Project Deliverable D: Conceptual Design

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1 Introduction

Bat populations are declining due to habitat loss, climate change, and disease, posing challenges for biodiversity and ecosystem stability. To address this, Tiree FS Inc. tasked our team with designing a solution that allows accurate monitoring of bat activity in artificial bat boxes. These users require a durable, non-intrusive, and cost-effective system that can withstand outdoor conditions while delivering reliable data on bat visits. The system must minimize maintenance, provide long-term operation, and avoid disrupting natural bat behaviors, all of which are essential for ensuring the success of conservation efforts. Our design addresses these user requirements by incorporating energy-efficient PIR sensors, a long-lasting lithium-ion battery, and a modular, weatherproof bat box. This ensures accurate monitoring while reducing the need for frequent maintenance, offering a practical solution that meets the needs of conservation programs aimed at promoting bat health and ecosystem stability.

2 Ideation Process

Subsystem 1 Concepts (Battery)	**Description**	**Advantages**	**Drawbacks**
Solar powered Lithium-ion Battery (combination of concept 1,2, 3)	A lithium-ion battery connected with a solar panel	helps to have a perpetual cycle of charging, reduces maintenance needs , high energy density compatible with renewable energy sources compact size and weight	more expensive may degrade in extreme temperatures
Swappable Modular Battery System	A modular design that allows cells to be individually replaced	Easy to replace and offers interesting energy storage possibilities	Bulky and requires a bit more maintenance so one of our needs can't be fulfilled
Nickel Hydride Battery	**Another type of rechargeable battery**	Rechargeable (From dead of partially charged) High capacity High energy density Longer lifespan Lower carbon footprint	Charges slowly and is less energy dense bulky

Subsystem 2 Concepts (Sensor)	**Description**	**Advantages**	**Drawbacks**

PIR motion sensor	Detects bat movements by sensing heat	Low power consumption Affordable Reliable	Temperature changes can affect it (humidity) Limited range
Wired Real-Time Voltage and Temperature Monitoring Sensors And : Wireless Sensor System		Helps to have more accurate data	Since these are not actual sensors that will track bat occupancy in the box they will not be considered as they are only a plus that will provide more accurate results. They could be considered for later prototypes
Pressure sensor	Detects pressure changes when bats land	High accuracy (even if the bats have other movement the landing and take-off will probably have distinctive pressure changes)	May obstruct bat movement since it is bulky
Combining pressure sensor and PIR motion sensor	Will detect bat presence by measuring pressure and heat changes	Precise monitoring	Is there really a point in using both since one sensor is already bulky adding another one would make matters worse and it would be better to find ways to make the PIR more accurate (by programming)

Subsystem 3 Concepts (Bat box design)	**Description**	**Advantages**	**Drawbacks**
Modular Bat Box Design made with composite material and integrating a compartmentalized design (combining 1,2 and 4)	Features a removable panel for easy access to the inside of the box for maintenance purposes. Isolating the sensor from its environment	-Durable material(no need to replace the box each season) Easy maintenance -Customizable (in case some changes need to be made on the sensor) -Assuring the functionality of the sensor	Complex construction The size of the box might be more noticeable and might deter bats from using it budget structural integrity causing weatherproofing problems the need for different compartments might complicate the structure and the size of the box

			might have to be re-evaluated
Lightweight Plastic Casing with Passive Cooling Vents	Use of plastic and passive cooling vents to manage internal temperature	Affordable Simple Lightweight	Not resilient enough to harsh weather conditions Poor heat control
Metal Enclosure with Integrated Heat Sink Fins	Metal design with heat sink fins for heat dissipation	Sturdy Excellent heat dissipation	Might pose maintenance problems Heavy Costly

3 Decision Matrix

Criteria	**Global Concept 1: Li-ion Battery + PIR Sensor + Modular Bat Box**	**Global Concept 2: Nickel Hydride Battery + Wired Sensor + Metal Bat Box**	**Global Concept 3: Modular Battery System + Pressure Sensor + Composite Bat Box**
Battery life	9 – The lithium-ion battery offers high energy density and long life between charges.	7 – Nickel hydride has lower energy density and slower charging times.	8 – Swappable cells extend the lifespan but require more manual maintenance.
Cost	7 – Lithium-ion batteries are moderately priced, and the modular box reduces overall costs.	6 – Metal enclosures and wired systems are more expensive.	5 – The modular system and complex construction increase the overall cost.
Ease of maintenance	8 – The modular design allows for easy access to the battery and sensor for maintenance.	6 – Wired sensors and a more complicated metal design make it harder to service.	9 – Swappable battery cells and easy-to-disassemble design improve maintenance.

Durability	8 – Weather-resistant wood provides durability with adequate environmental protection.	9 – The metal enclosure is very durable and has integrated heat dissipation.	7 – Composite material is lighter but may not withstand harsh conditions as well.
Energy efficiency	9 – The combination of a Li-ion battery and PIR sensor minimizes power usage.	7 – The wired sensor adds to the power drain, though the nickel hydride is still efficient.	8 – Modular batteries are efficient but the pressure sensor consumes more power.
Sensor accuracy	8 – The PIR sensor is generally reliable for tracking bat movements with low false positives.	9 – Wired sensors provide very accurate readings of voltage and temperature.	7 – Pressure sensors are accurate but can interfere with bat movement and need more power.

3.1 Benefits of Global Concept 1

- **Long-lasting Power:** Li-ion battery is highly energy-efficient and provides excellent battery life.
- **Low Power Consumption:** PIR sensor uses minimal energy, ideal for battery-powered applications.
- **Ease of Maintenance:** Modular design allows easy access to internal components without disturbing the bats.
- **Cost-effective:** Offers a good balance between performance and affordability.
- **Drawbacks:**
- **Temperature Sensitivity:** The lithium-ion battery can be affected by extreme outdoor temperatures.
- **Limited Range:** PIR sensors have a limited range, which may not capture every bat entry if placed improperly.

3.2 Considerations of Other Concepts

Global Concept 2 (Nickel Hydride + Wired Monitoring Sensor + Metal Box):
This concept excels in durability and sensor accuracy, especially with the metal enclosure providing excellent weather resistance and the wired sensor offering precise data. However, its higher cost, bulkiness, and more complex maintenance requirements make it less ideal for a long-term, low-maintenance solution in outdoor conditions.

Advantages: Extremely durable, precise monitoring.

Drawbacks: Higher cost, more difficult to maintain, and higher power consumption.

Global Concept 3 (Modular Battery System + Pressure Sensor + Composite Box):
This concept prioritizes flexibility, with swappable battery cells and an easily disassemblable box for maintenance. However, the pressure sensor could interfere with bat movement, and the composite material of the box may not withstand harsh environmental conditions as well as the other materials.

Advantages: Flexible and easy to maintain with swappable battery cells.

Drawbacks: Higher cost, less durable, pressure sensor may affect bat behavior.

3.3 Final Justification for Selection

Global Concept 1 is chosen for its optimal combination of energy efficiency, low cost, and easy maintenance. It addresses the project's need for a low-maintenance, long-term solution in outdoor conditions, with reliable tracking of bat movements. While other concepts offered stronger durability or sensor accuracy, the trade-offs in cost and complexity were deemed less suitable for this application.

4 Conclusions and Recommendations

In conclusion, this project ensures a sensor system to monitor bat activity that meets the goals of Tiree FS Inc., focusing on durability, cost-effectiveness, and non-intrusiveness. Global Concept 1, which includes a Li-ion battery, PIR motion sensor, and modular bat box design, was chosen as the optimal solution due to its balance of energy efficiency, durability, and ease of maintenance. The system provides accurate monitoring without disrupting bat behavior and is designed to withstand outdoor conditions, fulfilling the project's key requirements. Lessons learned throughout the process include the importance of minimizing system intrusion while ensuring reliable data collection and managing power efficiently in outdoor environments.

5 Future Work

For future work, several modifications could be made to improve the system's function. Solar integration could extend the battery's operational life and reduce maintenance. Also, advanced sensors, such as ultrasonic or pressure sensors, might increase accuracy in tracking bat movements. Improving the system's weatherproofing with advanced materials or cooling mechanisms would help ensure better durability in extreme conditions. Additionally, incorporating wireless data transmission could allow for real-time monitoring without needing physical presence, and designing the box to accommodate multiple bat species by adding adjustable compartments could increase its versatility in conservation efforts. Balancing these upgrades with cost management and sensor accuracy will be important in creating future prototypes.

6 Appendix (Brainstorm)

Subsystem(1): Battery life

Concept 1:Khadijetou: As mentioned by the client the box and sensor will have to require minimal maintenance some aspects have to be considered when choosing the battery such as:

-Battery type: We would have to choose a battery that is long lasting but also can be recharged efficiently. Since the box will be exposed to the sun for a couple of hours a day it would be practical to have something similar to a solar panel to the battery to make it last for as long as possible.

Concept 2: Miguel: **Rechargeable Lithium-ion Battery**

Advantages:	**Drawbacks:**
• **Long-lasting:** Lithium-ion batteries typically provide high energy density, allowing for extended use before requiring recharge.	• **Cost:** Lithium-ion batteries can be more expensive than other battery options.
• **Eco-friendly:** Rechargeable and compatible with renewable energy sources like solar panels, reducing environmental impact.	• **Temperature Sensitivity:** Their performance may degrade in extreme temperatures, which could be problematic in varying outdoor conditions.
• **Lightweight:** The compact size and weight make it easy to integrate into the overall bat box design without adding significant bulk.	•

Concept 3: ANA -- Manages the energy storage system, including battery type, energy efficiency, charge cycles, and lifetime. The battery life subsystem must be designed to be changed or upgraded separately from the sensor and box designs.

Concept 3.1: Large-capacity lithium-ion battery pack. High energy density, extended cycle life, lightweight, yet susceptible to harsh temperatures, greater cost.

Concept 3.2: A swappable modular battery system with quick-release cells. Individual cells can easily replaced or upgraded, and energy storage is versatile; but, the larger form demands more physical space and upkeep.

Concept 4: Sean:Nickel hydride battery

Advantages	Disadvantages
- Rechargeable (From dead of partially charged)	- Not as energy dense as lithium ion batteries.
- High capacity	- Bulkier
- High energy density	- Voltage may decrease if not charges properly.

- Longer lifespan	- Slow charge
- Lower carbon footprint	-

Nickel hydride batteries are reliable for long term, low power applications. Definitely a valid option for powering our sensor. However, lithium-ion batteries are more energy dense; one of the key factors for the performance of our sensor.

subsystem(2): Sensor

Concept 1: Khadijetou: The sensor is the most important part of the project since it is what will help us do what the client needs ; having more information about the occupancy of bat boxes and possibly learning more about bat behavior to help better them.

Type of sensor: The sensor used could be a motion sensor since the bats have to go through specific places on the box to get in and out of it.

Concept 2: Miguel **Passive Infrared (PIR) Motion Sensor**

Description: A Passive Infrared (PIR) motion sensor is proposed to track bat movements by detecting heat signatures and motion as they enter and exit the bat box.

Advantages:	**Drawbacks:**
• **Low Power Consumption:** PIR sensors consume very little power, making them ideal for battery-operated devices.	• **Limited Range:** PIR sensors have a limited range of detection, which could cause missed entries or exits if bats fly too quickly or too far from the sensor.
• **Affordable:** They are cost-effective and widely available, allowing for economical production.	• **Sensitivity to Ambient Conditions:** The sensor's performance may vary depending on environmental factors such as temperature and humidity
• **Reliable Detection:** PIR sensors work well in detecting warm-bodied animals, including bats, without the need for complex calibration.	•

Concept 3: ANA -- Monitors and gathers battery health data (for example, voltage, temperature, and state of charge), then provides input to the user or other systems. The sensor design must work with both the battery system (for real-time monitoring) and the box design (for temperature and ventilation control).

Concept 3.1: Wired real-time voltage and temperature monitoring sensors. Direct input on battery state, solid connection, but requires additional wiring and a more difficult installation.

Concept 3.2: A wireless sensor system (Bluetooth or Wi-Fi) for remote monitoring. There is no physical wire, which makes remote monitoring and diagnostics easier; nevertheless, communication dependability may suffer, and power consumption may increase.

Concept 4: Sean— A pressure sensor could be mounted on the entrance of the bat box. This would provide extremely accurate results because there would be a large change in pressure when the bat lands on the entrance. Disadvantages include, larger battery output, larger and bulkier, could inhibit bat movement.

subsystem(3): Box design

Concept 1:Miguel: Modular Bat Box Design

Description: The bat box will have a modular design, allowing for easy maintenance and part replacement. It will include a removable panel for accessing the battery and sensors without disturbing the bats. The entrance and exit will be designed to optimize airflow and provide adequate shelter from rain.

Advantages:	**Drawbacks:**
• **Customizable:** The modular design allows for future upgrades or changes to the battery and sensor subsystems without replacing the entire box.	•
• **Easy Maintenance:** The removable panel provides quick access to the electronics for repairs or upgrades, reducing downtime.	• **Complex Construction:** The modular design may require more advanced construction techniques, which could increase the production time and cost.
• **Durable Materials:** The box can be constructed from weather-resistant wood or composite materials, ensuring longevity in outdoor conditions.	• **Size:** A larger bat box may be required to accommodate the removable panel, which could make it more noticeable and affect bat behavior.

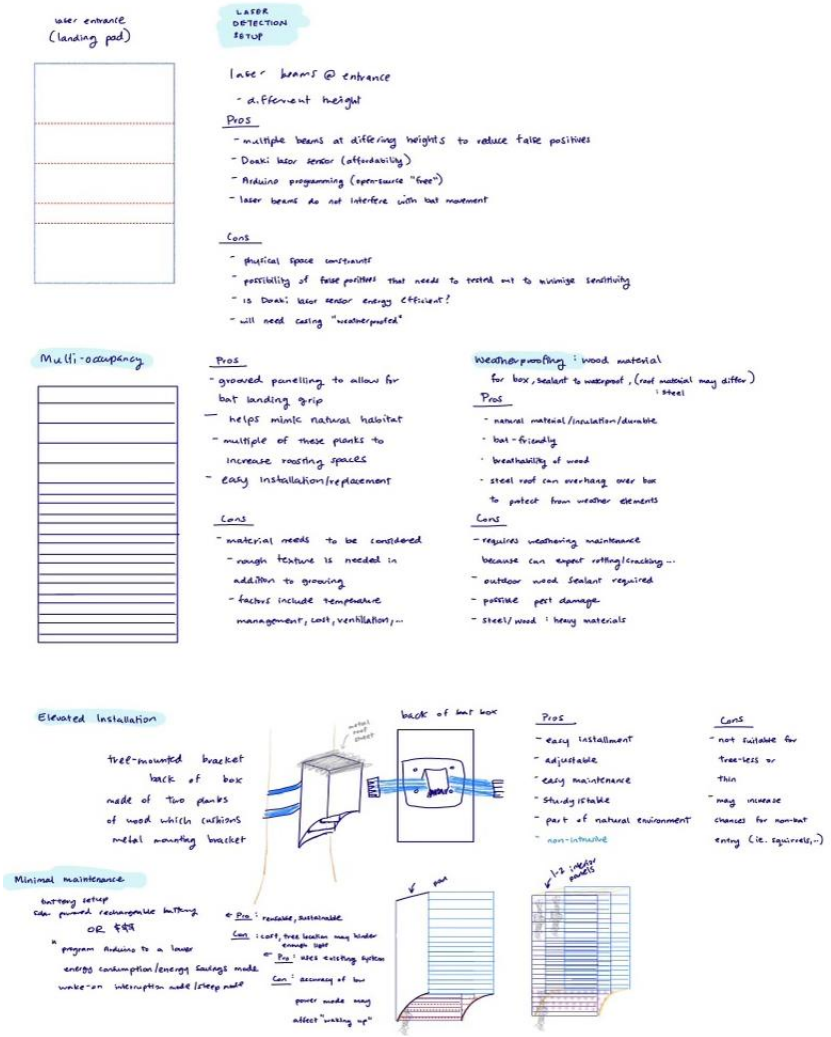
Concept 2(KC) : To answer to the weatherproofing need but also to be able to easily retrieve the sensor to recharge it/ retrieve data the box would have to be easily disassembled so a composite material could be used

Advantages: Would also allow to keep the boxes clean and make sure we can get the data and reuse it as many times as we want (should last a season)

Limitations: might be over budget , could potentially collapse if it isn't put back together the correct way

Concept 3: ANA -- Concentrates on physical shelter, protection, and environmental resilience. The design must support battery life and sensors while assuring safety and effective heat management.

> Concept 3.1: A lightweight plastic casing with passive cooling vents. Easy to manufacture and cost-effective, yet less resilient in hostile settings, with poor heat control.
>
> Concept 3.2: A metal enclosure with integrated heat sink fins. Excellent heat dissipation, sturdy design; yet, heavier and more expensive.

Concept 4: Sean---Our bat box prototype will be built in a way that allows the sensor to be isolated from the environment/weather and ambient light that may cause a motion sensor to be less accurate. We could build a compartment to seperate the sensor from the spaces the bats move through. This compartment would be next to the entrance but inside the box so that it can accurately track entries. This will be an important feature in our box because if we want our sensor to be reliable, it can not have any physical reactions with the bats and it can not interact with the external environment (outside the bat box).

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