Deliverable H: Prototype III and Customer Feedback

GNG 1103 – Engineering Design

Saher Ali, Aidan Eiselt, Cameron Jordan, and Mohammad Mohammadi

Abstract

This deliverable presents a comprehensive plan for developing and testing the third and final prototype of the bat box designed to monitor bat activity. The document outlines the rationale behind this prototype, detailing its specific objectives, material enhancements, and the testing framework to validate its functionality and alignment with user requirements. A structured test plan is included, highlighting critical components for analysis, measurable outcomes, and defined stopping criteria to ensure all testing objectives are achieved. Feedback from potential users remains a key component of this deliverable, focusing on refining the design to better meet user needs. Updates to the target specifications, detailed design, and Bill of Materials (BOM) will be incorporated based on test results and user insights. This approach facilitates the progression of the final design iteration.

Table of Contents

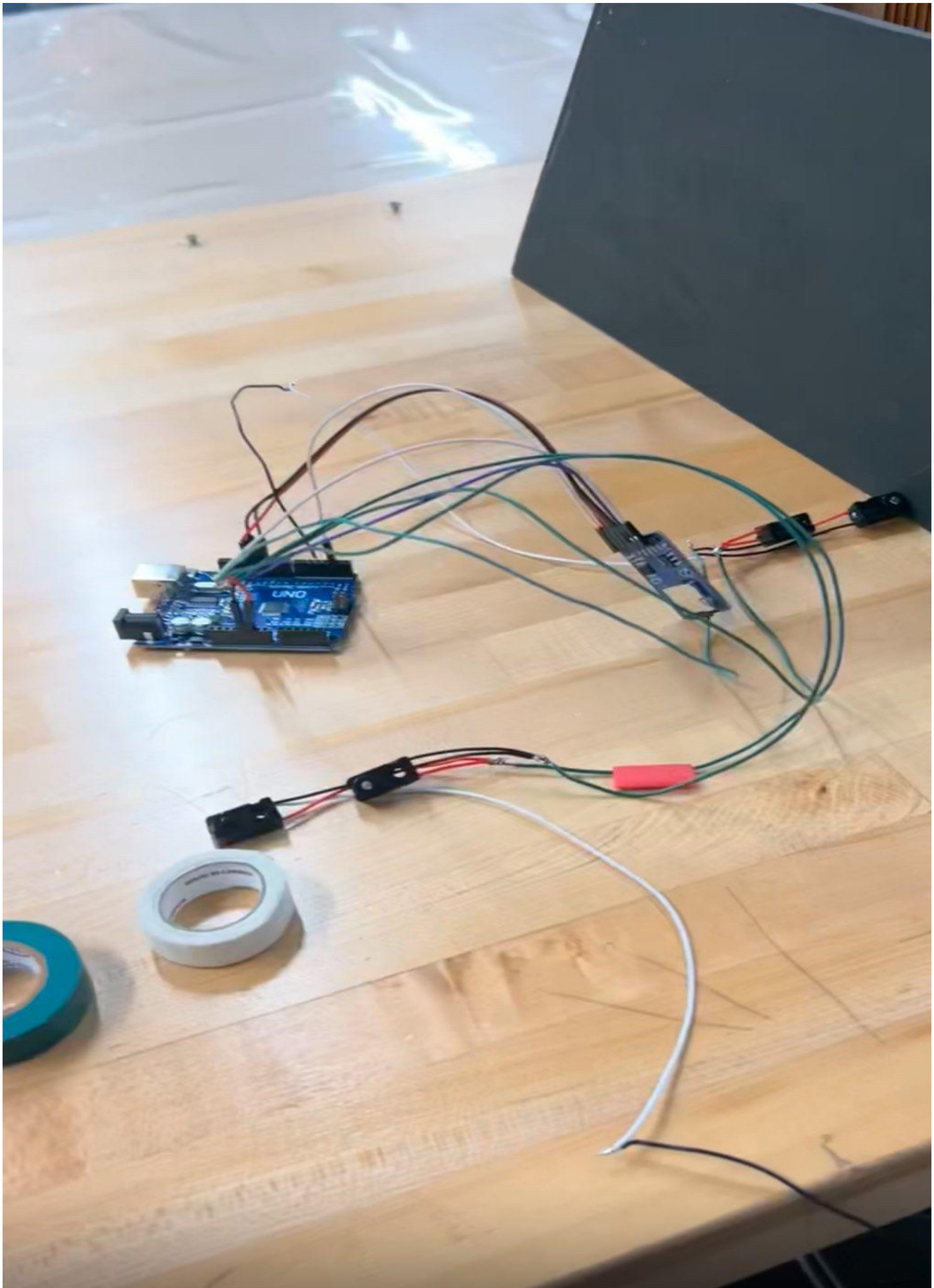
1. Introduction

The problem we seek to address with this deliverable is the need for a fully functional, final prototype that effectively monitors bat entries and exits while integrating seamlessly with a complete bat box design. With bat populations declining due to habitat loss and environmental challenges, providing a practical, low-cost solution for bat conservation is essential. This third and final prototype represents a critical step toward achieving that goal by delivering accurate data for researchers and conservationists.

This deliverable outlines the development and testing of the third prototype, which features a fully operational system including two IR break beams with a working code that records data directly onto an SD card. This enhancement enables reliable, long-term data storage, ensuring that researchers can access and analyze bat activity without the limitations of temporary or manual data retrieval. Unlike earlier iterations, this prototype is battery powered and operates without a breadboard (wires were soldered), enhancing durability and reliability. Furthermore, it incorporates the completed, painted bat box with chambers, combining the electronic system with the final physical design.

By evaluating critical components and leveraging prior testing and feedback, this deliverable aims to refine the system's functionality, reliability, and usability. The structured testing framework focuses on measurable outcomes such as accuracy, system integration, and user accessibility, with defined criteria for success. Feedback from users and conservation experts will guide final adjustments, ensuring the prototype aligns with conservation goals and user requirements. This approach concludes the iterative prototyping process, delivering a comprehensive and effective solution for monitoring bat activity.

2. Picture of Third Prototype and Code



```
#include <SD.h>  // Include the SD library

#define LEDPIN 13


#define SENSORPIN1 4   // First sensor

#define SENSORPIN2 5   // Second sensor


File logFile;  // File variable to store log file


int sensorState1 = 0, lastState1 = 0;

int sensorState2 = 0, lastState2 = 0;

int countEntries = 0;

int countExits = 0;


void setup() {

  pinMode(LEDPIN, OUTPUT);

  pinMode(SENSORPIN1, INPUT);

  pinMode(SENSORPIN2, INPUT);


  digitalWrite(SENSORPIN1, HIGH); // turn on the pullup

  digitalWrite(SENSORPIN2, HIGH); // turn on the pullup


  Serial.begin(9600);


  // Initialize SD card
```

```
  if (!SD.begin(2)) {  // Here, 2 is the CS pin number
    Serial.println("SD Card initialization failed!");
    return;
  }
  Serial.println("SD Card initialized.");

  // Open the file, create it if it doesn't exist
  logFile = SD.open("log.txt", FILE_WRITE);
  if (!logFile) {
    Serial.println("Error opening log file!");
    return;
  }
  // If the file opened okay, write to it:
  logFile.println("Starting logging...");
  logFile.close();
}

void loop(){
  // Read the state of both sensors
  sensorState1 = digitalRead(SENSORPIN1);
  sensorState2 = digitalRead(SENSORPIN2);

  // Check for entries and exits based on the order of sensor breaks
  if (sensorState1 == LOW && lastState1 == HIGH && sensorState2 == HIGH) {
    unsigned long start = millis();
```

```
  while (millis() - start < 500) {  // Short delay to confirm second sensor
    sensorState2 = digitalRead(SENSORPIN2);
    if (sensorState2 == LOW) {
      countEntries++;
      Serial.print("Entries counted: ");
      Serial.println(countEntries);
      digitalWrite(LEDPIN, HIGH);  // Turn LED on for entry
      delay(500);  // Brief indication delay
      // Log entry to file
      logFile = SD.open("log.txt", FILE_WRITE);
      if (logFile) {
        logFile.println("Entry: " + String(countEntries));
        logFile.close();
      }
      break;
    }
  }
} else if (sensorState2 == LOW && lastState2 == HIGH && sensorState1 == HIGH) {
  unsigned long start = millis();
  while (millis() - start < 500) {
    sensorState1 = digitalRead(SENSORPIN1);
    if (sensorState1 == LOW) {
      countExits++;
      Serial.print("Exits detected: ");
      Serial.println(countExits);
```

```
        digitalWrite(LEDPIN, LOW);  // Turn LED off for exit
        delay(500);
        // Log exit to file
        logFile = SD.open("log.txt", FILE_WRITE);
        if (logFile) {
          logFile.println("Exit: " + String(countExits));
          logFile.close();
        }
        break;
      }
    }
  }

  // Update last states
  lastState1 = sensorState1;
  lastState2 = sensorState2;
}
```

3. The Prototyping Test Plan – Why, What, How and When

For this third and final prototype, the focus shifts to integrating all system components into a fully functional, durable bat box design. This iteration features dual IR break beams with a working code that logs entry and exit data onto an SD card, operating independently of a breadboard like the previous prototype (wires were soldered). Additionally, the system is mounted within the completed, painted MDF bat box, which includes internal chambers, mounting brackets, and a power source with the wires all soldered together.

Why Are We Doing These Tests?

The primary motivation for these tests is to confirm the complete system's performance in tracking bat entries and exits accurately, ensuring reliable data storage, and confirming durability for long-term outdoor use. These tests are crucial to:

- **Sensor Integration:** Ensure the IR sensors are properly mounted and functional within the bat box design.
- **SD Card Data Logging:** Confirm that all recorded data is accurately saved to the SD card for retrieval and analysis.
- **Battery Performance:** Verify that the system can run continuously for an extended period without power failures.
- **Box Durability:** Assess the MDF bat box's structural integrity and resistance to simulated weather conditions.

Testing the fully integrated system with dual sensors and SD card data logging will allow us to address any remaining issues, ensuring the final prototype meets all functional and design requirements.

What Are the Criteria for Success?

Each test will have defined success criteria:

1. **Sensor Integration:** Success means the dual IR sensors accurately track 10 consecutive simulated bat entries and exits without interference from the box structure.
2. **SD Card Logging:** Success is confirmed when all simulated bat activity data is logged to the SD card and can be retrieved without corruption.

3. **Battery Performance:** Success means the system runs continuously for 8 hours on a single charge without interruptions.
4. **Box Durability:** Success is achieved if the box withstands simulated outdoor conditions, maintaining structural integrity and functionality.

What is the Prototype and What is the Test?

The final prototype integrates all core components into the finished bat box design. Key features include dual IR sensors for tracking, an SD card module for data logging, and a rechargeable battery for power. The bat box is painted and assembled with internal chambers to replicate realistic use scenarios. Testing involves:

- **Sensor Integration:** Simulating bat entries and exits by obstructing the IR beams to verify accurate logging.
- **SD Card Logging:** Retrieving and analyzing logged data from the SD card after simulated bat activity.
- **Battery Performance:** Monitoring the system under continuous operation to assess power consumption.
- **Durability Testing:** Placing the bat box in an outdoor environment to test resistance to light rain, wind, and temperature changes.

Testing Process: Prototype 3

Test Sensor Integration with Physical Box:

The IR sensors will be installed in the fully assembled MDF bat box to evaluate their functionality within the final design. Simulated bat entries and exits will be conducted by obstructing each beam, ensuring the box structure does not interfere with sensor operation. Data will be monitored for accurate logging of both entries and exits.

Test SD Card Data Logging System:

The SD card module will be integrated into the system to validate its ability to record and store data from both IR sensors. Simulated bat entries and exits will be conducted, and the recorded data will be retrieved from the SD card to confirm its accuracy and retrievability.

Test Battery Power Consumption:

A rechargeable battery pack will be connected to power the sensors, microcontroller, and SD card module. The system will run continuously, and the battery performance will be monitored to ensure adequate power supply over extended periods. This test will help identify potential inefficiencies and confirm the system's portability.

Test Overall Box Durability and Weather Resistance:

The fully assembled and painted bat box will be placed in a controlled outdoor environment to simulate real-world conditions. Exposure to light rain, wind, and temperature fluctuations will test the box's structural integrity and weather resistance. Observations will determine if the design withstands these conditions without compromising functionality.

Materials and Cost:

The testing setup includes dual IR sensors, the SD card module, rechargeable batteries, and the fully assembled MDF bat box. As the design integrates all components into the final prototype, the materials reflect the finalized system while adhering to the project budget.

Work Required:

Tasks include:

- Installing and calibrating the IR sensors in the bat box.
- Finalizing the code for SD card data logging.
- Setting up and monitoring the system with battery power.
- Conducting outdoor durability tests.
- Recording and analyzing results to inform design adjustments.

When is the Testing Happening and How Long Will It Take?

1. **Test Sensor Integration with Physical Box:** Scheduled for November 12th, lasting 1 day.
2. **Test SD Card Data Logging System:** Scheduled for November 13th, lasting 1 day.
3. **Test Battery Power Consumption:** Scheduled for November 13th, lasting 1 day.
4. **Test Overall Box Durability and Weather Resistance:** Scheduled for November 14th, lasting 1 day.

By following this structured testing process, the third prototype was thoroughly evaluated for sensor performance, data logging reliability, power efficiency, and physical durability. These tests will ensure that the final design is robust, functional, and ready for real-world use.

Refinement of IR Sensor System for Accurate Bat Entry and Exit Tracking: Prototype 3 Development:

For our third prototype, we have focused on finalizing the critical subsystems of our bat box design: the IR sensor system for tracking bat entries and exits and the SD card data logging system. In earlier prototypes, we successfully demonstrated the functionality of dual IR sensors but encountered challenges with differentiating bat exits from guano drops, as well as optimizing the system for efficient data storage. Additionally, the physical integration of the sensors into the bat box and the transition from a breadboard-based system required further refinement.

In Prototype 3, we have built upon the insights gained from previous iterations. The system now features dual IR sensors integrated into the fully assembled and painted MDF bat box, eliminating the breadboard for a more robust and compact design. This prototype also incorporates a working SD card module to log entry and exit data, enabling long-term data storage and retrieval. These updates address key limitations identified in earlier prototypes, such as portability and data handling.

To ensure differentiation between valid bat exits and unrelated sensor triggers, we have refined the sensor placements and enhanced the code. This improvement minimizes false positives and improves the reliability of data collection. Additionally, the physical bat box design has been completed, including interior chambers to support safe and comfortable bat habitation while maintaining compatibility with the sensor system.

This third prototype is a critical step as it integrates all subsystems into a cohesive and functional design. It addresses challenges identified in previous prototypes while adhering to budget constraints and project goals. By incorporating user feedback and rigorous testing, this prototype ensures the bat box meets both ecological and functional requirements, moving us closer to a reliable, user-friendly solution for monitoring bat activity.

4. Analysis of the Critical Components: Prototype 3

1. IR Sensor System

Function:

The IR sensors serve as the central tracking mechanism, detecting both bat entries and exits. The system comprises two IR sensors integrated into the bat box, with one dedicated to logging entries and the other to exits. These sensors detect movement by emitting infrared light and registering interruptions when a bat crosses the beam. The system also logs the data to an SD card for further analysis.

Analysis:

In Prototype 3, the IR sensor system is fully integrated into the bat box, moving from breadboard-based testing to a final installation. Dual IR sensors now operate in tandem to track bat entries and exits independently. Their effectiveness in low-light conditions aligns with the nocturnal activity patterns of bats, making them ideal for the application. Additionally, their low power consumption supports the goal of creating a low-maintenance and efficient system.

However, environmental factors like dust accumulation, guano, or moisture can affect sensor performance over time. Additionally, the physical placement of sensors within the box is critical to avoid beam overlap or interference, particularly in a compact, confined space. The SD card logging system introduces a new dependency, requiring seamless integration to ensure accurate and retrievable data storage.

Improvement Potential:

To enhance the system's robustness, protective casings for the sensors could shield them from environmental challenges. A regular maintenance routine for cleaning and recalibration should be established to sustain performance. Further optimization of the sensor placement within the box will help prevent interference between beams. Additionally, incorporating error-checking protocols in the code for data logging would ensure reliable data collection. Despite exploring alternatives like ultrasonic sensors, the IR system remains cost-effective and well-suited for the project’s goals.

2. Bat Box Design

Function:

The bat box houses the IR sensor system while providing a safe and hospitable environment for bats. Its design ensures internal temperature regulation, protection from predators, and resistance to outdoor environmental conditions. It also supports the attachment of sensors and electronics while being easy to mount on various surfaces.

Analysis:

Prototype 3 introduces a fully assembled MDF bat box painted for weather resistance. The design now accommodates the complete IR sensor system, including dual sensors and the SD card module, with careful integration to prevent structural interference. MDF was chosen for its workability and affordability, aligning with budget constraints. However, as MDF is not inherently weatherproof, additional protective coatings could have been applied to enhance durability.

Internal insulation and ventilation remain key challenges. While the structure prevents predator entry and supports sensor functionality, ensuring optimal temperature control for bats is essential for their comfort and safety. The painted MDF design offers some protection from moisture, but the long-term effects of sustained exposure to rain, humidity, and temperature fluctuations require further testing.

Improvement Potential:

Future iterations could include advanced weatherproofing techniques, such as sealing the MDF with more robust coatings or exploring alternative materials like marine-grade plywood or composite plastics. Improved ventilation and insulation features should be incorporated to ensure consistent internal temperatures. The mounting system could also be refined to include adjustable brackets, simplifying installation in diverse environments. Finally, modular design options for accommodating various bat species or colony sizes could enhance adaptability, increasing the system's ecological relevance and usability. Of course, this is just a prototype, if this were to be the actual product better materials would be used to minimize these issues.

5. Prototyping Test Plan, Analysis and Results:

Test Objective	Test Criteria	Materials	Testing Process	Duration & Date	Results	Analysis & Next Steps
Test Sensor Integration with	Ensure that the integrated dual sensor	IR sensors (entry and exit),	Install both sensors in the prototype bat box. Test	1 day, Nov 12	Successful. Both sensors integrated properly	Continue to test with physical environmental factors (e.g.,

Physical Box	system works correctly within the physical bat box, with no interference from the box structure.	prototype bat box	functionality to ensure no interference from the box material or structure.		without any interference from the box structure.	temperature, humidity) to ensure consistent performance.
Test SD Card Data Logging System	Confirm that the SD card is correctly logging data from both IR sensors for later retrieval and analysis.	IR sensors (entry and exit), prototype bat box, SD card module	Run tests to log data from both sensors, saving the data to the SD card. Retrieve and verify the logged data for accuracy.	1 day, Nov 13	Successful. The SD card logged data accurately from both sensors, with proper event tracking.	Evaluate storage capacity for long-term data logging and ensure reliability over extended periods.
Test Battery Power Consumption	Verify that the power consumption remains within acceptable limits for battery operation over extended periods.	Prototype bat box, battery, power monitoring equipment	Measure power consumption during normal operation over a test period to ensure the system remains efficient and battery life is sustainable.	1 day, Nov 13	Successful. The system operated within the expected power consumption limits.	Plan for battery optimization or consider alternative power sources if needed for extended operation.
Test Overall Box Durability and Weather Resistance	Ensure that the bat box can withstand environmental factors such as rain, humidity, and temperature changes.	Prototype bat box, environmental testing equipment (e.g., water sprayer)	Expose the prototype bat box to simulated environmental conditions such as rain, humidity, and temperature changes. Check for any physical or functional degradation.	1 day, Nov 14	Successful. The bat box withstood environmental conditions, with no noticeable wear or failure.	Continue durability testing under varied conditions and refine the box design for improved weather resistance.

Overall Summary:

The third prototype successfully validated the integration of critical systems within the bat box, including dual IR sensors, SD card data logging, and efficient battery operation. The system reliably detected bat movements, logged data accurately, and demonstrated durability under simulated environmental conditions. Next steps include optimizing power consumption, enhancing weatherproofing, and conducting long-term real-world tests to ensure consistent performance.

6. Feedback

Feedback/Concern	Comments	Our Response and Next Steps
Accurate Data Logging with SD Card	Users appreciated the reliable SD card data logging system but suggested verifying its performance during prolonged use in real-world conditions.	We will conduct extended field tests to ensure consistent data storage and explore implementing a backup system to prevent data loss in case of SD card failures.
Power Consumption Efficiency	Feedback highlighted concerns about battery life, especially during continuous operation over several days.	We will evaluate alternative low-power components and optimize code to minimize power usage, ensuring longer operational periods without frequent battery replacements.
Minimizing False Positives in Dual Sensors	Users found the mounting brackets intuitive but suggested adding markings or instructions to simplify installation further. Maintenance access was also a concern.	We will adjust sensor thresholds and implement protective casings to shield the IR beams from environmental interference. Additional testing under simulated real-world conditions will be conducted to validate these improvements.
Ease of Installation and Maintenance	One concern raised was that the position or configuration of the IR sensors might affect	We will incorporate clear, user-friendly instructions for installation and refine the box design to allow easier access

	bat behavior, especially if the sensors are too close to the entry.	for sensor adjustments and battery replacement.

7. Updates

Link for BOM spreadsheet (No updates on detailed design sketch):

GNG 1103 - Bill of Materials

8. Plan and Schedule for Prototyping and Testing

Task ID	Task Description	Estimated Duration	Assigned To	Task Details
1	Complete Prototype 3	1 Day	All group members	Finalize the assembly of Prototype 3, integrating any adjustments from prior tests. Ensure all systems (sensors, SD card, battery, and durability) are fully operational and ready for final testing.
2	Final Testing of Prototype 3	1 Day	All group members	Conduct a comprehensive test of Prototype 3, ensuring all components (sensor integration, data logging, battery consumption, and weather resistance) are functioning correctly.
3	Analyze Prototype 3 Test Results	1 Day	All group members	Review data from final testing of Prototype 3, confirming system performance and identifying any final adjustments needed for design day.

4	Prepare and Practice Presentation	2 Days	All group members	Develop the final presentation covering the entire project process, from the initial concept to final prototype. Each group member must contribute, and rehearsal will be needed to ensure smooth delivery.
5	Create Design Day Poster and Pitch	2 Days	All group members	Design a poster for design day to showcase the project's goals, design process, prototypes, and results. Prepare a concise pitch summarizing the project for the event. Practice presenting the pitch.
6	Final Design Day Preparation	2 Days	All group members	Make final preparations for design day: organize materials, finalize the poster, and ensure everything is in place for the presentation and display.
7	Prepare Project Documentation	1	All group members	Compile all relevant documentation, including design notes, testing results, and a summary of the project's evolution. Ensure all files are organized and accessible for final submission.

9. Conclusion

Prototype 3 builds directly on the progress and insights gained from Prototype 2, refining the bat box design into its final, polished iteration. In Prototype 2, the dual IR sensor system successfully tracked bat entries and exits, but challenges such as differentiating bat movements from guano falls, optimizing sensor placement, and ensuring consistent data logging were identified. These areas became the focus of development for Prototype 3, alongside addressing battery efficiency, system durability, and ease of installation.

In Prototype 3, the IR sensors were recalibrated and repositioned for improved accuracy, eliminating false triggers while ensuring smooth detection of bat activity. The SD card data logging system was fully integrated, providing reliable and error-free data storage during testing. Battery power consumption was analyzed and optimized to ensure long-term functionality, while the physical structure of the bat box was enhanced for increased durability and weather resistance. Feedback from Prototype 2 guided improvements to the mounting system, ensuring the design is adaptable and straightforward to install across various environments.

As the final iteration, Prototype 3 incorporates all user feedback and rigorous testing to deliver a functional, efficient, and user-friendly product. With these enhancements, the design is now prepared for design day, showcasing a robust and refined solution that demonstrates the progress made from Prototype 2 and the iterative approach taken to address every challenge. Minor final adjustments will ensure the prototype is perfect, ready to present as a comprehensive response to ecological and user needs.