Deliverable G: Prototype II and Customer Feedback

GNG 1103 – Engineering Design

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Abstract

This deliverable presents a comprehensive plan for developing and testing the second prototype of the bat box designed to monitor bat activity. The document outlines the rationale behind the prototype, detailing its targeted objectives, materials selection, and the testing framework to validate its functionality and user requirements. A structured test plan is included, specifying the critical components to analyze, measurable outcomes, and established stopping criteria to ensure that testing objectives are met. Feedback collection from potential users is a key component of this deliverable, aimed at refining the design and ensuring alignment with user needs. Additionally, updates to the target specifications, detailed design, and Bill of Materials (BOM) will be incorporated based on test results and user feedback. This approach will facilitate the effective development and assessment of the prototype, ultimately guiding the transition to the second prototype iteration.

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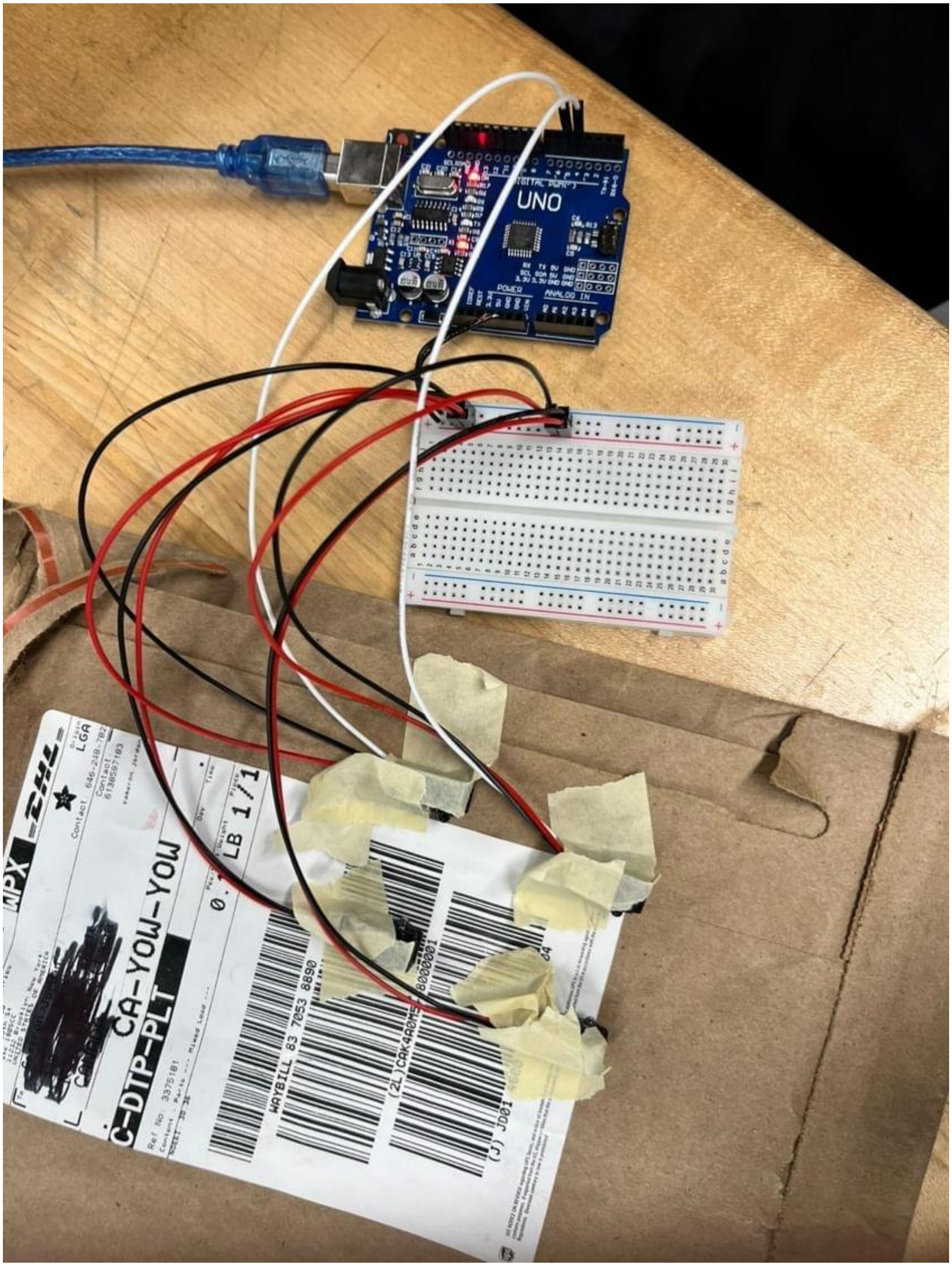
1. Introduction

The problem we seek to address with this deliverable is the need for a functional prototype two that effectively monitors both bat entries and exits. With bat populations declining due to habitat loss and environmental challenges, developing a practical, low-cost solution for bat conservation is essential. Our goal is to create the second prototype that provides critical data for researchers and conservationists.

This deliverable outlines the plan for developing the second prototype and establishing a testing framework based on user feedback. The second prototype will feature a working code for two IR break beams (as opposed to one in the first prototype) to accurately detect both entries and exits. Additionally, the physical bat box will be made from MDF, ensuring durability and ease of construction, testing the overall system together.

By analyzing the critical components and leveraging our current engineering knowledge, we aim to enhance the functionality and reliability of the design. Documenting the prototyping process and gathering feedback from identified users will enable us to refine our approach and ensure the second prototype aligns with both user needs and conservation goals. The testing plan will focus on measurable outcomes, including functionality, usability, and durability, with clear criteria to evaluate the prototype's success. This structured approach will support iterative improvements, ultimately leading to a more effective solution for bat conservation.

2. Picture of Second Prototype and Code




```
#define LEDPIN 13
#define SENSORPIN1 4    // First sensor
```

```
#define SENSORPIN2 5   // Second sensor

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);
}

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) {
    // Sensor 1 broken first, possible entry
    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
        break;
      }
    }
  } else if (sensorState2 == LOW && lastState2 == HIGH && sensorState1 == HIGH) {
    // Sensor 2 broken first, possible exit
    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);
        break;
      }
    }
  }

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

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

For this second prototype, the focus shifts to improving the accuracy and reliability of tracking both bat entries and exits. Unlike the first prototype, which used a single IR beam sensor, the second prototype integrates dual IR sensors to monitor both bat entries and exits. This prototype aims to ensure that the system can accurately log both events, with added emphasis on distinguishing exits from other potential interferences, such as guano falls.

Additionally, the physical design of the bat box has been initiated, with our team using MDF and laser cutting to produce the parts for the box. While the focus remains on refining the tracking system, the physical box is also being developed in parallel to support testing and integration with the sensors.

Why Are We Doing These Tests?

The primary motivation for these tests is to confirm that the dual IR sensors can accurately and independently track bat entries and exits without interference or false readings. By validating the system's functionality in this early stage, we reduce the risk of errors in the final design, ensuring it can reliably gather critical data for bat conservation. These tests are crucial to:

- **Track exit events accurately**: This test will confirm that the second IR sensor can effectively monitor exits.
- **Ensure differentiation between guano and bat exits**: We need to verify that the system does not mistake guano falls for bat exits, which would compromise data accuracy.
- **Assess system integration**: Ensuring that both entry and exit sensors work in sync without interference is essential for a robust, fully functional bat box.
- **Evaluate data consistency**: It's vital that the system logs data accurately over time, without discrepancies or missed events.

Testing the system's ability to handle dual sensors will allow us to address potential issues early, guiding the development of the final prototype.

What Are the Criteria for Success?

Each test has clear criteria for success or failure:

1. **Exit Tracking Accuracy**: Success means the exit sensor accurately logs 10 consecutive exit events without any missed or duplicate counts.
2. **Differentiation Between Guano and Bat Exits**: Success means no false exit logs are generated during 20 simulated guano falls.

3. **System Coordination with Dual Sensors**: Success is confirmed when 30 consecutive paired entries and exits are logged accurately, verifying that both sensors work independently without interference.
4. **Data Collection Consistency**: Success means that over a continuous 4-hour test period, all bat entries and exits are logged accurately, confirming the system's reliability.

What is the Prototype and What is the Test?

The second prototype integrates dual IR beam sensors, with one sensor dedicated to tracking entries and the other focused on exits. The physical prototype is assembled from MDF, following the design specifications, with a simplified structure to test the core tracking functionality.

Testing involves:

- **Simulating bat exits** by obstructing the exit sensor with controlled movement to mimic bat behavior.
- **Simulating guano falls** to ensure that the exit sensor does not mistake them for actual exits.
- **Simulating paired entries and exits** to verify the accurate coordination of both sensors.
- **Continuous testing** to assess data consistency over time.

Testing Process:

1. **Exit Tracking Accuracy**: The second IR sensor will be tested by simulating bat exits through controlled beam obstructions. Data will be recorded to verify that each exit is logged correctly.
2. **Differentiation Between Guano and Bat Exits**: Simulated guano falls will be triggered near the exit sensor to test for false positives. The results will inform adjustments to sensor placement or software calibration to reduce such errors.
3. **System Integration with Dual Sensors**: Paired entries and exits will be simulated, and both sensors will be tested to ensure they function independently and without interference.
4. **Data Collection Consistency**: A continuous test will be conducted with multiple bat entries and exits over a 4-hour period. Data from both sensors will be logged and analyzed for accuracy and consistency.

Materials and Cost:

The test setup includes the two dual IR sensors, basic electronics (wires, breadboard, etc.), and a data storage system. Since the materials are similar to the first prototype, the cost will remain minimal, ensuring the tests are feasible within budget constraints.

Work Required:

Tasks include:

- Coding the data logging software to handle dual sensors.
- Setting up and calibrating the exit sensor for accurate detection.
- Running the tests and recording the results for analysis.

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

Each test is scheduled for one day as follows:

1. **Exit Tracking Accuracy Test**: November 6th.
2. **Differentiation Between Guano and Bat Exits**: November 7th.
3. **System Integration with Dual Sensors**: November 7th.
4. **Data Collection Consistency**: November 7th.

The tests are strategically planned over two days to focus on individual aspects of the design. This schedule ensures that feedback from each test can be incorporated into subsequent iterations, improving the overall design as we proceed.

By following this structured approach, we will validate the functionality and reliability of the dual sensor system, laying a strong foundation for refining the design and moving toward a fully integrated final prototype. These tests will provide crucial data to guide the next stages of development.

Refinement of IR Sensor System for Accurate Bat Entry and Exit Tracking: Prototype 2 Development:

For our second prototype, we have focused on refining the most critical subsystem of our bat box design: the IR sensor system for tracking bat entries and exits. In our initial prototype, we successfully demonstrated the functionality of the entry sensor but faced challenges in differentiating between actual bat exits and guano drops, which could result in inaccurate data. Additionally, the system showed promising results in tracking bat entries but needed further refinement to reliably log both entries and exits in a way that minimizes false triggers.

In Prototype 2, we continue to build on the insights gained from our first iteration. We have incorporated a second IR beam sensor to specifically track bat exits, which is a key improvement. This modification will allow for more accurate tracking of bat movements, addressing the main limitation identified in the previous prototype. To mitigate the issue of false exits due to guano drops, we are experimenting with different sensor placements and refining the code to better distinguish between valid bat exits and unrelated sensor interruptions.

Furthermore, to ensure the system remains within budget while improving performance, we are optimizing the sensor setup by using cost-effective materials and simplifying the code for more efficient data logging. We have also integrated feedback from potential users about the mounting system, aiming to make the bat box easier to install and adapt to various surfaces.

This second prototype is critical to our project as it addresses the main issues identified in the first prototype, focusing on improving the tracking system's accuracy and reliability. The goal is to refine this subsystem before moving forward with the final design, ensuring that the bat box will be effective in real-world applications while staying within the constraints of the $50 budget. By continuing to iterate on our design based on testing results and user feedback, we are working towards a solution that not only meets ecological needs but also provides a user-friendly, practical tool for bat activity tracking.

4. Analysis of the Critical Components

1. IR Sensor System

Function:

The IR sensors are the primary tracking mechanism, responsible for detecting both bat entries and exits. The system consists of two IR sensors, one for detecting entries and the other for detecting exits. These sensors emit infrared light that is interrupted when an object (such as a bat) crosses the beam, triggering the sensor to log the event.

Analysis:

The dual IR sensor system is central to the second prototype, as it allows for distinct tracking of both bat entries and exits. IR sensors are highly accurate for short-range detection, making them suitable for tracking bat movements. They operate effectively in low-light conditions, which is essential since bat activity occurs primarily at dusk or night. Additionally, IR sensors have a low power requirement, making them ideal for a system that aims to be low maintenance. However, environmental factors like dust accumulation or interference between the beams of the dual sensors could affect performance over time. The precise calibration of the sensors will be crucial to avoid any potential issues, especially since the addition of the exit sensor increases the complexity of the system.

Improvement Potential:

Regular calibration and adding protective casings for the sensors could help mitigate the environmental challenges, such as dust and moisture. To ensure that the dual sensors work seamlessly together without interference, their placement and orientation should be carefully tested and adjusted. While alternatives like ultrasonic sensors were considered, the IR system remains effective and more cost-efficient for the needs of this project.

2. Bat Box Design

Function:

The bat box is designed to house the IR sensor system and provide a safe, comfortable environment for bats. It must maintain a suitable internal temperature, prevent predator entry, and withstand various weather conditions while allowing easy attachment to external surfaces.

Analysis:

The second prototype features a bat box made from MDF, which was chosen for its durability and ease of fabrication using laser cutting. The physical structure of the box needs to maintain a balance between being durable, lightweight, and capable of insulating against extreme weather conditions. The internal temperature regulation is crucial for ensuring that the box remains a comfortable environment for bats. Additionally, the box must be predator-proof, with a design ensuring that no larger animals can access the box.

The IR sensors are integrated into the design in a way that they are unobstructed, enabling them to accurately track bat movements without interference from the box's structure.

Improvement Potential:

While MDF provides a solid base for the structure, additional materials or coatings could be considered to improve weatherproofing and insulation. The design could also be refined to include better ventilation, ensuring the bat box remains at an optimal temperature for bat roosting. Moreover, as the prototype progresses, further testing of the box's ability to withstand outdoor conditions—such as rain, humidity, and temperature fluctuations—will be essential. Optimizing the box's mounting system to make installation easier and more versatile will also improve its usability, especially in varying environments. Additionally, incorporating flexible features in the box design to accommodate different bat species could be explored, such as adjustable entry points or modular components for future iterations.

5. Prototyping Test Plan, Analysis and Results:

Test Objective	Test Criteria	Materials	Testing Process	Duration & Date	Results	Analysis & Next Steps
Exit Tracking Accuracy	The exit sensor must detect each interruption accurately as an exit event, logging the correct data without errors or overlaps with entry logs.	IR sensors (entry and exit sensors), prototype bat box, simulation objects (to mimic bat exits)	Install the second IR beam sensor within the prototype. Simulate bat exits by interrupting the exit IR beam in a controlled manner. Observe if the exit events are logged separately from entries.	1 day, Nov 6	Successful (Exit sensor detected each exit accurately, and all exit events were logged separately from entries.)	- The second IR beam sensor for exits worked as expected logging exit events correctly. No false positives were recorded. Next steps: refine sensor placement to reduce potential environmental interference and continue testing dual sensor system coordination.
Distinguish Between Guano and Bat Exits	The exit sensor must differentiate between bat exits and simulated guano falls (no false exit logs	IR exit sensor, guano simulation objects, prototype bat box	Place simulated guano near the exit IR sensor. Simulate bat exits and guano falls	1 day, Nov 7	Successful (No false exit triggers from simulated guano falls).	The exit sensor successfully distinguished bat exits from simulated guano falls. The design proved reliable for this test. Next steps: optimize

	from guano falls).		separately, recording whether the exit sensor triggers correctly.			sensor placement for further reliability and continue refining sensor calibration.
System Integration with Dual IR Sensors	Both entry and exit sensors should function independently, tracking bat movements accurately without interference.	IR sensors (entry and exit sensors), prototype bat box	Simulate bat entries and exits in quick succession. Verify that no entry events are logged as exits and vice versa.	1 day, Nov 7	Successful (Both entry and exit sensors logged events without interference, accurately tracking bat movements).	The dual sensor system worked as intended. Both sensors logged distinct entry and exit events. Next steps: test continuous data collection over extended periods to ensure long-term consistency and prepare for full bat box integration.
Data Collection Consistency Across Dual Sensors	Data should be logged consistently with minimal errors over several hours. The bat count should match the expected results.	IR sensors (entry and exit sensors), prototype bat box,	Run a continuous test with multiple simulated entries and exits over several hours. Verify the total number of bat entries and exits against the actual events.	1 day, Nov 7	Successful (Data was logged consistently and accurately).	The data collection system proved reliable over the test duration. Next steps: integrate environmental adaptations (e.g., dust/moisture protection) and prepare for the final integration of the bat box design.

Overall Summary:

The second prototype successfully validated the dual IR sensor system, confirming the accurate detection of bat entries and exits. The system performed reliably, with clear differentiation between bat movements and false triggers like guano falls. Next steps involve preparing the full bat box integration with further environmental considerations and testing in real-world conditions.

6. Feedback

Feedback/Concern	Comments	Our Response and Next Steps
Accurate Tracking of Both Entries and Exits	Users were generally impressed with the dual IR sensor system that tracked both entries and exits. They suggested that having both functions could greatly improve the reliability of bat visit data.	We will continue refining the code to ensure that both entry and exit events are recorded with 100% accuracy, while testing the sensors under varying conditions to ensure consistent performance.
Sensor Sensitivity in Low-Visibility Conditions	A few users mentioned that while the sensors worked well in a controlled environment, there might be concerns about their reliability in real-world, low-light, or misty conditions, which could affect the infrared beam.	To address this, we will test the sensors in low-light and foggy conditions to assess performance. We will also explore options to enhance sensor sensitivity, such as increasing the beam's range or adding signal amplification.
Handling False Positive Exits (e.g., Guano Falls)	Some users noted that the sensors might register guano falls or other disturbances as false exits, potentially skewing the data collected.	We will further refine the sensor's programming to differentiate between guano falls and actual bat exits by adjusting the threshold for triggering the exit event. Future tests will focus on improving the sensor's detection algorithm.
Intrusiveness of the IR Sensors on Bat Behavior	One concern raised was that the position or configuration of the IR sensors might affect bat behavior, especially if the sensors are too close to the entry.	Based on this feedback, we will adjust the sensor placement and height to minimize disruption to the bats' natural movement patterns. We will continue experimenting with different sensor angles to ensure they do not interfere with bat entry or exit.

7. Laser Cut Design Blueprint for MDF Bat Box Prototype

8. Updates

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

GNG 1103 - Bill of Materials

9. Prototyping Test Plan (For Prototype 3)

Test ID	Test Objective (Why)	Description of Prototype and Basic Test Method (What)	Description of Results to be Recorded and Usage (How)	Estimated Test Duration and Planned Start Date (When)
1	Test Sensor Integration with Physical Box	Ensure sensors are properly mounted and functional within the final box design. Confirm that sensors track entries and exits without interference from the box structure.	Install IR sensors on the MDF bat box. Simulate bat entries and exits by obstructing each IR beam. Monitor if the sensors log accurate entries and exits, ensuring no interference from the box structure.	Duration: 1 day Start Date: November 12th
2	Test SD Card Data Logging System	Confirm that data is being saved to the SD card and is retrievable for analysis.	Integrate an SD card module into the system. Modify code to log entry and exit data onto the SD card. Simulate multiple bat entries and exits, then retrieve and verify the data from the SD card.	Duration: 1 day Start Date: November 12th
3	Test Battery Power Consumption	Ensure that the battery powers the system for an extended period without issues.	Integrate a rechargeable battery pack and power the sensors, microcontroller, and SD card. Run the system continuously, monitoring the battery's performance.	Duration: 1 day Start Date: November 12th
4	Test Overall Box Durability and Weather Resistance	Ensure that the MDF bat box is durable and can withstand simulated outdoor conditions.	Assemble the final bat box with all components and place it in an outdoor test environment. Expose the box to simulated weather conditions (light rain, wind, temperature fluctuations).	Duration: 1 day Start Date: November 12th

9.1 Stopping Criterion

Test ID	Stopping Criterion
1	Stop when sensors log 10 consecutive entries and exit without interference from the box structure, confirming proper integration.
2	Stop if 20 consecutive entries and exits are successfully logged to the SD card with no data retrieval errors, ensuring consistent functionality of the logging system.
3	Stop if the battery maintains system operation for a full 24-hour period without significant voltage drop or loss of performance, confirming power stability.
4	Stop if the bat box can withstand 48 hours of simulated weather conditions without structural damage, data loss, or component failure, ensuring durability.

10. Plan and Schedule for Prototyping and Testing

Task ID	Task Description	Estimated Duration	Assigned To	Task Details
1	Complete Prototype 2	2 Day	All group members	Finish finalizing Prototype 2, including assembly and sensor integration, and ensuring it's ready for testing.
2	Test Prototype 2 for Bat Count Tracking and Exits	1 Days	All group members	Conduct tests on Prototype 2, focusing on verifying entry and exit tracking, sensor accuracy, and data logging functionality.
3	Analyze Test Results from Prototype 2	2 Days	All group members	Analyze the data collected from the Prototype 2 tests, assess performance, and identify any necessary design adjustments.
4	Build Prototype 3 with Adjustments	2 Day	All group members	Modify and assemble Prototype 3, incorporating adjustments from Prototype 2 test results, and integrating SD card and battery systems.
5	Test Prototype 3 (Sensor Integration, Data Logging, Battery, and Durability)	2 Days	All group members	Run multiple tests on Prototype 3, including sensor integration with the final box, SD card data logging, battery consumption, and weather resistance.
6	Analyze Prototype 3 Test Results	2 Days	All group members	Review the data from Prototype 3 tests, check system reliability, and make any final adjustments to ensure full functionality.
7	Prepare Presentation and Documentation	1	All group members	Compile and document test results, prototype developments, and design iterations for the final presentation.

11. Conclusion

In this phase of our prototyping process, we have gathered valuable insights into the performance and reliability of our bat box design, particularly regarding the use of IR beam sensors to track bat entries and exits. Through comprehensive testing of Prototype 2, we confirmed the functionality of our entry sensor and identified potential challenges, such as differentiating between actual bat exits and guano drops. These findings have emphasized the importance of sensor placement, data logging accuracy, and the need for a more refined filtering system to improve tracking precision.

Building on the success of Prototype 2, we are now transitioning to Prototype 3, where we will focus on enhancing the IR beam system and integrating additional features. Our primary objectives for Prototype 3 include optimizing sensor positioning to reduce interference with bat movement, improving the differentiation between exits and guano, and ensuring consistent data logging to an SD card. Additionally, we will address key challenges, such as battery power consumption and the overall durability of the bat box in various weather conditions.

Moving forward, we will continue to integrate feedback from potential users, particularly regarding mounting systems and ease of installation. This input will be essential for refining the design's practicality and usability. With ongoing testing and iterative design adjustments, we aim to develop a functional, reliable, and user-friendly bat box that effectively tracks bat activity while contributing to conservation efforts.

Overall, Prototype 2 has laid the groundwork for the continued development of the bat box, and Prototype 3 will build upon these insights as we work toward a final product that meets both ecological needs and user expectations.