Deliverable F: Prototype I and Customer Feedback

GNG 1103 – Engineering Design

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Abstract

This deliverable presents a comprehensive plan for developing and testing the first 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

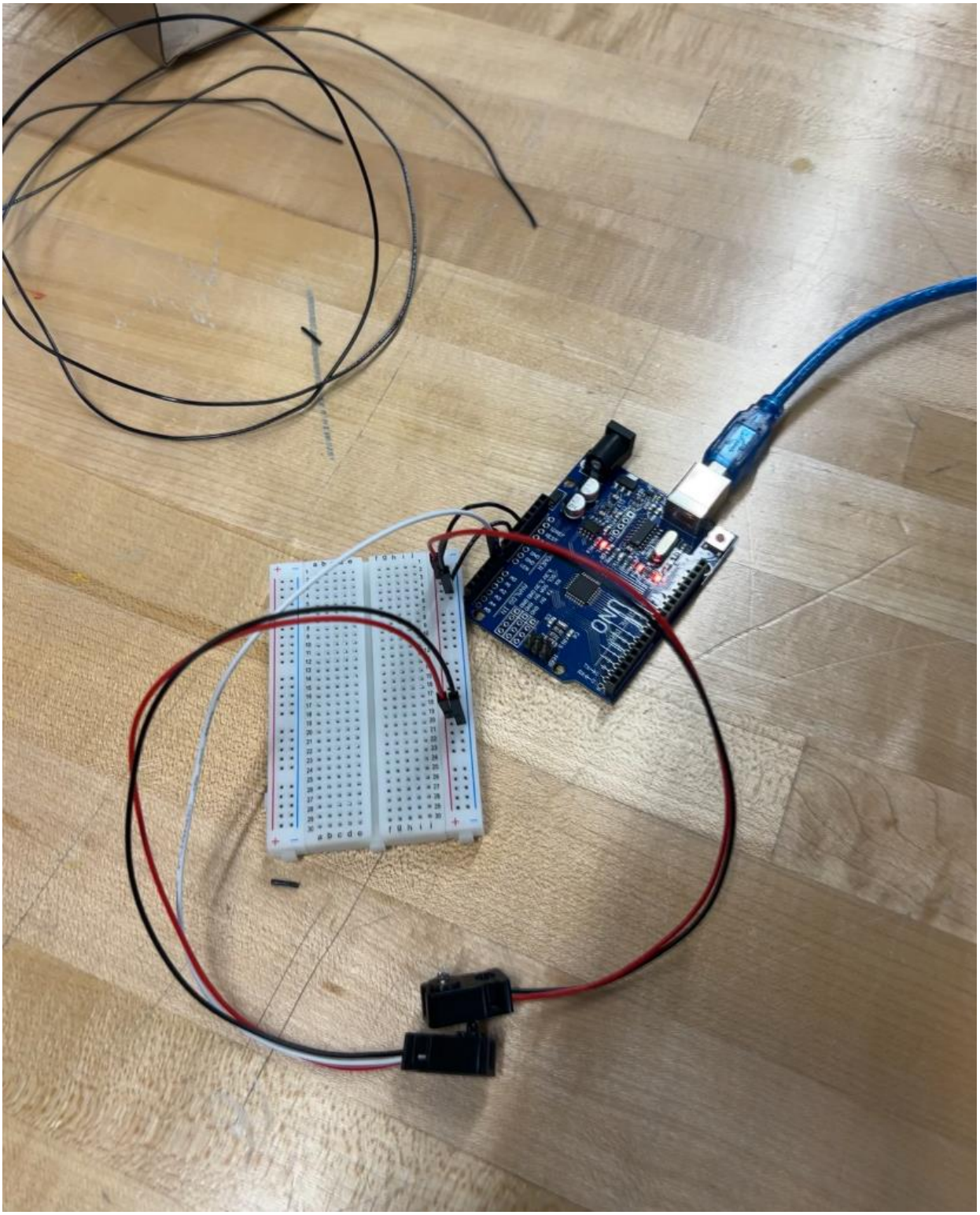
The problem we seek to address for this deliverable is the need for a functional prototype that monitors bats entries activity effectively. Given the declining populations of bats due to habitat loss and other environmental factors, developing a practical and low-cost

solution for bat conservation is imperative. Our goal is to create a first prototype that provides crucial data for researchers and conservationists.

This deliverable outlines the plan for developing our first prototype and establishing a testing framework based on user feedback. The prototype will be designed to meet specific objectives; ensuring there is a working code that detects the entries and exits of the bat box. We will conduct a thorough analysis of the critical components involved in the design, leveraging our current engineering knowledge to enhance functionality and reliability.

By documenting the prototyping process and carefully collecting feedback from identified users, we will refine our approach and ensure the prototype aligns with user needs and conservation goals. The testing plan will focus on measurable outcomes, including functionality, usability, and durability, while establishing clear criteria for evaluating the success of the prototype. This structured approach will pave the way for iterative improvements, ultimately leading to a second prototype that is even more effective in supporting bat populations.

2. Picture of Prototype and Code



```
const int irLedPin = 9;        // Pin for IR LED
const int phototransistorPin = A0; // Pin for phototransistor
```

```
int count = 0;                // Counter for beam interruptions
int threshold = 100;          // Threshold for detection

void setup() {
  pinMode(irLedPin, OUTPUT);
  digitalWrite(irLedPin, HIGH); // Turn on IR LED
  Serial.begin(9600);           // Start serial communication
}

void loop() {
  int sensorValue = analogRead(phototransistorPin); // Read the sensor value

  if (sensorValue < threshold) { // Check if the beam is interrupted
    count++;
    Serial.print("Entrances counted: ");
    Serial.println(count);
    delay(500); // Debounce delay to avoid multiple counts
  }

  delay(100); // Short delay for reading
}
```

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

For this initial prototype with the code and IR beam sensors, our testing objectives focused on validating the primary function of tracking bat entries. This prototype, though not the full bat box, centers on the main goal: effectively detecting and recording bat visits. By analyzing these functions separately, we can efficiently address specific design and functionality questions before building the final prototype.

Why Are We Doing These Tests?

The primary motivation for these tests is to de-risk the core functionality of bat tracking and data accuracy while confirming that the design allows safe bat entry. Without these tests, there's a risk that the full prototype might not perform its essential purpose reliably, leading to costly redesigns later in development. Testing the IR sensors' accuracy and accessibility early will allow us to validate the design's usability for bats, confirming that they can safely enter and that our system can detect and log their entries effectively.

Each test serves to provide specific insights that help mitigate the primary uncertainties of this project:

1. **Evaluating Entry Accessibility and Safety**: This test ensures the entrance design is bat-friendly, allowing them to enter safely and comfortably. This is essential, as any issues with bat entry would compromise the product's core functionality.
2. **Testing Data Collection Accuracy**: This test confirms that the IR sensors and data storage system reliably capture and record bat entries. Precise data collection is the central function, and an error here would defeat the purpose of the product.

These tests also help communicate and validate key aspects of the project concept to potential users, supporting our iterative design process by identifying and resolving issues before moving to a fully integrated prototype. Although there are more accurate, laboratory-grade methods for testing sensor data, we opted for this practical and cost-effective approach due to constraints on time and resources.

What Are the Criteria for Success?

Each test has clear criteria for success or failure:

- **Entry Accessibility and Safety**: Success means that the bats (or simulated entry conditions) can access the entry point without obstruction, allowing safe landing and roosting. Recorded data should show a high success rate of entries without triggering false positives or allowing predators through the entryway.
- **Data Collection Accuracy**: Success for this test means that the sensor system accurately detects each simulated bat entry and exit, with minimal errors. All entries should be logged correctly in the data storage, with timestamps, if possible, to confirm the sensors and data system are reliable.

What is the Prototype and What is the Test?

The prototype is a focused, physical prototype designed to test the tracking and entry functionality. This prototype uses IR beam sensors, code for data logging, and a simplified structure simulating the entryway of the final bat box. The choice of a focused prototype allows us to test these essential elements without committing to a full build, which reduces costs and time spent on features that are still uncertain.

Testing Process:

1. **Entry Accessibility and Safety**: We place the prototype in a simulated environment and use a small object to mimic bat entry, observing whether the entry and landing surfaces allow smooth access.
2. **Data Collection Accuracy**: The IR sensors and tracking software are tested by simulating multiple entries and exits, logging data, and verifying that each entry is recorded accurately.

Materials and Cost: This test setup includes IR sensors, basic electronic components (wire, breadboard, etc.), and a data storage module. Estimated cost is minimal due to using readily available components, making this test feasible within budget constraints.

Work Required: Coding the data logging software, setting up the sensors, and calibrating the entry mechanism are the main tasks, all within our team's current skills and available resources.

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

Each test is scheduled for **one day**:

- **Entry Accessibility and Safety Test**: November 4th.

- **Data Collection Accuracy Test**: November 4th.

The one-day duration to test is sufficient, as each test has a focused objective. These dates align with our project timeline, allowing us to analyze and incorporate feedback and results into the next iteration before advancing to the full prototype. The timing ensures we can make necessary adjustments early, minimizing the risk of having to make major changes later when resources and time are more limited.

By following this structured approach, we ensure that the prototype will effectively address the primary objectives of tracking and safe entry for bats, laying a solid foundation for further development stages. This prototype will confirm the feasibility of our design and refine the core elements, contributing essential insights that will guide the completion of the final bat box.

4. Analysis of the Critical Components

1. IR Sensor System

Function: The IR sensors are the primary tracking mechanism, responsible for detecting bat entries. They emit infrared light that is interrupted when an object (e.g., a bat) crosses the beam, triggering the sensor to log an entry or exit.

Analysis: IR sensors are suitable for this project due to their accuracy in short-range detection and their ability to operate in low-light conditions, which is essential for bat activity that peaks at dusk or night. They also have a relatively low power requirement, which is beneficial for a system intended to be low maintenance. However, IR sensors can be sensitive to environmental factors like dust, which could accumulate and affect performance over time.

Improvement Potential: Regular calibration or adding a simple protective casing for the sensors could mitigate some environmental challenges. Alternative sensors, such as ultrasonic sensors, were considered but were ultimately deemed unnecessary due to the IR's effectiveness in this application and lower cost.

2. Entry Design

Function: The entry mechanism is designed to allow bats to access the box safely while preventing predator entry and minimizing obstructions to the IR sensors.

Analysis: The design must accommodate bats' natural flight and landing patterns, ensuring an accessible entry while keeping the sensor area clear. This involves configuring the entry point with dimensions that allow bats to enter comfortably while blocking larger animals. Additionally, the entry structure should be stable and durable enough to withstand weather exposure.

Improvement Potential: Testing different entry angles or surface textures could optimize bat usability, as bats might require a rough surface to grip while landing. Testing this in simulated conditions will verify that the entry mechanism is bat-friendly and safe.

5. Prototyping Test Plan, Analysis and Results:

Test Objective	Test Criteria	Materials	Testing Process	Duration & Date	Results	Analysis & Next Steps
1. Entry Accessibility and Safety	Entry must allow unobstructed access for bats (or simulation objects) with detection each time IR beam is broken	- IR sensors - Prototype entry frame	- Place prototype in controlled environment - Simulate bat entries by interrupting IR beam - Observe for smooth access without obstructing IR sensors	1 day Nov 4	Successful (Entry structure allowed smooth access and triggered IR sensor)	- IR sensors reliably detected each entry - No recalibration needed, but adding dust guards may protect sensors in future prototypes

						- Entry design met initial criteria
2. Data Collection Accuracy	Each beam interruption must log as an entry without errors or duplicate counts	- Basic data logging system	- Program microcontroller to log sensor trigger as an entry - Simulate consecutive entries by interrupting IR beam multiple times - Verify logs match entry events	1 day Nov 4	Successful (Data logging system accurately recorded each entry)	- System logged each entry without errors, confirming code and sensor accuracy - Confirmed reliable function of tracking system - Next prototype to integrate full box

Overall: - Initial prototype confirmed feasibility of IR sensors and data logging for tracking

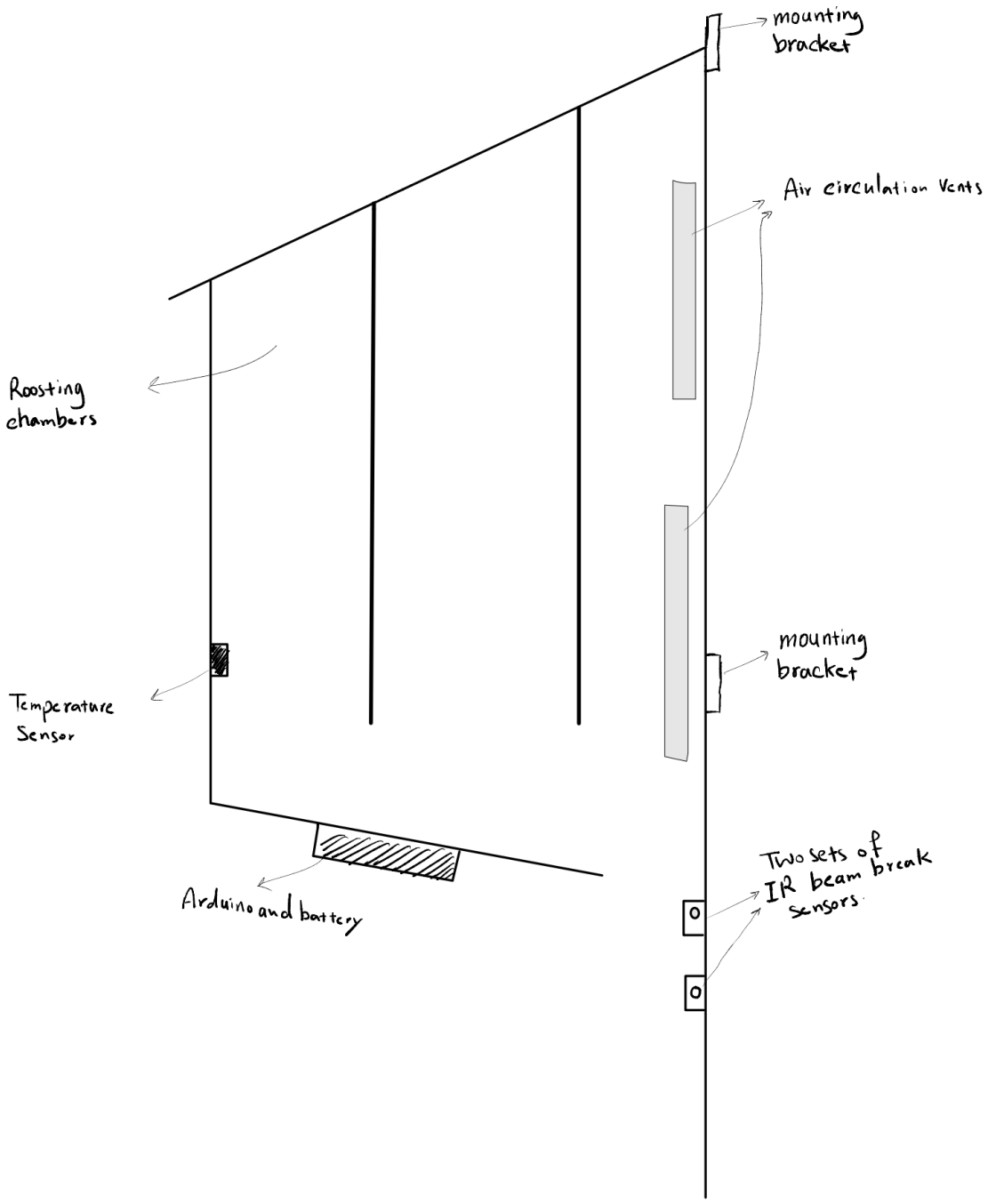
- Next steps include integrating a second set of IR Beam sensors and code to track exits.

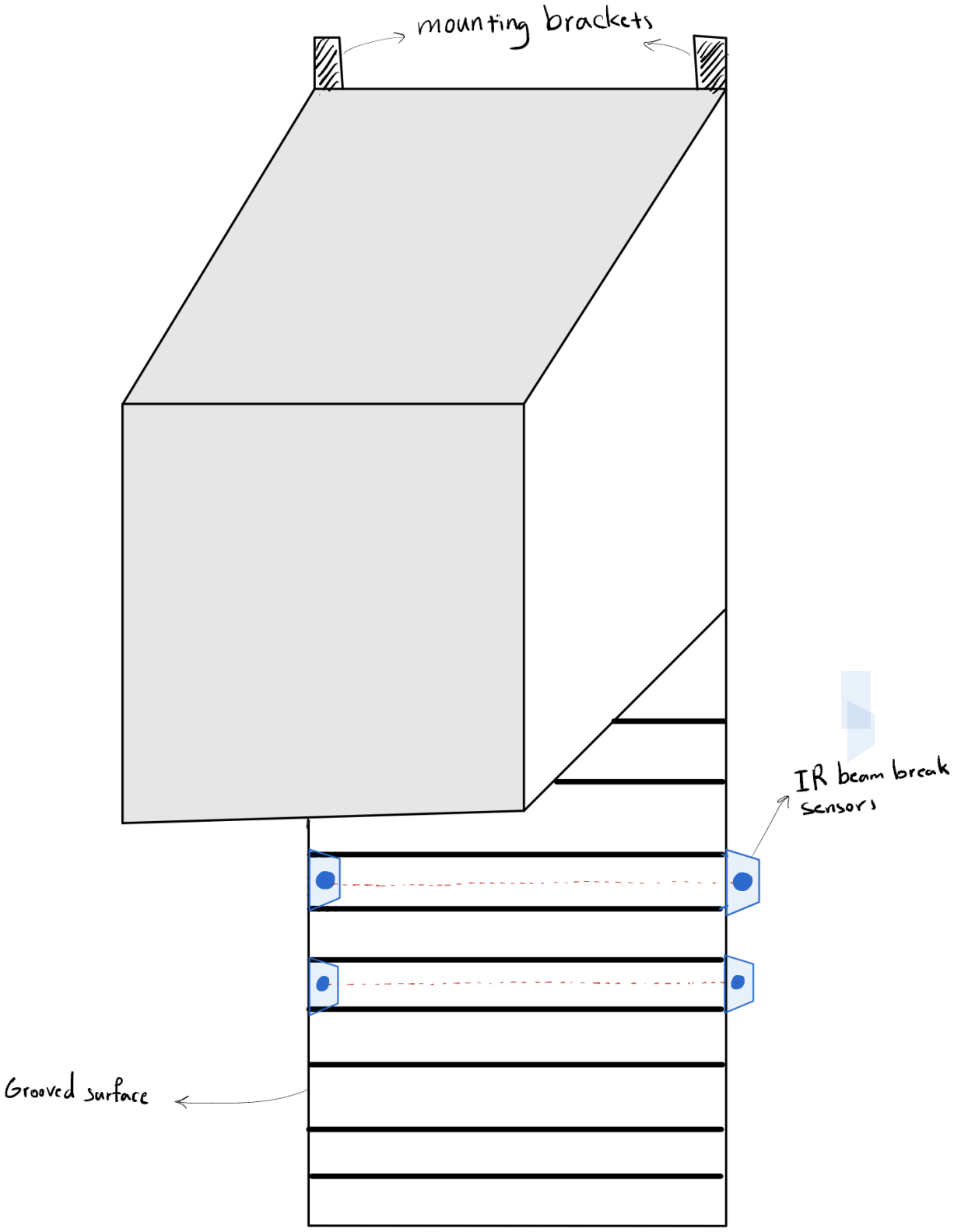
6. Feedback

Feedback/Concern	Comments	Our Response and Next Steps
Positive Reception and Interest	Users liked the concept and saw potential in tracking bat activity with minimal maintenance, particularly appreciating the compact design and tracking feature.	We will continue refining the box to meet user expectations, especially focusing on usability and ease of installation
Mounting System	Users inquired about how the box would be mounted and if it could be attached to various surfaces.	We're including mounting brackets that allow easy installation on any surface. These brackets will offer versatility in setup.
Differentiating Exits from Guano Drops	Users expressed concerns that the sensors might misinterpret guano drops as	We'll address this by testing sensor placement and refining the code to recognize specific entry/exit patterns

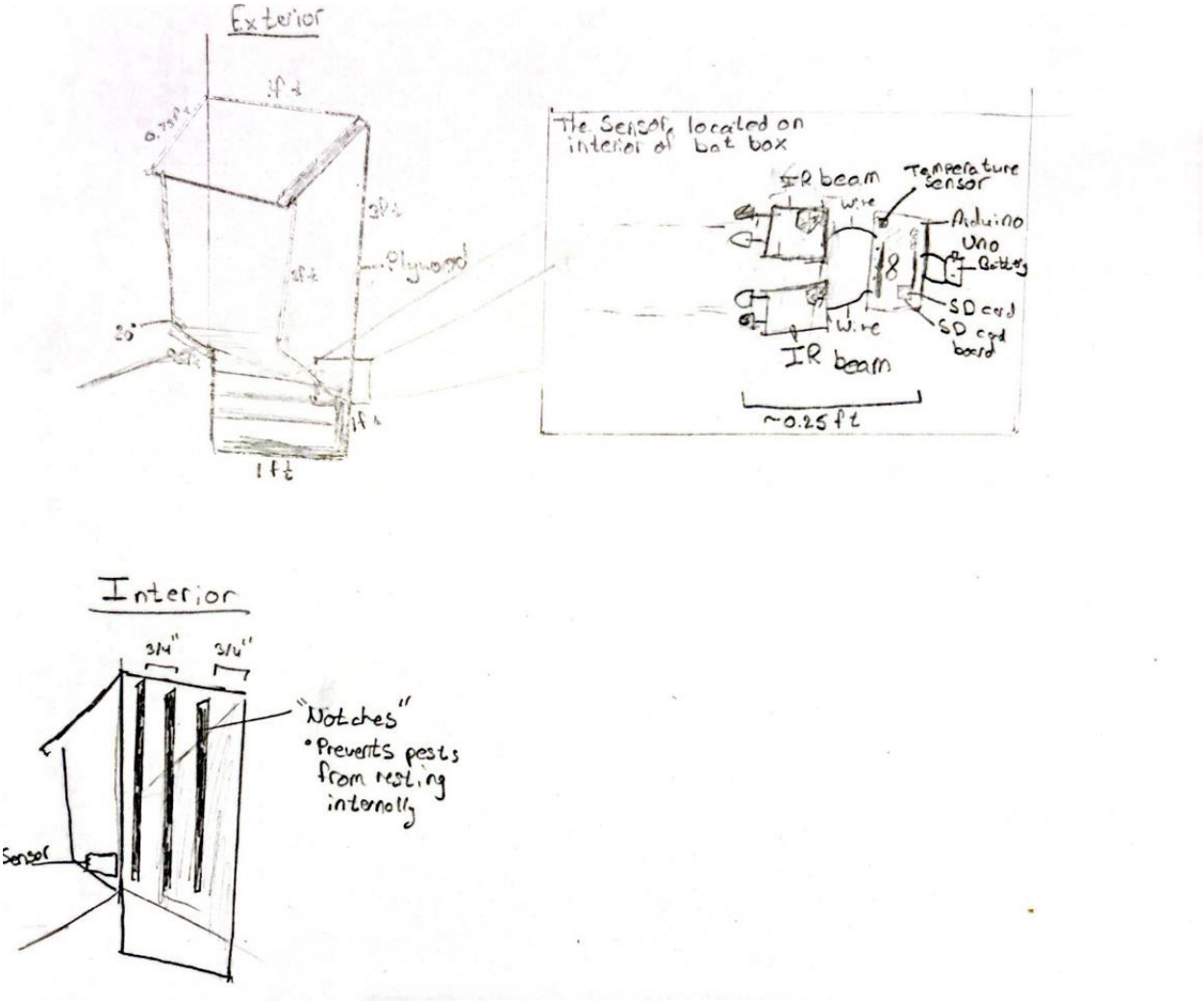
	bat exits, leading to inaccurate data collection.	rather than isolated single triggers. Future prototypes could also explore adding a filtering mechanism for more accurate detection, but there will always be uncertainties.
Sensor Placement and Bat Entry Disruption	Users worried that the placement of the IR sensors might inadvertently interfere with bats entering the box, especially if the bats crawl upward upon entry.	Based on this feedback, we will experiment with positioning sensors at various angles to minimize interference with bat flight paths. Testing will also include adjustments to sensor height and detection sensitivity to avoid obstructing bat entry.

7. Detailed Design Drawing (Improved and Updated)


mounting bracket
Air circulation vents
Roosting chambers
mounting bracket
Temperature Sensor
Two sets of IR beam break sensors
Arduino and battery


mounting brackets
IR beam break sensors
Grooved surface

7.1 Original Design (for reference)



8. Updated BOM

Link for spreadsheet:

GNG 1103 - Bill of Materials

9. Updated List of Equipment (For Prototype One):

Additional Temporary Materials (for Initial Prototyping)

1. **Breadboard** (not listed in BOM)

a. Purpose: Quick and flexible prototyping of circuits.

2. **Wire Strippers**
    a. Cut the black wire to connect the breadboard and Arduino.

Required Software

1. **Arduino IDE**
    a. Purpose: Program Arduino for handling sensor data and storing it on the SD card.
2. **Serial Monitor (in Arduino IDE)**
    a. Purpose: Real-time data monitoring for debugging.
3. **Data Analysis Software** (e.g., Excel, Google Sheets)
    a. Purpose: Analyze data collected on the SD card.

10. Prototyping Test Plan (For Prototype 2)

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 exit tracking accuracy	Install a second IR beam sensor within the prototype to specifically track exits. Simulate bat	Record each beam obstruction and verify that it is logged as an exit, distinct from entries. Data will confirm the	Duration: 1 day Start Date: November 6th

		exits by obstructing the beam in a controlled manner, mimicking actual bat movement patterns.	exit sensor's accuracy and reliability in detecting true exits.	
2	Ensure differentiation between guano and bat exits	Test exit sensor's ability to distinguish bat exits from potential guano falls by simulating both scenarios near the exit beam.	Record any false exit logs caused by simulated guano falls. Use this data to adjust sensor placement, angle, or code to reduce false triggers.	Duration: 1 day Start Date: November 7th
3	Assess system integration with dual IR sensors	Test the coordination of both entry and exit sensors by simulating bat entries and exits in quick succession. Ensure both sensors function independently without interference.	Record data from both entry and exit logs to confirm accurate and distinct tracking of each. This data will help verify the integrated system's reliability.	Duration: 1 day Start Date: November 8th
4	Test data collection consistency across dual sensors	Run a continuous test with multiple simulated entries and exits over several hours to confirm consistent logging accuracy over time.	Record and verify bat count accuracy; confirm data logging functionality. Results will confirm sensor and system reliability.	Duration: 1 day; Start Date: November 5th

10.1 Stopping Criterion

Test ID	Stopping Criterion
1	Stop when 10 consecutive exit events are logged accurately without any missed or duplicate counts.
2	Stop if 20 simulated guano falls are tested with no false exit triggers logged, confirming the sensor's accuracy.
3	Stop when 30 consecutive paired entry and exit events are logged accurately, demonstrating system coordination and reliability.
4	Stop if all data from a 4-hour test period shows consistent and accurate entry and exit tracking without missed events.

11. Plan and Schedule for Prototyping and Testing

Task ID	Task Description	Estimated Duration	Assigned To	Task Details
1	Complete prototype 1	1 Day	Saher, Cameron and Aidan.	Complete the first prototype using the sourced materials and follow the design specifications.
3	Build Prototype version 2	3 Days	All group members	Assemble the second prototype using the sourced materials and follow the design specifications.

4	Test prototype version 2 for bat count tracking (exits)	2 Days	All group members	Monitor and record the testings of the tracking device under various conditions to ensure accurate data collection.
5	Analyze bat count test results with exits.	1 Day	All group members	Evaluate data from the bat count tests and identify any necessary adjustments to the tracking system or design.
6	Build prototype version 3 with adjustments	3 Days	All group members	Modify and build the third version of the prototype incorporating adjustments from the second test results.
7	Prepare presentation and documentation	2 Days	All group members	Compile all test data, designs, and findings into a presentation format for the presentation.

12. Conclusion

In this phase of our prototyping process, we have gained valuable insights into the functionality and reliability of our bat box design, specifically regarding the use of IR beam sensors for tracking bat entries and exits. Through rigorous testing, we confirmed the accuracy of our entry sensor and the potential challenges associated with distinguishing between actual bat exits and guano drops. These lessons highlighted the importance of sensor placement, data logging accuracy, and the need for a robust filtering mechanism to improve tracking precision.

The success of our initial prototype has paved the way for future iterations, particularly in refining the IR beam system. Moving forward, we plan to focus on optimizing sensor positioning to minimize interference with bat movement while ensuring reliable detection

of both entries and exits. Additionally, integrating feedback from potential users regarding mounting systems and usability will be crucial in enhancing the design's practicality.

Key challenges remain, particularly in achieving an effective differentiation between bat exits and guano. Addressing this issue through iterative design adjustments and further testing will be essential for our next prototypes. By continuing to engage with users and gathering feedback, we aim to create a bat box that not only meets ecological needs but is also user-friendly and effective in tracking bat activity.

Overall, this deliverable serves as a foundation for continued development, emphasizing the need for adaptability and ongoing testing as we work towards creating a final product that significantly contributes to bat conservation efforts.