Aviator Design Document

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GTA: Zixiao Ma
Professor: Ryan Beasley

Figure 0.0.1: [Caption]

Contents

List of Figures

List of Tables

Revision Log

Date	Revision	Changes
5/3/2024	v0.1	Initial Release
9/18/2025	v1.0	First Draft

Table 1: Revision Log

Glossary

- **API** Application Programming Interface.

1 Introduction

1.1 Executive Description

Retro nearby flight information display.

1.2 User Stories

The Long-Time Aviation Hobbyist

As a long-time aviation hobbyist who has spent years tracking flights through phone apps, I'm tired of paying for subscriptions just to unlock basic features. I want a device that gives me real-time flight information without hidden costs, while also providing a tactile, nostalgic experience that reminds me of classic aviation boards. By having the Aviator on my desk, I can finally stay connected to the aviation world without feeling like I'm paying a premium for something that should be standard and accessible.

The Casual Aviation Enthusiast

As someone with a general interest in aviation, I don't need a full cockpit-level tracker, but I do want something that feels engaging and easy to use. Standard apps are flat, cluttered, and frankly too much for a novice like myself, but the Aviator project makes flight tracking simple, physical, and fun. I can glance at the board, see arrivals and departures, and feel connected to the aviation scene effortlessly. The setup process was simply plug and play. Additionally, I don't have to pay a dime for the product. For me, it's about accessibility and enjoying aviation in a personal,low-effort, high-impact way.

The Purdue ECE Student

As a Purdue ECE student, I'm drawn to the Aviator not only as a hobby project that I can tinker with, but also as a nod to Purdue's deep aviation legacy. It's inspiring to own a piece of tech that bridges my academic interests in circuits and embedded systems with Purdue's reputation in aerospace. I want a tracker that feels hands-on, customizable, and personal—something that makes me feel part of both my field of study and Purdue's aviation history every time I glance at it. Given the nature of the project and its ability to be completed by an individual excites me, as it gives me the stepping stone I needed to start tracking flights.

2 Design Requirements

2.1 Requirements

1. The device must display accurate information.
2. The display must not interfere with user's well-being by, for example, displaying at excessive luminosity, updating rapidly in a distracting manner, or being excessively bulky.
3. The device must not infringe on any person's reasonable expectation of privacy.
4. The device must be language-agnostic wherever possible.
5. The device must be responsive and intuitive.
6. The device must have robust error handling and recovery.
7. The physical device should be easily replicated with widely available parts.
8. The code for the device must be open-source and well-documented.
9. The device should be as durable and environmentally friendly as possible so as not to contribute to e-waste.
10. The device must not contribute to noise or visual pollution of any space.
11. The device must be energy-efficient.
12. The device must minimize construction and recurring costs.
13. The device must not infringe on right to repair.
14. The device must mount and dismount without damage to vertical surfaces.

2.2 Factors Influencing Requirements

2.2.1 Public Health, Safety, and Welfare

1. User well-being
2. Privacy

2.2.2 Cultural Factors

1. Language differences
2. Ease of use

2.2.3 Social Factors

1. Ease of replication
2. Open-source and documentation

2.2.4 Environmental Factors

1. Environmental friendliness and e-waste
2. Noise and visual pollution
3. Energy efficiency

2.2.5 Economic Factors

1. Cost
2. Repairability

3 System Overview

3.1 System Block Diagram

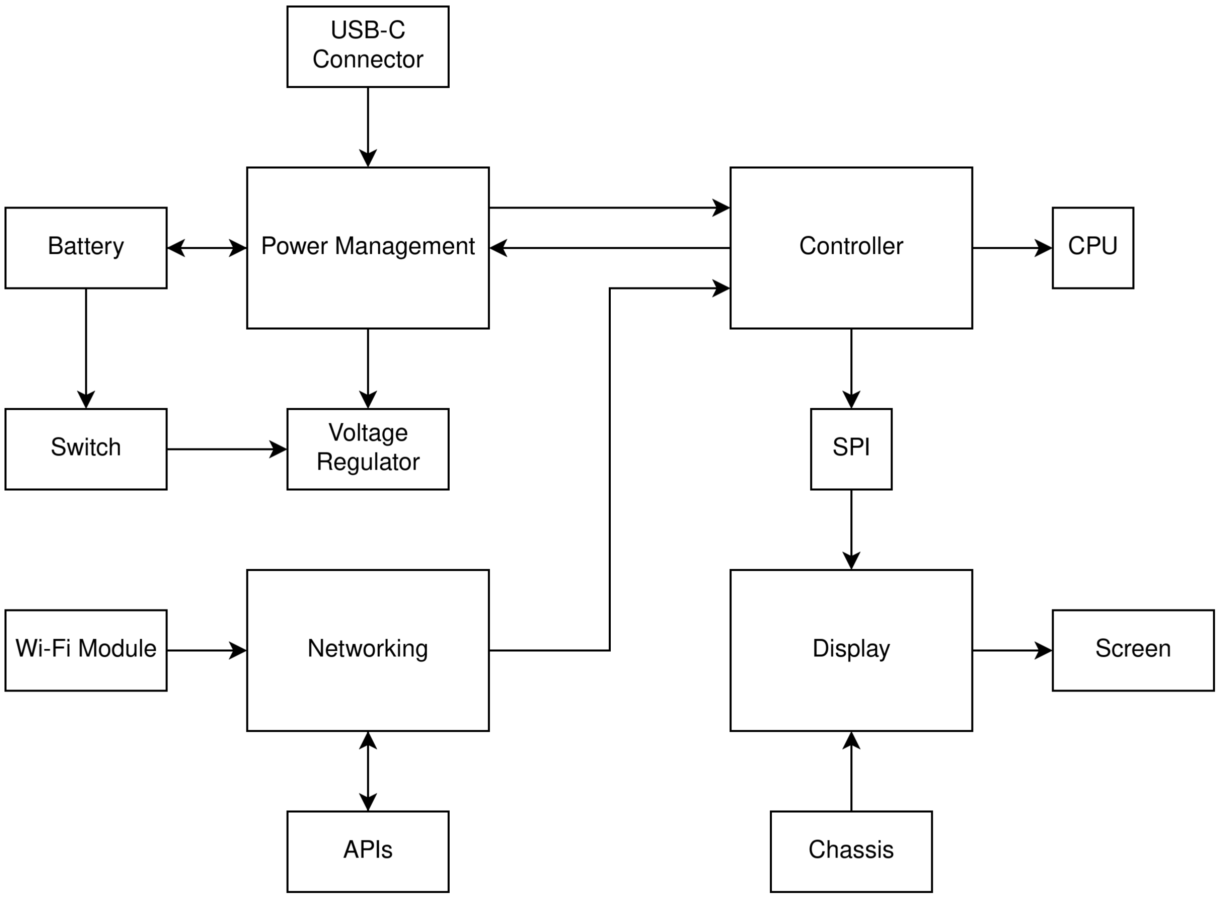


Figure 3.1.1: System Block Diagram

3.2 System Activity Diagram

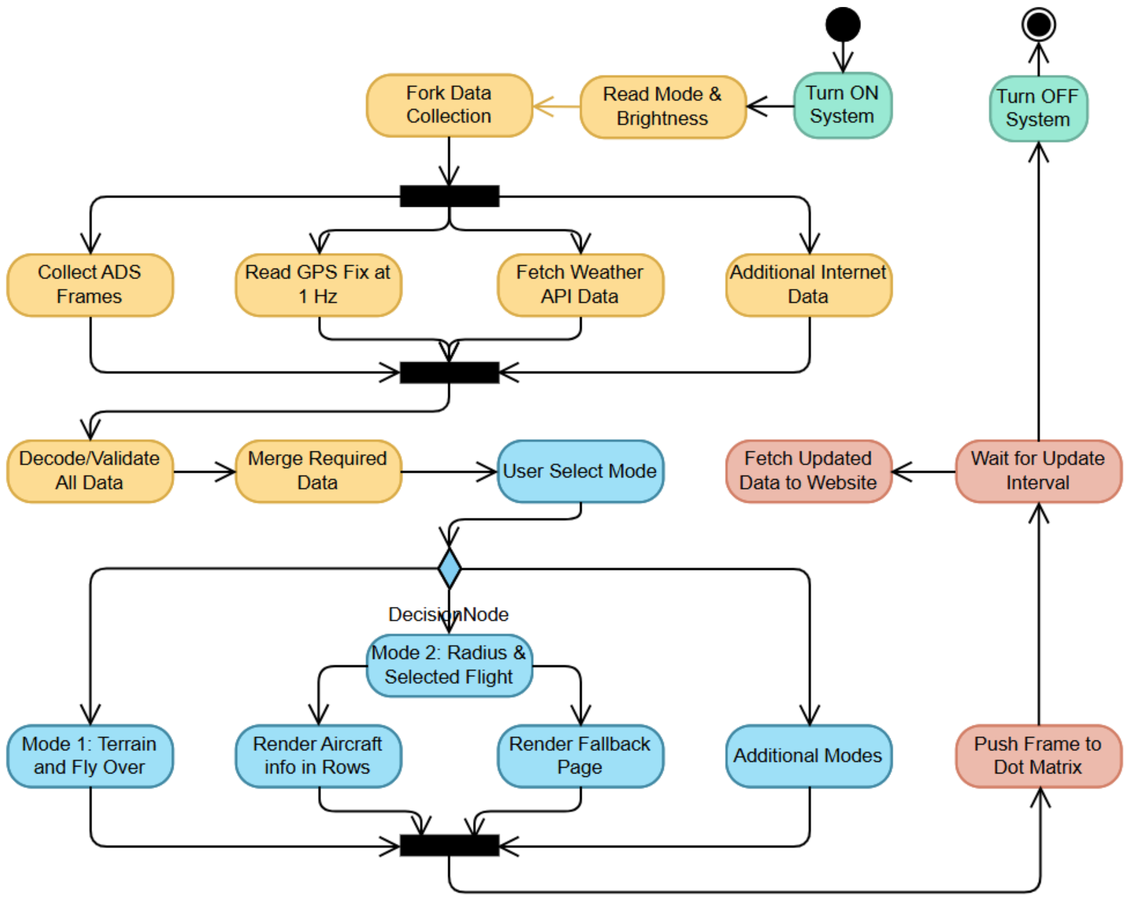


Figure 3.2.1: System Activity Diagram

3.3 System Mechanical Design (Extra Credit)

[**DD3+**]

Figure 3.3.1: System Mechanical Design

3.4 Integration Approach

[**DD3+**] [Theory behind the system design, with reference to subsystem integration within your system – i.e., explain how it is supposed to work, but not whether it did actually work]
[Type here]

3.5 System Photographs

[**DD3+**] [Photograph of assembled system, intended to highlight user interaction / controls. If system is split into multiple parts, show a composite of more than one photograph with all key user interactions / controls.]

Figure 3.5.1: [Photo Name]

4 Subsystems

4.1 Subsystem 1: Processing

4.1.1 Subsystem Diagrams

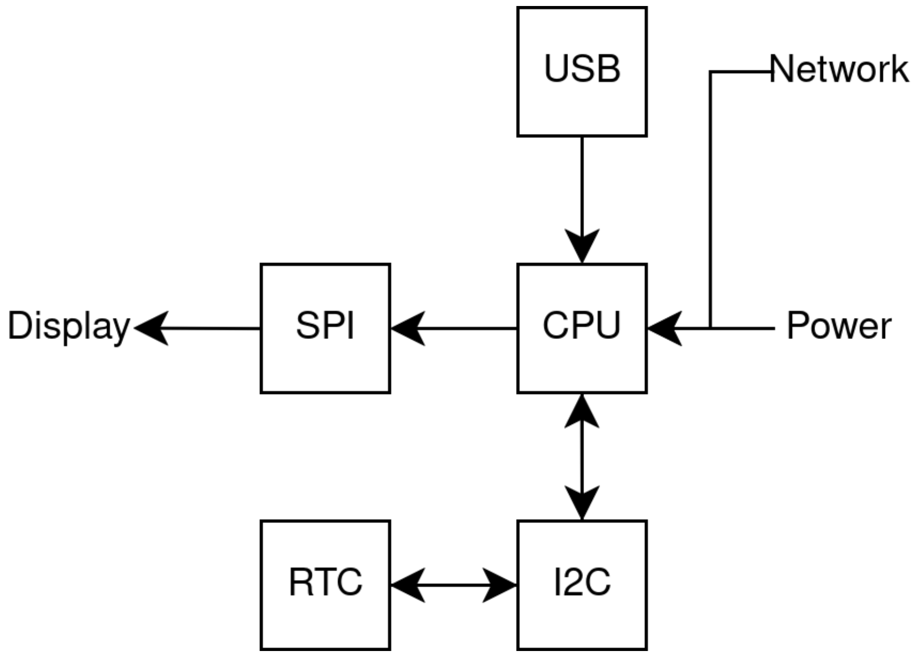


Figure 4.1.1: Subsystem Block Diagram

4.1.2 Specifications

1. Support SPI clock ≥ 20 MHz
2. SPI support up to 40 MHz, full-duplex, DMA capable
3. Display update latency ≤ 16 ms
4. Support configurable API refresh interval between 60 and 300 s
5. API end-to-end fetch latency ≤ 2 s
6. Clock drift $\leq \pm 1 \frac{\text{sec}}{\text{day}}$
7. Operating voltage: 3.3 ± 0.1 V

4.1.3 Subsystem Interactions

The core computer interfaces with all other subsystems. The battery/power management unit supplies it with power. Running processes direct and receive information from the network module. It communicates with the digital dot matrix display via SPI according to display drivers on the controller.

4.1.4 Core ECE Design Tasks

- **ENGR 16100**: Teamwork & project documentation.
- **CS 15900**: Fundamentals of programming.
- **ECE 36200**: PCB design and embedded software development.

4.1.5 Parts

- ESP32-S3
- DS3231
- PCB

4.1.6 Algorithm

```
initialize clock, network, display, location
DATA = {}

always
    wifi keep alive
    error handling
    if power button pressed
        save and shut down

every minute
    update display time

    read ADS-B sensor
    if ADS-B valid
        add to DATA
        if internet connected
            upload ADS-B data
        else
```

```
            cache ADS-B data
    else
        if internet connected
            make API call for flight data
            add to DATA
        else
            add warning ADS-B out of date to DATA


    if battery powered
        update battery level in DATA

    update time, weather in DATA
    convert DATA to pixel buffer
    push pixel buffer to displar
every hour
    sync with network time
    make API call for weather
```

4.1.7 Theory of Operation

The processing subsystem is responsible for coordinating all other subsystems and serving as the "brain" of the Aviator device. At startup, the ESP32-S3 initializes its real-time clock, connects to the Wi-Fi network, and configures the SPI interface for display communication. During normal operation, the processor maintains a persistent network connection to ensure timely access to APIs.

Every minute, the processor updates the displayed time, retrieves the latest flight information from the network subsystem, and parses the response into a standardized data structure. If the device is battery-powered, it also queries the power management subsystem for voltage information and appends this to the displayed data. The processor then converts the compiled information (time, weather, and flight updates) into a pixel buffer and transmits it to the display subsystem.

On an hourly basis, the processor synchronizes the real-time clock with network time servers and fetches weather data for local context. Error handling routines ensure that loss of network, corrupted data, or power fluctuations do not crash the system; instead, the subsystem retries API calls or falls back to cached data, with a warning that the data is out of date.

4.1.8 Specifications Measurement

[**DD3+** Every specification here should match the specification above.]

1. [Copy specification here.]
   [Explain the specification here. Add photoes if necessary.]

4.1.9 Standards

- **IPC-2221**: Governs PCB trace width, spacing, creepage/clearance, via rules, grounding, etc.
- **IPC-A-610**: Covers soldering quality and workmanship.
- **RFC 5905**: Protocol for syncing ESP time to internet.

4.2 Subsystem 2: Power Management

4.2.1 Subsystem Diagrams

[**DD1+**]

4.2.2 Specifications

1. [Type here **DD1+**]

4.2.3 Subsystem Interactions

[Type here **DD1+**]

4.2.4 Core ECE Design Tasks

[**DD1+** Write tasks and course that helps accomplish that task]

- **ECE xxxxx**: [Type the relationship here.]

4.2.5 Schematics

[Type here **DD2+**]

4.2.6 Parts

- USB-C 5 V input module
- Li-ion battery pack (3.7 V, 8000 mAh)
- Buck-boost regulator IC (for 3.3 V and 5 V rails)
- Battery charging IC (USB-C PD or simple Li-ion charger).
- Basic protection devices (fuse, MOSFET switch, TVS diode).
- (Optional) Solar panel (5–20 W) + MPPT controller IC.

4.2.7 Algorithm

[Type here **DD1+**]

4.2.8 Theory of Operation

[Type here **DD2+**]

4.2.9 Specifications Measurement

[**DD3+** Every specification here should match the specification above.]

1. [Copy specification here.]
   [Explain the specification here. Add photoes if necessary.]

4.2.10 Standards

- **USB-C Power Delivery Specification**: ensures safe and standard input power.
- **IEEE 1625**: covers battery system reliability for portable electronics.
- **UL 2054**: safety standard for rechargeable batteries in consumer devices.
- **IEC 61215**: (Optional solar) performance and reliability for PV modules.

Figure 4.2.1: Subsystem Block Diagram

Figure 4.2.2: [Schematic Name]

4.3 Subsystem 3: Text Display & Chassis

4.3.1 Subsystem Diagrams

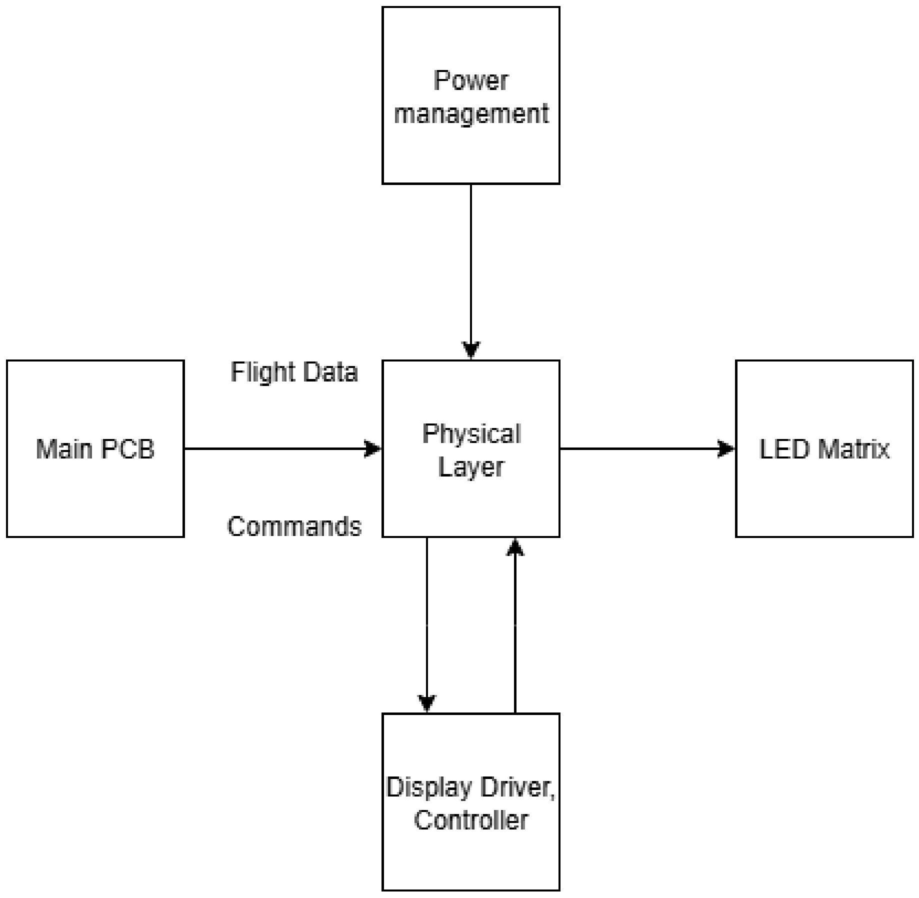


Figure 4.3.1: Subsystem Block Diagram

4.3.2 Specifications

1. Feature a 2056-pixel Dot Display (128 x 256px)
2. Physical dimensions of housing within 5% of 64 x 128 x 256 mm.

4.3.3 Subsystem Interactions

The display subsystem links the main PCB and the LED Matrix. This subsystem will interface with the power management system and the main PCB. It will recieve data and commands from the main PCB, interpret the commands, and display the data.

4.3.4 Core ECE Design Tasks

- **ECE 27000**: Provides a solid foundation in logic circuits. Helps for designing registers, data paths, logic that drives the LED panel.
- **ECE 25500**: Provides a base understanding of transisters, amplifiers, and fundamentals into I-V behavior.
- **ECE 40862**: Teaches valuable STM concepts such as programming, interrupts, and DMA which are needed to drive the display controller efficiently.

4.3.5 Schematics

[Type here **DD2+**]

4.3.6 Parts

- 32 x 64 px LED Matrix (ADAFruit from DigiKey)
- Custom PCB (possibly a hat or extension) for driving display

4.3.7 Algorithm

```
Initialize:
Configure GPIOs (DATA, CLK, LAT, OE, row select lines (A,B,C,D))
Initialize interface for incoming data
Initialize timer for refresh interrupts
Set PWM resolution (e.g., 8-bit)

Main Loop:
while (true):
    if new frame data available from main PCB:
        copy frame buffer into local memory (double buffer optional)

    for each row_index in 0 .. NUM_ROWS-1:
        select_row(row_index)
        OE = HIGH

        for pwm_bit = 7 downto 0:      // for 8-bit PWM
            for col_index = 0 .. NUM_COLS-1:
                pixel = frame_buffer[row_index][col_index]
                if pixel.red  & (1 << pwm_bit) != 0:
                    DATA_R = HIGH
                else:
                    DATA_R = LOW
                if pixel.green & (1 << pwm_bit) != 0:
                    DATA_G = HIGH
                else:
                    DATA_G = LOW
                if pixel.blue & (1 << pwm_bit) != 0:
                    DATA_B = HIGH
                else:
                    DATA_B = LOW

                pulse(CLK)

            pulse(LAT)
            OE = LOW
            delay(PWM_DELAY[pwm_bit])

    repeat indefinitely
```

4.3.8 Theory of Operation

[Type here **DD2+**]

4.3.9 Specifications Measurement

[**DD3+** Every specification here should match the specification above.]

1. [Copy specification here.]
   [Explain the specification here. Add photoes if necessary.]

4.3.10 Standards

- **IEC 61010**: Safety for low-voltage electronic equipment; ensures protection against shorts, overcurrent, and handling risks.
- **SPI/I^{2}C**: If MCU/controller communicates with peripheral ICs over standard buses.
- **HUB75**: Standard for 32×64 RGB LED matrices; timing, row multiplexing, and data latching must be followed.

- **JESD51**: Important for high-current LED arrays; ensures heat dissipation and junction temperatures are within safe limits.

Figure 4.3.2: [Schematic Name]

4.4 Subsystem 4: Network and Communications

4.4.1 Subsystem Diagrams

[**DD1+**]

4.4.2 Specifications

1. [Type here **DD1+**]

4.4.3 Subsystem Interactions

[Type here **DD1+**]

4.4.4 Core ECE Design Tasks

[**DD1+** Write tasks and course that helps accomplish that task]

- **ECE xxxxx**: [Type the relationship here.]

4.4.5 Schematics

[Type here **DD2+**]

4.4.6 Parts

- Weather API
- Flight API
- Time Sync API
- GPS/Geolocation API
- Network Interface
- Data/Signal Interface

4.4.7 Algorithm

[Type here **DD1+**]

4.4.8 Theory of Operation

[Type here **DD2+**]

4.4.9 Specifications Measurement

[**DD3+** Every specification here should match the specification above.]

1. [Copy specification here.]
   [Explain the specification here. Add photos if necessary.]

4.4.10 Standards

- **NMEA 0183**: Used by GPS receivers to format location/time data, ensuring compatibility with processing algorithms.
- **REST/HTTPS**: Secure, standardized communication with weather servers and external data sources.
- **IEEE 802.11 (Wi-Fi) / IEEE 802.3 (Ethernet)**: Provides reliable networking for internet-based data exchange (when we add website interference).
- **TCP/IP, Checksum validation**: Ensures robustness in communication so that even non-technical users get accurate, reliable results.

Figure 4.4.1: Subsystem Block Diagram

Figure 4.4.2: [Schematic Name]

5 PCB Design

5.1 PCB Schematics

[**DD3+**]

Figure 5.1.1: PCB Schematic

5.2 PCB Layout

[**DD3+**]

Figure 5.2.1: PCB Layout

6 Final Status of Requirements

[**DD3+**] [If met, give a detailed explanation of the requirement. If partially met, mention what has been met and a reason for why the complete requirement couldn't be achieved. If not met, give an explanation for why the requirement couldn't be met in the product. Add as many requirements as you had in your earlier design documents here.]

1. Requirement 1: [Copy your requirement above here]
   Met: [Explanation]

2. Requirement 2: [Copy your requirement above here]
   Partially Met: [Explanation]

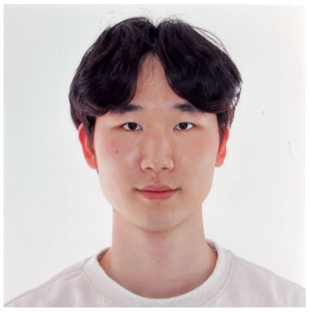
3. Requirement 3: [Copy your requirement above here]
   Not Met: [Explanation]

7 Team Structure

7.1 Team Member 1

David Thoe
Major: Electrical Engineering
Contact: dthoe@purdue.edu
Team Role: Team Leader
Bio: In charge of graphics drivers and text display, I will be focused on the final presentation of the information as well as subsystem integration. I will also be paying special attention to the housing of the prototype, aided by CAD and 3D printing, ensuring the product appears polished when complete. At Purdue, I concentrate in Wireless and Optical engineering and participate in the club Autonomous Motorsports Purdue, where we place our fully autonomous go-kart in competition with other univiersities. In my free time, I work on hobby electrical projects usually related to my computer or decoration.

7.2 Team Member 2



Joshua Kim
Major: Electrical Engineering
Contact: kim3503@purdue.edu
Team Role: Communication Lead
Bio: In my role as Communication Lead, I am responsible for ensuring that communication on our team, with GTA, and the Professor is clear and consistent. I manage communications on updates, facilitate collaboration on progress reporting, and keep everyone engaged

and aligned within the subsystem groups to further our design as a cohesive project. My background in Electrical Engineering enables me to contribute directly to the technical aspects of the project and also help translate technical details into clear explanations for our team and other stakeholders. Balancing the communication and development of the subsystem, I can keep both the engineering work and project coordination rolling smoothly.

7.3 Team Member 3

Zeke Ulrich
Major: Computer Engineering
Contact: pulrich@purdue.edu
Team Role: Treasurer
Bio: Zeke is the processing and PCB design specialist. He's responsible for designing the PCB schematics and integrating the disparate subsystems on the processor. At Purdue, Zeke belongs to the Marine Corp Officer Candidate Program, Eta Kappa Nu, Tau Beta Pi, and Purdue's Effective Altruism community. Outside Purdue, he is president of the nonprofit DuelGood and works for the government in cybersecurity. In the future he hopes to study international relations as a Truman scholar, start a family, and volunteer as a firefighter. He enjoys athletics and spending time with his friends.

7.4 Team Member 4

Juan Vargas
Major: Electrical Engineering

Contact: varga105@purdue.edu
Team Role: Facilitator
Bio: As the Facilitator, my primary role is to keep our team organized, collaborative, and on track throughout the project. I focus on making sure discussions are productive, tasks are clearly divided, and deadlines are met without overwhelming any single member. By bridging technical conversations and helping resolve roadblocks quickly, I ensure that progress stays steady and balanced across subsystems. Alongside this coordination, I contribute to the technical development by assisting with software and system integration specially in the network/communication part, ensuring our device works as intended while maintaining the retro, aviation-inspired feel that defines Aviator.

8 Bibliography

[Here are some examples. IEEE format can be found on Purdue OWL.]

References

[1] “Data Platform - Open Power System data,” Apr. 15, 2020. https://data.open-power-system-data.org/household_data/

[2] Author,”Title,” *Journal*,volume,number, page range, month year, DOI.

[3] Author. ”Page.”Website. URL(accessed month day,year)

9 Appendices

[This section is mainly designed for code. You can directly generate a somewhat decent display of your code file or psuedo code by using the template provided below. You can have as many appendix as you want. In the document, you can refer to the code posted here instead of pasting the whole code in the body.]