Deliverable E

Project Schedule and Cost

GNG 1103C

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Group 15

Anson Moorey

Dina Jamani

Nicola Bonardi Rivard

Matthew Rispoli

Jordan Boulé

Abstract

This document will break down the team's budget and show what materials will be needed to build a prototype. The main purpose of this deliverable is to describe the process of building and testing the team's chosen design.

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1 – Introduction

To ensure that the project is constructable under the given time and monetary constraints, a prototyping plan, testing plan, and detailed budget have been made. To do those, the chosen design concept has been reiterated and internally confirmed after some design uncertainties in the completion of Deliverable D. To support the prototyping plan, all foreseeable possible risks have been identified and outlined, including the courses of action to be taken in those cases and how current actions in design or purchasing will reduce the impact of risk later.

2 – Chosen Design Concept

As outlined in deliverable D, option 2 was chosen as the optimal design (as per the selection matrix, having achieved the highest score). This design was further developed, and the final design and subsystems are as follows.

The Arduino Nano is the core of this design, connected to all electrical components. These components are also weatherproofed, which is an important design aspect as weather is the most dangerous damaging agent for the design components. The sizing and exterior-heavy design concept is to prevent any obstruction for bat movement, which considers the fact that the bats use the landing kerfs to climb instead of swooping directly into the slats.

The team also plans to add an adaptable clamping mechanism (seen in Figure 1). This clamping mechanism allows for the sensor to be attached to any type of bat box (no matter the size or material). This versatility is important because it allows for ease of mounting and dismounting (thus, any non-engineer could easily use it and repair it if necessary). The design shown uses simple knobs and M4 hex nuts to clamp the jaw of the mechanism to the side of the bat box. At the moment, this clamp falls outside the project's budget. Should anything change in the team's design, the clamp will be implemented if possible.

The box itself is scaled down to provide more room in the budget for more critical elements (ex: sensors, wires) and will be 16 inches tall, with a depth of 5 inches and a width of 8 inches (as seen in Figure 2). The material (plywood) is to account for budgeting, but it also provides a certain protection against climate-induced warping. A particularity of this design is the ability for bats to traverse chambers using small ¾ inch large holes, which prevents bats from being trapped in dangerous temperature pockets. The ¾ inch slat openings also prevent wasps from entering, eliminating a natural destructive agent to the bat boxes. Epoxy is being used to aid the construction of the box, which will help seal roof seams and avoid intrusions from warped paneling. A plastic mesh was considered instead

of landing kerfs, but budgeting constraints prevented them from being added to the final design.

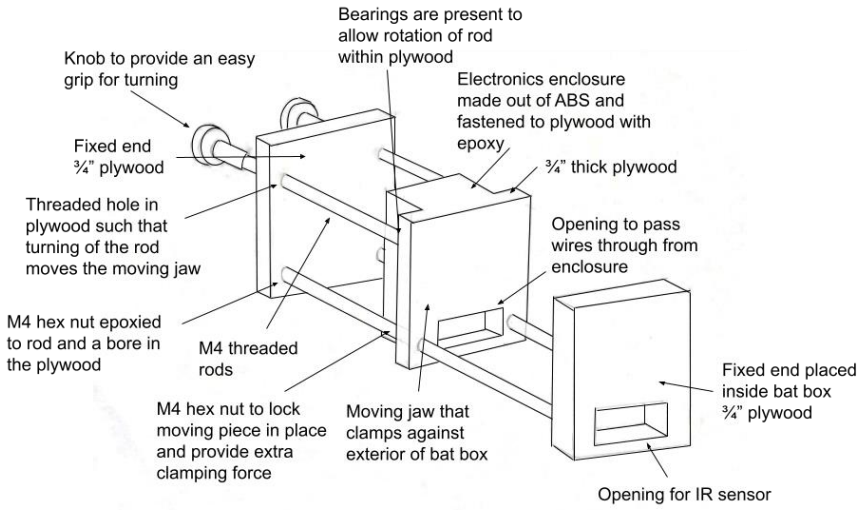

Figure 1: A look at the clamping mechanism. The team will continue to source materials, and should the project budget allow, this clamp will allow all components to attach to any bat box design. It will also safely hold and protect many of the electronic components.

The chosen sensor is an active IR sensor because of its limited interference with the bats (other sensors, such as ultrasound, were found to affect the bats, which are sensitive to certain sounds and vibrations). The IR sensor also provides a simple and robust data collection framework. By simply counting the entries and exits of the bats, it leaves very little room for error and uses much less power than other less accurate and high-energy concepts. The sensor placement will be near the back panel of the box (the client specified the importance of this, as the bats are small in dimension and crawl upwards using the landing kerfs, meaning sensor is important). Data will be stored via an SD card (which could be retrieved when engaging in monthly repairs or checkups). This data collection method is efficient and cost sensitive. Bluetooth data-streaming to handheld devices (such as phones) was considered, but due to budgetary constraints SD card data collection was chosen as the prime concept. Power will also be generated using solar panels (as seen in Figure 3), connected by weatherproofed wires to the Arduino control electronics box on the clamp. The surface area used by the solar panels will impede heat-absorption (because the box is heated by the box absorbing the sun's heat, if the material is blocked by the panels less heat will be absorbed and thus the box could become

dangerous for the bats). To counteract this, darker paint will be used to absorb more heat and keep the box at the optimal temperature. The solar panels, connected to a charge controller (which avoids overcharging the system, necessary for a solar panel framework), will feed lithium-ion batteries. The system is seen as the most efficient, using the natural environment to leverage a lower-cost alternative.

In conclusion, the final design is a modified version of option 2. The modifications were mostly made to preserve the budget (ex: bat box material, data storage) as well as adjustments made after the client meet (temperature sensors in individual chambers). The design keeps simplicity at its core, as well as a robust sensor framework (simply entries and exits) and is tailored to respond to our problem statement as well as the needs of our client.

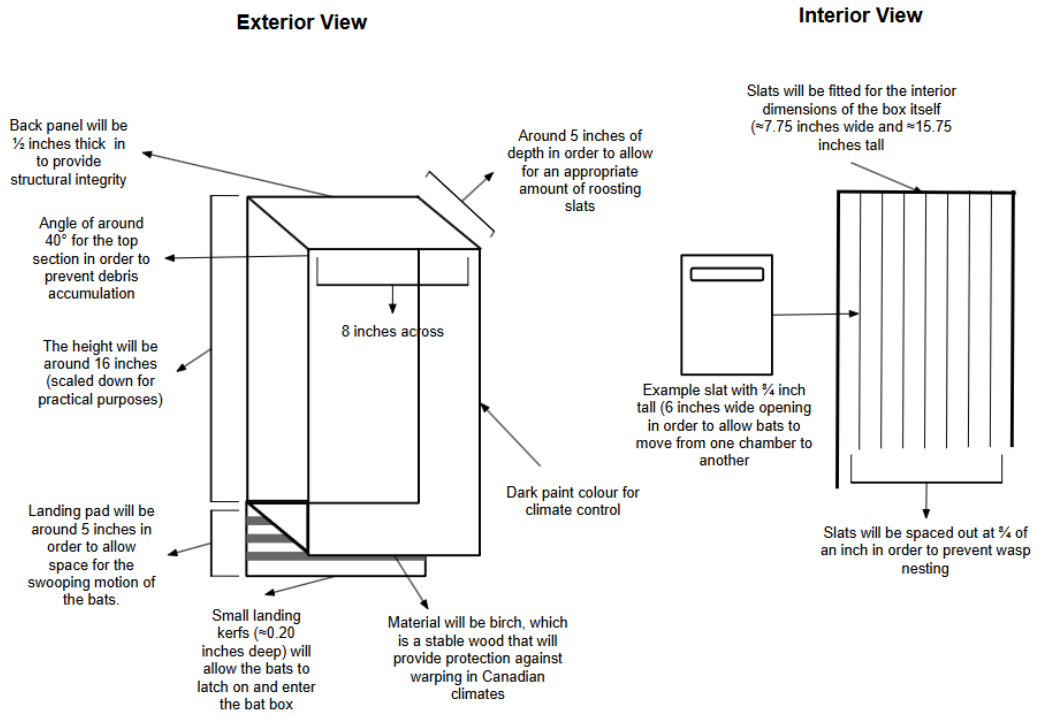

Figure 2: An outside view of the team's final design. This will be the model that the demonstration prototype is built to look like. The team plans to create a scale model with an exploded side to allow viewing of all components.

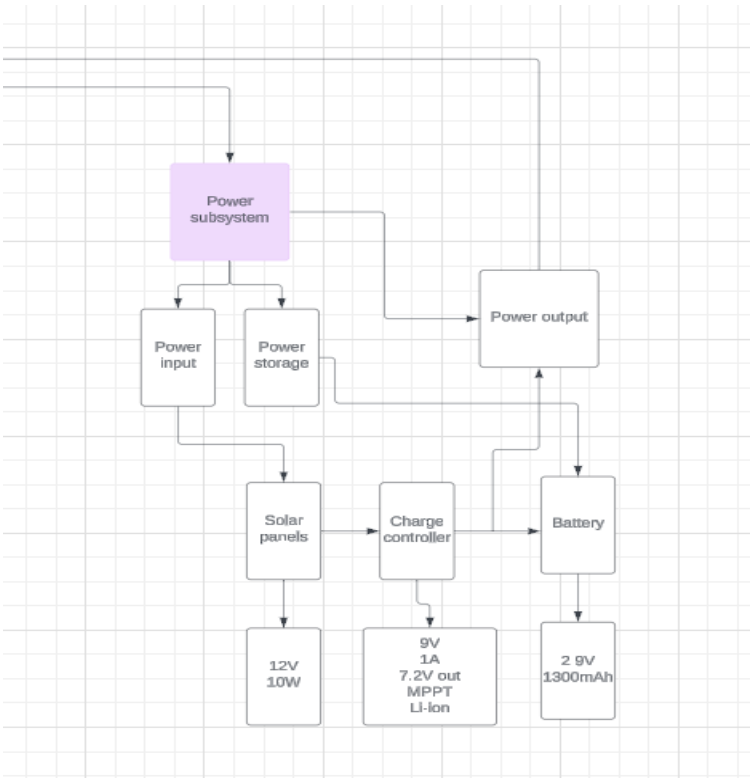

Figure 3: A brief overview of the power system. The solar panels charge the batteries, which then power the Arduino Nano. The Nano provides power for all other electrical components.

3 – Tasks and Agenda

3.1 – Task Plan

Task	Description	Duration
Assemble Arduino and IR sensor.	Build a circuit that allows the Arduino Nano to receive information from the SHARP IR sensor.	1 hour
Draft code for data collection and operation.	Create a code that can print and export data from the sensor. Interrupts will be used.	2 hours
Simulated load testing of clamp and case.	Create a model of the relevant components and test them under different loads.	2 hours
Test charging and discharging of batteries.	Using a multimeter, check the amp-hours and voltage that the batteries can store and release.	4 hours
Assemble sensor and power system.	Assemble the sensor and power system. Check if they can run without any external power	4 hours
Assemble bat box and clamp.	Build the scale model of the bat box, as well as the clamping system.	6 hours
Combine the circuit with the physical model.	Place the sensor and power system onto the dummy bat box.	2 hours
Prepare for the demonstration.	The team will prepare a poster board to present. A dummy bat will also be used to demonstrate the values the sensor can output.	8 hours

Table 1: A task plan for the three prototypes the team plans on creating. Each task is a major step that, cumulatively, will create the design that the team plans to present. This task list is not the same as a task list for assembling the completed design.

3.2 - Risks and Contingency Plans

There are a few risks the team could encounter during the building and testing of the prototypes.

One risk is the chance of certain components breaking. The team will be ordering specific electronic components for the bat box sensor. Should one of these components break during assembly, testing, or delivery, it could seriously affect the project's timeline. Ordering a new part would take some time, and it would eat into the team's budget. None of the components in these designs are particularly fragile, so this has a low risk of happening. The team's contingency plan involves ordering a few extra parts. These components are very cheap, and the team will use its leftover budget to order extra parts just in case.

It is possible that, for an unforeseen reason, a team member may not be available to work on future deliverables. Many unfortunate things could happen to a team member between now and December; this includes sickness, emergencies, or dropping out of the course altogether. These scenarios are not likely, but in the event of them happening the team needs to be prepared to dramatically alter its way of working. First, the team will contact the professor and inform them of a team member's absence. Next, the entire designation of tasks will need to be changed. Finally, all team members need to be prepared to spend more time on the course. Hopefully a situation like this never occurs.

One final risk that is more likely to occur is the chance that the testing and iterating takes a lot of time and skill to ensure the team's design works. During the testing, it is expected that the team will need to alter the physical placement of the sensors, as well as the code controlling the collection of data. Since the design needs to collect and output very specific data, it is possible that the team will struggle to code or secure the sensor during this testing. Should this process take longer than expected, it will certainly impact on the timeline for the rest of the project. To prepare for this, the team will create drafts of the code beforehand, as this will significantly reduce the time spent coding after everything is connected. Also, additional research will be performed to ensure the sensor collects data without interference.

4 – Project Budget

Bill of Materials (BOM)

Item	Quantity in Pack	Quantity needed	Cost Per Pack	Packs needed to buy	Real Cost	Project Cost	Exclude from Alt. Project Cost
IR Sensor	1	1	$13.37	1	$13.37	$13.37	☐
3.7V/3100mAh battery	1	2	$10.00	2	$20.00	$20.00	☐
9V/333mA Solar Cell	1	1	$16.01	1	$16.01	$16.01	☐
9Vin/7.4Vout Charge controller	1	1	$12.98	1	$12.98	$12.98	☐
Arduino nano	1	1	$8.00	1	$8.00	$8.00	☐
Wire	1	1	$0.34	1	$0.34	$0.34	☐
SD card reader	3	1	$10.06	1	$10.06	$3.35	☐
Micro SD card 32Gb	1	1	$5.64	1	$5.64	$5.64	☐
Prototyping board 3*7cm	1	1	$1.25	1	$1.25	$1.25	☐
Zinc-Plated Steel Hex Nuts	100	2	$3.11	1	$3.11	$0.06	☑
Uxcell 304 Stainless Steel Fully Threaded Rod	5	2	$15.54	1	$15.54	$6.22	☑
Birch Plywood Handy Panels	1	1	$11.16	1	$11.16	$11.16	☐
Epoxy	1	1	$3.11	1	$3.11	$3.11	☐
Bearing	4	2	$7.90	1	$7.90	$3.95	☑
ABS filament	1	1	$3.90	1	$3.90	$3.90	☐
SPI.h library						**$0**	
SD.h library						$0	
					$132.37	**$109.34**	
						Alt Project Cost:	
						$99.11	

Table 2: A bill of materials for the team's prototypes. This bill of materials reflects how much money the team will need to spend on each component. As the budget is only $100, the team had decided to exclude some of its more ambitious ideas from the design, resulting in the final Alt. Project Cost. For example, the clamping mechanism and thermistors are excluded from this BOM as they do not fit within the budget. The team will try to implement these features as the project continues if there is any way to do so.

Note that the project cost is less than the real cost because certain items are only available in multipacks or in bulk, so they raise the initial cost for a single prototype. In the real world, more than one would be manufactured at a time, and that is represented in the table as the project cost which is a true BOM cost per unit produced.

Links:

IR Sensor	https://www.amazon.ca/GP2Y0A21YK0F
Battery	Makerspace
Solar Cell	https://www.amazon.ca/Polycrystalline-Battery-Charger
Charge Controller	https://www.amazon.ca/DKARDU-Lithium-Battery-Charger-Protection
Arduino Nano	Makerspace
SD card reader	https://www.amazon.ca/CANADUINO%C2%AE-Micro-SD-Adapter-Arduino-Converter
SD card	https://www.canadacomputers.com/
Prototyping board	Makerstore
Nuts	McMaster
Threaded Rods	Amazon

Plywood	Home Depot
Epoxy	Dollarama
Bearings	Great Hobbies
ABS Filament	Makerspace

List of Equipment

Item Name	Description	Type	Prototype #	Source
Soldering Iron	Can connect wires and components.	Equipment	#2-3	Already owned by group members.
Arduino Coding IDE	Downloadable on any laptop, necessary for coding.	Software	#1-3	
Multimeter	Can be used to check circuit current and voltage.	Testing	#1-3	
Electrical Drill	Used to attach components to the bat box.	Equipment	#2-3	
Paintbrush	Will paint final prototype.	Equipment	#3	
Hacksaw	Will shape wood into bat box prototype.	Equipment	#2-3	
Breadboard	Will build an initial circuit to test.	Temporary Material	#1	
Bat Dummy	Used to check sizes and movement throughout prototype.	Testing	#3	Can be sourced from a Halloween store, attached to a pully.
Laser Cutter	Used to cut out specific shapes from plywood.	Equipment	#3	Maker Space
3D printer	Used to print electronics enclosure and knob.	Equipment	#3	JMTS
M4 Thread Tap	Used to tap threads into the plywood.	Equipment	#3	JMTS
Drill press	Used to drill holes into plywood for rod to pass through.	Equipment	#3	Brunsfield
SolidWorks	Used to model bat box and sensor attachment mechanism. Used for FEAs.	Software	#1-3	Already owned by group members

Table 3: A list of equipment that the team will need to create the prototypes. This equipment will not be included in any of the prototypes, nor will it be presented alongside the design.

5 – Prototyping Test Plan

There will be a few tests the team can perform to see if the prototype will be successful. The first thing the team should test is the IR sensor connected to the Arduino Nano. This can easily be tested by printing values the sensor is sending and comparing it to the distance to the object in front of the sensor. This will be a test of both the team's code as well as sensor functionality. Other sensors can then be added on to fully test the code and experiment with formatting the received data. The team can also begin testing the clamp mechanism during this stage, through CAD models and FEAs. This will ensure that the design is theoretically sound before committing to a physical model.

The next test the team will perform involves the solar panels and batteries. The team will test the charging capabilities of the power system and compare the data to what we expect the sensors to use. After, the team can test how long the sensors remain operational and see if any changes in sensor operation need to be made. For example, the team could change how often the sensors collect data. As this sensor should be able to work independently of the laptop power source, the team will also test whether exporting data back onto a laptop works.

For the prototype meant for design day, a test of structural stability of the final bat box should be performed. First, a SolidWorks simulation will be made, testing different possible loads on the box. The team will also test the clamping mechanism and see if it can be implemented. Next, the team will observe how the bat box demo holds up when moved around, and when all components are attached. The worst case-scenario is a rapid unscheduled disassembly during the design day presentation.

Below is a list of the tests the team will complete:

Test ID	Test Objective	Description of Prototype used and of Basic Test Method	Description of results to be recorded and how they will be used	Estimated Test duration and planned start date
1	Check circuit integrity of IR sensor and Arduino Nano.	With prototype 1, a multimeter will be used to test each component of the circuit.	If voltage and current are reading as expected while the sensor is operational, this test will be a success.	2 hours 31/10/2024
2	Test the code and ensure all data will be accurate under the known constrictions.	Using prototype 1, run all code and print all values.	Observe if printed values are accurate, consistent, and repeatable in the case of a demonstration.	2 hours 31/10/2024

3	Check power input and output of batteries when connected to the solar panel.	Using a multimeter on prototype 2 and some good lighting conditions, the watts in and out can be recorded.	If the battery and solar panel behave as advertised, the team will know that there will be no issue with the system's power supply.	12 hours 2/11/2024
4	Test the combined power system and sensor.	Prototype 2 will involve the sensor and power system to be connected. This model will be independent of any external power.	The sensor must maintain its accuracy and functions. The team will record how long the sensor is successfully active, as well as how the volume of data can affect this	10 hours 9/11/2024
5	The objective of this test is to determine if the parts of the clamping mechanism can move as intended relative to each other. The purpose of this is to ensure a full range of motion such that the mechanism can fit onto any dimension and place enough clamping force. Furthermore, the smoothness of the movement will be observed in this test.	The prototype will be a physical model that accurately depicts the final product. This prototype will follow the drawing outlined in Section 2. The test will consist of turning the threaded rod to move the moving jaw to its minimum and maximum forward position.	The maximum and minimum distance will be recorded. The intended results are for the moving jaw to contact both fixed ends, thus indicating the clamp has a full range of motion. If this criterion is not met, the length of the threaded rod or distance between both fixed ends will need to be adjusted. To analyze the ease of movement, visual observations will be made and any resistance when turning the knob will be noted. If there's any impedance present adjustments will need to be made to the contact surface between the plywood and threaded rod.	4 hours 9/18/2024
6	The objective of this test is to determine the clamping force the mechanism produces.	Using the same prototype as above, weights will be added within the enclosure at increasing increments. The weights that will be tested will start from	The maximum weight capacity that the clamping mechanism can carry will be recorded. This will determine the max operating conditions of the mechanism to ensure it is being used within its limits.	3 hours 9/20/2024

		100 g and increase until the mechanism slides off. The clamping mechanism will be secured on to a suspended piece of plywood.	If the maximum weight is not enough to carry the electronics adjustments to the grips of the jaws will be done.	
7	Test all components together	Assemble all parts of the project in prototype 3. Check all functionalities.	The prototype should work as intended. It will output accurate values in a demonstrable way. This will be important, as it will be the model the team is presenting.	5 hours 25/11/2024

Table 4: A description of the various tests the team plans on performing on the prototypes. Each test is instrumental in ensuring the team has a working design. If the Test ID number is red, it means that this test cannot be completed until all the previous tests have demonstrated satisfactory results. For the green Test ID numbers, these are tests should the clamping mechanism be implemented.

6 – Conclusion

Our detailed plan explains all the metrics of the design we need to test as well as what will be a part of each prototype iteration. This provides a strong framework for the next stages of the project and will ensure the final design is functional and completed on time. Also, our budget spreadsheet outlines the cost of all the aspects of the project and keeps our outline within the $100 constraint. This budget can be altered as we test our prototypes. For example, if we find alternative materials for the construction of the bat box that are cheaper, we would update the budget accordingly. If extra leeway is permitted in the budget, the team plans to implement its more ambitious designs.