AdheraScent Pill Container

ECE 445 Design Document - Spring 2026

Project #26

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1 Introduction

1.1 Problem

Modern healthcare faces a “silent epidemic” that occurs after the patient leaves the hospitals or clinics: the failure to execute prescribed care. Even though medical diagnostics have advanced rapidly, the actual execution of care remains a significant failure point. As of 2026, approximately 50% of patients with chronic conditions fail to follow their prescribed treatment plan [1]. For most people, this is not a deliberate choice but a result of cognitive overload. Forgetfulness is the most frequent barrier, cited by 62 % of non-adherence patients [2], a struggle caused by the rise of “polypharmacy” where individuals must manage complex schedules involving five or more daily medications [3]. This gap in care is extremely acute for the one in four adults who report experiencing memory loss or cognitive interference with daily tasks [4], making the development of automated adherence tools a critical necessity for maintaining public health and safety.

This widespread non-adherence presents a severe threat to public welfare and safety. Medication errors and missed doses lead to approximately 125,000 preventable deaths annually in the United States [5]. Beyond mortality, non-adherence is a primary driver of system-wide safety risks, currently linked to up to 25% of all hospital admissions [6]. Since consistent dosing is fundamental to controlling conditions like hypertension and diabetes, improving adherence is now recognized as a top public health priority, essential for reducing morbidity and ensuring that medical interventions achieve their intended life-saving outcomes.

The implications of this problem extend to global economic and environmental factors. Economically, non-adherence drains the U.S. healthcare system of $100 billion to $300 billion every year in avoidable emergency visits and complications [7]. Environmentally, suboptimal adherence is a major driver of pharmaceutical waste, contributing to a healthcare carbon footprint that accounts for nearly 5% of global greenhouse gas emissions [1]. Socially, the burden often falls on family caregivers who experience significant emotional and physical strain while managing the repercussions of a patient’s missed doses [6]. By addressing the technical barriers to medication timing, this project aims to mitigate these broad societal costs while promoting a more sustainable and effective model of care. From an engineering perspective, the challenge lies in developing a reminder mechanism that is independent of smartphones or external connectivity, physically present in the user’s environment, difficult to ignore yet non-disruptive, energy-efficient for long-term battery operation, and safe for use around medication storage.

1.2 Solution

The proposed solution, AdheraScent, is a battery powered pillbox that integrates time-based monitoring, compartment open and close detection, and a controlled scent emission mechanism to provide adaptive medication reminders. The system would continuously monitor scheduled medication windows with a real-time clock integrated with an ESP32 microcontroller. Each daily compartment of the 7-day pill container is equipped with an open/close sensor to determine whether medication has been accessed during its assigned time window. If the container remains closed after the scheduled window expires, the control unit activates the scent emitter.

The scent emission subsystem consists of a replaceable scent pad, a mechanically controlled airflow path, and a variable-speed DC fan. When triggered, airflow is enabled across the scent pad to release scent into the environment. The emission intensity is modulated using pulse width modulation (PWM), allowing gradual increases in scent if the medication is still missed. Once the container is opened, the emission will stop immediately.

To ensure long-term reliability, the system assumes a predetermined scent pad lifetime (e.g. 20 days). The microcontroller tracks elapsed time since installation of the scent pad and activates a blinking LED when the pad approaches the end of its effective service life. The system operates without smartphone integration and employs power management to extend battery life.

1.3 Visual Aid

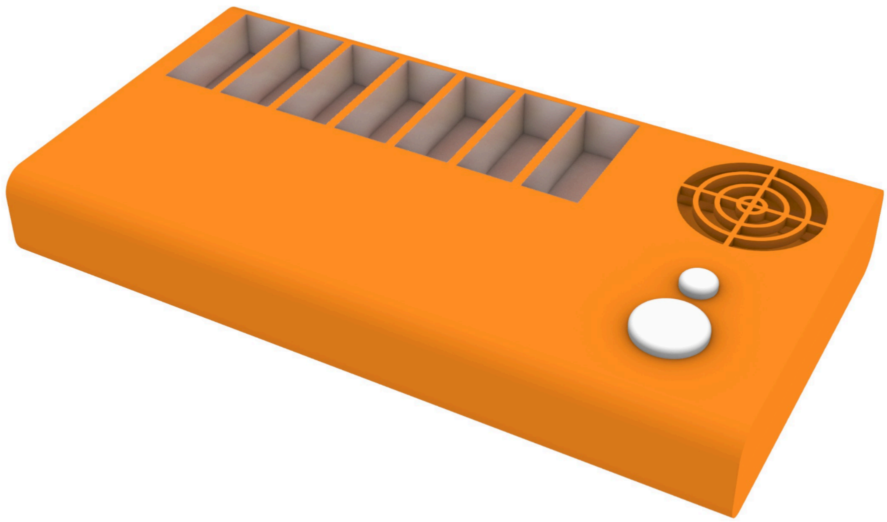

Figure 1: AdheraScent System 3D view. This view is to showcase the overall form factor for the user.

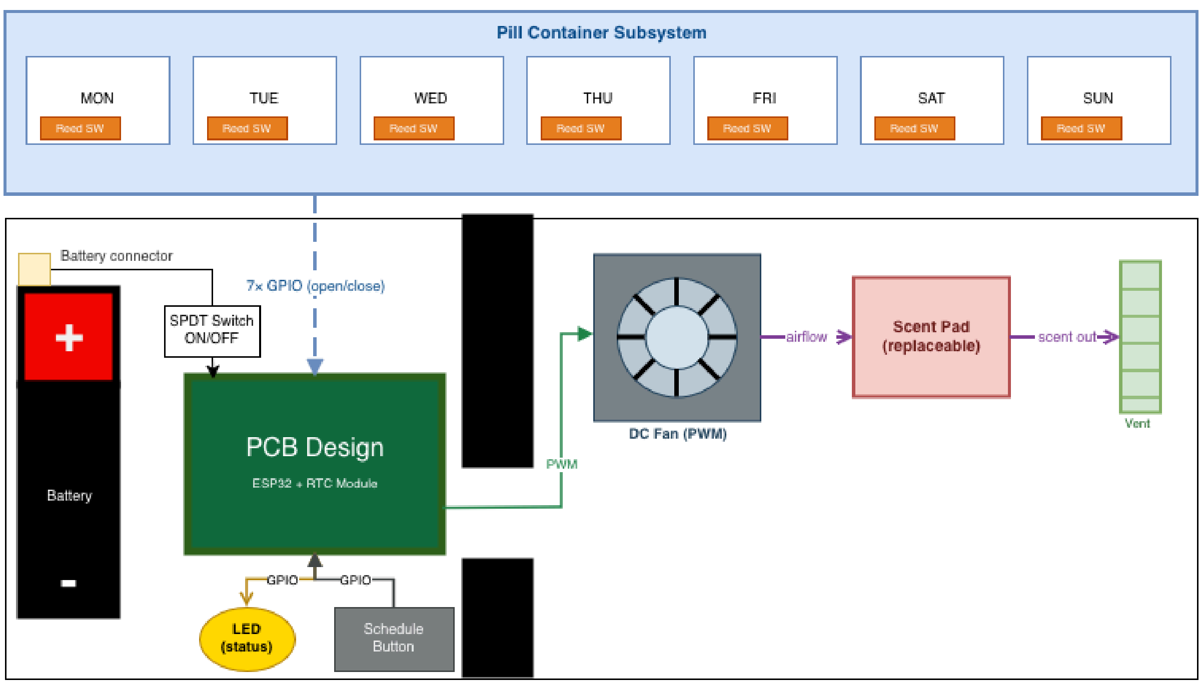

Figure 2: AdheraScent System Internal view. This view reveals the spatial allocation of the ESP32, the Timing Control Unit, and the mechanical components of the Scent Emitter Subsystem.

1.4 High Level Requirements

To consider our project successful, our safety suite must fulfill the following:

1. The system should correctly detect whether a pill compartment has been opened or closed, with no false positives or false negatives during a 10-trial test sequence under normal operating conditions.
2. The scent emitter shall activate automatically within 10 seconds after the scheduled medication window has elapsed, if and only if the corresponding compartment has not been opened during that window.
3. Once any compartment is opened, the scent emitter shall fully deactivate within 10 seconds of the open event being detected.
4. The status LED shall begin blinking when the scent pad age reaches the replacement threshold (day 15 of a 20-day pad life) and shall stop blinking within 10 seconds of a pad replacement being detected.
5. The LED starts blinking when the replaceable scent pad has to be changed and stops blinking once a change in the scent pad has been detected.
6. The system shall operate fully without requiring a smartphone, external application, or external display at any point during normal use.
7. The system shall complete a minimum of 14 consecutive medication cycle detections (one per day) without any subsystem failure or requiring a reset. This means all subsystems must be able to function and integrate seamlessly without risk of device interruption or failure.
8. All subsystems shall be integrated into a single self-contained prototype with dimensions no greater than $5 \times 2.8 \times 0.5$ inches, suitable for a live demonstration.
9. The scent emitter shall produce a recognizable odor detectable by individuals in a standard indoor environment at a distance of up to 1 meter.
10. The system shall operate for a minimum of 14 to 30 days on a single battery charge under normal use conditions (one medication window checked per day), before requiring battery replacement.

2 Design

2.1 Block Diagram

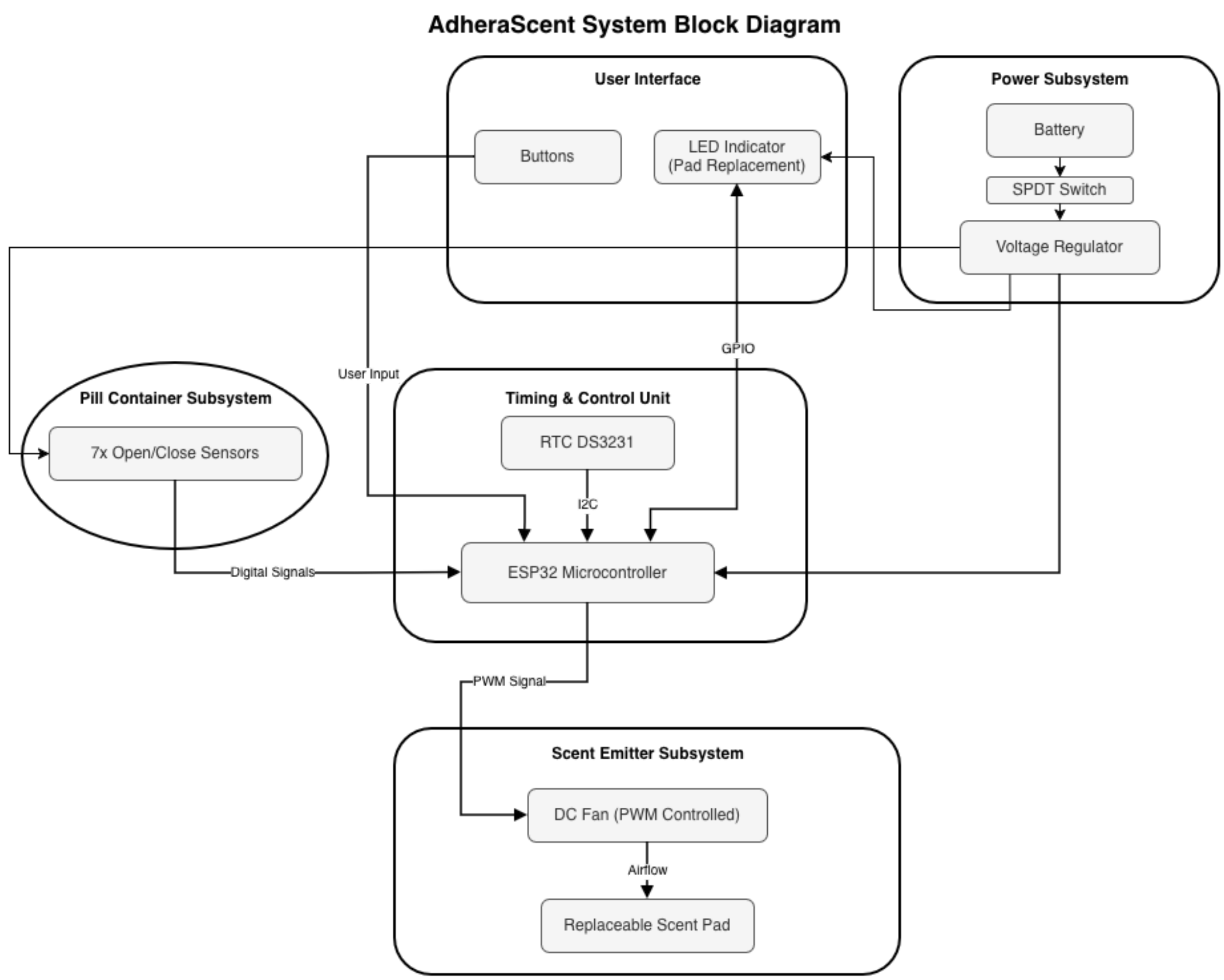

Figure 3: AdheraScent System Block Diagram. This diagram illustrates the high-level architecture of the pillbox, detailing the interconnections between the Power Subsystem, Timing & Control Unit (featuring the ESP32 and RTC DS3231), and the Scent Emitter output stage.

2.2 Functional Overview & Block Diagram Requirements

2.2.1 Power Subsystem

The Power Subsystem is responsible for supplying regulated electrical energy to all the electronic modules within our AdheraScent device. This subsystem should convert the battery's raw voltage into stable voltage rails required by the system electronics, which include the following. The ESP32 microcontroller, DS3231 real-time clock, 7 compartment sensors, and the user interface circuitry (buttons and LEDs) operate from a regulated 3.3V rail. The DC fan requires a regulated 5V rail.

The Power Subsystem includes a battery source, voltage regulation circuitry, and a mechanical power switch. The voltage regulation stage consists of a 3.3V regulator for our logic components and also a 5V converter for the fan. The power switch should allow the user to completely disconnect the battery from the system to prevent drain when standby. This subsystem should directly support the high-level design requirements of portability and a minimum battery life of two months, and without a proper voltage regulation and power management, it will not meet the timing requirements for 2 month operation. In order to ensure that our Power Subsystem fulfills its requirements of providing stable voltage, supporting different load current, and also minimizing standby drain, a requirements and verification table is provided below.

Table 1: Power Subsystem – Requirements & Verification

Requirements	Verification
The power subsystem should provide a regulated 3.3V ± 5% supply to ESP32, RTC, compartment sensors, LED, and buttons.	We can connect the battery to the regulator input and measure the 3.3V output using a multimeter under various load conditions, confirming voltage remains within 3.135V ~ 3.465V.
The subsystem should provide a regulated 5V ± 5% supply to the fan.	We can apply maximum load to the fan output rail and measure output voltage using a multimeter to confirm voltage remains within 4.75V - 5.25V.
The total standby current when the switch is off should be less than 10μA.	We can measure the battery current using an ammeter when the mechanical power switch is off, and confirm the current to be below 10μA.
The power subsystem should support an average system current enabling at least 60 days of battery operation.	We can measure average current draw over a simulated 24-hour cycle, and calculate the projected battery life using the battery capacity to confirm the calculated lifetime to be larger than 60 days.
The power switch should completely disconnect battery voltage from the downstream circuits.	With the switch turned off, we can measure the voltage at regulator input and logic rails to confirm the voltage to be below 0.1V.

2.2.2 Timing and Control Subsystem

The Timing and Control Subsystem is the core logic unit of our AdheraScent device, and this subsystem is responsible for maintaining the system time, monitoring if the medication is taken, executing the scheduling logic, and controlling the scent emitter and user interface subsystem.

The subsystem is built around the ESP32 microcontroller and a DS3231 Real-Time Clock module, which the DS3231 should provide us with accurate global timekeeping and communicates with the ESP32 over the I2C interface. The ESP32 microcontroller should continuously read time data from the RTC and compare it against the daily medication window we stored in its non-volatile memory. The ESP32 microcontroller should also poll the seven digital GPIO inputs corresponding to the 7 pill compartment sensors, which these inputs would indicate whether a compartment has been opened (medication has been taken) during the scheduled medication window. If the medication window has passed and the compartments have remained closed, the ESP32 would enter a state indicating missed medication, and outputs a control signal to the scent emitter subsystem. The output signal would control the fan speed with a PWM duty cycle increase in discrete levels of 25%, 50%, and 100% as the missed medication time increases. The subsystem should also track the scent pad lifetime by maintaining an internal day counter, and once the scent pad age exceeds a predefined threshold (e.g. 15 days of a 20-day lifespan), the subsystem should activate the LED to indicate the pad has to be replaced. In order to ensure the Timing and Control Subsystem fulfills the requirements, the following requirements and verification table are provided below.

Table 2: Timing and Control Subsystem — Requirements & Verification

Requirements	Verification
The subsystem should maintain accurate time using our DS3231 RTC and retain correct time even when power is off.	We can set RTC to a known reference time, and we disconnect the main battery and restore the power and compare the time with our reference to confirm the difference to be within 1 minute.
The subsystem should allow a medication window to be set and stored in a non-volatile memory.	We should be able to set the medication window through the user interface, and then when we power the device, we can verify if the stored window persists and can be correctly retrieved.
If the pill compartment remains closed after the scheduled window has passed, the subsystem should activate scent emission in 10 seconds.	We can simulate a scheduled window expiration, and we measure the time from the window expiration to PWM output activation to confirm its under 10 seconds.
When any of the 7 compartments is opened during scent emission, the subsystem should disable scent emission in 10 seconds.	We can trigger the scent emission states and simulate the open sensor signal to measure the time between the signal and the PWM output to be disabled, and confirm the time to be less than 10 seconds.
The subsystem should continuously monitor all 7 sensor inputs and detect state changes in 1 second.	We toggle the sensor input and measure the time for the state to change through a serial debug output and confirm the detection time to be less than 1 second.
The subsystem should track the scent pad lifetime and activate LED warning when pad age exceeds 15 days.	We can simulate a 15-day runtime by an accelerated firmware counter and verify if the LED begins to blink at the threshold.

2.2.3 Pill Container

The Pill Container Subsystem is responsible for storing the medication and detecting whether a compartment has been opened. This subsystem should provide us with the primary detection mechanism for the AdheraScent device.

The subsystem consists of 7 compartments for pill storing with one digital sensor per compartment. Each sensor should be able to produce a binary signal indicating whether the corresponding compartment is open or close. These digital outputs would be connected directly to ESP32 GPIO inputs and operate at 3.3V.

The Timing and Control Subsystem would continuously monitor these seven sensor inputs to determine whether medication has been accessed during the scheduled medication window. If a compartment remains closed after the window expires, a missed-dose event is declared and the Scent Emitter Subsystem is activated. If any compartment is opened while scent emission is active, the sensor signal is used to terminate scent emission. In order to ensure proper operation, the following requirements and verification table is provided.

Table 3: Pill Container – Requirements & Verification

Requirements	Verification
Each compartment sensor should provide a stable digital signal representing if it's open or closed.	We can measure sensor output voltage using a multimeter when it's opened and closed to confirm logic LOW < 0.8V and logic HIGH > 2.4V.
The subsystem should be able to detect an open event within 1 second.	We can open a compartment while monitoring serial debug output timestamps to confirm state change detection to be less than 1 second.
The sensor outputs should include debounce behavior to prevent false transitions.	We can toggle the compartment lids and monitor GPIO readings to confirm no false transitions occur within the debounce interval.
When scent emission is active, opening a compartment should terminate scent emission within 10 seconds.	We can trigger the scent emission and open a compartment to measure and confirm the time to PWM disable signal to be less than 10 seconds.
The sensors should be able to operate reliably over repeated mechanical cycles.	We can perform more than 100 open and close cycles per compartment to confirm no missed detections or false triggers occur.

2.2.4 User Interface

The User Interface Subsystem would provide us with a few minimal but essential interactions between the user and our AdheraScent device. AdheraScent is intentionally designed to operate without a smartphone and external display. The goal of this user interface subsystem is to maintain simplicity and accessibility to our stakeholders, particularly elderly users or individuals struggling with complex digital interfaces.

Our User Interface Subsystem consists of two primary components, a push-button input and a status LED indicator. The button connects to a digital GPIO input of the ESP32 and is used for resetting the scent pad lifetime counter after each of the replacements. The button input would be processed through debounce logic to ensure reliable state detection.

The status LED would be connected to a GPIO output of the ESP32 and provide the visual feedback to the user. It is used to indicate when the scent pad has exceeded its warning threshold (e.g., 15 days out of a 20-day lifespan we tested). When it exceeds the threshold, the LED will blink to notify the user that the pad should be replaced. Once the pad replacement is confirmed from the button being pressed, the LED will stop blinking within 10 seconds. This subsystem would satisfy the design requirement that the device operate without the use of smartphones or external applications, while ensuring that the user receives essential system feedback. In order to ensure that the User Interface Subsystem fulfills its responsibilities, the following requirements and verification table is provided.

Table 4: User Interface Subsystem – Requirements & Verification

Requirements	Verification
The button should provide reliable digital input to the ESP32 with debounce.	We can connect the button to GPIO input, and we press and release the button repeatedly while monitoring serial debug output to confirm a single state transition per press with no false triggers.
The status LED should be visible under normal indoor lighting conditions.	We can power our LED at intended operating current and observe its visibility in typical indoor lighting to confirm the LED is clearly distinguishable further than 1 meter.
The LED should blink when the scent pad age exceeds the warning threshold.	We can simulate scent pad age counter to reach the threshold and confirm if the LED enters blinking state at our programmed frequency.
When the user replaces the scent pad and presses the button, the LED should stop blinking within 10 seconds.	We can trigger the warning phase first, and we press the button to simulate replacement, and we can measure the time between button pressed to LED off to confirm it to be under 10 seconds.

2.2.5 Scent Emitter

The Scent Emitter Subsystem would provide us with the primary physical reminder mechanism of the AdheraScent device. The subsystem should convert electrical control signals from our Timing and Control Subsystem into a regulated airflow across a replaceable scent pad.

The Scent Emitter Subsystem consists of a replaceable scent pad cartridge, a DC micro-fan, and a driver circuitry. When the subsystem is triggered by the ESP32 output signal, the DC fan operates at a PWM-controlled speed, leading the airflow passes across the scent pad, dispersing scent into the surrounding environment. The PWM duty cycle should increase in discrete steps (25%, 50%, 100%) as the time of the missed medication increases.

When the Timing and Control Subsystem detects that any of the 7 pill compartments has been opened, the ESP32 should send a signal to stop the DC fan, and this must occur within 10 seconds to prevent unnecessary scent emission. In order to ensure proper operation, the following requirements and verification table is provided.

Table 5: Scent Emitter Subsystem – Requirements & Verification

Requirements	Verification
The subsystem should support a continuous scent emission when it is signaled.	We can activate the fan at 100% PWM and run continuously for 10 minutes to confirm stable airflow and no thermal shutdown or reset.
The fan should produce measurable airflow across the scent pad to ensure the user receives the scent.	We can trigger the state and confirm if the scent is noticeable in different intensity level further than 3 meters in various environments.
When a disabled signal is sent, the subsystem should stop scent emission within 10 seconds.	We can activate scent emission and simulate a compartment open signal, and we measure time to fan disable to confirm its less than 10 seconds.
The subsystem should not cause voltage droop or any system reset during fan startup.	We can monitor 3.3V rail using an oscilloscope during fan activation to confirm voltage remains within ±5% and the ESP32 microcontroller does not reset.
The scent pad should be replaceable by the user without any tools.	We can perform removal and replacement tests to confirm replacement can be completed in under 30 seconds by a person with low strength required without tools.
The subsystem should operate without excessive heating under maximum fan strength.	We can run at 100% for 10 minutes and measure the temperature of the fan driver and motor to confirm the temperature remains below manufacturer rating.

2.3 Tolerance Analysis

The primary risk to the successful operation of the pillbox is temporal desynchronization. The system relies on the ESP32's internal crystal oscillator to track elapsed time between the "close" and "open" states of the box. If this clock drifts significantly, the scent-based notification may trigger outside of the prescribed medical window, leading to user confusion or missed doses.

To demonstrate the feasibility of using the ESP32 without an external Real-Time Clock (RTC), we must analyze the Worst-Case Drift (ΔT). A standard ESP32 crystal oscillator has a frequency tolerance (ϵ) of approximately $\pm\ 100\ ppm$ (parts per million).
For a standard 24-hour medication cycle ($T_{total} = 86400\ s$). The maximum deviation is calculated as:

$$\Delta T = 86400\ s * (100 * 10^{-6}) = 8.64\ seconds\ per\ day \qquad (1.1)$$

Even under varying thermal conditions – such as the heat generated by the scent-emission motor – where the tolerance might degrade to $\pm\ 500\ ppm$, the drift is calculated as:

$$\Delta T_{worst} = 86400\ s * (500 * 10^{-6}) = 43.2\ seconds\ per\ day \qquad (1.2)$$

The feasibility of this design is confirmed by comparing the hardware error to the functional requirements of medication adherence. This involves a safety margin and a cumulative error mitigation.

Safety Margin: Medical experts generally define a "missed dose" window as 30 to 60 minutes past the scheduled time. Our worst-case hardware drift of 43.2 seconds represents only 0.05% of a 24-hour cycle, or roughly 2.4% of the most conservative (30-minute) medical grace period.

Cumulative Error Mitigation: To ensure long-term feasibility, the software will utilize the ESP32's Wi-Fi capabilities to perform an NTP (Network Time Protocol) sync once every 24 hours. This "resets" the accumulated drift to zero, ensuring that the error never exceeds the sub-minute daily maximum.

The analysis confirms that the internal timing tolerance of ESP32 is sufficient for the pillbox's mission. The hardware error is orders of magnitude smaller than the acceptable human-factor window for medication intake.

2.4 Cost Analysis

The total cost for parts as seen below in Figure 18 before shipping is \$302.00. 5% shipping cost adds another \$15.1 and 10% sales tax adds another \$30.20. We can expect a salary of \$40/hr×2.5 hr×60 = \$6000 per team member. We need to multiply this amount with the number of team members, \$6000× 3 = \$18,000 in labor cost. This comes out to be a total cost of \$18,347.3.

Component	Description / Purpose	Qty	Est. Unit Cost
ESP32-S3-WROOM-1-N16	Main microcontroller; handles scheduling and I2C	1	$3.90
ESP32-S3 Dev Board	For initial firmware development and testing	1	$10-15
DS3231 RTC Module	Real-time clock with battery backup (ZS-042)	1	$3-5
32.768kHz Crystal	Backup for RTC integration	1	$0.50
Neodymium Magnets	6x2mm disc magnets to trigger reed switches	7	$5-8 (pack)
Hall Effect Sensor	Alternative magnetic field detection	1	$7.30
5V DC Mini Fan	Pushes air across scent pad; PWM speed control	1	$5-12
SG90 Micro Servo	Controls airflow valve to scent pad	1	$3-5
Replaceable Scent Pads	Aromatherapy pads (peppermint/lavender)	5	$5-10 (pack)
3.7V Li-Po Battery	Primary power source; 1000-2000mAh	1	$8-12
TP4056 Charger Module	USB-C charging with battery protection	1	$2-3
5V Boost Converter	Boosts 3.7V to 5V for fan and servo	1	$2-3
Slide Switch (SPDT)	Main power on/off disconnect	1	$0.50
IC BATT CHG LI-ION	Lithium-ion battery charger IC	3	$14.82
IC REG LINEAR 3.3V	Voltage regulator for logic	3	$2.04
5mm LED Diodes Kit	Multi-color kit for status and warnings	1	$4.99
Buzzer 5V	Audible alert for missed windows	2	$1.90
3D Printed Enclosure	Custom pillbox chassis with 7 compartments	1	$5-10
Small Screws (M2/M2.5)	Mounting hardware for internal components	1	$5-8 (kit)
HATCHBOX PLA Filament	3D printing material for enclosure	1	$22.99
Breadboard (Full size)	For initial circuit prototyping	1	$3-5
Jumper Wire Kit	For breadboard connections	1	$5-8
Hookup Wire	22-26 AWG for internal enclosure wiring	1	$3-5

Figure 4: Itemized list of components and costs

2.5 Schedule

The figure below showcases a tentative schedule for the design and construction of this product.

Week	Task	Person
Feb 21 – Feb 28	DEADLINE: Design Document Due (Feb 26)	Everyone
	Timing & Control: Breadboard RTC-ESP32 I2C handshake; verify 3.3V logic levels.	Cindy
	Power: Bench test battery charging circuit (TP4056) and boost converter stability.	Anshul
	Research: Quantify scent pad diffusion rates to determine fan duty cycles.	Albert
Feb 28 – Mar 7	DEADLINE: Design Reviews (Mar 2-5)	Everyone
	PCB Design: Initialize KiCad project; assign footprints for all SMT components.	Cindy
	Mechanical: 3D print "Sub-Unit A" (compartment latch) to test magnet tolerances.	Albert
	Firmware: Develop debouncing logic for 7-day bin detection (Hall Effect sensors).	Anshul
Mar 7 – Mar 14	DEADLINE: Breadboard Demo (Mar 9-12)	Cindy
	PCB Design: Route high-current paths for Scent Emitter (MOSFETs/Fan) and Ground planes.	Cindy
	Mechanical: Finalize 3D CAD for the main chassis; ensure clearance for ESP32-S3.	Albert
	Firmware: Integrate RTC time-of-day interrupts with pill-access logging.	Anshul
Mar 14 – Mar 21	SPRING BREAK	Everyone
	Project Goal: Self-imposed PCB audit and design freeze.	Everyone
Mar 21 – Mar 28	DEADLINE: 4th Round PCB Orders (Mar 26)	Cindy
	PCB Design: Final DRC (Design Rule Check); generate Gerber files and submit order.	Cindy
	Mechanical: Print final 7-bin enclosure; verify lid-locking mechanism.	Albert
	Firmware: Develop low-power sleep modes to extend 3.7V Li-Po battery life.	Anshul
Mar 28 – Apr 4	DEADLINE: Individual Progress Reports (Mar 30)	Everyone
	Power: Verify voltage regulator thermal performance under full fan/valve load.	Cindy
	Firmware: Build API for schedule configuration via Wi-Fi/Web interface.	Anshul
	Scent Emitter: Assemble fan and valve manifold; test airflow directionality.	Albert
Apr 4 – Apr 11	DEADLINE: Progress Demo (Apr 6-9)	Everyone
	Assembly: Solder through-hole connectors and SMT components onto received PCBs.	Cindy
	Testing: Unit test Scent Emitter subsystem (PWM fan speed vs. scent intensity).	Albert
	Firmware: Finalize error-handling for missed medication windows.	Anshul
Apr 11 – Apr 18	DEADLINE: ADHERASCENT DEMO (APR 13)	Everyone
	Integration: Final assembly of PCB into chassis; finalize internal cable management.	Albert & Cindy
	Verification: Perform full 24-hour cycle test (Schedule -> Alert -> Access -> Log).	Everyone

Figure 5: Schedule for Project Progression

2.6 Risk Analysis

The nature of riding electric skateboards is inherently dangerous, and requires a skilled, attentive operator at high speeds. Nearly every subsystem of the electric longboard is integral to upholding the safety of the user. When focusing specifically on components which we aim to build ourselves, the most important among them is the main microcontroller. It is ultimately responsible for directing the throttle of the electronic speed controllers, which in turn direct the powerful motors. If our microcontroller fails to perform this duty properly, control of the longboard is lost, potentially leading to serious bodily harm to users or pedestrians. To reduce this risk of injury, we will incorporate the following safety principles into our design. Should the wireless connection to the remote control fail, our microcontroller must disengage the motors entirely - not braking if the user is still riding, as this can upset the balance of the user. Because we are using belt-driven motors, our longboard will coast with high resistance, slowing down gradually over a small period of time. Furthermore, should our pressure sensors fail, a similar situation as the one just described will occur. The user will maintain his or her momentum with constant resistance, and can still use the small amount of motor power if the need arises. Finally, should our wheel revolution sensors fail, our main microcontroller will apply the wheel-slip mitigation protocol that reduces motor power over time. In turn, the user will be put again in the aforementioned scenario of coasting with resistance. In short, we will attempt to mitigate any component failures to the best of our ability by utilizing the inherent resistance of our belt-driven motors.

3 Ethics and Safety

As engineers, we have a professional responsibility to prioritize the safety and welfare of the public, as outlined in IEEE Code of Ethics 1.1. The primary ethical concern for this project is the reliability of the olfactory alert and the open-detection logic. Since the device is intended to assist with medication management, any failure of the scent-release mechanism or a false "completed" reading (incorrectly sensing the box as open) could lead to a missed dose and subsequent health complications. To avoid ethical breaches regarding IEEE Code 1.3 (Honesty and Transparency), we will clearly state the device's scope: it is an assistive notification system, not a dispensing system that guarantees ingestion. Furthermore, per ACM Code of Ethics 1.6, all data regarding the user's medication timing – even if the user manually fills the box – will be treated as sensitive personal health information and protected from unauthorized access.

To ensure the safety of our engineering solution, we have identified several potential risks with the scent-based notification and physical interaction. A primary safety concern is system logic or sensor failure, where the device fails to accurately detect the open/clsoe state of the medication compartment. If the sensor fails to register that the user has accessed their medication, the system may incorrectly continue to trigger alerts or fail to record the adherence data, leading to confusion and double dosing. To mitigate this, our design will include redundant sensor checks and a visual status indicator (such as an LED) to confirm to the user that their action was successfully recorded. Secondary to technical failure is the risk of accidental misuse, such as the user failing to fully close the box. To address this, the system will be programmed to trigger a 're-close' alert if the compartment remains open for an extended period, ensuring the device remains ready for the next scheduled window.

Regarding the olfactory mechanism, we will ensure that all aromatic materials used are non-toxic and comply with consumer safety standards to prevent respiratory irritation or allergic reactions. During development, we will adhere to IEC 60601-1 standard [8] for medical electrical equipment to ensure the components powering the scent release are properly insulated to prevent fire or shock hazards. The project will also comply with campus safety policies and FCC regulations regarding wireless interference if Bluetooth is utilized for data logging.

The impact of this engineering solution extends far beyond the individual user. Societally, this scent-based notification system aims to restore autonomy to adults managing medical conditions by a non-invasive, dignified reminder that doesn't rely on loud alarms or complex digital interfaces. By promoting independence, the device significantly reduces the caregiver burden – the emotional and physical strain placed on family members who must currently supervise medication schedules. From an economic perspective, improving adherence addresses a major drain on the U.S. healthcare system, which currently spends between $100 billion and $300 billion annually on avoidable emergency visits and complications [7]. Finally the project has a positive environmental impact by reducing pharmaceutical waste. By ensuring medications are used as intended rather than discarded, we help mitigate a source of pollution that contributes to the healthcare sector's carbon footprint, which currently accounts for nearly 5% of global greenhouse gas emissions [1].

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