Progress Report

Industrial Ground Vibration Simulator for Investigating Vibration Effects on the Development of Turtle Eggs

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December 9, 2022

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Abstract

The Davy Lab, in the Department of Biology at Carleton University, conducts conservation studies to better understand how environmental changes affect locally vulnerable bats, amphibians, and reptiles. This experiment looks at how ground vibrations from nearby industrial activity and highways impact turtle egg growth. Meia Copeland, Shawaiz Khan, Talal Jaber, Marwan Zeyada, and Ranishka Fernando are engineering students working on a tool that can replicate the ground vibrations caused by diverse industrial operations so that the lab may explore these effects in a controlled setting.

To simulate vibrations from diverse industrial sources, this device will replicate ground vibrations between 2 and 20 Hz, with displacements ranging from 0.1 to 1 mm. The device's surface will be 30 cm X 30 cm, large enough to accommodate one egg incubation tub. This surface will be used to calculate displacement. The device will be able to produce vibrations constantly or at regular intervals for up to 95 days, the incubation period for snapping turtle eggs [11].

This report will begin by addressing issues about an engineering project, such as health and safety, professionalism, project management, and the justification and applicability of the project to each team member, as well as current progress made up to date. The research that influenced the team's approach to developing the vibration simulation device and its components will be discussed, including approaches that worked and did not work. The simulator's design will be discussed as well. Finally, the work plan will include project milestones, activities, and a budget breakdown.

The team aims to have a research-ready version of this device available by April 2023, so that the Davy lab may begin research and share the results with other laboratories that require such a device.

1 Introduction

The Davy Lab at Carleton University conducts conservation research to better comprehend how local environmental changes impact threatened species of bats, amphibians, and reptiles. One of these projects investigates how ground vibrations from adjacent industrial activities and roadways affect the growth of turtle eggs.

Engineering students Meia Copeland, Shawaiz Khan, Talal Jaber, Marwan Zeyada, and Ranishka Fernando are developing a tool that can simulate the ground vibrations produced by various industrial activities so that the lab may investigate these impacts in a controlled environment.

1.1 Background

As Ontario's population steadily grows, so too does the urban sprawl of its cities. In Canada, three out of four Canadians live in urban areas, with the highest growth being in city suburbs [1]. This urban sprawl requires extensive road networks, housing, power, and other amenities—all of which impact the local ecosystems present in these areas. Roadways and other industrial activities disturb local ground-dwelling species by destroying burrows, fragmenting habitats, contributing to wildlife death through collisions, and influencing survival and breeding success of species [2] [3]. Most research addresses the effects related to the presence of roadways, industrial activities, and power generation. However, the effects of ground vibration produced by these sources is not as well understood.

Industrial sources of vibration come primarily from construction, including blasting, pile driving, bulldozing, vibratory compaction, jackhammering, and general use of heavy machinery. These vibrations have a frequency range of 20 – 45 Hz, and a displacement range of 0.27 – 1 mm [4]. These vibrations do not occur continuously, rather in intervals over a long period of time [5].

Road- and railways are a significant source of ground vibration, especially highways which contribute consistent vibration for long periods every day. Vibration due to road traffic is between 10 – 20 Hz, with a displacement range of 0.16 – 0.8 mm. Railways generate a similar vibration, but do not consistently produce vibration the same way highways can.

Power-generation are also sources of ground vibration, and stations or facilities are often located further from cities, where animals are more likely to live. Wind power, hydroelectric, and nuclear are the most common power-generation facilities found in Ontario. On-shore wind farms have been shown to produce low-frequency ground vibrations for many kilometers surrounding the turbines [6]. Some studies have investigated the impacts these vibrations have on the stress levels and behavior of ground-dwelling animals. While some terrestrial animals have shown increased levels of stress-hormones around wind turbines [7], the behavior of most terrestrial animals has not been shown to be significantly affected [8]. The ground vibration produced by wind turbines depends on the distance from the base of the turbine. Approximately 90 m from

the base of a turbine, the typical vibration has a frequency range of $2 - 10$ Hz, with a displacement around 300 nm [9]. Hydroelectric power plants can also generate ground vibrations from the turbines inside the facility, as well as the flow of water exiting the facility. These vibrations are particularly intense during flooding, where a significant amount of water is passing through the dam, however vibrations are detected during regular water flow as well [10]. However, most conservation research studies the impacts on fully aquatic species, and little literature is available on the effects on ground-dwelling species. Further, no literature could be found with exact measurements on the ground vibration produced. This was also the case for nuclear power plants.

1.2 Motivation

Initially, the motivation for this project was to determine the effects wind turbines have on native species that may live or nest nearby. However, due to the small displacement created by the ground vibration of wind turbines, the scope was increased to include industrial activities, roadways, and power generation. The Davy Lab would like to investigate the effects of ground vibrations from various sources on the development of turtle eggs.

Our objective is to develop a system that will enable the Davy Lab to measure environmental parameters like temperature and humidity while simulating and controlling these ground vibrations in a laboratory setting.

1.3 Project Objectives

This device will simulate ground vibrations between 2 and 20 Hz, with displacements of $0.1 - 1$ mm to simulate vibrations caused by various industrial sources. The device will have a 30 cm X 30 cm surface, large enough to place one egg incubation tub. The displacement will be measured from this surface. The device will be able to create vibrations continuously or in intervals for up to 95 days, which is the incubation period for snapping turtle eggs [11].

1.4 Report Outline

This progress report will begin by addressing concerns regarding an engineering project, such as health and safety, professionalism, project management and justification and suitability of the project to each team member. The research behind the team's approach to creating the vibration simulation device and its components will be explained in detail, including concepts that did and did not work. Then, the design of the simulator will be described. Finally, the work plan with project milestones, activities, and a budget breakdown will be included.

2 The Engineering Project

2.1 Health and Safety

The Health and Safety Manual provided by Carleton is used to keep in mind and address the standards and practices for a safe and healthy system for the project. The focus is Section 13 of the Health and Safety Guide (Tools and Machinery). Any defects in equipment would be reported as soon as noticed and would be taken care of. The user (Davy Lab) will be instructed and trained to operate the system properly, with thorough documentation provided to enable the lab to perform regular scheduled maintenance. Section 6.12 (Electrical Equipment and Apparatus) was also kept in mind. More specifically, Extension cords (if used) for the system will not be used for permanent installations. If applicable, ground fault circuit interrupters will be used if there is a risk of an operator encountering water and electrical equipment simultaneously (depending on the placement of the system in the biology lab).

2.2 Project Management

One of the goals of this engineering project is to get real experience in working on a long-term team project. Therefore, the team uses industry level project management techniques to coordinate, manage, and execute project. Instead of sticking with one management technique, multiple techniques are utilized.

A Work Breakdown Structure (WBS) is applied as a tool to break down the project into chunks of manageable tasks for the team to understand and accomplish (e.g. Research, Implementation, Testing). Additionally, Gantt charts are also used as an organizational tool to emphasize visuality. It is used in the project to see task dependencies, duration, and various deadlines ranging from report deliverables to chunks broken down from WBS. Using the WBS allows for tasks to be accurately defined in the Gantt chart.

A Waterfall development method is used as the primary project management technique, due to the distinct phases that require few iterations throughout the project lifecycle. Activities and tasks flow linearly through five phases (Requirements, Design, Implementation, Verification, Maintenance).

2.3 Justification and Suitability for Degree Program

Table 1 - Roles, tasks, and relevant experience for each team member.

Team Member	Tasks	Justification
Meia Copeland *Computer Systems Engineering*	Linear Actuator Design	CAD experience from ECOR 1010 and personal projects
	Simulation	Simulation using ANSYS in ELEC 3105, and personal projects in Fusion 360
	Signal processing	Knowledge of signal processing from SYSC 3600 and SYSC 4505
	Hardware-Software interfacing	Experience in multiple hardware-software projects in SYSC 3010 & 4805
	System integration	Significant experience through degree program and professional experience
	Project management	Extensive experience working on projects through CO-OP, and knowledge from SYSC 3010 & 4805
Shawaiz Khan *Computer Systems Engineering*	Database	Experience in projects in SYSC 3010
	User Interface	Experience in projects in SYSC 3010 and an intro in SYSC 2004
	Hardware Integration	Experience in multiple hardware-software projects in SYSC 3010 and SYSC 4805
	Software Integration and testing	Experience in multiple hardware-software projects in SYSC 3010 and SYSC 4805
Talal Jaber *Electrical Engineering*	Electrical design	Designing required PCB for the system
	Hardware integration	Choosing the right motor and driver for the project in Elec 3907
	Simulation	Simulation using ANSYS in ELEC 3105
Marwan Zeyada *Computer Systems Engineering*	User Interface	Experience in projects in SYSC 3010 and SYSC 2004
	Hardware Integration	Experience in projects where hardware is the focus: SYSC 3010
	Database	Extensive experience in SYSC 3010 and other projects
	Software integration and testing	Great experience in software integration and testing due to working on multiple projects of that nature
Ranishka Fernando *Electrical Engineering*	Electrical design	Designing required PCB
	Hardware integration	Construct required circuitry and setting up the motor for testing – Experience from ELEC 3907 and past work experience as a Hardware Consultant

	Debugging	Extensive experience in development and operations through CO-OP and knowledge acquired from ELEC 2607 and ELEC 3500
	Simulation	Simulation using ANSYS in ELEC 3105
	Linear Actuator Design	CAD experience from ECOR 1010

Collectively, the team has all the necessary skills and knowledge to be successful on this project. Requirements for this project mostly involve electronics or computer systems techniques previously learned, with some very basic mechanical engineering and CAD that was learned in first year general engineering courses such as ECOR 1010 and ECOR 1101.

Further, this project involves working closely with a client, the Davy lab. These project management and client-interaction skills were learned in courses such as CCDP 2100, ELEC 3907, SYSC 3010, SYSC 4805, and ECOR 4995. Most team members have some co-op experience, where working professionally with other engineers and clients was learned.

2.4 Individual Contributions

2.4.1 Project Contributions

Table 2 - Contributions of each team member to the project components.

Component		Contributor
Linear Actuator	3D modelling	Meia Copeland
	Simulation Testing	Talal Jaber
	3D printing	Meia Copeland and Ranishka Fernando
	Motor Control	Meia Copeland, Talal Jaber, and Ranishka Fernando
	Actuator Testing	Ranishka Fernando
Shake Table	Table Support Design	Meia Copeland and Talal Jaber
	Assembly	Meia Copeland, Talal Jaber, and Ranishka Fernando
	Suspension System Testing	Ranishka Fernando
Wiring	PCB Design	Talal Jaber
	Assembly	Meia Copeland and Talal Jaber
Motors	Step Motor testing	Talal Jaber

Environmental Sensors	Hardware connection	Shawaiz Khan and Marwan Zeyada
	Software Integration	Shawaiz Khan and Marwan Zeyada
	Testing	Shawaiz Khan and Marwan Zeyada
Database	Schema design	Shawaiz Khan
	Implementation	Shawaiz Khan and Marwan Zeyada
	Testing	Shawaiz Khan
User Interface	UI Design	Marwan Zeyada
	Implementation	Marwan Zeyada and Shawaiz Khan
	Testing	Marwan Zeyada

2.4.2   Report Contributions

Table3 3 - Contributions from each team member to the Progress Report document.

Progress Report			Contributor
Introduction	Abstract		Ranishka Fernando
	Background		Meia Copeland
	Motivation		Meia Copeland
	Project Objectives		Meia Copeland
	Report Summary		Meia Copeland
The Engineering Project	Health and Safety		Shawaiz Khan
	Project Management		Shawaiz Khan
	Justification and Suitability for Degree Program		All members
	Individual Contributions	Project Contributions	Meia Copeland
		Report Contributions	Meia Copeland
Research	Measuring Linear Displacement		Ranishka Fernando and Meia Copeland
	Methods of Vibration Simulation	Linear Actuator	Ranishka Fernando
		DC Brushless Motor	Talal Jaber
	Database Options		Shawaiz Khan
	User Interface Framework		Marwan Zeyada

Vibration Simulator Design	Simulation of Linear Displacement	Meia Copeland, Talal Jaber, and Ranishka Fernando
	Database	Shawaiz Khan
	User Interface	Marwan Zeyada
Work Plan	Project Milestones	Meia Copeland and Shawaiz Khan
	Schedule of Activities/Gantt Chart	Meia Copeland and Shawaiz Khan
Budget Breakdown	Hardware	Meia Copeland
Conclusion		Meia Copeland

3 Research on Simulator Design

3.1 Measuring Linear Displacement

To ensure that the correct displacement is achieved, the movement of the surface must be measured. Since the device will only be vibrating the surface up and down in the Z-direction, a linear displacement sensor can be used. These sensors are available with many different technologies, such as linear potentiometers, linear variable differential transformers, capacitive displacement sensors, or laser displacement sensors. Due to budget constraints of the project that will be discussed later in this document, the sensor used would ideally be under $500 to implement.

Linear potentiometers are sensors that use variable resistance to measure position. Linear motion is converted to a changing resistance which can be directly converted to a voltage or current output. This output can be read by a computer to determine the displacement of the measured surface. Technically, potentiometers have infinite resolution due to the analog nature of the changing voltage, however the smaller the measurement, the more it is affected by factors such as noise and the number of bits needed to convert to a digital value. The downside to using a potentiometer is the physical movement of the measuring device. Most potentiometers use a mechanical piece that moves to create resistance, which is subject to wear and tear. Since for one experiment, a slider would be expected to move up to 42 million times (5 Hz for 95 days), any sensor used would have to be made of industrial uses.

Capacitive sensors are no-contact sensors, which use an electric field to detect the target's position thanks to interference with the electric field. This would eliminate the risk of wear and tear, as the device would not be in contact with a moving surface. However, upon inquiring about

prices, sensors capable of detecting displacement within the desired range were over the budget of $500 for the sensor, and an additional $5000 for the required signal processing unit and cables.

Another measurement tool that uses capacitance to measure displacement are calipers. Digital calipers are capable of measuring with extreme precision. However, these are generally used as diagnostic or testing tools, not for continuous measurement. The frequency at which this tool can measure the displacement is not clear and suspected to be lower than the desired minimum of 2 Hz. Further, wear and tear is an issue since these measurement tools use contact to measure displacement. However, these devices are under $500 and may be useful as a testing and diagnostic tool during the development cycle of the project.

Laser displacement sensors, often known as point lasers, use triangle reflection to measure a single point. Laser profilers, on the other hand, measure the complete length of a line. The measurement precision of laser displacement sensors is great, but the efficiency is low due to point-by-point data collection [26]. Given the precision, using a laser to measure linear displacement would be ideal. However, it does not fit within the price point. Conducting laser measurements for millimeter range is within the price point, but measuring nanometers is beyond price point as it exceeds over a thousand dollars per sensor or instrument that is available to be purchased off the shelf.

Linear variable differential transformers (LVDTs) convert the mechanical motion of an object, usually a tubular element that can move along a rod, into an electrical signal using induction. Therefore, LVDTs are not subject to wear and tear like the linear potentiometer and could be used continuously or in intervals many experiments. Preliminary searches show that LVDTs capable of measuring within the desired range of 0.1 – 1 mm and with sampling frequency of over 100 Hz are within budget [12]. Further inquiries have been made to suppliers.

3.2 Methods of Vibration Simulation

Over the course of the turtle eggs' 65 to 95-day incubation cycle, vibration treatment would need to be given continuously or in intervals [8]. The use of DC brushless motors was studied over the course of literature research and investigation on prospective vibration methods, and they will be presented here.

3.2.1 Linear Actuator

A linear actuator is a device that converts the rotational motion of an AC or DC motion into linear motion, usually with a series of gears and a lead screw to create a push and pull motion. Since a linear actuator may be used to push or pull with the same force, it can be used to raise, lower, slide, modify, and tilt things. [13]

The primary reason linear actuators were investigated was due to the desired motion being in one direction. Simple linear actuators are available off the shelf, however most are not capable

of running at the desired frequency of 2 – 20 Hz. Upon further research, a solution using a different design for a linear actuator was found. Using a flexure, which deforms in one direction when subjected to the rotational motion of a motor, a much higher frequency can be achieved. The design investigated was the fine positioning mechanism of the linear actuators used to control the mirrors on the James Webb Space Telescope (JWST), as design by Ball Aerospace [14]. An openly available 3D replica of this actuator was created by Thingiverse user Polyfractal [15]. The design is capable of a 26 μm displacement as-is. The model can be customized by changing the dimensions of the flexure, to achieve the desired displacement of 0.1 – 1 mm. This solution is extremely cost-effective, as it can be printed for no cost using tools provided by Carleton University.

3.2.2   DC Brushless Motor

A mechanical solution was revisited, as most students in the group had some experience with systems involving motors. This solution first examines a simple vibrating motor attached under a tabletop with some insulating pads near the legs for eliminating noise. First looked at was a brushless 3-phase motor with a PWM controller to control the RPM of the motor. PWM, or pulse-width modulation, is a way to control the input power by pulsing the signal which reduces the average voltage. RPM (revolutions per minute) is directly proportional with the frequency of vibrations. However, most small motors have a limit where the vibration frequency stops decreasing at around 30 Hz which is the minimum vibrations a normal vibrating motor can go due to the size and weight constraint of the motor and shaft (Figure 1).
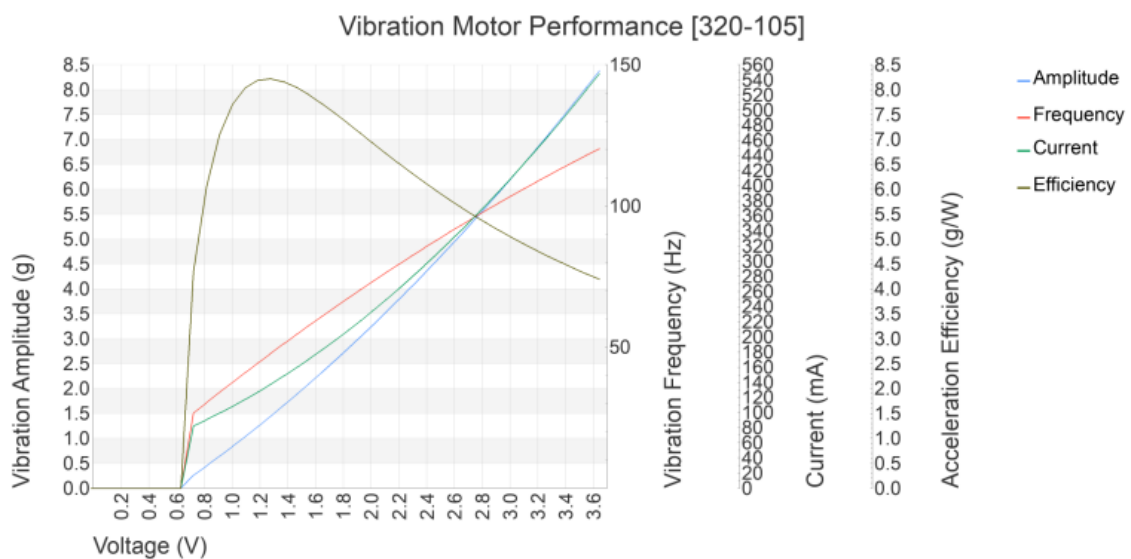

Figure 1 - DC motor frequencies [16]

The team settled on a three-phase brushless DC motor and the DRV10970EVM motor driver to control the motor using PWM. This motor was chosen because it hits the frequency needed without causing too much noise. Testing of a stepper motor will still be held since a stepper motor turns in both directions which can make the amplitude of vibrations even smaller using just small steps in alternating directions.

3.3 Database Options to Store Data Acquired

Keeping in mind the requirements of this project, a database was needed to store and retrieve data collected from various sensors of the design. A database schema is included in Section 3.4 of the proposal to further explain and illustrate the design.

Focusing on Relational database management systems due to them being the most widely used databases [17] and having previous experience related to it, our first choice was narrowed down between a 'Structured query Language' (SQL) and a 'Not only Structured Query Language' (NoSQL) types of databases, with pros and cons for both.

Other than being the most common database management approach, using SQL offered us faster query processing, and standardized and user-friendly language [17]. NoSQL on the other hand offers flexible scalability and flexible data types [18]. Taking the needs of the lab into consideration, flexibility would not be a big concern since our schema will stay consistent over time, NoSQL seemed excessive for this project, which is why we eventually prioritized SQL, although using NoSQL will be set as a stretch goal.

Under SQL, we narrowed our choices to industry standards, MySQL, and SQLite [19]. SQLite is a software library providing a relational database management system, not requiring servers to run, and is relatively easy to master when compared to MySQL [20]. MySQL on the other hand offers remote access and data security as well as the possibility of handling much larger amounts of data.

Keeping in mind the requirements of the project, although MySQL did seem like a better alternative considering its popularity and the scalability aspect of our design, its implementation on the Raspberry Pi is not as straightforward as initially expected. Raspberry pi uses a fork of MySQL called MariaDB. The lack of sufficient documentation and resources online gave us enough reason to implement SQLite first, more of which will be discussed in section 3.4.

3.4 User Interface Framework

The User Interface (UI) is one of the main components that determines the user experience and how effectively the device can be used. After researching the various options of frameworks available, mainly the python ones, our results got narrowed down to 2 options: Kivy and PyQT6.

Kivy and PyQT6 [21] are two of the most used python GUI frameworks in the industry. Kivy, was made from the ground up for mobile GUI design, with the purpose of making clean modern

looking GUIs that can be used on most system software like Linux, Windows, macOS, and Raspberry pi. It has great documentation but lacks on the online resources.

PyQT6 on the other hand, has almost all the same features as Kivy but has an extra important feature that will be of great use in our project. This feature is called QTDesigner [22], it's a program that allows you to seamlessly create GUIs by designing it on a 2D plane in a drag and drop fashion, and then adding functionality and style using python code. This allows for beautiful looking graphical interfaces that can be made with ease. Thus, we will be choosing the PyQT6 framework for our graphical user interface.

4 Vibration Simulator Design

4.1 Simulation of Linear Displacement

The 3D model replica (Figure 2) used as a starting point for the design is available under a Creative Commons license, provided by user Polyfractal on Thingiverse.com [15]. The specific components that will be used from the print are the flexure, frame and camshaft.
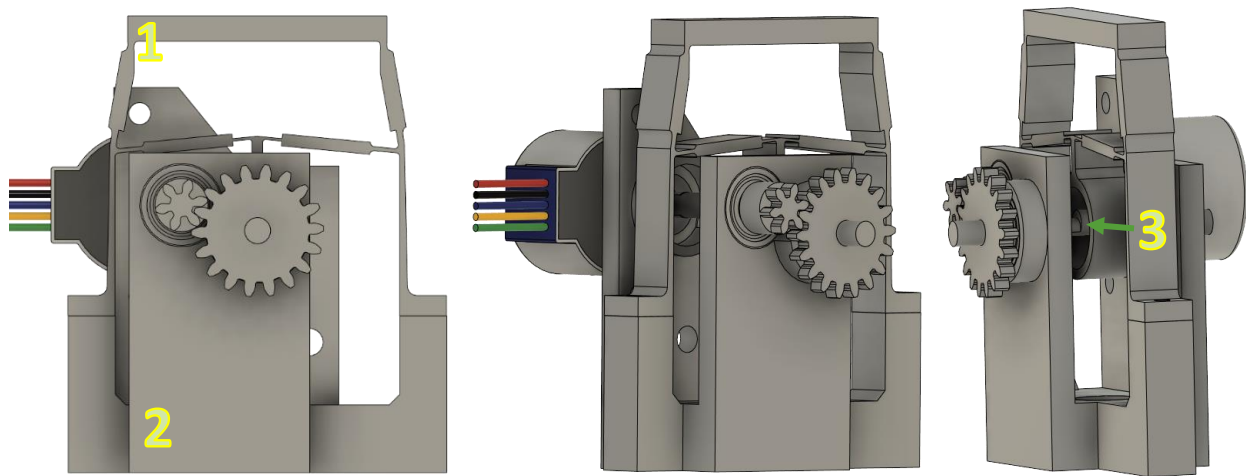

Figure 2 - Front and side views of the JWST Mirror fine positioning mechanism as designed by Polyfractal [15]. Components to be used are the flexure (1), frame (2), and camshaft (3).

This model replicates the James Webb Space Telescope (JWST) Mirror Actuator fine positioning mechanism, as described in a research paper by Ball Aerospace engineer Robert Warden [14]. The flexure and camshaft of this design can be altered to achieve the correct amount of displacement. Currently, the flexure is capable of 26 μm of displacement given a 1 mm offset on the camshaft (Figure 3). Changing the camshaft offset or the width/height of the flexure can increase or reduce the displacement further.

The flexure model was simulated in Fusion 360 [23] to test displacement capability. This method allowed for faster iteration on the flexure and camshaft design, which can then be printed and integrated into the system for further testing. To increase the displacement, decreasing the

height and/or widening the top of the flexure proved to be effective. Increasing the camshaft offset also increases the displacement.
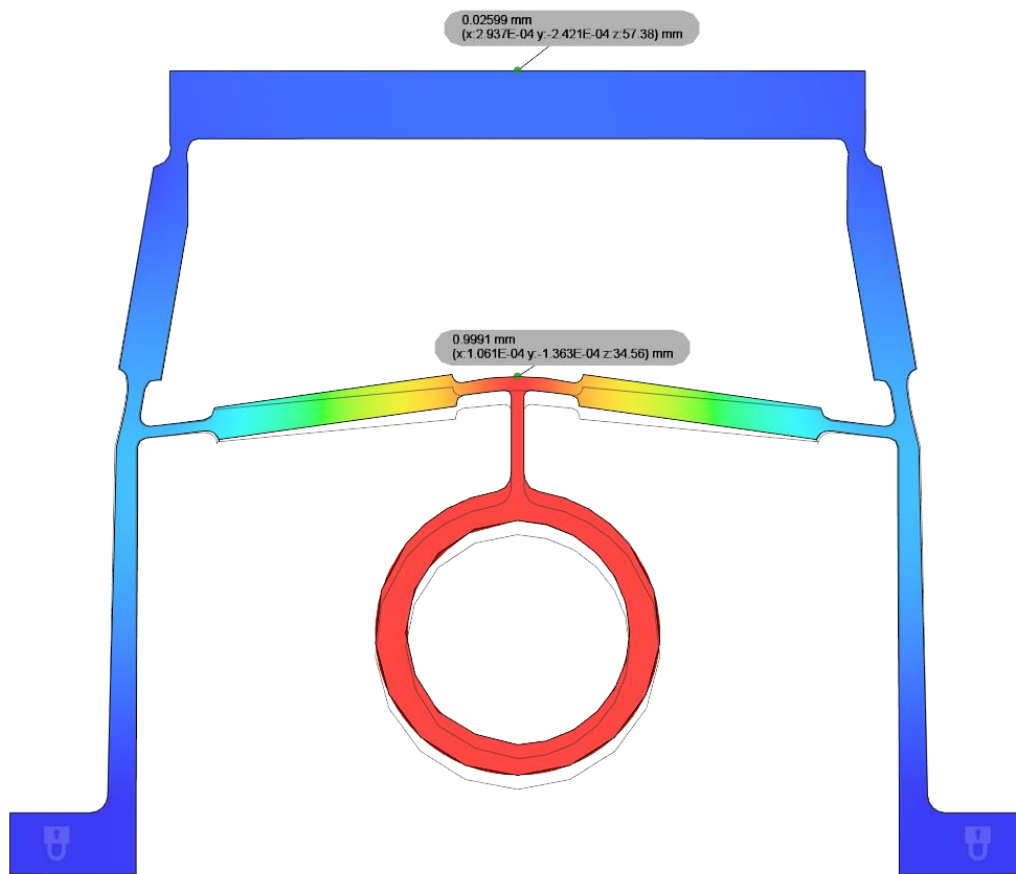

Figure 3 - Simulation result from Fusion 360. Simulation tested the original flexure design, with a 1mm camshaft offset. The displacement is measured to be 26μm.

A desirable displacement of 0.11 mm was achieved by widening the top of the flexure by ~2 mm and shortening the height by ~8 mm (Figure 4). The camshaft offset was increased to 3 mm. Importantly, the width at the bottom of the flexure was not changed, as to ensure it would fit with the frame. Further experimentation is required to determine dimensions required for various displacements from 0.1 – 1 mm to allow for a modular design.
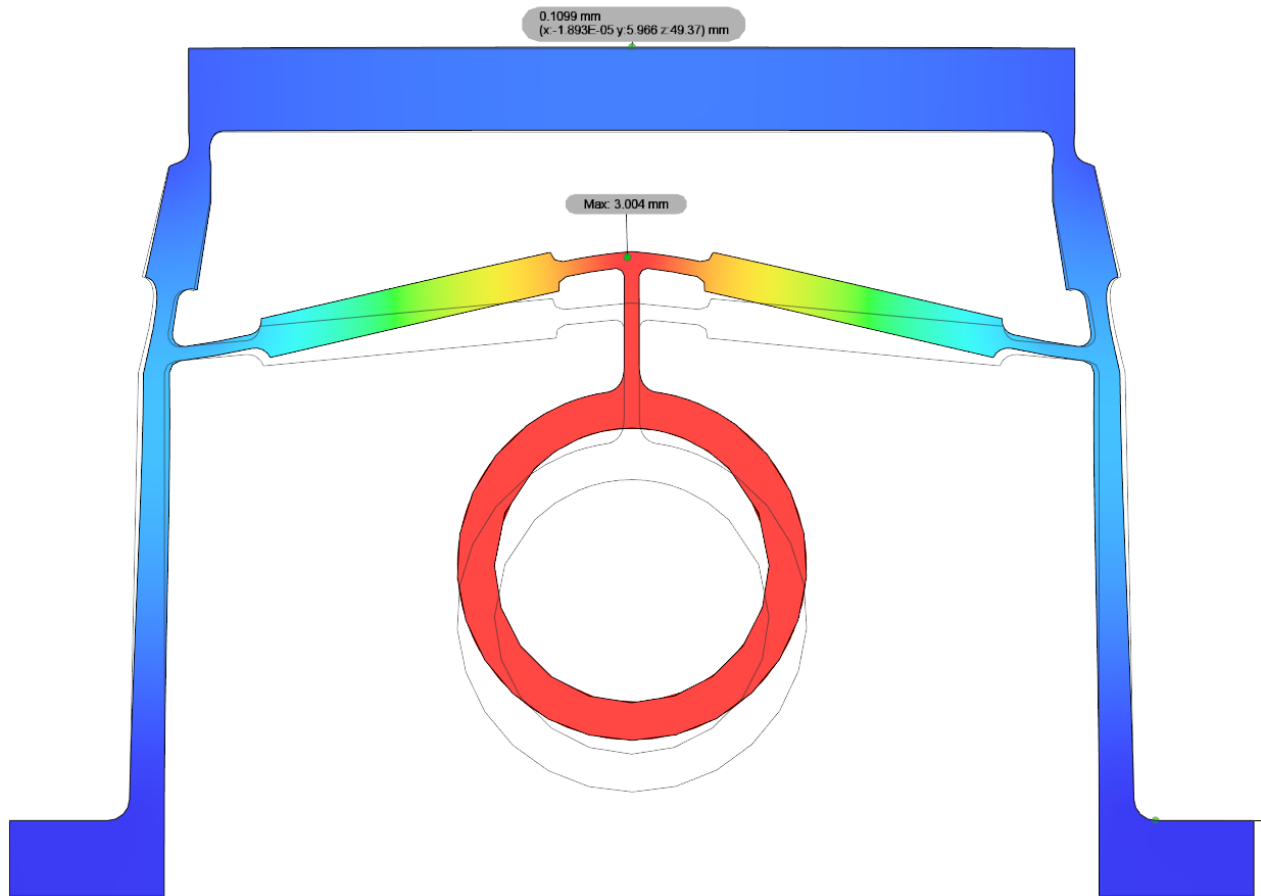
Figure 4 - Simulation result from Fusion 360. Simulation tested updated version of the flexure, with a 3 mm camshaft offset. The displacement is measured to be 0.11 mm.

Mechanical tests will use a 28BYJ-48 stepper motor and DC brushless motors. The gears from the print will be replaced by metal spur gears intended for RC cars. These gears are available as a 64-tooth output gear, and options of 17-tooth, 21-tooth, 26-tooth, and 29-tooth input gears. Other configurations are also available and will be tested as needed. The combination of these gears offers a significant reduction to the input frequency. The gears will be mounted to the actuator using 3 mm and 5 mm metal shafts, also intended for use in RC cars.

This design takes advantage of students' knowledge of electronics, CAD design, and control systems as was learned in courses such as ELEC 2507, ELEC 3105, ELEC 3509, ECOR 1010, SYSC 3600, and SYSC 4505. As well, this concept will exercise the team's ability to understand that where expertise is lacking, intuition and ingenuity can be used to take an existing solution and transform it to work for a new problem.

To arrive at a conclusion, a vigorous analysis will be conducted after considering the frequency, torque, and RPM along with noise produced and the motor that aligns with the required frequency, torque and amplitude with least noise will be chosen for the project. External factors

such as temperature will affect the experiment data thus a controlled environment at room temperature will be considered for the experiment.

4.2 Database

A Relational Database Management System (RDMS) using the MySQL tool was initially proposed to keep track of all the required stats. After further research and implementation, a database using SQLite was setup. This resulted in a schema different than the one presented in the proposal (see Figure 8 in Appendix 2).

Figure 5 below illustrates the updated schema used to store the project data. Every experiment would have an individual ID number, a species type, a collection date, a start time, an email associated with the experiment, a timestamp for when the values where taken, and a field to check the error status of the hardware.

id	INTEGER
species	TEXT
collection_date	DATE
start_time	DATETIME
email	TEXT
frequency	FLOAT
displacement	FLOAT
temperature	FLOAT
humidity	FLOAT
pressure	FLOAT
timestamp	DATETIME
error_detected	TEXT

Figure 5 - Database Schemas

Moreover, linked to each experiment would be the values gathered from the temperature, humidity, and pressure sensors, as well as the vibration frequency and displacement detected by the appropriately chosen sensor (accelerometer/linear position sensor) at a specified time interval. Additionally, a field would be used to keep track of hardware failures (a bit output of 1 for example in case of a part malfunction), and another field would be used to keep track of the exact time the above data was collected at.

id	species	Collection Date	Start Time	Email	Frequency	Displacement	Temperature	Humidity	Pressure	Error	Time
1	snapback	2023-06-23	2023-06-23 12:00	xyz@gmail.com	123.456	123.456	123.456	123.456	123.456	0	1:45
1	snapback	2023-06-23	2023-06-23 12:00	xyz@gmail.com	123.456	123.456	123.678	123.456	123.456	0	1:47

Figure 6 - Output as a CSV file.

The database will be stored as a ".db" file on the system. We will use a python code to convert it into a .CSV file (an example .CSV file is in figure 5 above) and email it to the email account associated with the specific experiment. A temporary email account associated with the lab to send out emails has been set up. However, an issue arose with emails regarding 2 Factor Authentication. Google's new security update restricts access to 3rd party applications without a

phone number. [24] Currently we are working on a way to send out emails without using a phone number for privacy reasons.

4.3 User Interface

The user interface (UI) provides a way that a user can interact with our device; therefore, it must be designed for efficiency and simplicity. Our design philosophy is to create a single interface for all devices (when there is more than one), which allows for easier access and control of all the devices present in the lab which will be done by having a tab for each device/experiment.

The framework and language to be used in the building of this UI is PyQT6 and Python respectively. A great feature of PyQt6 is its 2D design which allows for real-time designing of the UI on a 2D plane to then add functionality using code. This will streamline the UI process and allow for designs that are not as achievable as a pure code solution.
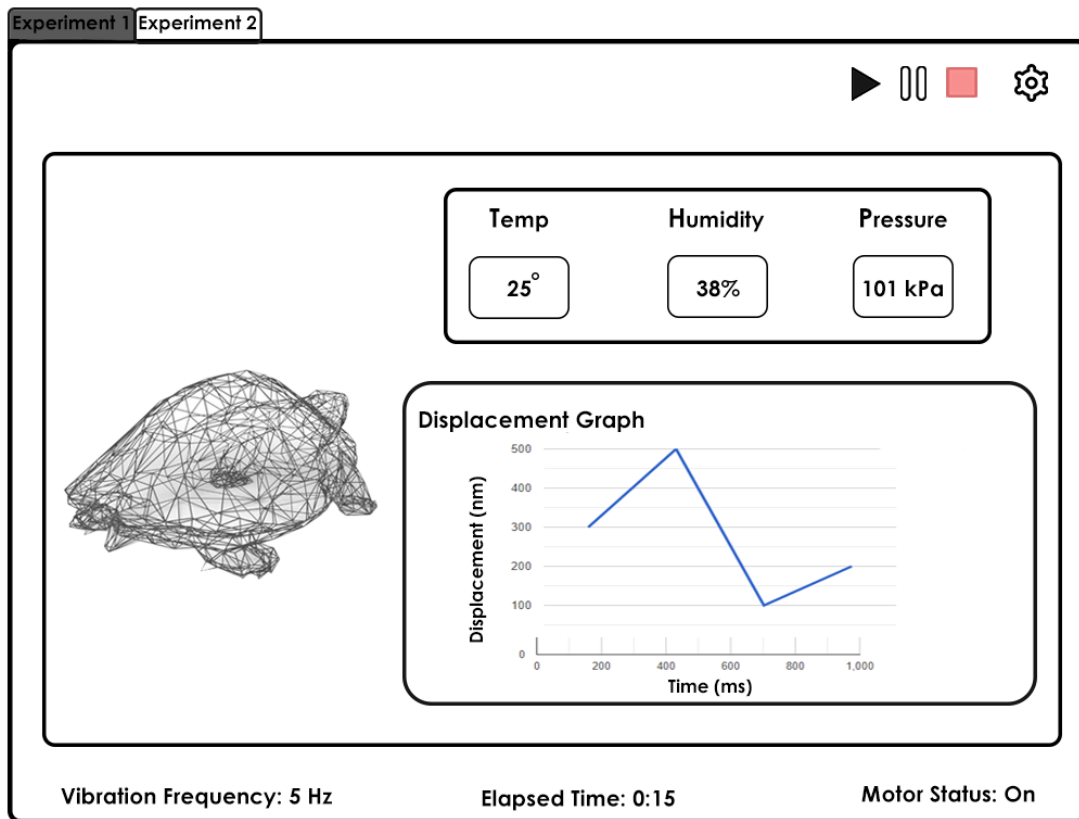

Figure 7 – Home screen UI Wireframe

Our UI consists of tabs, each tab is its own device/experiment. This allows for seamless switching and configuring of any device connected.

The main screen (Figure 7) provides plenty of useful information that can be seen in real-time such as data from the sensors, time elapsed in the experiment, and the status of the motor. From this screen you can stop, play, or pause the experiment. There is also a settings navigation icon which allows you to setup or change the experiment details on the fly.
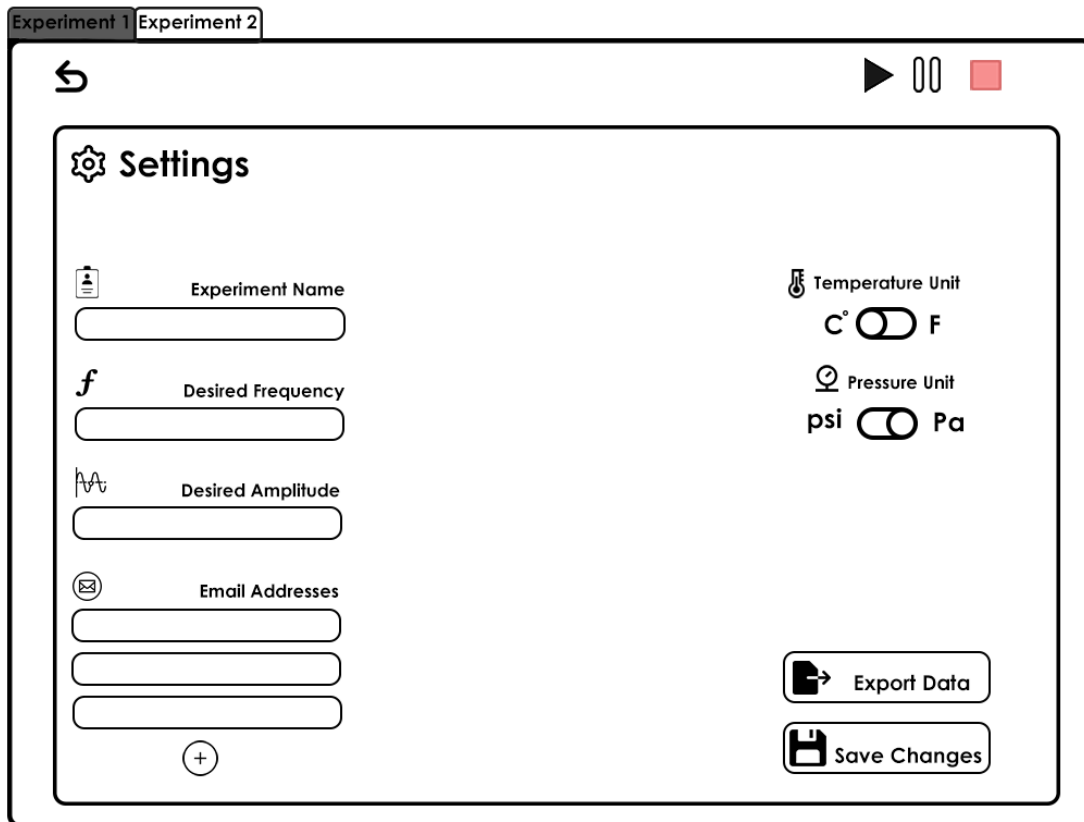

Figure 8 – Settings UI Wireframe

Once you navigate to the settings on any of the tabs/devices you are presented with options to change the parameters or units of your information (Figure 8). Lab members can input their email addresses so exported data can be sent as a spreadsheet file to them directly, or they can export data onto a USB flash drive.

The user interface for the project is progressing at a steady rate. The Qt Designer and the PyQT6 library is proving to be very useful for creating a graphical user interface, they both allow for approaching the GUI in a way which allows you to freely design the look of the user interface without worrying about the functionality until the end. The basic layout is complete and most of the widgets are in place. The next step is to finish up the last few widgets and start applying the functionality to the various systems. We have been meeting with the Davy Lab to understand and address all their needs and solve any problems relating to the UI.

5 Work Plan

5.1 Collaboration

To communicate updates to one another, supervisors, and the Davy lab, the team has used a variety of communication platforms. Microsoft Teams is used for sharing documents and for discussion. A repository for code, documents, and designs is used on GitHub. All work completed will be made available in the repository as an open source so that other labs may use it for future research. Every Monday at 2:30 pm, the team members, managers, and Dr. Davy gather for progress meetings. Additionally, Jelena Nikolic-Popovic, a Senior Member of Technical Staff at Texas Instruments Canada, is working with the team (TI). She is donating some hardware and offering the team her knowledge of the TI equipment being used for the project.

5.2 Project Milestones

Table 44 - Milestone descriptions and completion dates.

Milestone	Completed	Description	Status and Remarks
Hardware Design	Oct. 21	Research will be used to come up with final designs for the vibration mechanism and measurement to be implemented.	Complete
Software Design	Oct. 21	Different components of the software system will be chosen and designed, such as GUI wireframes, framework for GUI development, operating system to be used, database schemas, and languages/libraries to use for software-hardware interfacing.	Complete
Finalize Part Orders	Oct. 21	Parts required for the final designs can be ordered to enable development as soon as possible.	In Progress
Hardware Testing Phase	Dec. 10	Tests will be conducted as the linear actuator design and hardware setup is iterated upon. Different motors, gear configurations, and flexure and camshaft designs will be examined to determine the final design is able to hit all required frequencies and displacements.	In Progress
Software Development	Feb. 1	Various components will be implemented such as GUI, database, communication	In Progress

		protocols, custom libraries to retrieve data, and signals to control vibration mechanism.	
Hardware Development	Feb. 1	Once a final design is decided upon, the project's hardware components will be assembled. This phase includes having parts manufactured as needed.	In Progress
Software-Hardware Integration	Feb. 15	Final integrations between the hardware and software will be completed, such as retrieving data from all sensors and controlling the vibration mechanism.	N/A
Integration Testing	Feb. 15	Final integrations between the hardware and software will be thoroughly tested.	N/A
Acceptance Testing	Feb. 28	Tests will be conducted to ensure the project works as is required by the Davy lab.	N/A

5.3 Schedule of Activities/Gantt Chart

Table5 5 - Schedule of activities for project completion, documentation, and presentations.

Task	Begin	Draft	Completed	Status
Kickoff meeting between engineering team and lab	-	-	Aug. 26	Complete
Research	Summer	Sept. 7	Sept. 30	Complete
Proposal	Sept. 7	Sept. 30	Oct. 21	Complete
Hardware & Software Designs	Sept. 7	Oct. 8	Oct. 21	Complete
Finalize Part Orders	-	-	Sept. 30	In Progress
Hardware Test Phase	Oct. 1	-	Dec. 10	In Progress
Test Plan	Oct. 31	-	Jan. 15	N/A
Development – Software & Hardware	Sept. 30	Jan. 1	Feb. 1	In Progress
Software-Hardware Integration	Feb. 2	-	Feb. 15	N/A
Progress Report	Nov. 1	Nov. 18	Dec. 9	Complete
Oral Presentations	Jan. 9	Form – Dec. 9	Jan. 23-27	N/A
Integration Testing	Feb. 15	-	Feb. 28	N/A
Acceptance Testing	Feb. 28	-	March 10	N/A

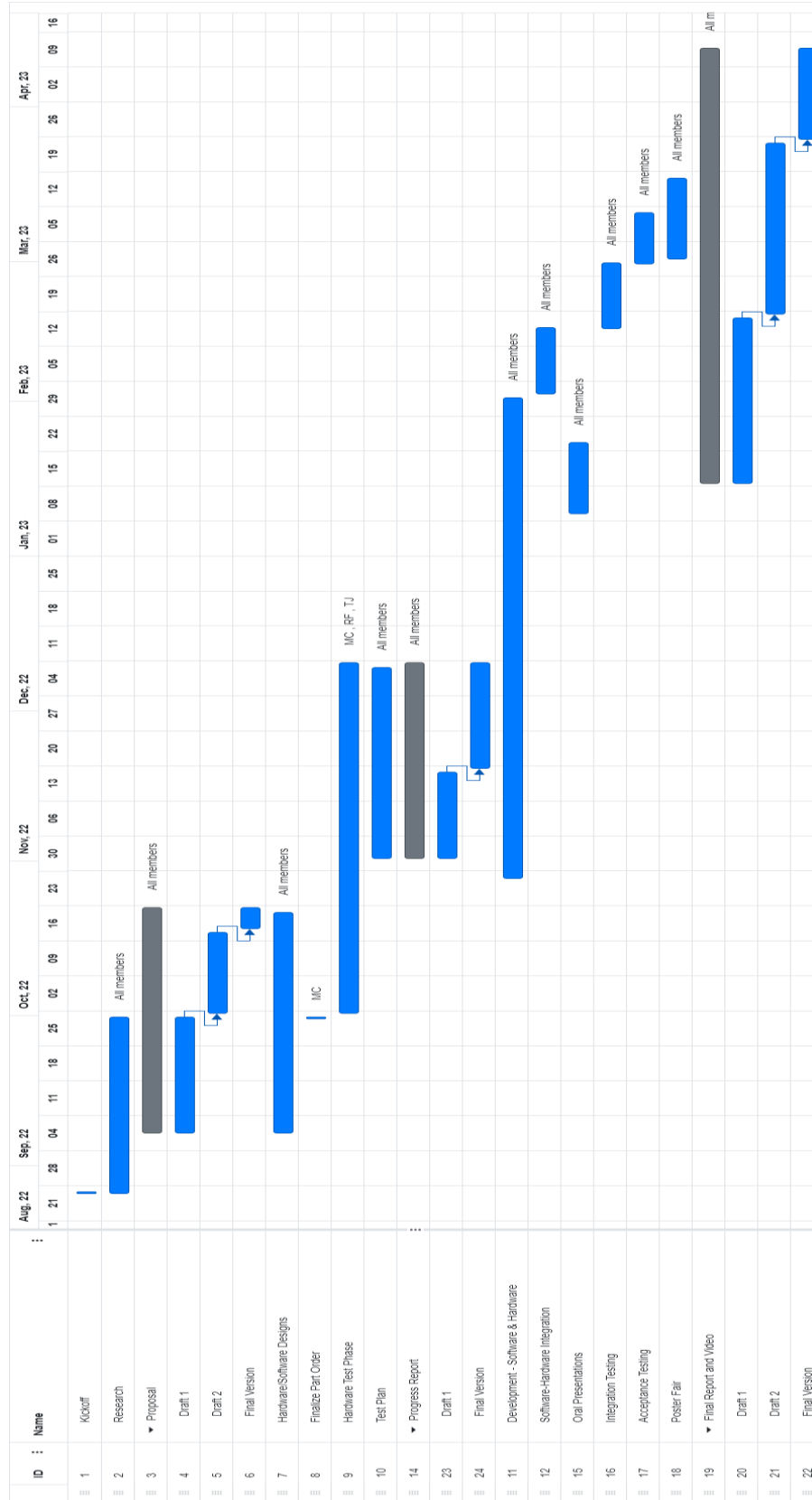|				
Poster Fair	March 1	-	March 17	N/A
Final Report and Video	Jan. 15	1st – Feb. 17 2nd – March 24	April 12	N/A

Figure 9 - Gantt chart

6 Budget Breakdown

6.1 Hardware

Note, hardware does not include 3D-printed components, as Carleton University's MacOdrum Library provides 3D printing services to students for free.

The project budget is currently $1000, provided by the Davy Lab. Additional funding is available as needed from the Faculty of Engineering and Design, and some hardware has been donated by Texas Instruments Canada.

Table 66 - Hardware required to complete project, with sources and pricing.

Item	Source	Price	Acquired?
NEMA 17 Stepper Motor	Amazon.ca	$18.99	☐
DC Brushless motor	Amazon.ca	$23.53	☐
Motor driver	TexasInstrument.com	$54.53	☒
MC3479 Accelerometer	Digikey.ca	$21.47	☒
MSP430 LaunchPad MCU	Digikey.ca	$22.94	☒
Differential Gears 64T, 17T, 21T, 26T, 29T	Amazon.ca	$16.29	☒
5mm Motor shaft	Amazon.ca	$8.54	☐
3mm Motor shaft	Amazon.ca	$7.59	☐
3mm to 5mm Shaft coupler	Amazon.ca	$11.99	☐
625-2rs Ball Bearings (x4)	Amazon.ca	$16.03	☒
Linear shaft 12mm x 150 mm (x2)	Amazon.ca	$14.99	☐
Linear shaft 12 mm bearing PIL (x2)	Digikey.ca	$18.74	☐
Linear shaft 12mm clamp	Amazon.ca	$17.49	☐
Stiff springs	Amazon.ca	$22.41	☐
Melamine surface	Homedepot.ca	$26.75	☐
Incubator	Provided by lab	$0	☐
Raspberry Pi 4, 4GB	Digikey.ca	$80.95	☒
Temperature & Humidity sensor	Amazon.ca	$16	☒
Touch screen for interface	Amazon.ca	$80	☒
LVDT MHR Series ±2.54mm	Mouser.ca	$380.58	☐
	Total	$859.81	

7 Conclusion

The main objective of this project is to provide a vibration simulator with which the Davy lab can investigate the effects of ground vibration from various industrial sources on the growth of turtle eggs. Shaking tables exist that can produce frequencies between 2 – 20 Hz, however none were found that could achieve the fine precision of 0.1 – 1 mm displacement that is required. This extreme precision in displacement can be attained by utilizing the James Webb Space Telescope Mirror Actuators' elegant yet straightforward linear actuator design. By April 2023, the team hopes to have a research-ready model of this device available so that the Davy lab may start conducting research and share its findings with other labs that also require such a device.

7.1 Reflections

The team has learned a tremendous amount about the engineering process through the research and design phase of the project conducted so far. It has been important for the team to acknowledge when an idea will not work out, and how to salvage work done to still produce a final product.

The initial goal of this project was to simulate vibrations detected in the presence of wind turbines. During the research and design phase, it was determined that the target displacement of these vibrations, ~300 nm, would be difficult to produce, and even harder to measure. Measurement devices capable of measuring within the nanometer range were extremely expensive and out of budget. Upon discussing these issues with the Davy Lab, it was decided to shift goals. Vibrations at the same frequency but a larger displacement would still be very useful to the lab, and the scope of the research was expanded to include a variety of industrial sources of vibration.

The team was able to find new vibration targets, and the research and designs to date could still be used with some tweaks. This has given the team a valuable experience in understanding limitations, and repurposing work for new goals.

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Appendix 1: Relevant Courses

The team has collectively taken many different courses relevant to the project. For reference, the course codes and course titles mentioned throughout the document will be outlined here:

Table 77 - Cumulative relevant courses for required knowledge and experience.

Course Codes	Title
ECOR 1010	Introduction To Engineering
ECOR 1101	Mechanics I
SYSC 2004	Object Oriented Software Development
SYSC 3600	Systems and Simulation
SYSC 3010	Computer Systems Development Project
SYSC 3020	Introduction to Software Engineering
SYSC 4805	Computer Systems Design Lab
SYSC 4505	Automatic Control Systems I
ELEC 2501	Circuits and Signals
ELEC 2507	Electronics I
ELEC 3105	Basic EM and Power Engineering (previously), Electromagnetic Fields (current)
ELEC 3907	Engineering Project
ELEC 3509	Electronics II
CCDP 2100	Communication Skills for Engineering
ECOR 4995	Professional Practice

Appendix 2: Additional Diagrams

Database:

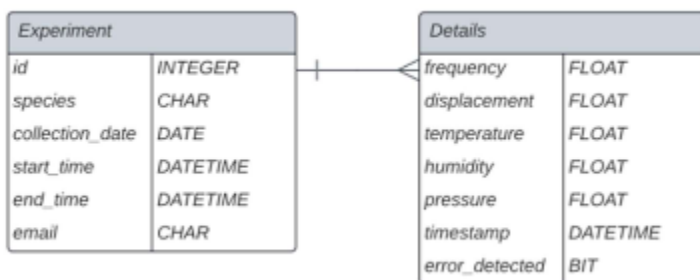The figure below illustrates the database schema presented in the initial proposal.

Figure 10 - Database schema from the proposal.