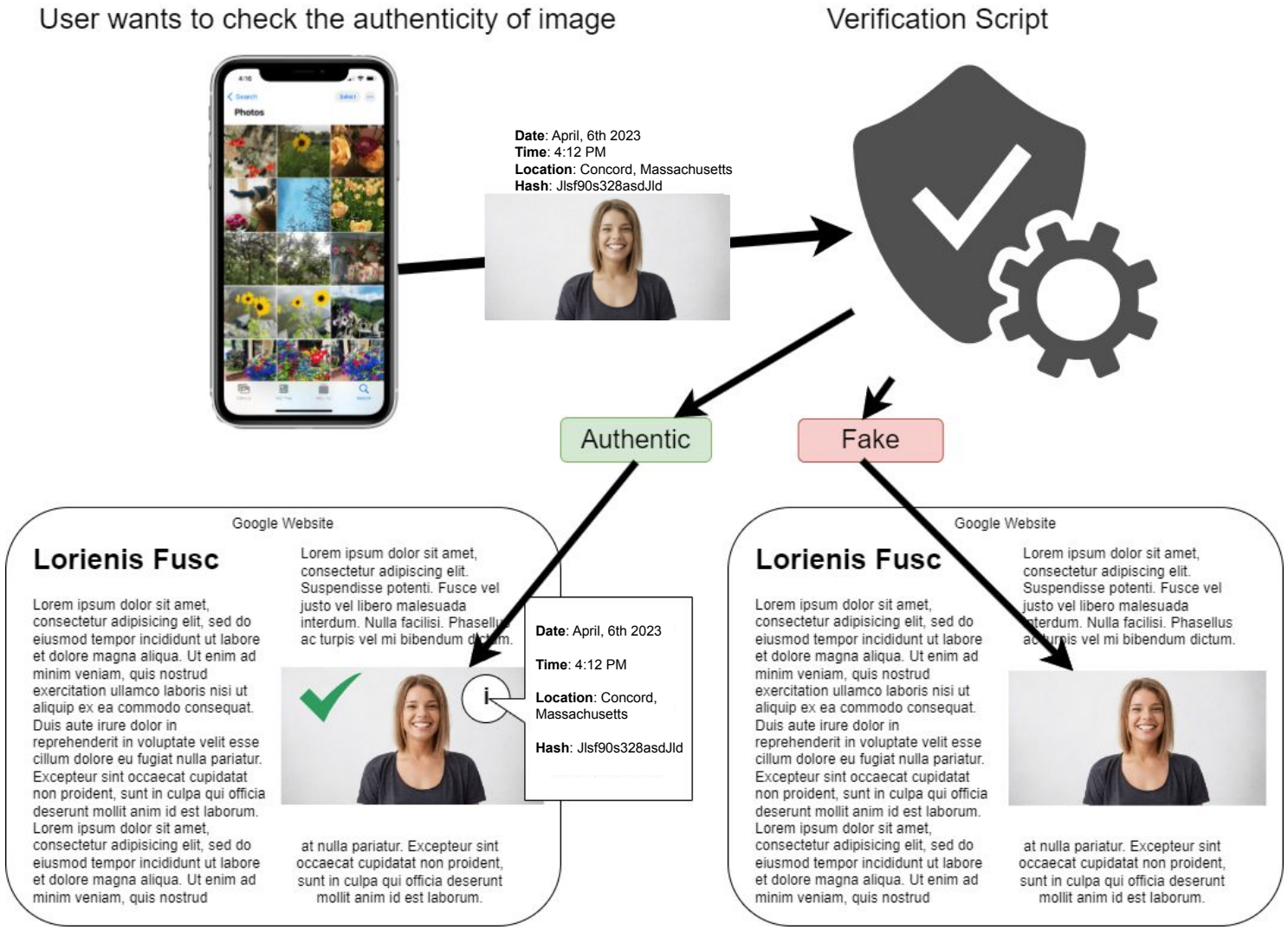
Signature: JLCI9J12SZ J6H3NI9KV2

Updated Solution Overview



Hardware Root of Trust

Solution Overview Part 2



Assumptions

1. **Raspberry Pi 4 memory is tamper-proof**
   a. Media can only be sent off the camera through WiFi upload

2. **Sensor to Microcontroller interfaces are secure**
   a. GPS
   b. Camera

3. **GNSS Time and Location data are only used when possible**

4. **Storing images and video locally when WiFi is unavailable**

Solution Comparison:

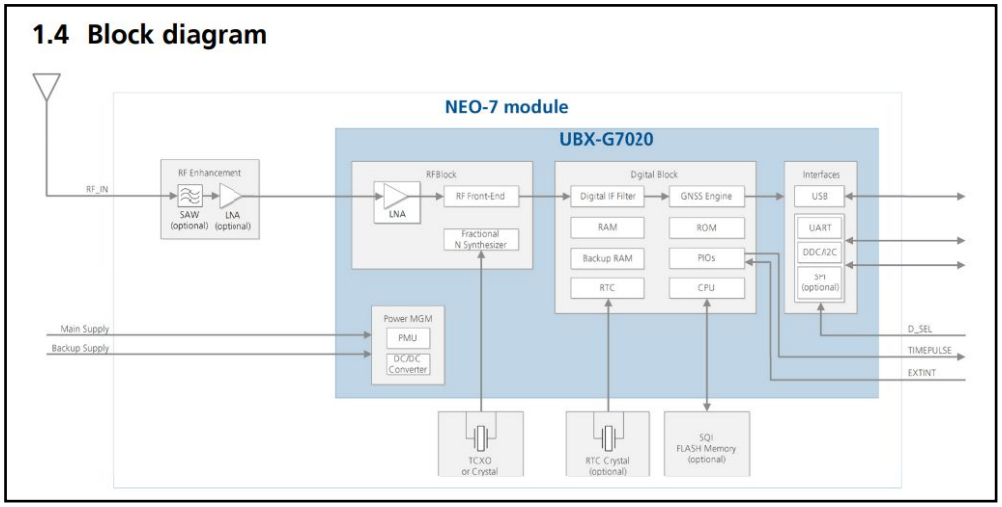
	Sony Alpha 7 IV camera	Capture Cam - Photo Verify (Image block chain)	Google Reverse Image search	**Our Solution**
Cost	**$2,499.99**	**FREE**	**FREE**	**$350**
Root of Trust	**YES**	**MAYBE**	**N/A**	**YES**
Online Media Verification	**NO**	**YES**	**NO**	**YES**
Automatic Wireless Upload	**NO**	**NO**	**N/A**	**YES**
Open Source	**NO**	**YES**	**NO**	**YES**
Location and Time	**NO**	**NO**	**NO**	**YES**

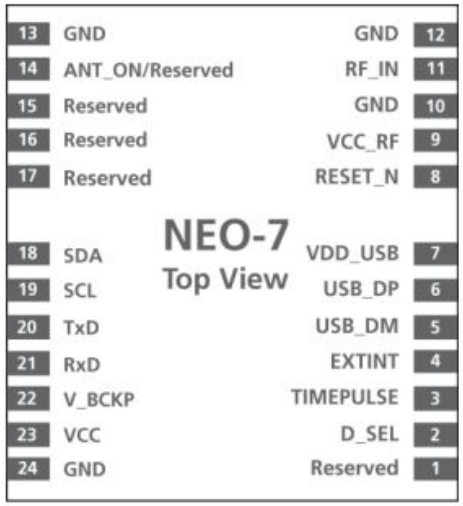
PhotoLock: Our Solution Goals

1. Hardware Root of Trust
2. Online Media Verification
3. Automatic Wireless Upload
4. Open Source Transparency
5. Location and Time Metadata
6. Reasonable Cost (<$500)

GNSS Sensor: NEO-M7N Module

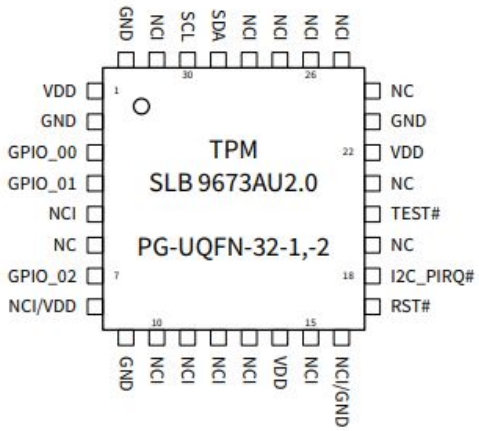
- Crystal and TXCO LCC (surface mount) oscillator options available for the NEO-7 series
- Schematics and datasheets support integration into PCB design
- Over 2,000 units available on Digikey
- Many compatible interfaces allow for alternative options (SPI, USB, **UART**)
- GPS and GNSS functionality





Trusted Platform Module: Infineon 9673

- 4 Endorsement Keys
- SPI interface
- Low standby power consumption
- FIPS 140-2 Level 2
    - Formally validated by US and Canadian Governments
- AVA_VAN.4 Certification
    - Methodical vulnerability analysis and resistance against a moderate attack potential



Raspberry Pi 4

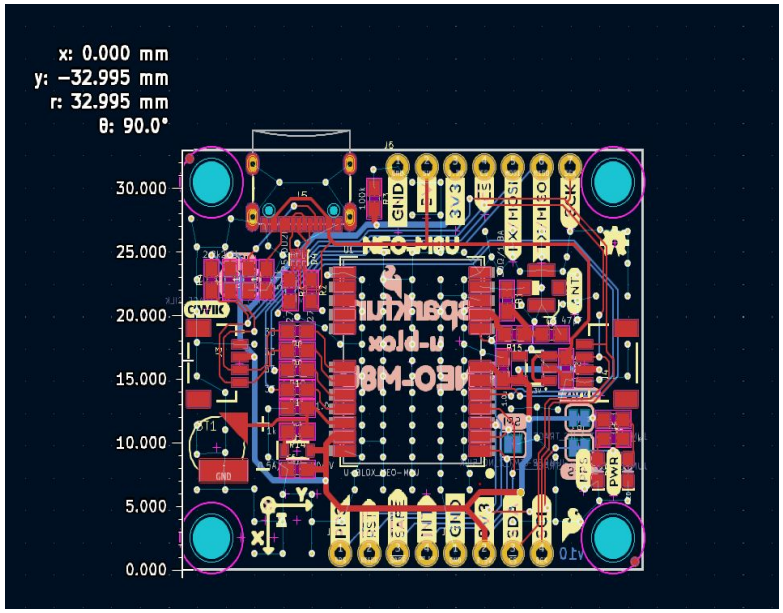
- RAM memory: 2 GB
- Memory storage capacity: 2 GB
- Connectivity: Bluetooth, WIFI, USB, ethernet, HDMI, GPIO
- Micro SD card slot for loading operating system and data storage

Linux Version

- Raspberry Pi OS
- Best compatibility for Raspberry Pi 4
- Debian based OS

PCB Design

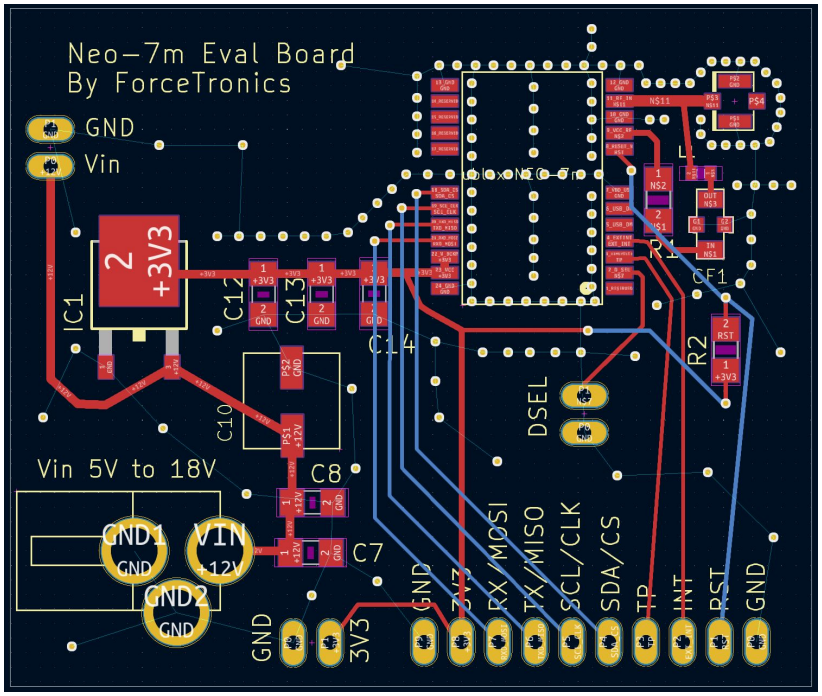
- **Custom PCB → integration of breakout boards**
  - GPS evaluation board
  - TPM evaluation board
  - Linear regulator to minimize noise (instead of buck converter)
    - capacitors and diodes



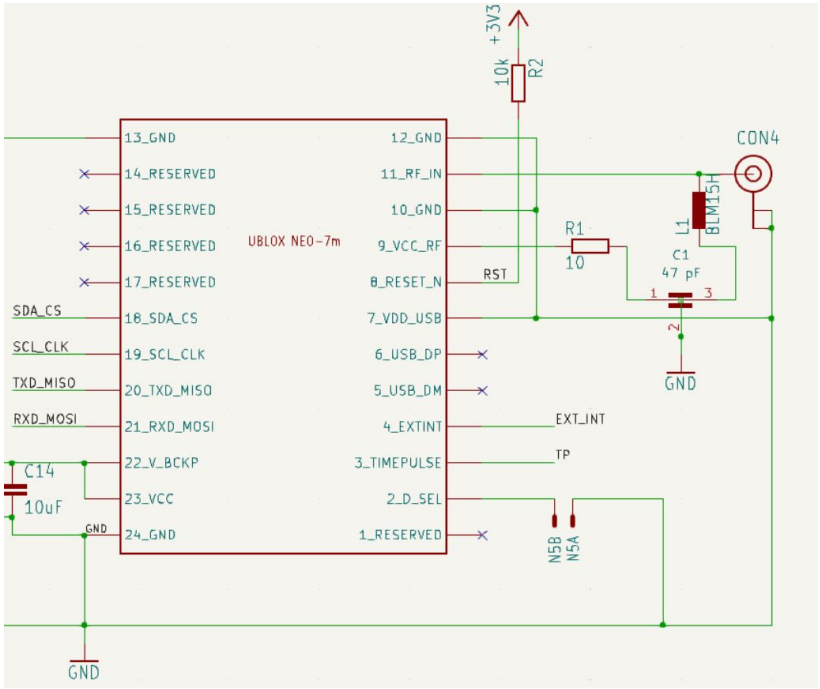
Layout of GPS Breakout Board

Benefits of Breakout Board Integration

- Ease of access to components
- Minimize errors by removing RF design component
- Ease of integration from Raspberry Pi to PCB
- Ensure proof of concept

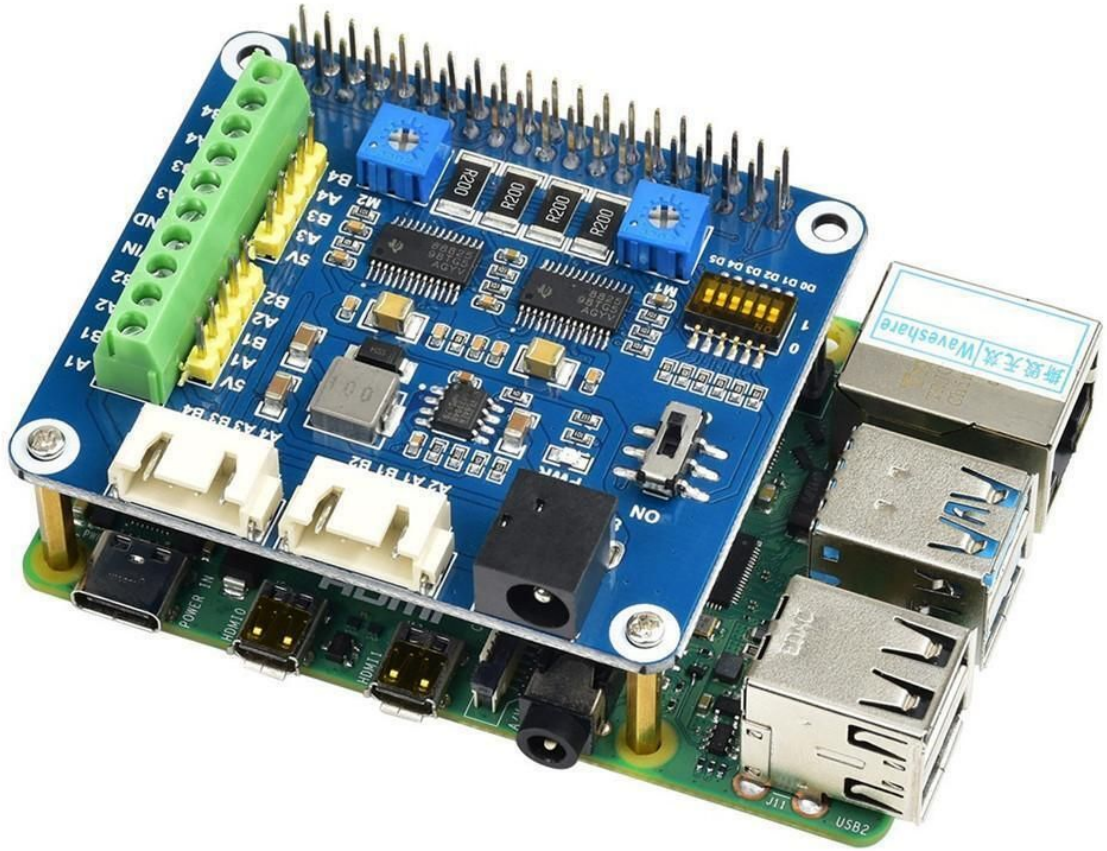


Example layout showing difficulty of RF shielding



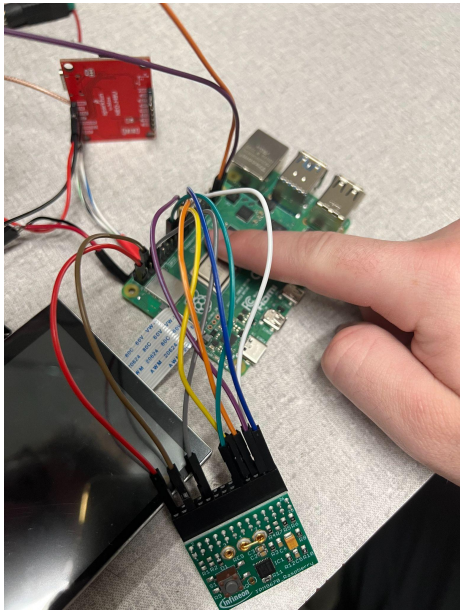
Example schematic showing filtering for antenna

Generic Model: PCB Integration through Raspberry Pi Hat

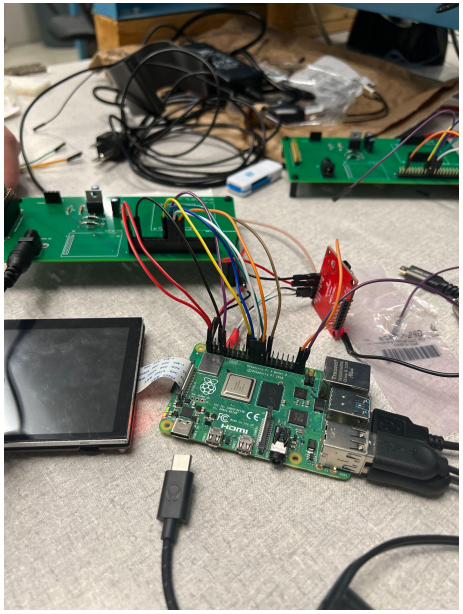


Previous PCB Integration Issues Solved

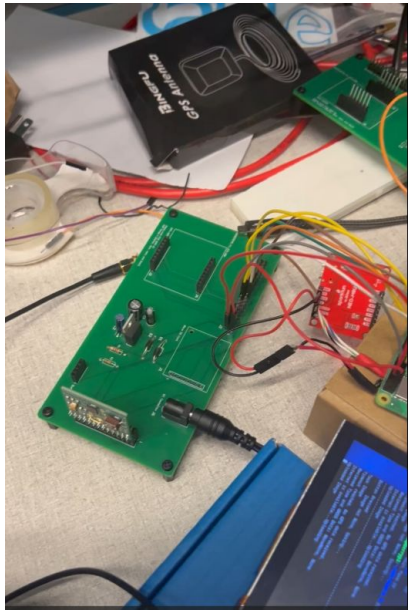
- Difficulty connecting to TPM
  - SPI interface operates at high frequency **SOLVED✅-Closer traces from pi header to TPM**
    - Jumper cables did not provide stable connections
    - Inability to connect TPM from PI to jumpers
  - TPM library closed source (limited pin selection) **SOLVED✅-Adjusted pin configuration**
- Integration of GPS to PCB
  - GPS interface not compatible with PCB pinout due to library **SOLVED✅-Access to two interfaces**



TPM connection to PI unreliable

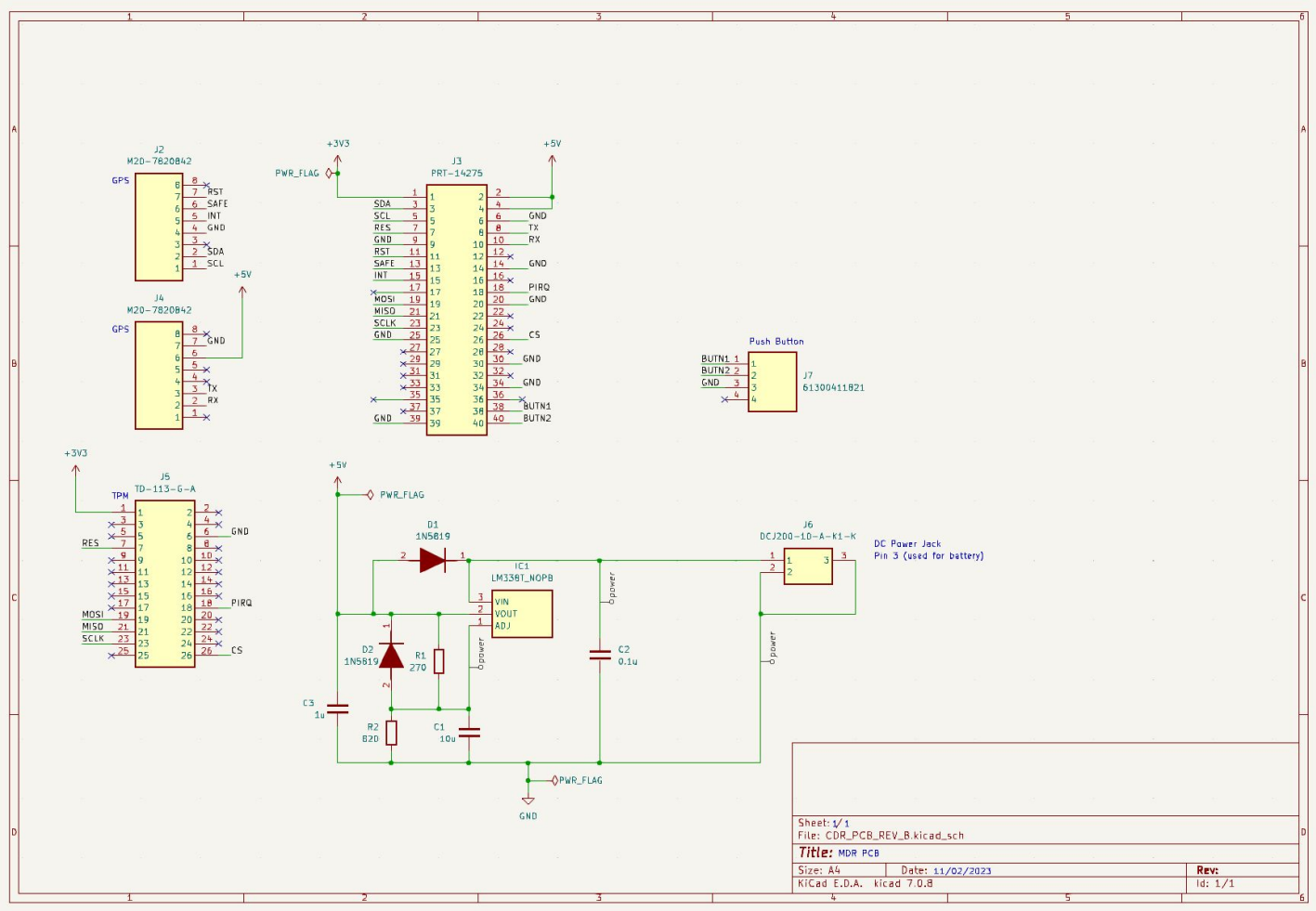


TPM fails to connect through PCB

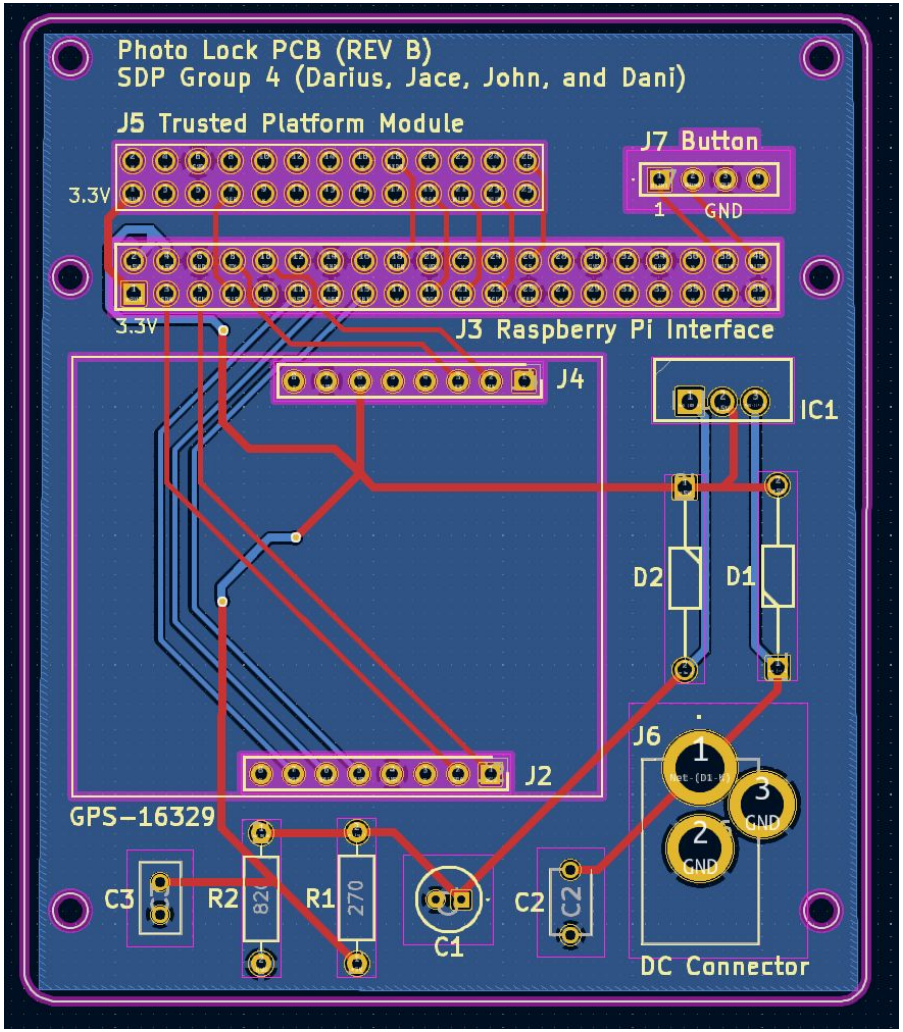


TPM connects through PCB but connection is lost

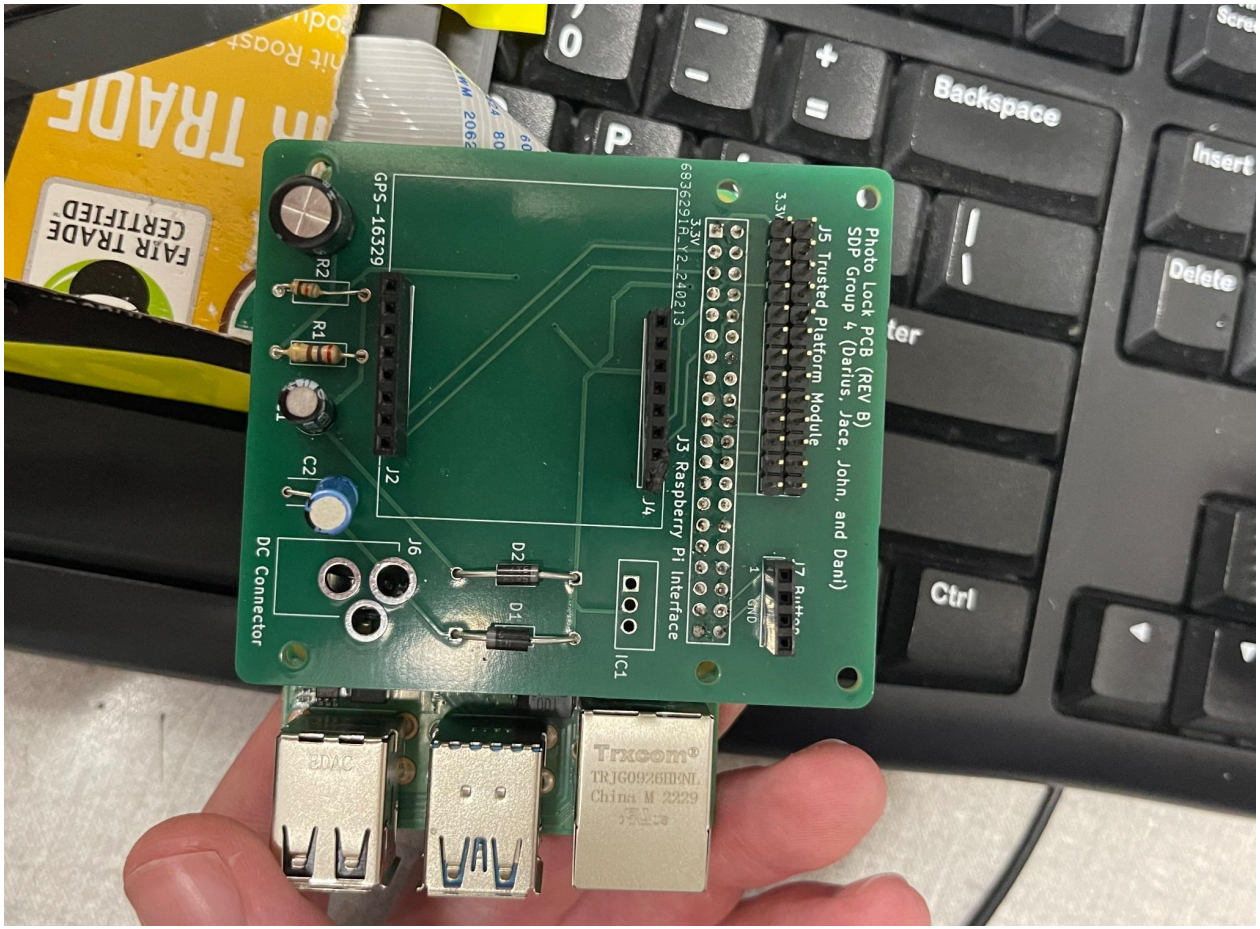
PCB Schematic Design



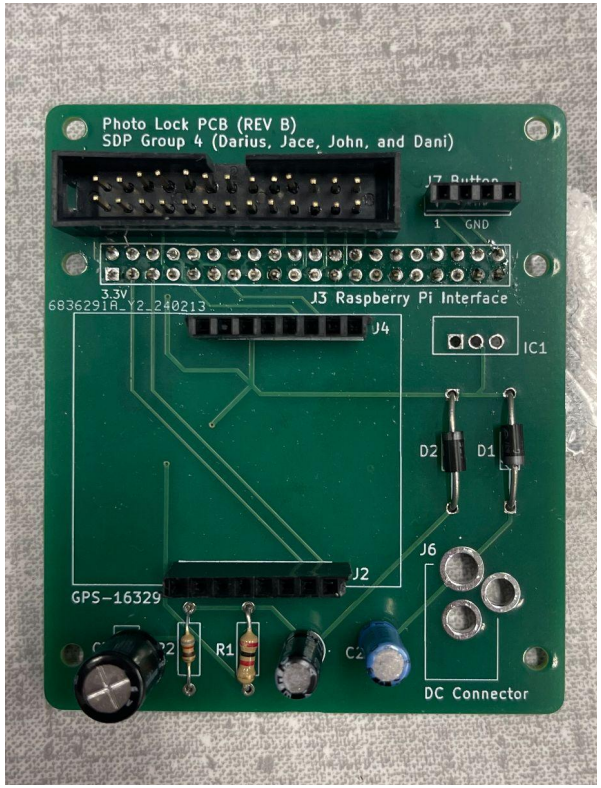
PCB Layout Design



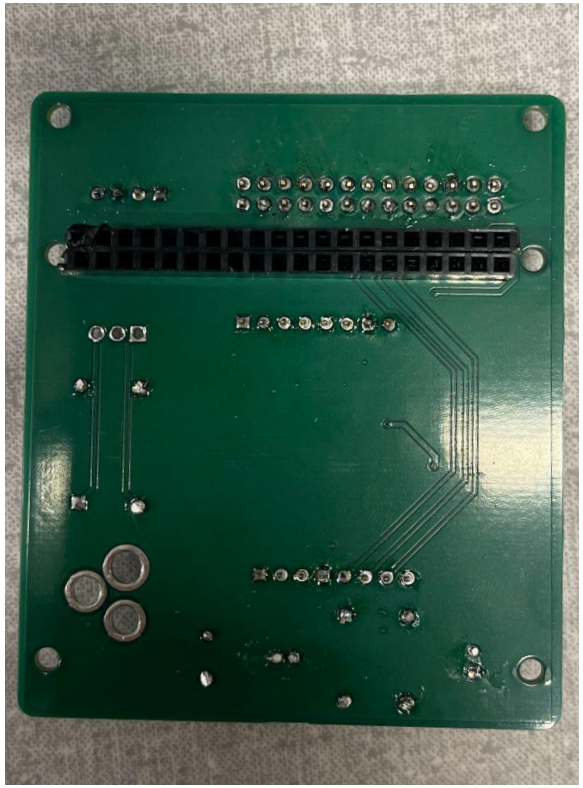
PCB Integration through Raspberry Pi Hat



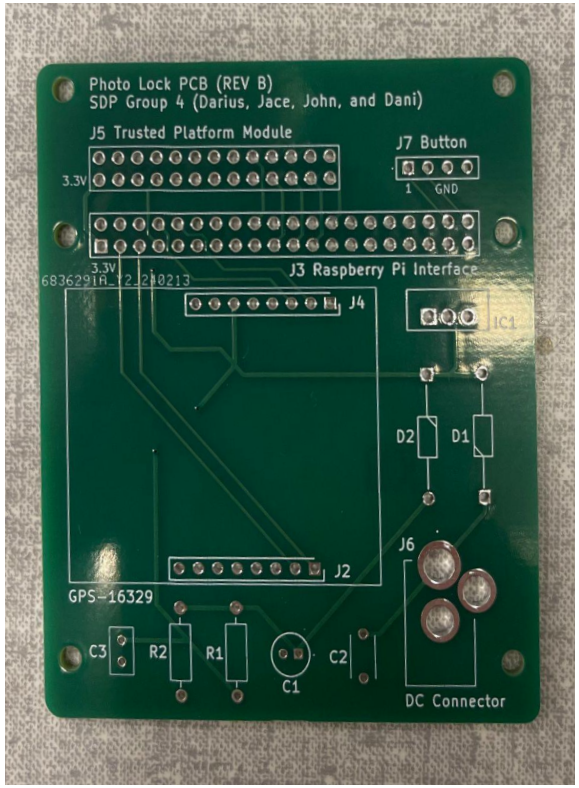
PCB



Front side of populated PCB



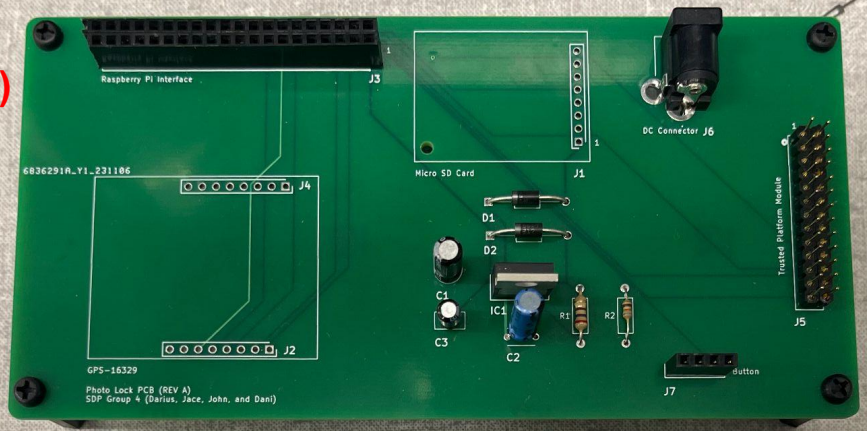
Back side of populated PCB with Raspberry Pi header interface



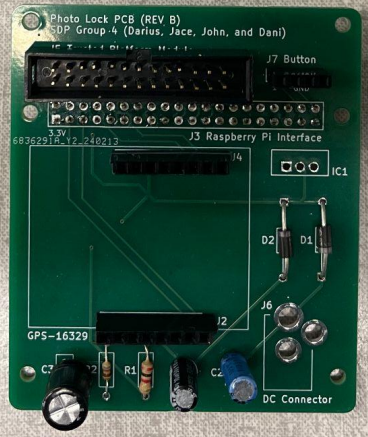
Unpopulated PCB

PCB Size Comparison

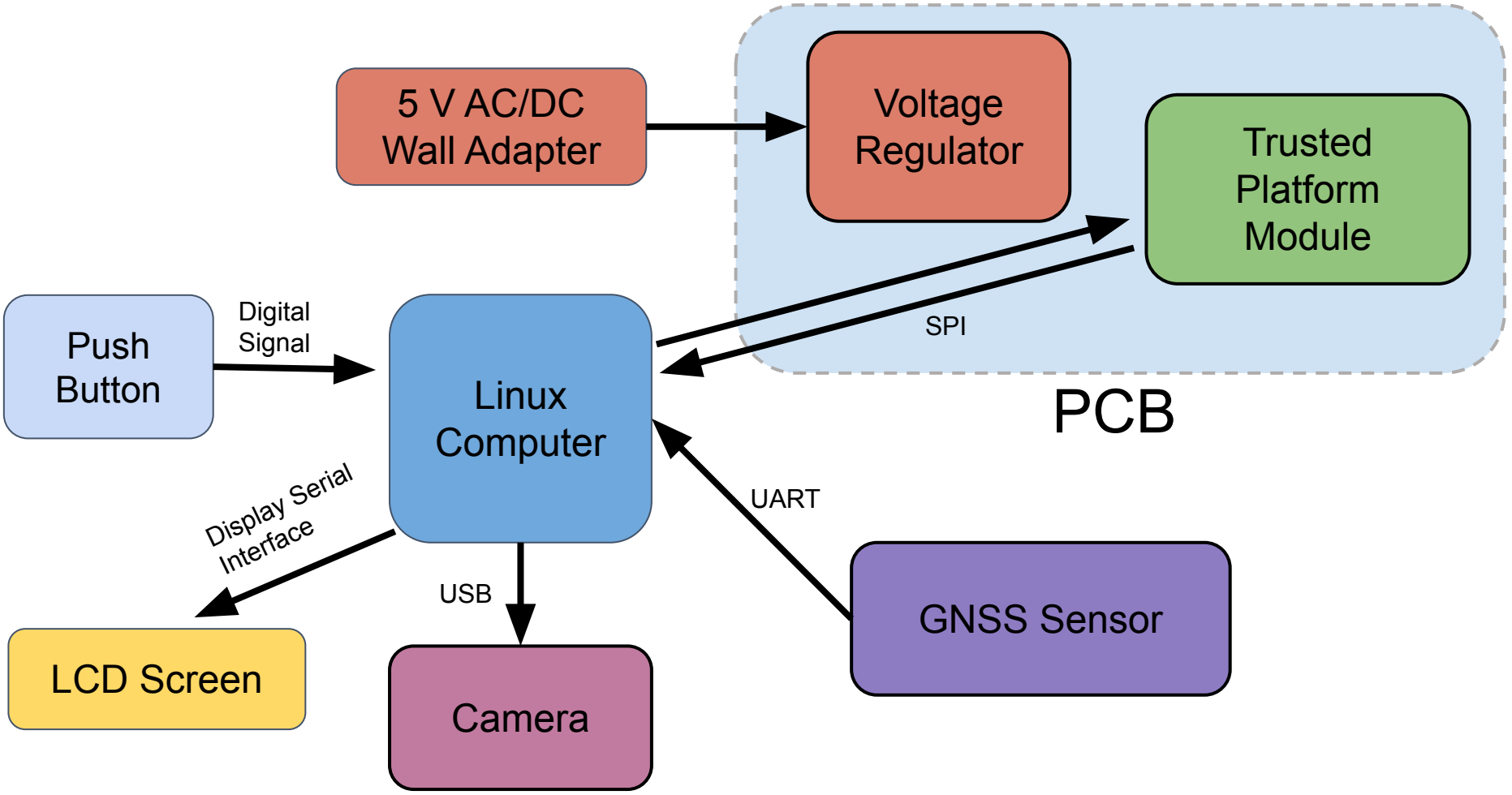
REV A (MDR)



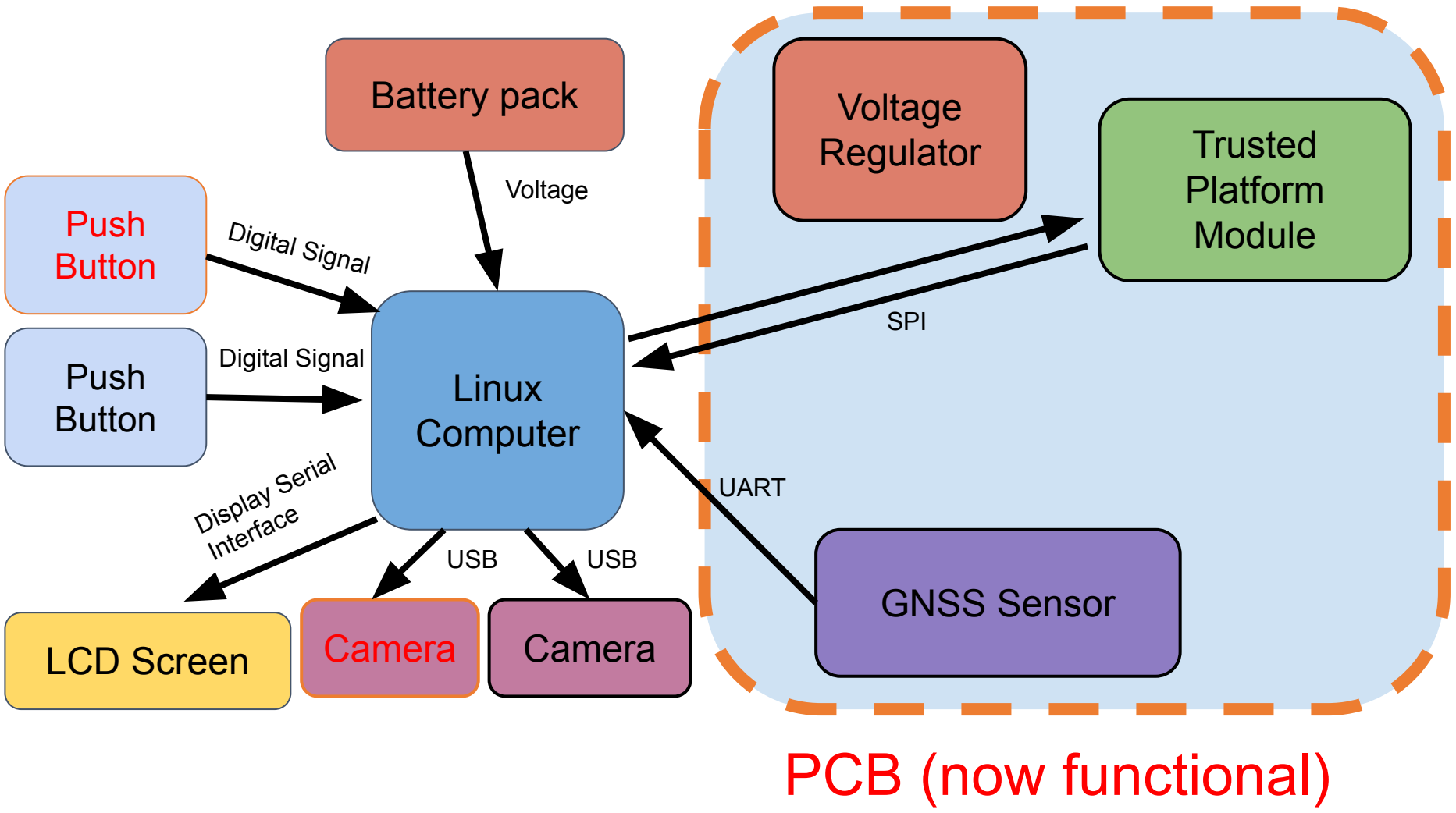
REV B (CDR)



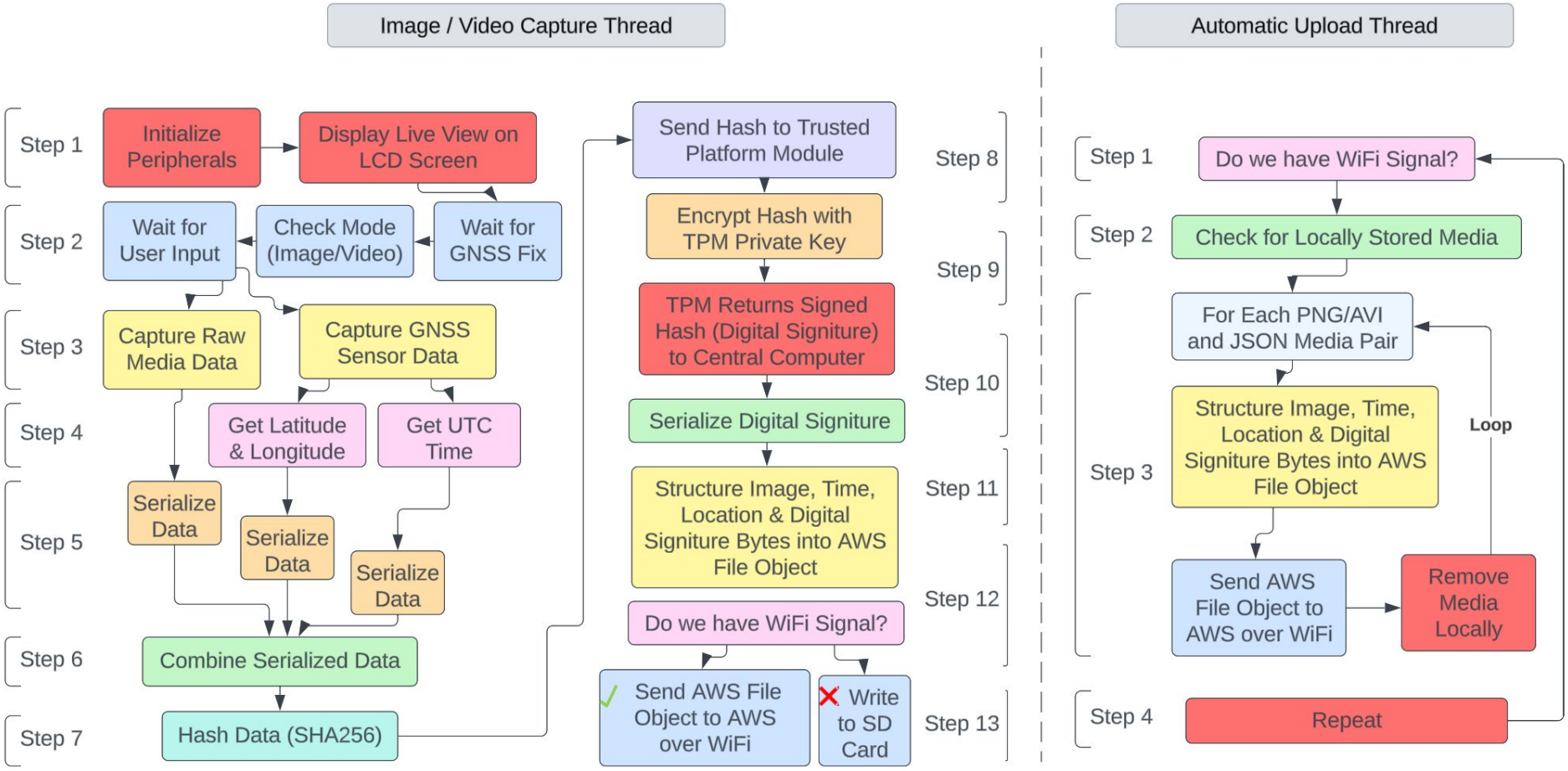
Review: MDR Hardware Block Diagram



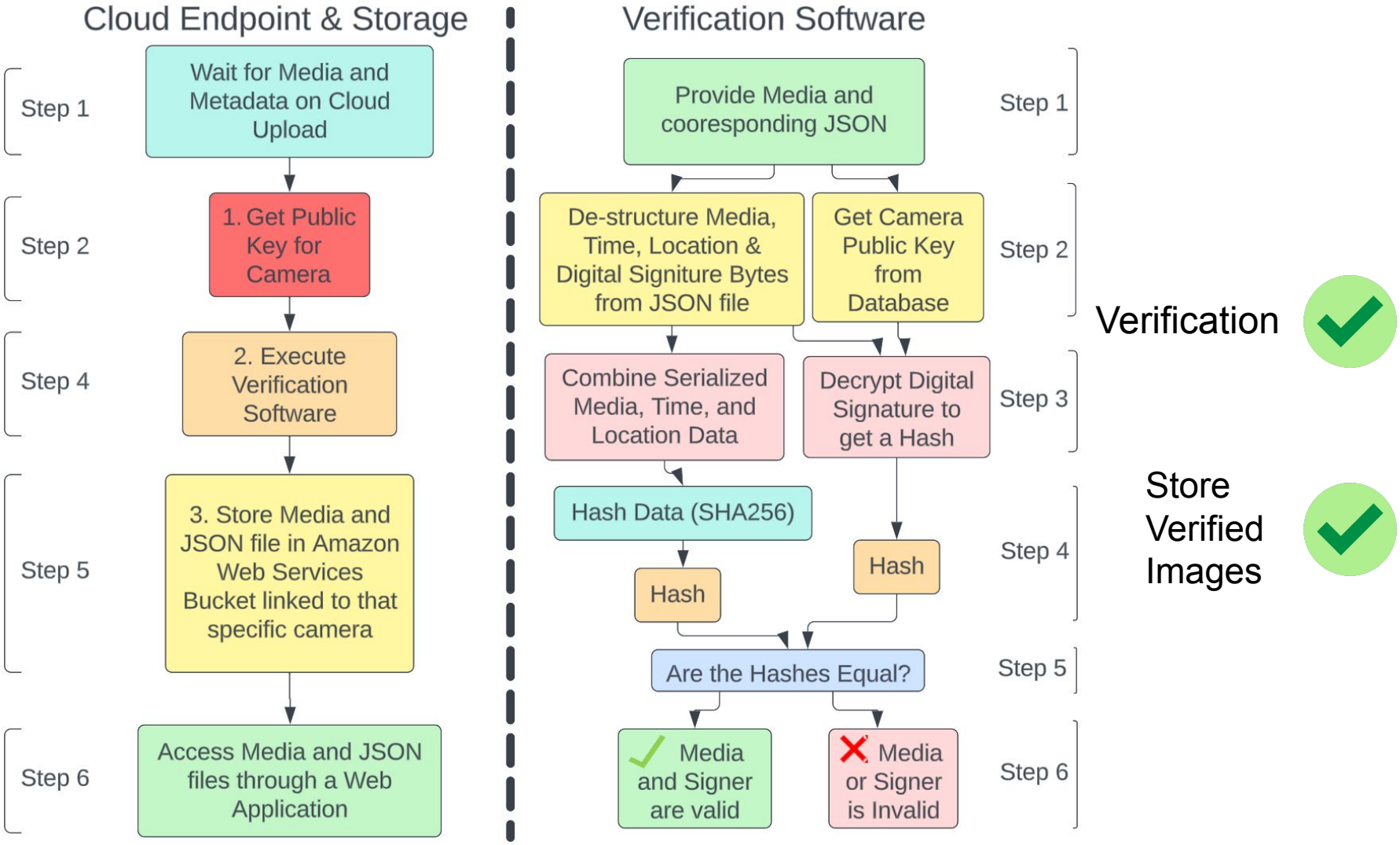
CDR Hardware Block Diagram



Embedded Software Block Diagram



Cloud Software Diagram



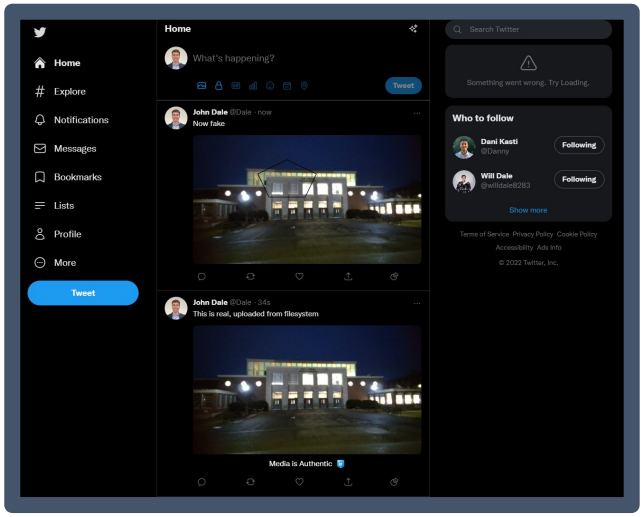
Cloud Software Diagram Part Two

team4SeniorDesignProject.com

- Display all media captured on camera
- Refresh ~10 seconds
- Download, delete, view

Display images through Web Application

team4SeniorDesignProject-twitter.com



- Twitter Clone
- Verify media live in application
- View media metadata

Verify images in Web Application

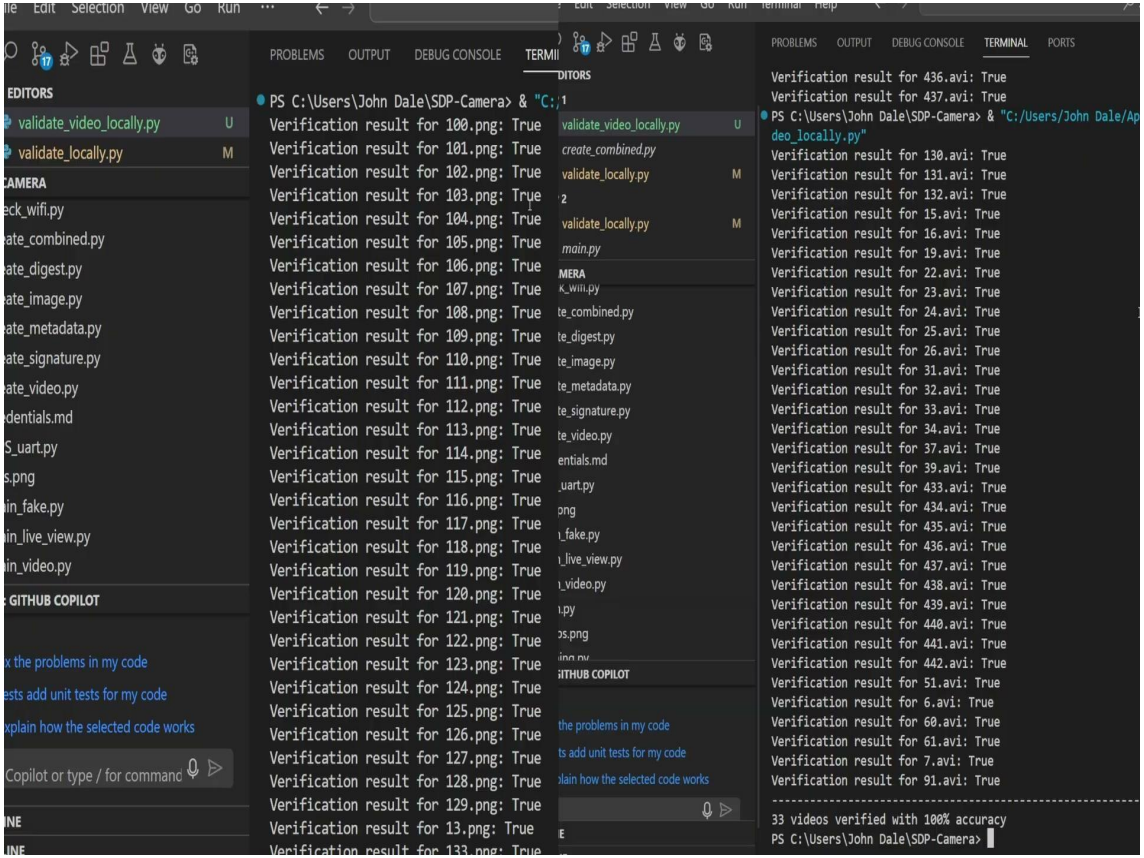
Previous CDR Specifications & Test Plan

Image Specification	Video Specification	Test Plan
1. Authenticate images camera source with **100%** accuracy for **100** photos (Digital Signature)	1. Authenticate videos camera source with **100%** accuracy for **100** videos (Digital Signature)	Upload media from known or unknown camera source to verify whether digital signatures are correct
2. Verify image has not been modified with **100%** accuracy for **100** photos (Prevent false positives)	2. Verify video has not been modified with **100%** accuracy for **100** videos (Prevent false positives)	Upload media and compare raw data of image, time, location with actual
3. Verify image has been modified with **100%** accuracy for **100** photos (Prevent false negatives)	3. Verify video has been modified with **100%** accuracy for **100** videos (Prevent false negatives)	Upload modified media and verify it has been rejected by the cloud
4. Store at least **350** photos at **1080p** on the SD card (remote location - no WiFi)	4. Store one **15** minute video or store **15** one minute videos at **24fps/1080p** on the SD card (remote location - no WiFi)	Verify 350 photos at 1080p or 15 minutes worth of video can be stored when wifi access is denied
5. Upload at least 10 photos at **1080p** to the Cloud	5. Upload at least **10** videos at **24fps/1080p** to the cloud	Verify 10 photos/videos at 1080p can be uploaded to Cloud when there is wifi access
6. System can take one photo per **10 seconds**	6. System can take **one video per one minute**	Measure time between two consecutive media types
7. System can take 350 photos in one charge	7. System can take **four** separate **15** minute videos in one charge	Complete tasks in one charge (separately)

Updated CDR Specifications Test Plan

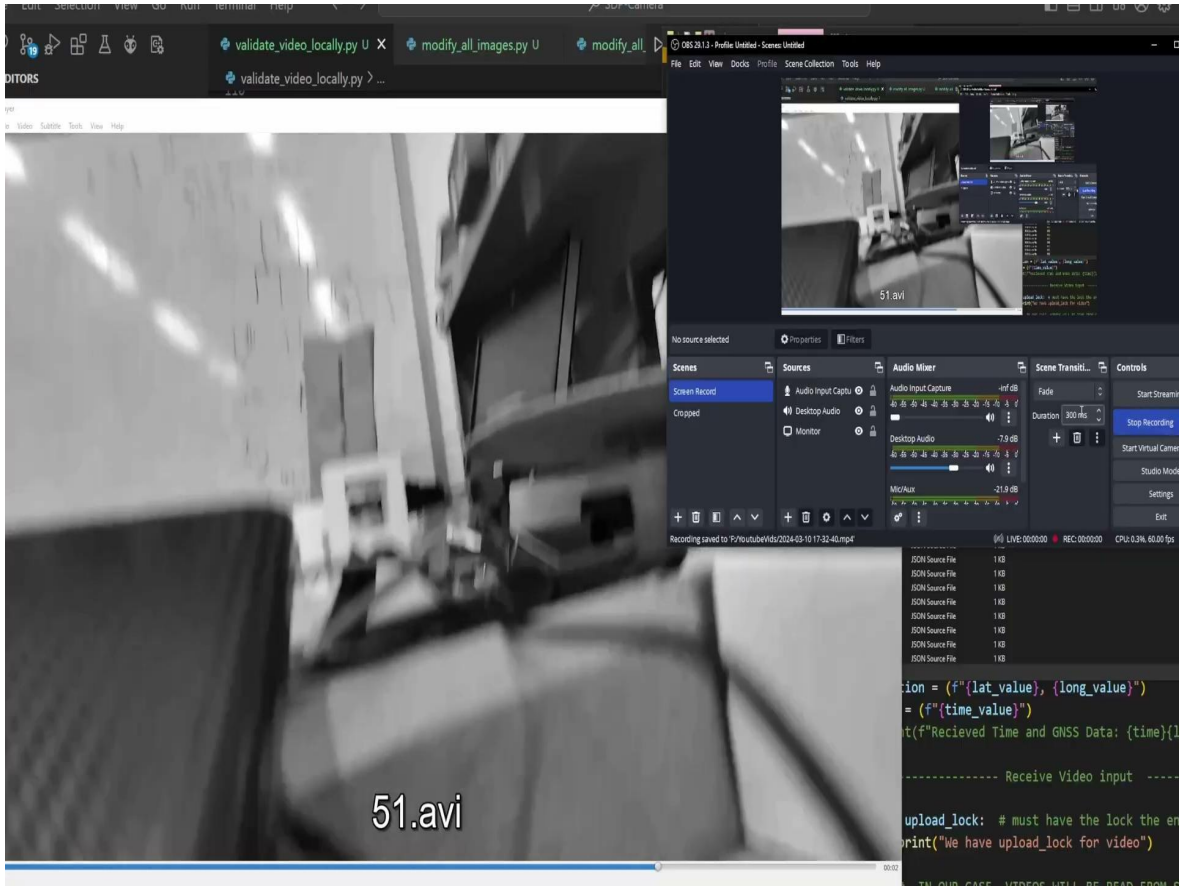
Image Specification	Video Specification	Test Plan
1. Authenticate images camera source with **100%** accuracy for **100** photos (Digital Signature)	1. Authenticate videos camera source with **100%** accuracy for **10** videos (Digital Signature)	Upload media from known or unknown camera source to verify whether digital signatures are correct
2. Verify image has not been modified with **100%** accuracy for **100** photos (Prevent false positives)	2. Verify video has not been modified with **100%** accuracy for **10** videos (Prevent false positives)	Upload media and compare raw data of image, time, location with actual
3. Verify image has been modified with **100%** accuracy for **100** photos (Prevent false negatives)	3. Verify video has been modified with **100%** accuracy for **10** videos (Prevent false negatives)	Upload modified media and verify it has been rejected by the cloud
4. Store at least **350** photos at **1080p** on the SD card (remote location - no WiFi)	4. Store one 5 minute video or store **15** one minute videos at **24fps/1080p** on the SD card (remote location - no WiFi)	Verify 350 photos at 1080p or 15 minutes worth of video can be stored when wifi access is denied
5. Upload at least 10 photos at **1080p** to the Cloud	5. Upload at least **10** videos at **24fps/1080p** to the cloud	Verify 10 photos/videos at 1080p can be uploaded to Cloud when there is wifi access
6. System can take one photo per **10 seconds**	6. System can take **one video per one minute**	Measure time between two consecutive media types
7. System can take 350 photos in one charge	7. System can take **10** separate 1 minute videos in one charge	Complete tasks in one charge (separately)

Media False Negatives Test Results



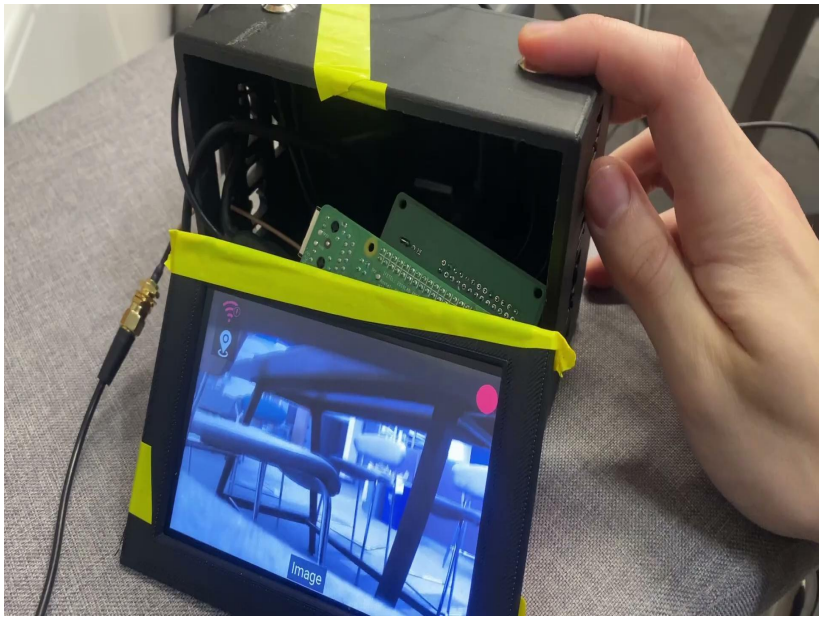
100% Effective at preventing false negatives

Media False Positives Test Results



100% Effective at preventing false positives

Storage & Consecutive Capture Requirements



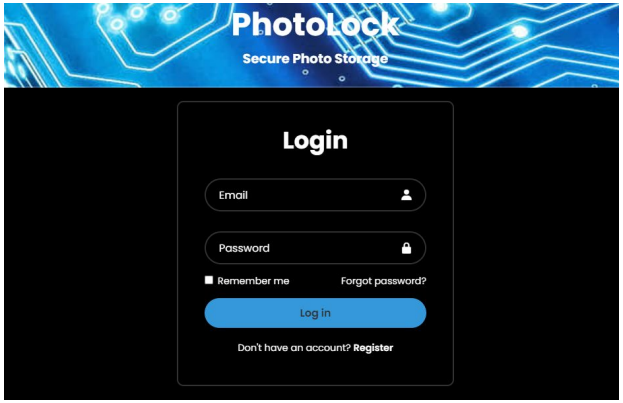
~Takes one image per 3 second, spec: <10 seconds

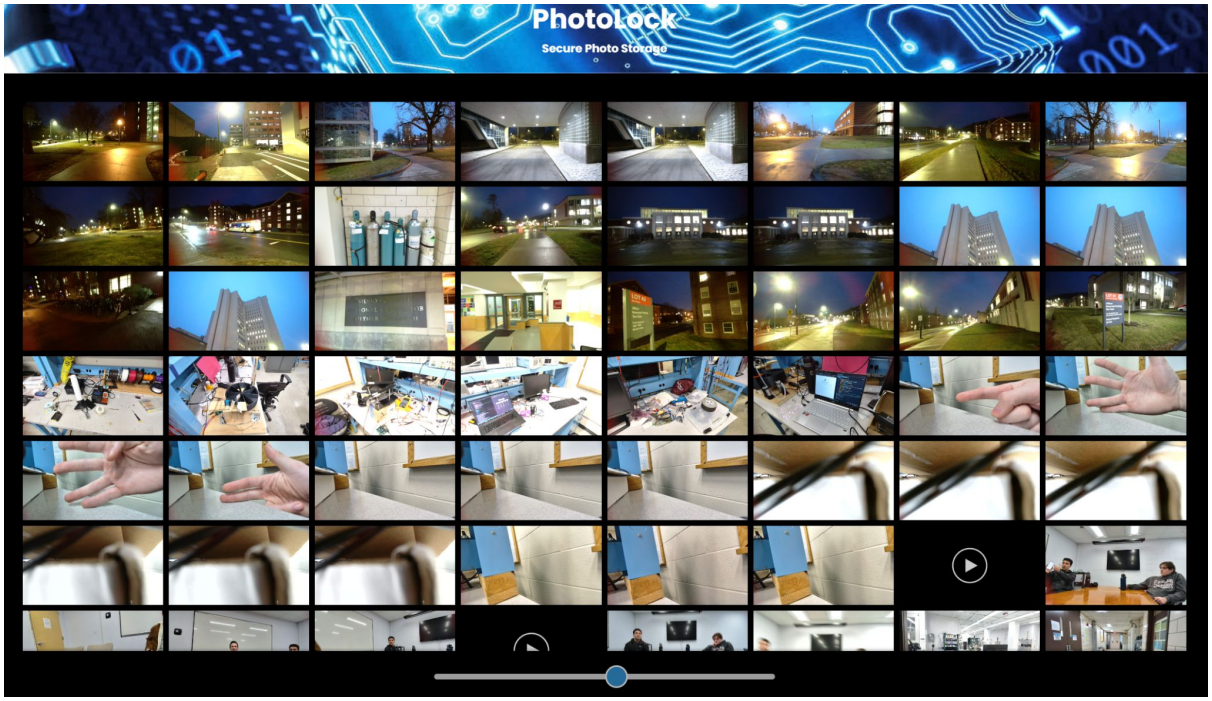
~Takes one video per 3 seconds, spec: <60 seconds

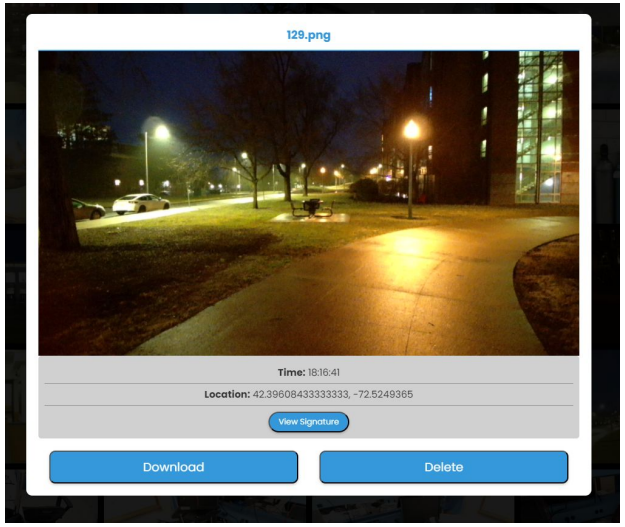
Stores 300+ images without Wi-Fi

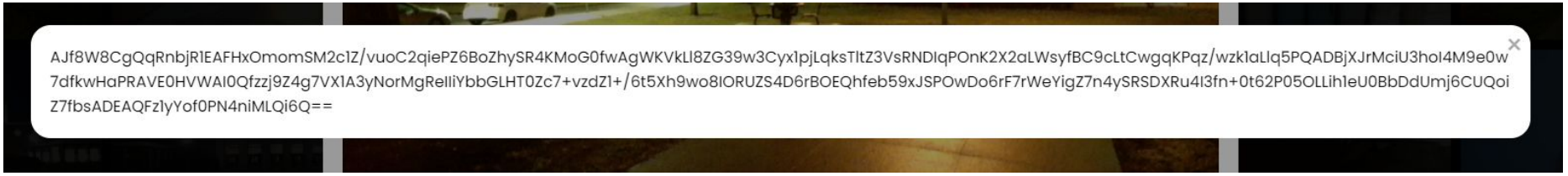
Store 10 one minute (30fps/1080p) videos without Wi-Fi

Online Media Storage

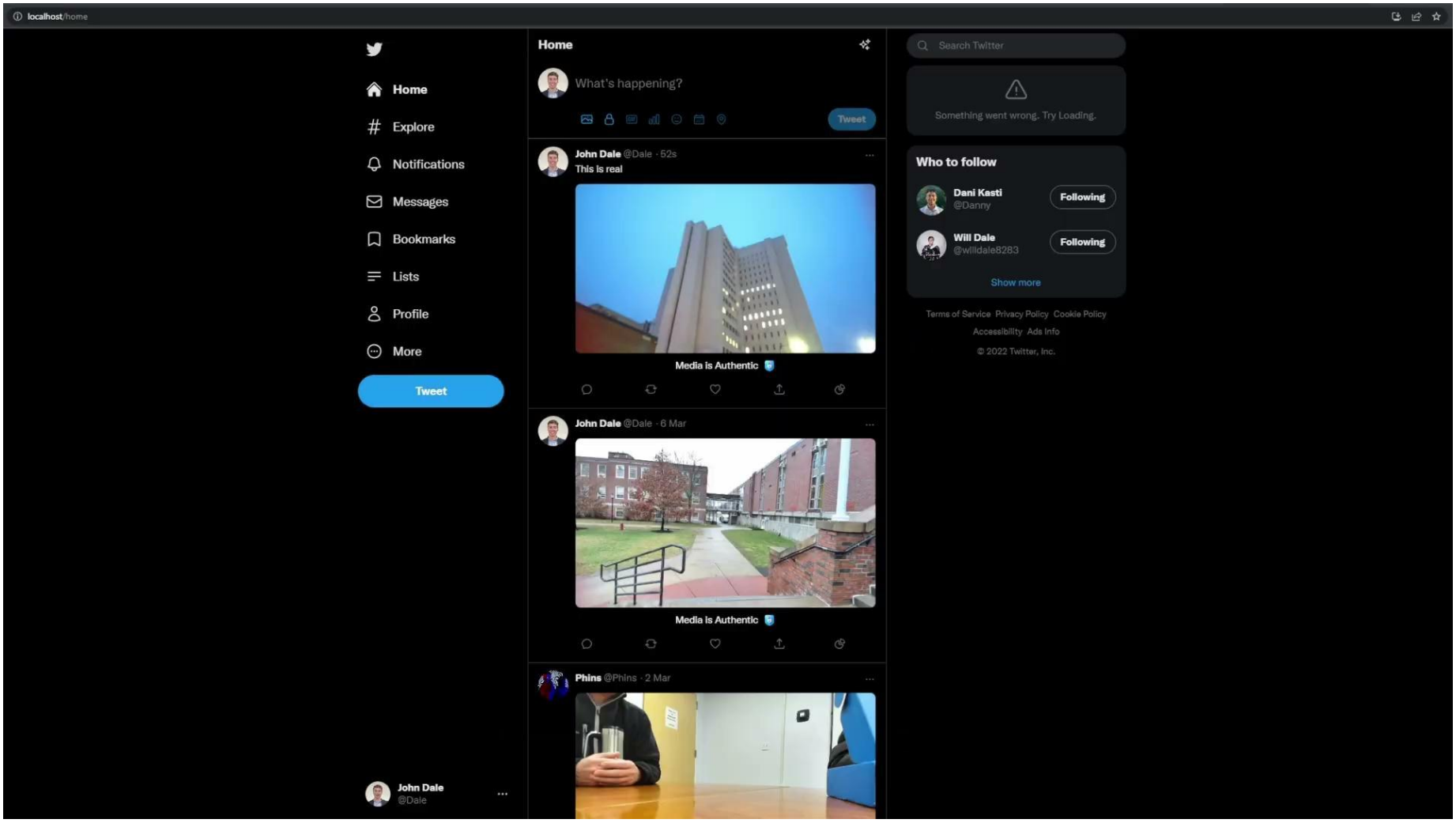




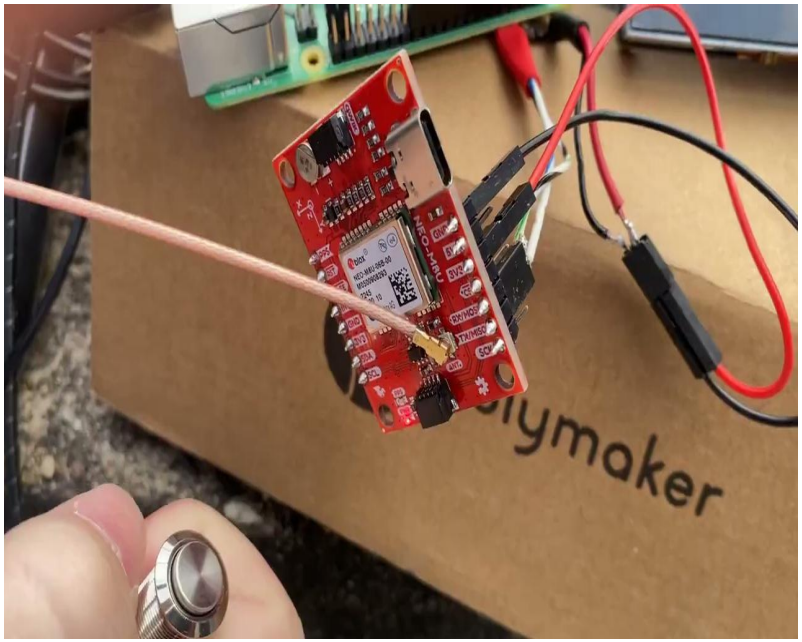




Solution Overview: Twitter Clone



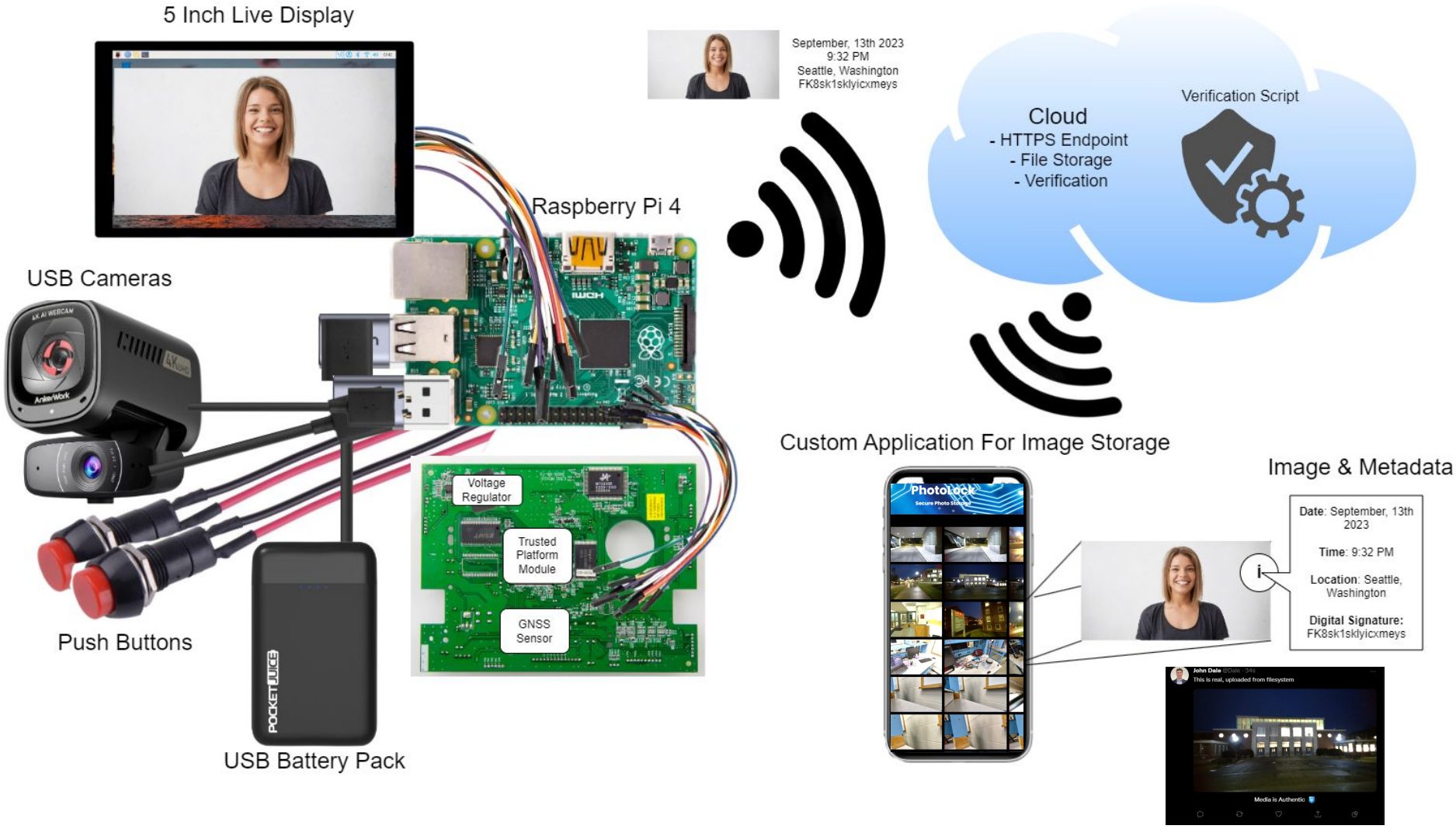
GPS : Time and Location Demonstration



Live Demo Details

- **Image/video capture and upload with WiFi**
  - View image/video on media gallery website
  - Download image/video
  - Delete image/video
- **Image/video capture without WiFi**
  - Ensure image/video is being saved
- **Post image/video to Twitter clone**
  - Upload through media gallery website
    - Verify media
    - Check metadata
  - Upload through file system
    - Verify media
    - Check metadata
  - Alter a real image
    - Verify media
  - Show multiple verified and unverified images in same post

CDR Demonstration



Review: System Capabilities at MDR…

-Camera system capable of:

1. Taking images with button ✅
2. Signing them ✅
3. Uploading them to the Cloud through WiFi ✅
4. Saving them on SD card and uploading to Cloud later ✅
   - **4.1. Threaded upload later scheme: in progress**
5. Proving that the images have not been modified ✅
6. Proving the images were taken on specific hardware ✅

-Cloud system capable of:

1. Receiving images from the camera ✅
2. Validating the images are signed from the camera ✅
3. Verifying image and metadata is authentic ✅
   - **3.1. Authentication Text Messaging ✅**
4. Storing images ✅

Original CDR Deliverables

-Camera system capable of:

1. Taking videos
2. Signing them
3. Uploading them to the Cloud through WiFi
4. No WiFi: saving them in memory and uploading to Cloud later
5. Proving that the videos have not been modified
6. Proving the videos were taken on specific hardware

-Threaded camera capture and saved media upload

-Live view of camera on screen

-Boot-Up Two-Factor Authentication (if WiFi available)

-Private User Application (Twitter clone)

-Website that allows anyone to upload image/videos to

- Photo/video verification

-Two cameras if budget allows

Updated CDR Deliverables

-Camera system capable of:

1. Taking videos ✅
2. Signing them ✅
3. Uploading them to the Cloud through WiFi ✅
4. No WiFi: saving them in memory and uploading to Cloud later ✅
5. Proving that the videos have not been modified ✅
6. Proving the videos were taken on specific hardware ✅

-Threaded camera capture and saved media upload ✅

-Live view of camera on screen ✅

-Additions: WiFi indicator, GPS indicator, image mode, video mode ✅

-Boot-Up Two-Factor Authentication (if WiFi available) ☒

-Private User Application ✅

-Website that allows anyone to upload image/videos to ✅

- Photo/video verification ✅

-Two cameras if budget allows* ☒

***Can't do two realistically, need TPM, screen, gps, pi, two cameras**

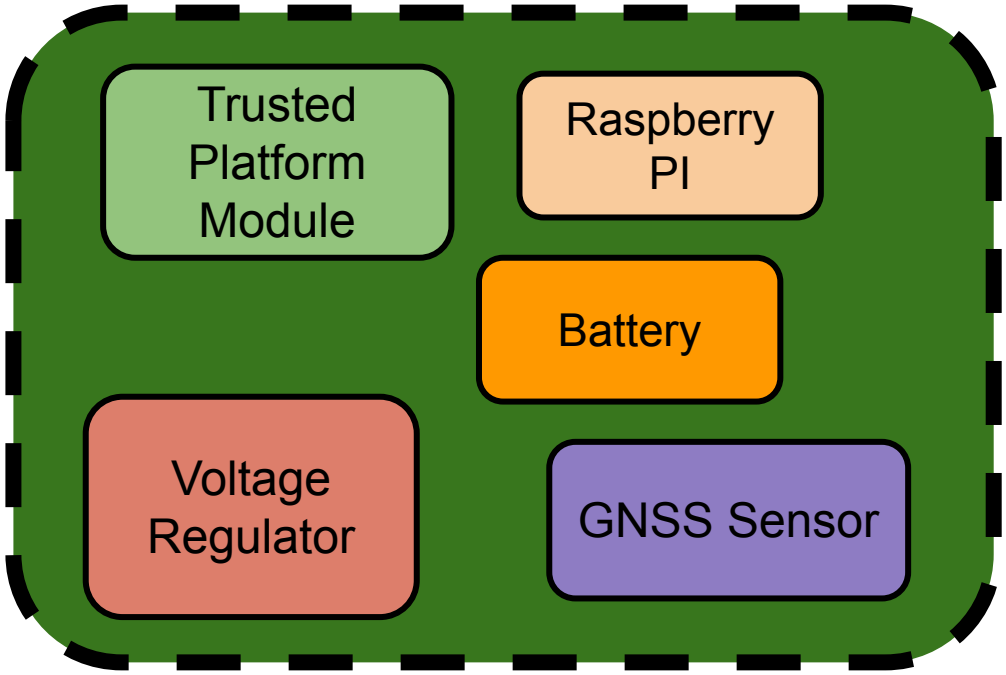
CDR Deliverables (PCB)

Adaptable PCB interface with the following components:

- Trusted platform module ✅
- GNSS Sensor ✅
- Voltage Regulator ✅
- Raspberry PI ✅
- Battery* ☒
- DC power jack for household power** ✅
- Pin headers for switching interfaces (2 for GPS) ✅

*Adjusted in next slide

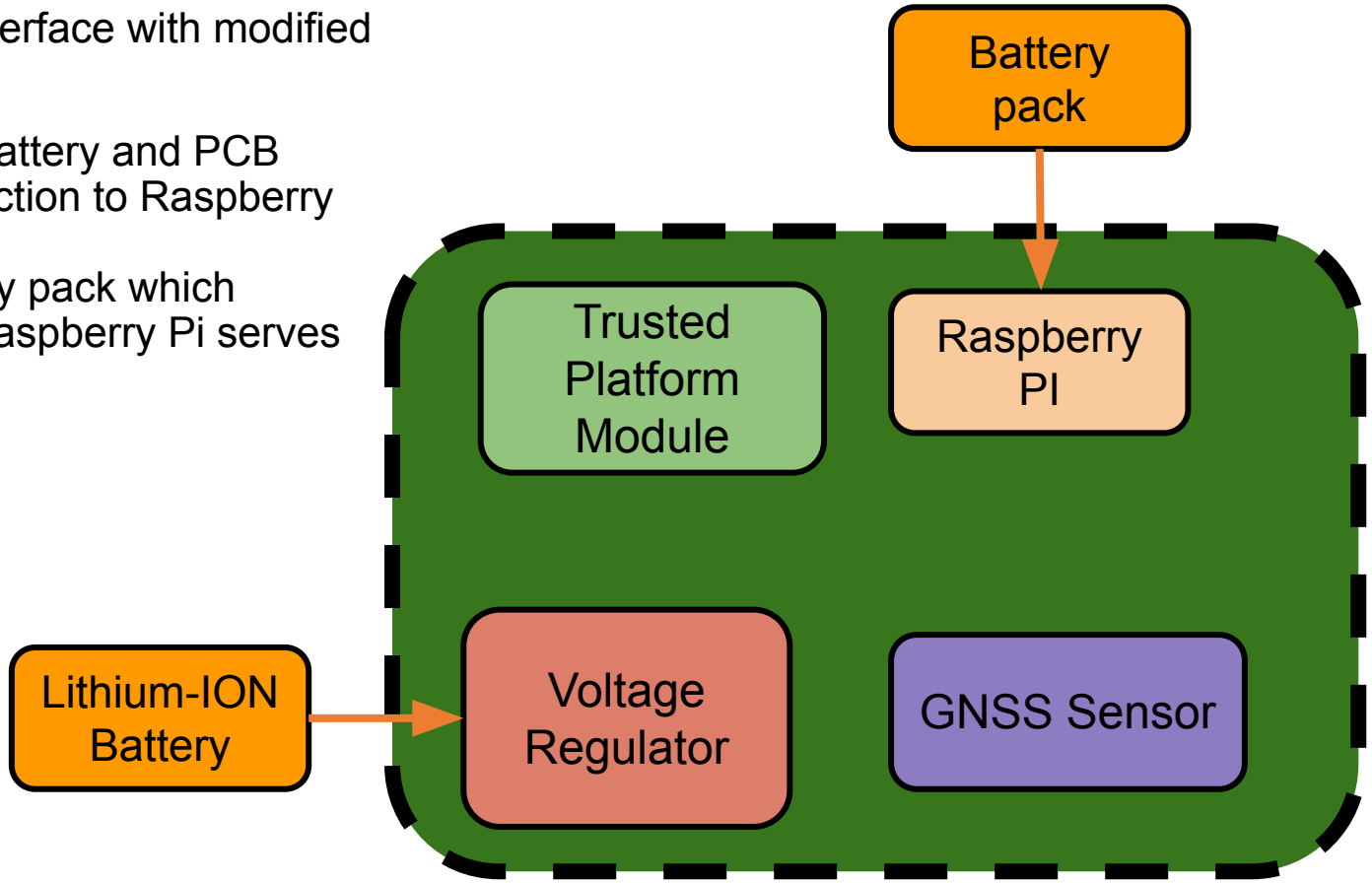
**Functional in last demo, due to current limit on Raspberry Pi pin, not testable, adjusted in next slide



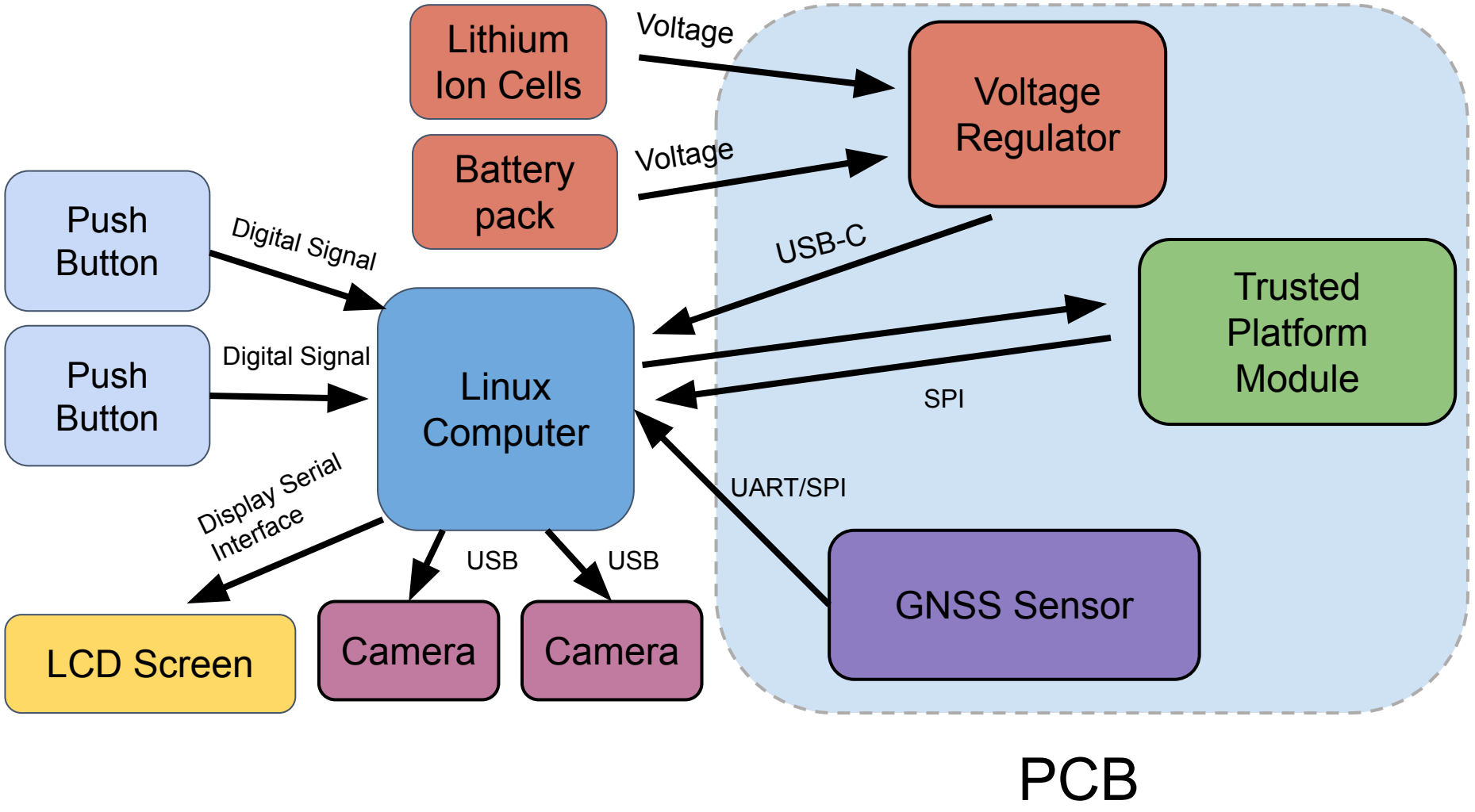
FPR Deliverables (PCB)

Adaptable PCB interface with modified battery interface

- Lithium-ION battery and PCB USB-C connection to Raspberry pi
- Current battery pack which connects to Raspberry Pi serves as backup



FPR Hardware Block Diagram



FPR Specifications & Test Plan

Image Specification	Video Specification	Test Plan
1. Authenticate images camera source with **100%** accuracy for **100** photos (Digital Signature)	1. Authenticate videos camera source with **100%** accuracy for **10** videos (Digital Signature)	Upload media from known or unknown camera source to verify whether digital signatures are correct
2. Verify image has not been modified with **100%** accuracy for **100** photos (Prevent false positives)	2. Verify video has not been modified with **100%** accuracy for **10** videos (Prevent false positives)	Upload media and compare raw data of image, time, location with actual
3. Verify image has been modified with **100%** accuracy for **100** photos (Prevent false negatives)	3. Verify video has been modified with **100%** accuracy for **10** videos (Prevent false negatives)	Upload modified media and verify it has been rejected by the cloud
4. Store at least **350** photos at **1080p** on the SD card (remote location - no WiFi)	4. Store one 5 minute video or store **15** one minute videos at **24fps/1080p** on the SD card (remote location - no WiFi)	Verify 350 photos at 1080p or 15 minutes worth of video can be stored when wifi access is denied
5. Upload at least 10 photos at **1080p** to the Cloud	5. Upload at least **10** videos at **24fps/1080p** to the cloud	Verify 10 photos/videos at 1080p can be uploaded to Cloud when there is wifi access
6. System can take one photo per **10 seconds**	6. System can take **one video per one minute**	Measure time between two consecutive media types
7. System can take 350 photos in one charge	7. System can take **10** separate 1 minute videos in one charge	Complete tasks in one charge (separately)

Budget Estimates:

Item	Cost	Shipping Time	
Raspberry Pi	$55.00	1 Week	https://www.mouser.com/ProductDetail/358-SC01949
Custom PCB	$30.00	1.5 Weeks	
Trusted Platform Module Evaluation Boa	$59.40	1 Week	https://www.mouser.com/ProductDetail/726-IRIDIUMSLI9670TP
Sparkfun GNSS Breakout board	$71.76	1 Week	https://www.mouser.com/ProductDetail/474-GPS-16329
5 Inch TFT Touchscreen Display	$47.38	1 Week	https://www.digikey.com/en/products/detail/dfrobot/DFR0550/9608214?utm_adgroup=&utm_source=goo
PCB Standoff Assortment Kit	$14.99	1 Week	https://www.amazon.com/Standoffs-Motherboard-Assortment-Threaded-Circuit/dp/B0CBPGKDP4/ref=sr
40p to 40p GPIO Ribbon Cable	$7.00	1 Week	https://www.amazon.com/NulSom-Inc-Ribbon-Cable-Raspberry/dp/B00QE3KZQ6/ref=sr_1_3?crid=1MD021
Momentary Push Buttons	$11.99	1 Week	https://www.amazon.com/DaierTek-Momentary-Waterproof-Pushbutton-Automotive/dp/B0C8HPN318/re
Active GNSS Antenna	$10.99	1 Week	https://www.amazon.com/Bingfu-Waterproof-Navigation-Adhesive-Receiver/dp/B083D59N55/ref=sr_1_1
12V 5A Power supply	$15.99	1 Week	https://www.amazon.com/ALITOVE-Adapter-Converter-100-240V-5-5x2-1mm/dp/B01GEA8PQA/ref=sr_1_3
Voltage Regulator (LM888T)	$1.76	1 Week	https://www.mouser.com/ProductDetail/926-LM338T-NOPB
270 Ohm Resistor	$0.05	1 Week	https://www.digikey.com/en/products/detail/stackpole-electronics-inc/CF14JT270R/1741362
820 Ohm Resistor	$0.04	1 Week	https://www.digikey.com/en/products/detail/stackpole-electronics-inc/CF18JT820R/1741779
Schottky Diode	$0.29	1 Week	https://www.digikey.com/en/products/detail/stmicroelectronics/1N5819/1037326
0.1 UF Capacitor	$0.26	1 Week	https://www.digikey.com/en/products/detail/nichicon/UKT1H0R1MDD1TD/4317271
1 UF Capacitor	$0.47	1 Week	https://www.digikey.com/en/products/detail/nichicon/UDB1H010MPM1TD/4332986
10 UF Capacitor	$0.13	1 Week	https://www.digikey.com/en/products/detail/kemet/ESH106M050AC3AA/3082958
U.FL to SMA Coaxial Cable	$3.56	1 Week	https://www.digikey.com/en/products/detail/pulse-electronics/W9006/2267902
DC Power Jack	$0.75	1 Week	https://www.digikey.com/en/products/detail/gct/DCJ200-10-A-K1-K/9859579
Pin Headers	$1.89	1 Week	https://www.digikey.com/en/products/detail/sullins-connector-solutions/PEC26SACN/859251
26 Pin Header	$10.08	1 Week	https://www.digikey.com/en/products/detail/samtec-inc/TD-113-G-A/1105513
Black PLA 3D printing filament	$18.99		https://www.amazon.com/dp/B089S2QDHD?psc=1&ref=ppx_yo2ov_dt_b_product_details
10,000 mAh portable charger	$15.00		https://www.amazon.com/dp/B0BLGB1RXD?psc=1&ref=ppx_yo2ov_dt_b_product_details
Total	$377.77		

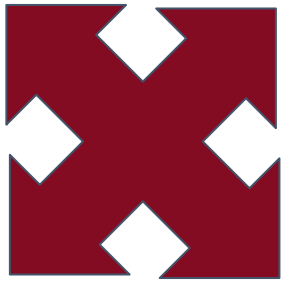
Team Roles and Work Division

John

- Cloud Software lead
- Application Lead
- Budget Lead

Darius

- PCB Lead



Jace

- PCB assist

Dani

- Embedded Software lead
- Logistics lead

QUESTIONS & ANSWERS

University of Massachusetts Amherst

Updated Gantt Chart

Category	Task	Team Members	Week of 3/18	Week of 3/25	Week of 4/1	Week of 4/8	Week of 4/15
APP	App/Website improvments	John					
PCB	PCB layout tool and environment training	Darius/Jace					
Embd Software	Specification testing	Dani / John					
PCB	PCB REV C	Darius/Jace					
Embd Software	code improvments	Dani/John					
PCB	Lithium Ion Battery Build and Integration	Darius/Jace					

Citations

[1] "Forgery-Detection Digital Signature Solutions - Sony Pro," *pro.sony*. https://pro.sony/ue_US/solutions/forgery-detection (accessed Oct. 10, 2023).

[2] J. Schneider, "This Company Wants to Protect Image Integrity Using Blockchain," *PetaPixel*, Jan. 13, 2021. https://petapixel.com/2021/01/13/this-company-wants-to-protect-image-integrity-using-blockchain/ (accessed Oct. 10, 2023).

[3] K. Koptyra and M. R. Ogiela, "Imagechain—Application of Blockchain Technology for Images," *Sensors*, vol. 21, no. 1, p. 82, Dec. 2020, doi: https://doi.org/10.3390/s21010082.

[4] Vinaypamnani-Msft, "Trusted platform module technology overview - windows security," Windows Security | Microsoft Learn, https://learn.microsoft.com/en-us/windows/security/hardware-security/tpm/trusted-platform-module-overview (accessed Oct. 11, 2023).

Reference Slides

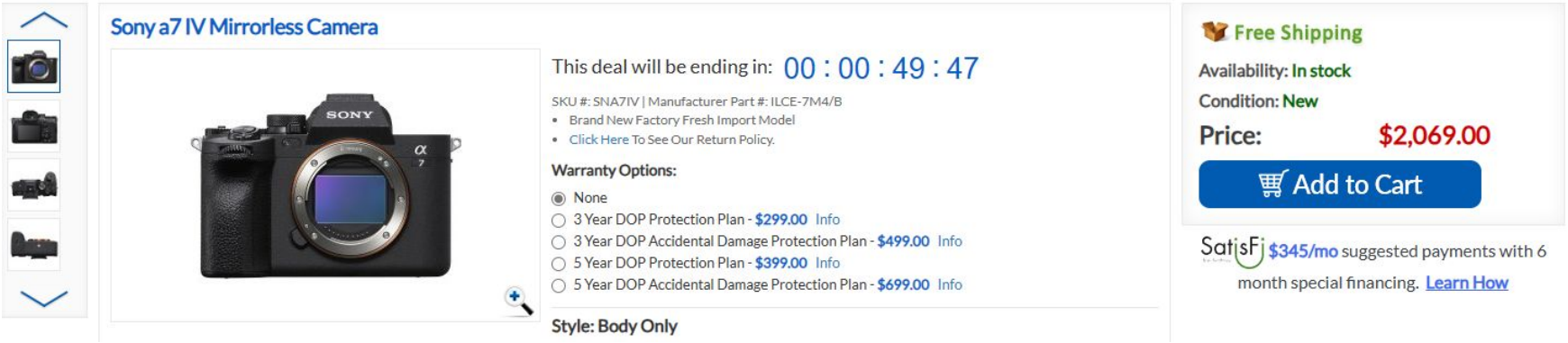
Survey of Similar Solutions

Sony Alpha 7 IV camera [1]

- Supports detection of any modification to an image, thus protecting it from fraudulent usage
- Eliminates unauthorized editing and misconduct around digital photo data
- For corporate users only

But this method is:

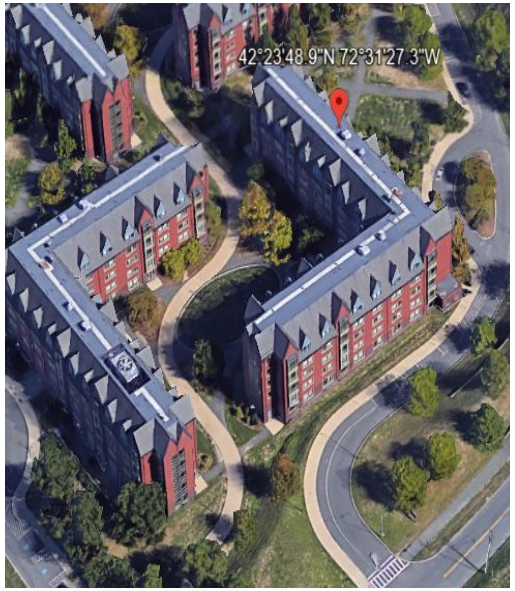
1. Expensive: Unaffordable for the general public
2. Not open source

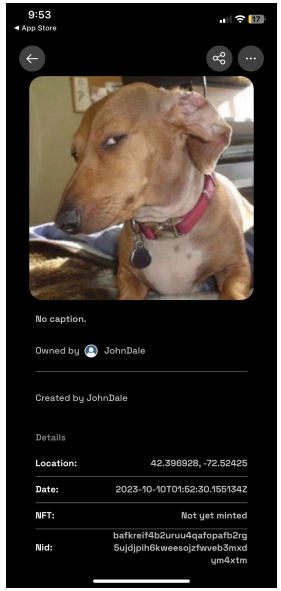


Survey of Similar Solutions

Capture Cam - Photo Verify (Image block chain) [2]

- An application that uses the camera of mobile phones with blockchain technology to transform photos into verifiable and secure digital assets.
- Marketed to protect against AI generated fake images





But this method is:

1. Not spoof-proof: Cannot guarantee whether an image has been modified or artificially generated

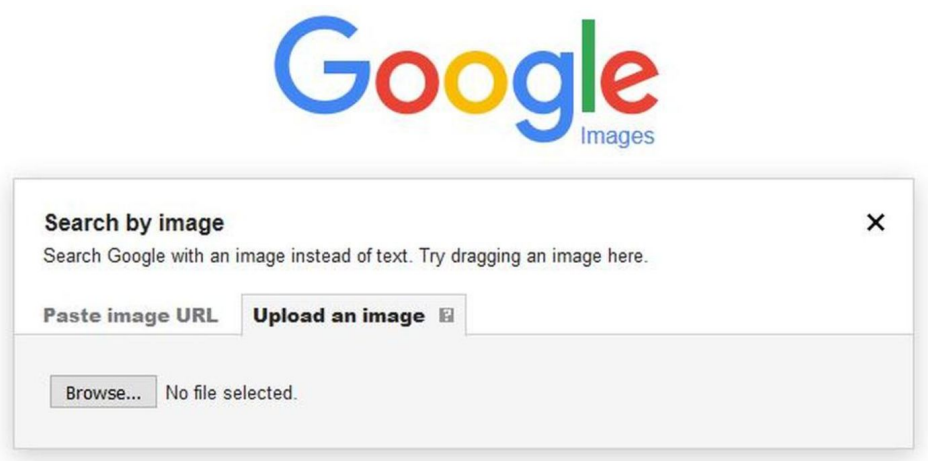
Survey of Similar Solutions

Other solutions of verifying image integrity involve

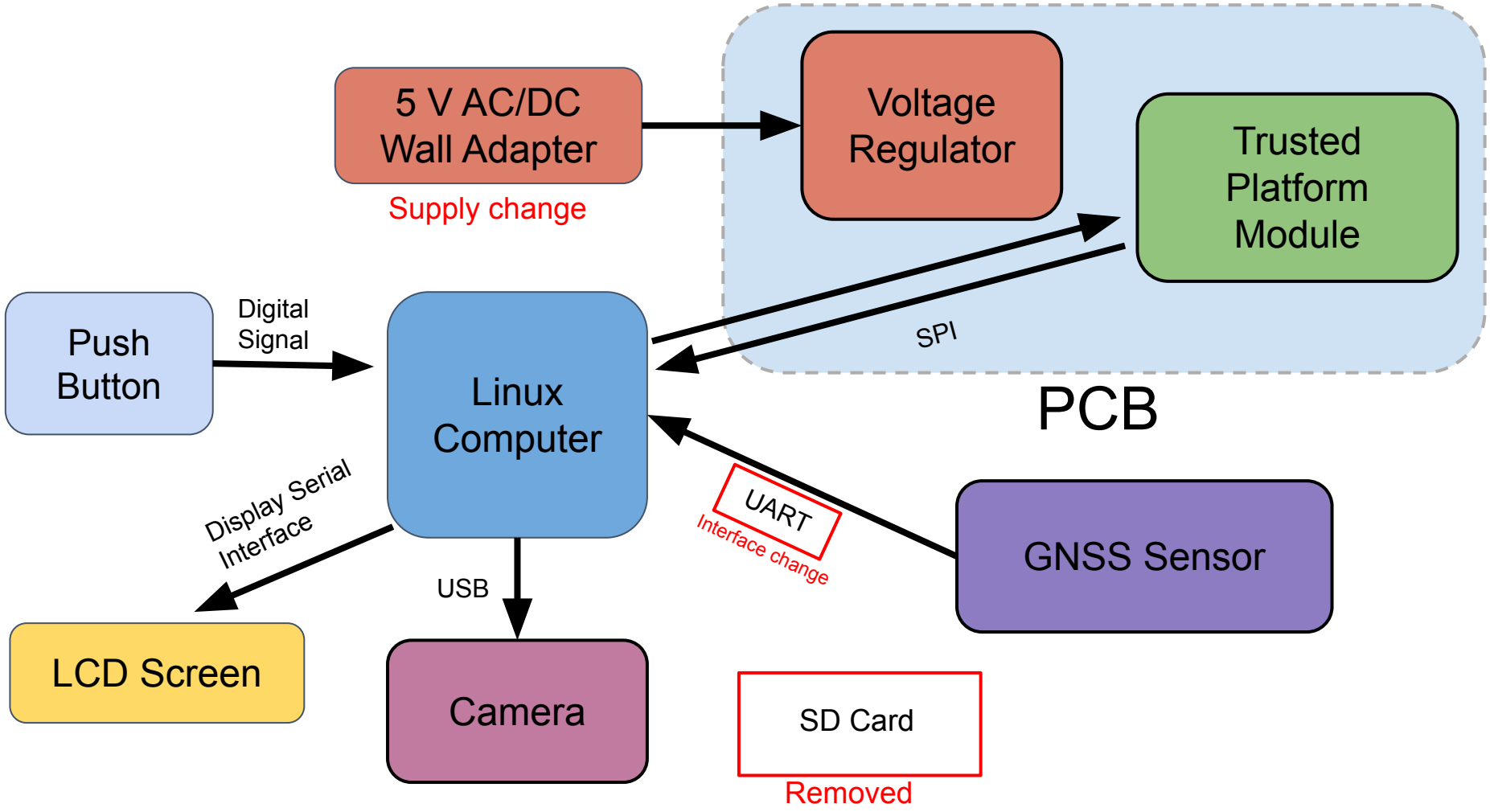
- Individual fact-checkers
- Reverse-image searching
- Image forensics

But these methods are:

1. Inefficient/slow: Not practical when waves of images are populating social media feed



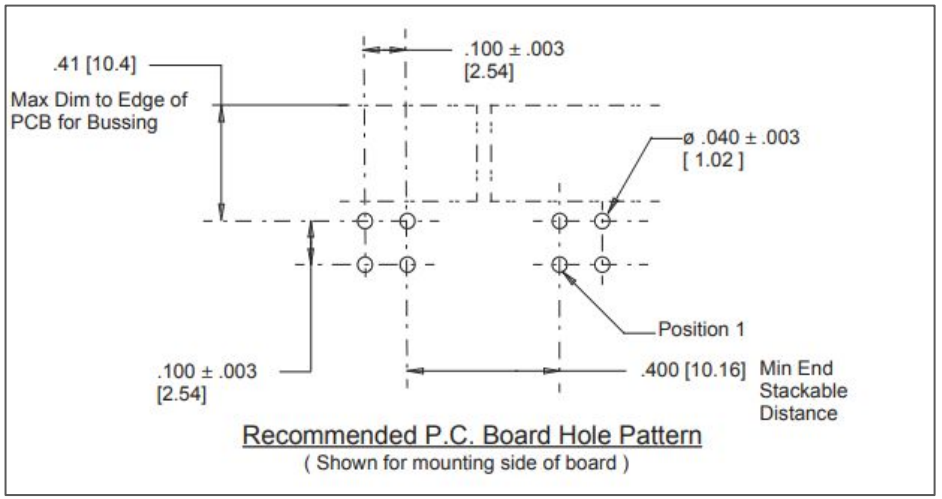
Hardware Block Diagram Changes



PCB Design Process

- Emphasize importance of part selection
- Ensure correct orientation (evaluation board placement, ease of access, etc)
- Double check measurements
- Visualize integration (Raspberry Pi → 40 pin PCB header, etc.)
- Investigate pin and footprint compatibility

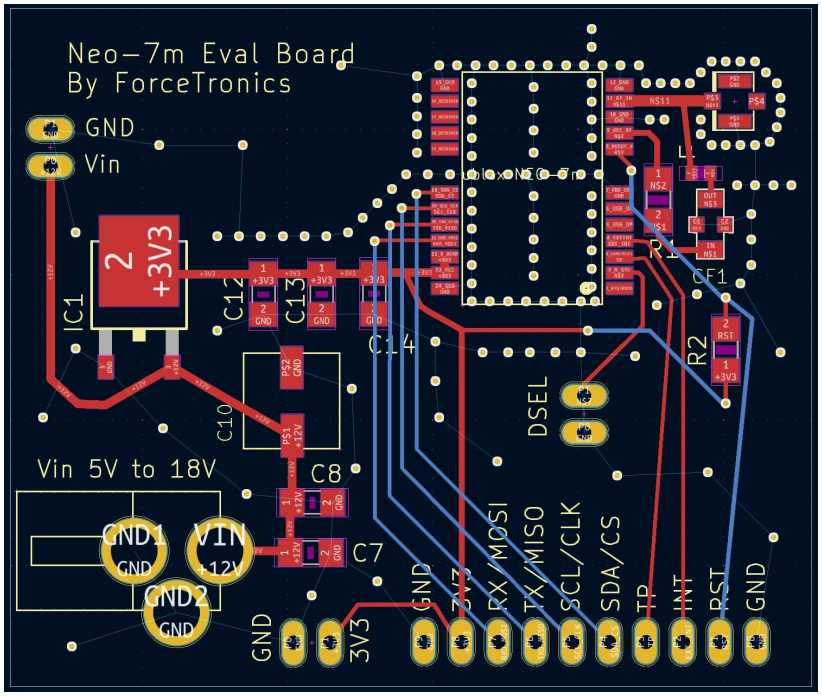
Orientation



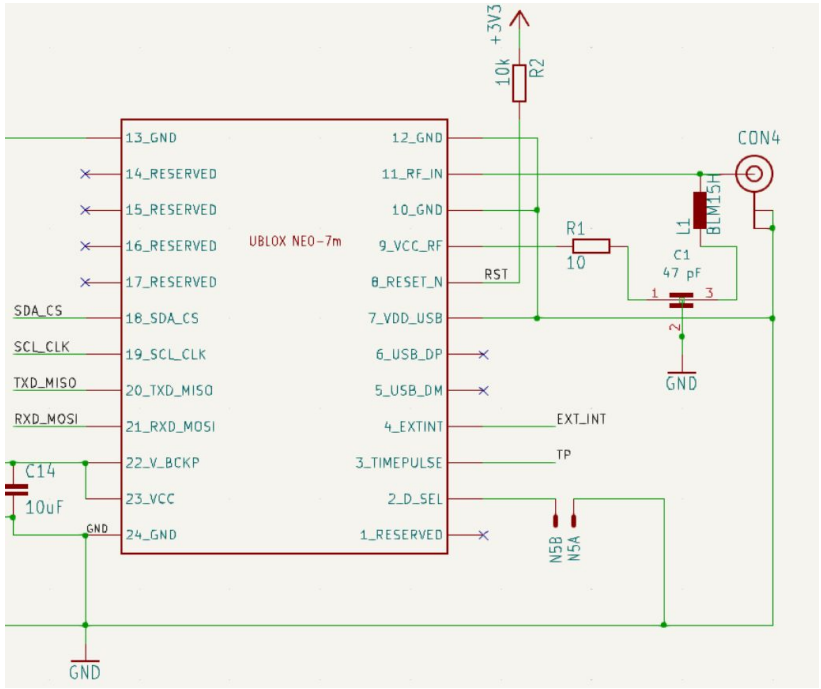
Footprint compatibility

Benefits of Breakout Board Integration

- Ease of access to components
- Minimize errors by removing RF design component
- Ease of integration from Raspberry Pi to PCB
- Ensure proof of concept



RF Shielding in PCB Layout



Filtering for antenna