Project Proposal

Team 52

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INTRODUCTION:

Problem:

LabEscape is a science-themed escape room that wants to use a hologram-style spinning globe to show clues and countdown timers to players. While this project has been attempted in the past, the resulting device had several limitations that made it difficult to use in a real game environment. One major issue with the previous version was that the electronic chips used on the board did not match the original blueprints or instructions. This discrepancy made it very hard for anyone to understand how the machine was wired or how to fix it if something went wrong, as the map of the inside didn't match reality.

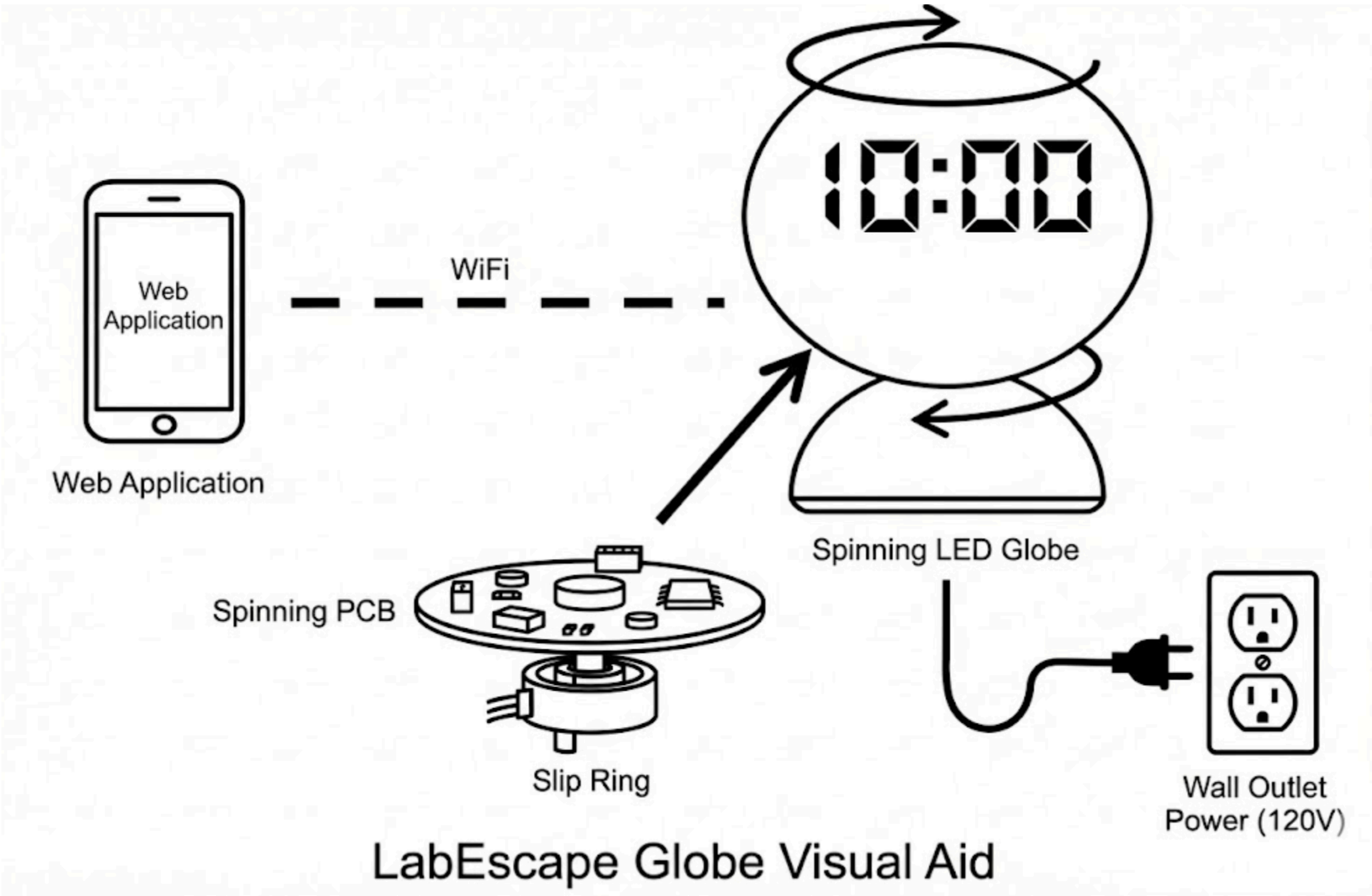
Additionally, the previous attempt was not flexible enough for a live escape room experience. It was restricted to displaying a simple clock or a single, pre-saved picture that could not be changed. In a real game, the staff needs to be able to send new hints, update the text instantly, or manage a countdown timer that can be adjusted, for example, adding or removing time based on how the players are doing. Because the old version could not change its display in real-time, it wasn't interactive enough to be a core part of the puzzle experience.

Solution:

We are going to build a completely new, robust LED sphere that solves these hardware and usability issues. The device works using Persistence of Vision, where a strip of lights spins so fast that your eyes blend the flashes together to see a solid, floating image. We are designing the electronics from scratch to ensure that every single part matches our blueprints perfectly. This ensures that the device is reliable, robust, and can be easily maintained or repaired by future students or staff.

To make the device truly useful for the escape room, we are making it smart and wireless. We are adding a WiFi connection that allows the escape room staff to control the globe from a simple website on a phone or laptop. Instead of being stuck with one preloaded image, they will be able to type in new text to show clues in real-time or start a countdown timer. We are specifically designing this timer to be adjustable, meaning the gamemaster can wirelessly add minutes to the clock if a team solves a puzzle, or take time away. We are also using a precise magnetic sensor to track the spinning speed, ensuring the image stays steady and clear at all times.

Visual Aide:

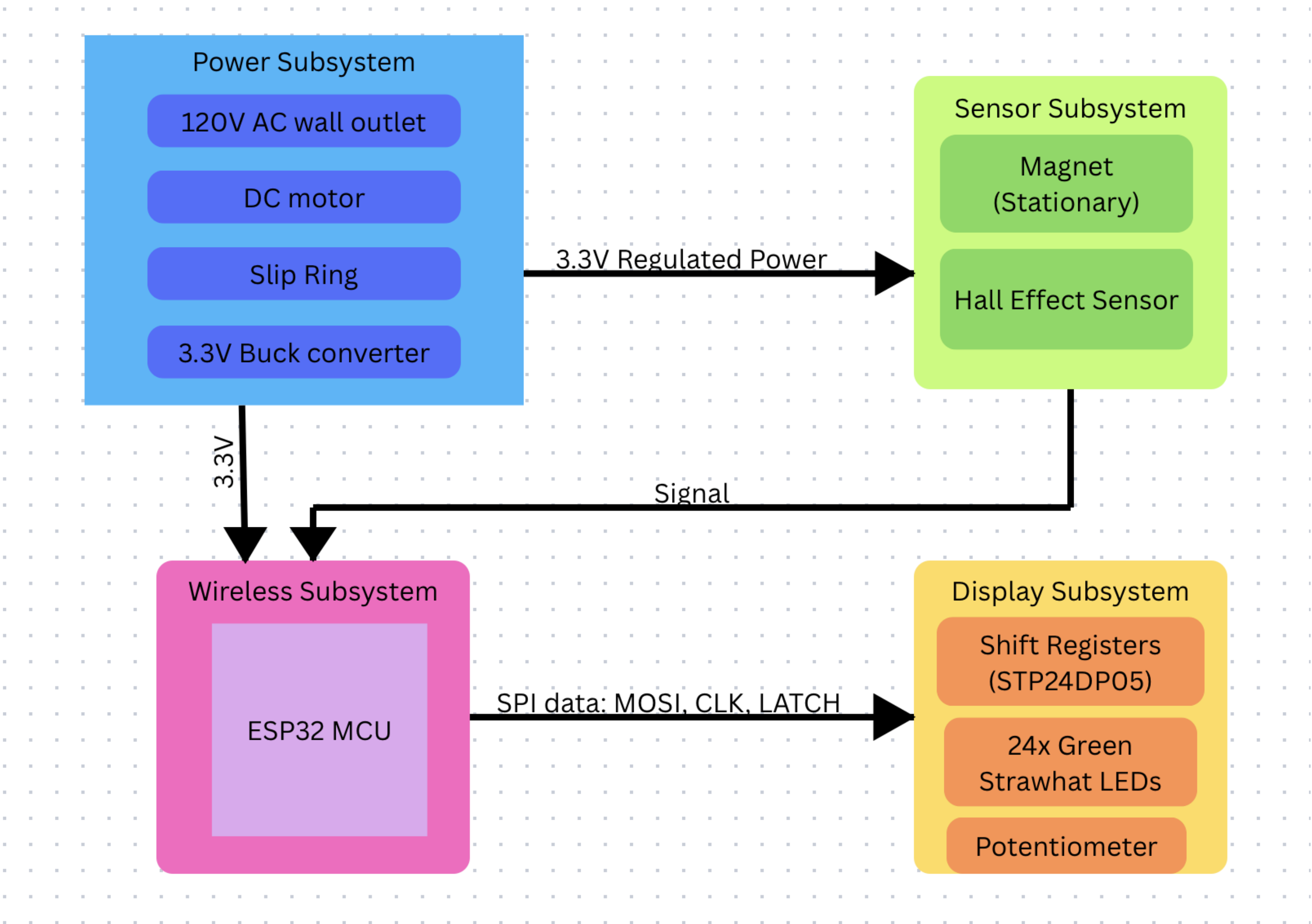


High Level Requirements list:

- When operating at full speed, the displayed text and image should be clearly legible from 5 feet away over a period of 10 minutes.
- The rotating assembly remains balanced while operating, with no audible thumping exceeding 50 dB or visible oscillation for the duration of 10 minutes.
- The LED Globe successfully receives and displays image and text uploads within 1 minute per image, without requiring any physical connections.
- A Hall effect sensor accurately detects when the rotating assembly has completed one revolution, with less than 2% missed detections over 10 minutes.
- LED brightness is sufficient to display images and text from 5 feet away under standard indoor lighting (300 lux).
- Timer mode: Timer can be set to a time up to 1 hour in the web application and counts down, resets, and pauses via web application.

DESIGN:

Block Diagram:



Subsystem Overview:

Power Subsystem:

The Power Subsystem acts as the central energy source for the entire device. It utilizes a wall socket connected to a 5V usb charger to power the motor. This voltage is distributed to the DC Motor to drive rotation and passed through the Slip Ring to the Rotating Assembly. Once on the rotating side, a buck converter changes noisy 5V output into a stable 3.3V logic supply required by the ESP32 and shift registers.

Control & Wireless Subsystem:

This subsystem is the main part of the device. It consists of the ESP32 wireless module. The ESP32 hosts the web application and receives user uploads (images/text) and does the LED output processing. To handle the high-speed logic it reads the SD card for stored sprites, calculates rotational speed, and coordinates the precise timing required to drive the Display Subsystem.

Sensor Subsystem

The Sensor Subsystem provides the physical feedback necessary for Persistence of Vision (POV). It uses a Hall Effect sensor (US5881LUA) on the rotating board to detect a stationary magnet on the base. This generates a digital interrupt pulse once per revolution, allowing the Control Subsystem to calculate RPM and reset the image rendering position (Theta = 0).

Display Subsystem

The Display Subsystem visualizes the data. It consists of STP24DP05 Shift Registers and an array of Strawhat RGB LEDs. Receiving high-speed serial data (SPI) from the Control Subsystem, the shift registers drive the LEDs with constant current. This subsystem is responsible for flashing the LEDs at precise microsecond intervals to create the illusion of a solid image as the globe spins. A potentiometer is included to allow manual user adjustment of parameters like color hue or brightness.

Mechanical & Motor Subsystem

This subsystem provides the physical rotation required for the POV effect. It includes the DC motor and the physical housing. The motor drives the rotating platform at a constant angular velocity. The slip ring is mechanically integrated here to bridge the electrical connection between the stationary wall power and the spinning electronics.

Subsystem Requirements:

Power Subsystem Requirements:

The Power Subsystem must provide stable electrical energy to both the high-current motor and the sensitive digital logic.

- Voltage Regulation: The regulator must output 3.3V ± 5% with a maximum ripple of 50mV to prevent logic errors in the RP2040.
- Current Capacity (Rotating): The subsystem must supply a continuous current of at least 800mA to the rotating electronics (accounting for ~24 LEDs at 20mA + ESP32 current spikes)..
- Interface: The Slip Ring must maintain electrical continuity up to 1000 RPM with a contact resistance variance of less than 100 mOmega to avoid power flickering.

Control & Wireless Subsystem Requirements

This subsystem must process input data and coordinate timing with microsecond precision.

- Processing Speed: The RP2040 must process Hall sensor interrupts and update LED output buffers within 50 μs to ensure pixel alignment at rotation speeds up to 1500 RPM.
- Wireless Latency: The ESP32 must receive and transfer a monochrome bitmap image (approx 1KB) within 5 seconds.
- Memory: The interface with the SD card must support SPI read speeds of at least 2 Mbps to load frames in real-time.
- Synchronization: The system must utilize the Hall sensor signal to maintain a refresh rate jitter of less than 1% to prevent image drift.

Display Subsystem Requirements:

The Display Subsystem renders the visual output.

- Refresh Rate: The shift registers must support a clock frequency of at least 10 MHz to enable full column updates within the discrete time slots allocated per degree of rotation.
- Brightness: The LEDs must emit a luminous intensity of at least 300 mcd per channel to be visible in an indoor lit room (300 lux environment).
- Color Depth: The system must support at least 3-bit color (8 colors) by driving the RGB pins of the Strawhat LEDs

Tolerance Analysis:

The biggest risk to this project is that the slip ring might not be capable of handling the current required to power all the lights at once. Although we have unlimited energy from the wall outlet, the physical slip ring connector is a bottleneck limited to 2.0 Amps. If the system draws more current than this, the contacts could overheat or cause a voltage drop that resets the microcontroller.

To check if this is safe, we calculated the power needed for green light only. White light is made by mixing three colors (Red, Green, Blue), which consumes significant energy. Green light uses only one channel. If we turn on all 24 green LEDs at full brightness, plus the ESP32 Wi-Fi chip, the system will calculate to roughly 0.77 Amps of peak current.

This is excellent news because 0.77 Amps is well below the 2.0 Amp limit of our slip ring. This proves that by using single-color green LEDs and a wall-powered supply, the globe will operate reliably without melting the connector or suffering from brownouts.

For the persistence of vision (POV) illusion to work correctly, the LEDs on the sphere need to refresh with the correct bits at a rate of at least 60 fps per column (360 degrees with about 60 LEDs). If this is not achieved, the illusion fails.

ETHICS AND SAFETY:

Ethics:

As engineering students, we have a responsibility to keep people safe and be honest about our work, following the IEEE Code of Ethics. Our project is a spinning light display that will be used in a public escape room, so our top priority is making sure it does not hurt anyone or cause problems. Since the device flashes lights very quickly to create the image, it creates a risk for people who have photosensitive epilepsy. To handle this ethically, we must be transparent and place clear Flashing Light warning signs near the exhibit so visitors can make informed choices before entering the room.

Another big ethical issue is digital responsibility. Since our new design uses a WiFi chip (ESP32) to let staff update the text wirelessly, there is a risk that a hacker or a prankster could break into the system and display offensive or inappropriate messages. It would be unethical to release a device that could be used to harass others. To prevent this, we are building a secure, password-protected login page so that only the authorized LabEscape staff can change what the globe displays.

Safety:

- Mechanical Hazards: The globe spins at a very high speed to make the image appear. If any part, like a screw or an LED is loose, it could fly off and hit someone like a bullet. To prevent this, we are making sure the spinning part is perfectly balanced so it doesn't shake. We will also use strong glue on all screws and recommend placing a clear plastic box around the device to catch any flying parts if something breaks.
- Electrical Safety: In the past, spinning electronics had issues with wires getting twisted and snapping, which creates a fire hazard. Our new solution uses a "slip ring" connector to transfer power safely without twisting any cables. We will also use "heat shrink" tubing to cover all exposed metal connections so that no one can accidentally touch a live wire and get shocked while the device is on.
- Visual Safety: Strobe lights can be disorienting or headache inducing even for people without epilepsy. We will program the LEDs so they are bright enough to be seen, but not so bright that they hurt people's eyes or leave spots in their vision after looking at them.

REFERENCES

Maker Electronics Projects, "Rotating LED Sphere – Building a RP2040 POV Display Step by Step," YouTube, Apr. 18, 2025. https://www.youtube.com/watch?v=TCV0LSV6ubA. Accessed 12 Feb, 2026.

Raspberry Pi Ltd., "RP2040 Datasheet," version 1.4, Cambridge, U.K., Jun. 2023. https://datasheets.raspberrypi.com/rp2040/rp2040-datasheet.pdf

Melexis, "US5881: Unipolar Hall Switch - Low Sensitivity," Datasheet, Ieper, Belgium, Feb. 2018. https://www.melexis.com/-/media/files/documents/datasheets/sensors/latch-and-switch/us5881-datasheet-melexis.pdf. Accessed 12 Feb, 2026.

Espressif Systems, "ESP32-WROVER-B & ESP32-WROVER-IB Datasheet," version 1.4, Shanghai, China, 2021. https://www.espressif.com/sites/default/files/documentation/esp32-wrover-b_esp32-wrover-ib_datasheet_en.pdf. Accessed 12 Feb, 2026.

STMicroelectronics, "STP24DP05: 24-bit constant current LED sink driver with output error detection," Datasheet, Geneva, Switzerland, Oct. 2008. https://www.st.com/resource/en/datasheet/stp24dp05.pdf. Accessed 12 Feb, 2026

IEEE. "IEEE Code of Ethics." *IEEE Policies*, Section 7.8, 2024. https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed 11 Feb, 2026