

SYSC 4907 – ENGINEERING PROJECT

Wind Turbine Ground Vibration Simulator



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Commented [MP1]: @Ranishka Fernando please add student number

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1 Introduction

Carleton University's Davy Lab is a conservation research group that works to better understand how environmental changes affect local threatened species of bats, amphibians, and reptiles. One such project involves investigating the effects of seismic vibrations from nearby wind turbine operations on the development of turtle eggs. Further, nearby highways can also generate ground vibrations that may have similar effects that must be studied.

Meia Copeland, Shawaiz Khan, Talal Jaber, Marwan Zeyada and Ranishka Fernando are working to create a device that can simulate the ground vibrations around wind turbines, so that the lab can study these effects in a laboratory setting.

1.1 Background

In the past decade, wind power has been the fastest growing source of new energy in Canada [1]. As the country moves towards its climate goal of increasing the share of zero-emitting energy sources to 90% by 2030, wind power will be instrumental to success. While an extremely useful tool in emission-free power generation, there are a variety of potentially negative effects on wildlife. The most thoroughly studied are the impacts on flying animals, such as bird and bats. Mortality from collision with the turbine rotors, as well as general avoidance of areas around turbines has been described [2]. However, wind energy's impacts on ground-dwelling animals are less known.

On-shore wind farms have been shown to produce low-frequency ground vibrations for many kilometers surrounding the turbines [3]. 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 [4], the behavior of most terrestrial animals has not been shown to be significantly affected [5]. Most studies so far have focused on terrestrial mammals. The effects on egg development of reptiles and amphibians have not been examined.

The ground vibrations from wind turbines are predominantly caused by interactions between the wind and the entire turbine system, rather than just the spinning of the blades [6]. These frequencies typically range between 0.1 – 100 Hz [3]. To simulate these extremely low frequencies in a lab setting, a shake-table will be needed. The turtle eggs may be placed in an incubator, which in turn is attached to the top of the shake-table. Devices capable of such low frequencies exist, such as the Low Frequency Portable Shaker Table by the Modal Shop, which is capable of frequencies as low as 0.7Hz. However, the price on such a device is prohibitive to the Davy lab. The device is also not rated for continuous use throughout the incubation period of turtle eggs.

1.2 Motivation

As wind power becomes commonplace around Canada and the world, it is important to determine the effects wind turbines have on native species that may live or nest nearby. The

Davy Lab would like to investigate these effects on the development of turtle eggs, particularly the ground vibrations caused by wind turbine use.

Our goal is to create a device that will allow the Davy Lab to simulate these ground vibrations in a laboratory environment, while also tracking environmental variables such as temperature and humidity.

1.3 Project Objective

This device will simulate frequencies between 2 – 10 Hz, with amplitudes around 10^{-4} mm/s and 10^{-6} mm/s to simulate vibrations directly around the turbine, and up to 2.5 km away. A tabletop will be used to hold multiple incubation tubs. Vibrations on each tub will be measured independently. The device will be able to create vibrations for up to 95 days, or the incubation period of the eggs.

Specific Goals

VIBRATION – Motor angular motion will be translated to linear displacement using a linear actuator system. This system uses a camshaft and flexure that can reduce the linear displacement to a nanometer scale. A stepper or DC motor will be used, with the angular motion reduced through gears as necessary.

VIBRATION MEASUREMENT – The amplitude and frequency of the vibration can be measured using an accelerometer, or a linear displacement sensor.

CONTROL SIGNALS – System must be able to take a frequency and amplitude inputs and operate the motor accordingly. System must also be able to take measurement outputs and calculate frequency and amplitude.

USER INTERFACE – A small screen will be attached to the system and allow lab members to start and stop the experiment, set the frequency, set the length of experiment, and export data in a spreadsheet to a list of emails. Environmental and vibration variables will be displayed for monitoring while the experiment is active.

DATABASE – Data for the frequency and amplitude of the vibrations will be captured at a rate of . Environmental variables will be captured at a rate of . System must be able to convert the data into a spreadsheet for viewing after the experiment.

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2 Research

2.1 Vibrations to be simulated

Several papers on the ground vibrations around wind turbines were examined to determine the target frequencies and amplitudes for the simulation device. Much of this research has been conducted to examine the interference wind turbine ground vibrations may have on sensitive seismic monitoring systems [3] [7]. Reports have shown that vibrations from wind turbines can interfere with these systems as far as 62 km away when wind speeds are high [3].

Several reports agreed that there are distinct structural bending modes detected around typical 80m tall turbines [3] [7]. These modes correspond to vibrations of 0.32 Hz, 2.56 Hz and 5.88 Hz.

The amplitude of vibrations is also needed to create an accurate simulation of the vibrations around turbines. Botha found that, at approximately 5.8 Hz and 90 m from the base of the turbine, the amplitude was 10^{-4} mm/s [8]. At 2 km from the base, the vibration attenuation reduced the amplitude to 10^{-6} mm/s, with the same frequency.

Most of the literature measured the vibrations using triaxial seismometers and accelerometers, therefore capturing the vibrations along the X-, Y-, and Z-axes. However, many only presented the data along the Z-axis, as this vibration was far more significant the horizontal movement [8] [3]. Other research only measured the Z-axis for this reason [9].

For this simulator, creating vibrations like those felt close to the base of the turbine will be prioritized. A frequency of 5.8 Hz and amplitude of 10^{-4} mm/s will be targeted. If these variables are achieved, reducing the amplitude and frequency will be attempted.

2.2 Methods of simulation

Creating vibrations of both extremely low frequency and small amplitude is the hardest and most critical piece of achieving success with this project. The vibration treatment would have to be applied continuously over the incubation period of the turtle eggs, 65-95 days [10]. Over the course of research, many methods were investigated, and will be discussed here.

2.2.1 Earthquake shake table

The first method investigated was to recreate a shake table, like those used in civil engineering research to examine the natural frequency of structures. These machines can produce extremely small frequencies, as earthquakes generate vibration frequencies between 0.2 Hz and 20 Hz [11]. However, the amplitude of these machines is too high for our uses. Further, most shake tables act in an X- or Y-axis direction, whereas the most significant vibrations from wind turbines is accepted to be vertical, in the Z-axis. While this idea was overall scrapped, some elements were eventually reconsidered, such as the linear actuators used in many shake table designs.

2.2.2 Sub-woofers and Haptic Transducers

A mechanical solution overall was not ideal, considering the expertise of the students involved in the project. Because of this, an electrical solution was investigated. First, sub-woofers and speakers capable of extremely low bass were looked at. Most sub-woofers can reach frequencies as low as 25 Hz, with some specialty designs going lower. Being able to turn up or down the volume would allow for more customization regarding the amplitude, as well. However, no realistic and cost-effective options were available in the 2-10 Hz range needed for this project.

Another option that was considered was a haptic transducer, such as those used in gaming and home theater setups. These transducers are capable of much lower frequencies, some

purportedly as low as 5 Hz [12]. These devices are also able to be turned up and down, like sub-woofers and speakers. However, these devices are not built to use continuous sine waves, as would be needed for this application. The devices are meant to be active in short bursts, such as to accentuate rumbling in a video game or movie. Using a continuous sine wave at frequencies lower than 20 Hz, the transducer will run out of excursion potential and attempt to self-brake to prevent physical collision between internal components [13]. To solve the issue of using a continuous sine wave, it is recommended to pulse the sine wave [13]. However, transducers could also over-heat when used continuously. Finally, if the desired frequency could be achieved, damping the amplitude to the desired values would also be difficult. Testing with surfaces of different weights and materials would be conducted.

2.2.3 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. However, most small motors have a limit where the vibration frequency stops decreasing at around 30 Hz due to weight and size constraints (**Error! Reference source not found.**).

TYPICAL DC MOTOR PERFORMANCE CHARACTERISTICS

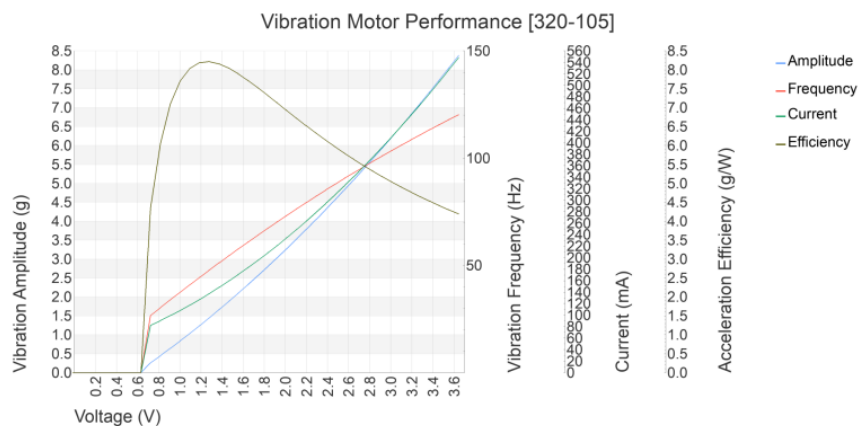


Figure 1 - DC motor frequencies [11]

2.2.4 Stepper Motor and Fine Control Linear Actuator

Finally, stepper motors were considered since they generally have a maximum frequency limit around 15 Hz. Once again, an issue arose in deciding how to attach the stepper motor to the bottom of a tabletop to produce the correct frequencies. Simply attaching the motor would produce equal vibrations in a vertical and horizontal direction.

Linear actuators in earthquake shake tables were revisited. These actuators could operate at low enough frequencies and provide vibrations in one direction. Depending on the actuator, the amplitude could also be controlled. Further, a linear actuator could be designed to be controlled by a simple and cheap stepper motor. In fact, such a design exists and is used on the James Webb Space Telescope, to position the mirrors [14]. Due to the precision required by the JWST, the linear actuators used are capable of amplitudes in the micron range. The fine positioning mechanism involves gears to reduce the frequency of the stepper motor, which controls a camshaft with a small offset. This camshaft is coupled to a flexure, which in turn creates an amplitude on the micron-scale at the top of the flexure. Open-source 3D model replicas are available under a Creative Commons license, and the flexure and camshaft can be altered to reduce the amplitude further. This solution will be used going forward.

2.3 Software

2.3.1 Database options

Keeping in mind the requirements of this project, a database was needed to store and retrieve data. Various options were available. Our first choice was between SQL and a NoSQL type of database, with pros and cons for both.

Other than being the most common database management approach, using SQL offered us faster query processing, standardized and user-friendly language. NoSQL on the other hand offers flexible scalability and flexible data types. Taking the needs of the lab into consideration, flexibility would not be a big concern since our schema will stay consistent over time, which is why we chose SQL over NoSQL.

Under SQL, we narrowed our choices to the industry standards, namely MySQL and SQLite. SQLite is a software library providing a relational database management system, not requiring servers to run, and relatively easy to master when compared to MySQL. 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, MySQL seemed overkill, which is why we chose SQLite as our database management approach for now. Further development may result in a change in approach and further consideration might be given to MySQL if required.

2.3.2 User Interface Framework

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 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, 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.

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3 System Design

3.1 Motor Test Plan

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 used from the print are the frame, flexure, motor shaft, and camshaft.

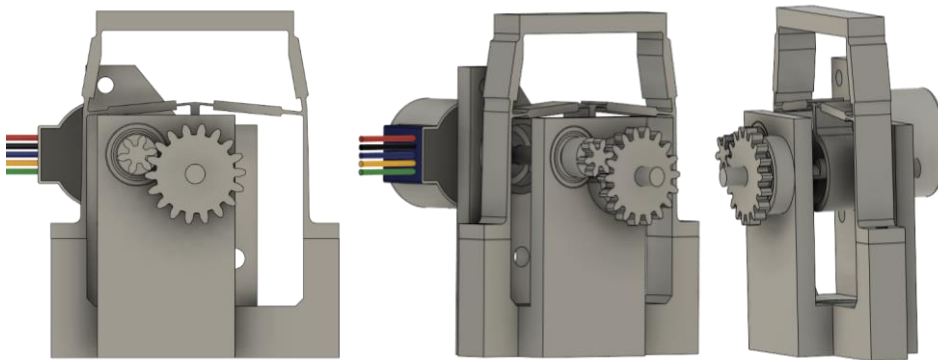


Figure 2 - Front and side views of the JWST Mirror fine positioning mechanism as designed by Polyfractal [15]

This model replicates the JWST Mirror Actuator fine positioning mechanism, as described in a research paper by Robert Warden. The flexure and camshaft of this design can be altered to achieve the correct movement. As is, the flexure has an amplitude of approximately $40\ \mu\text{m}$. Changing the camshaft offset or the width/height of the flexure can reduce the amplitude further.



The flexure model will be simulated in **ANSYS** to test displacement capability. This method allows for faster iteration on the flexure and camshaft design, which can then be printed and integrated into the system for further testing.

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 64T output gear, and options of 17T, 21T, 26T, and 29T 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.

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.

3.2 Measurements

To ensure accurate data for research, several measurements devices will be included in the project. Sensor setup and data retrieval involves students' knowledge of data capture with microcontrollers and I2C as was learned in courses such as **SYSC 3010** and **SYSC 4805**.

3.2.1 Vibration Sensor

Measuring the displacement and frequency of the vibrations will be essential for matching the simulated vibrations to measured vibrations in the field. By using an accelerometer, the acceleration of the surface moving up and down can be measured. Calculations can convert this data to displacement and frequency. However, due to the small frequency and extremely small displacement, further filtering is likely required to cancel out noise outside of the accepted ranges of vibration. Appropriate accelerometers will be examined and tested to find the right fit.

Another option for sensing vibration is a linear position sensor. Because the displacement will only be in the vertical direction, a sensitive linear position sensor could be set up in contact with the table surface. Frequency can be calculated from the data.

3.2.2 Environmental Sensors

Research involving the incubation of reptile eggs requires knowledge of the environmental variables. Temperature, humidity, and pressure sensors can be placed on or inside the incubation containers to keep track of these variables.

3.3 Database

The figure below illustrates the schema used to store the project data. A list of experiments will be stored where each experiment will have an individual id, a start/end date and an email

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Commented [MP7]: @Talal Jaber and @Ranishka Fernando please add other relevant courses

associated with it. Every experiment will have a set of details including frequency, amplitude, temperature, humidity, pressure and a timestamp.

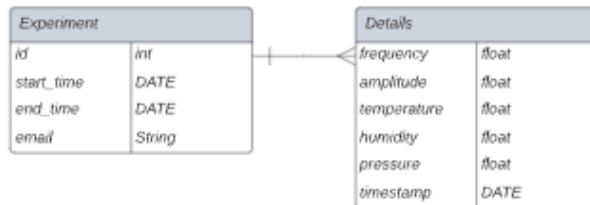


Figure x. Database Schemas

3.4 User Interface

3.5 Use Cases

3.4.1 Use Case 1 – Begin New Experiment

Intent: Turning on the system and setting up a new experiment.

Primary Actor: Biologist/Student

Precondition: The system is connected to power.

Postcondition: The user successfully turned on the system and set up a new experiment. The parts operate at the intended settings.

Failed Postcondition: Either one of the motor, accelerometer, temperature sensor, humidity sensor fails to operate.

Basic Flow:

- Press the manual On/Off button.
- Navigate through the touch screen interface.
 1. Press “New experiment”.
 2. Enter an experiment name, desired frequency, desired amplitude in the given space and press “Next”.
 3. Review the details entered; Enter your email in the given space and press “Start”.

Alternative Flow:

1. Repeat step 3 if more emails need to be added.

Commented [MC8]: @Marwan Zeyada you can go over your designs, wireframes, etc. here. Talk about formatting, what languages/frameworks you plan to use

Commented [MC9]: @Shawaiz Khan (I know you know this already, but putting here for tracking)
Use cases need to be cleaned up a bit format-wise, and finalized

3.4.2 Use Case 2 – Change temperature/humidity units.

Intent: Changing the temperature/humidity unit.

Primary Actor: Biologist/Student

Precondition: The system is connected to power, ON, and NO experiment has been setup.

Postcondition: The user successfully changed the unit to the desired option.

Failed Postcondition: The system fails to record data in the chosen unit.

Basic Flow:

- Navigate through the touch screen interface.
- 1. Press “Settings”.
- 2. Press “Change Units”.
- 3. Press “Temperature” or “Humidity”.
- 4. Choose one of the given temperature or humidity units and press “Done”.

3.4.3 Use Case 3 – Change frequency/amplitude.

Intent: Changing the frequency and amplitude of the vibrations by the motor.

Primary Actor: Biologist/Student

Precondition: The system is connected to power, ON, and an experiment has been set up and is running; The UI displays the home screen.

Postcondition: The user successfully changed the frequency/amplitude to the desired setting. The system uses the accelerometer to measure the change and display a confirmation notification.

Failed Postcondition: The accelerometer fails to detect a change or detects readings not intended by the user.

Basic Flow:

- Navigate through the touch screen interface.
 1. Press “Settings”.
 2. Press “Change Frequency/Amplitude”.
 3. Use the slider to choose the desired frequency and enter the desired amplitude in the given space and press “Finish”.

Alternate Flow:

- ? Press “Change Frequency/Amplitude” shortcut on the Home Screen.
- ? Step 3 from the Basic Flow

4 Work Plan

4.1 Project Team

Team Member		Relevant Courses
Meia Copeland	Meia is a fourth year Computer Systems Engineering student and has a minor in Physics. Through seven co-op placements and internships, she has gained extensive experience in software development. Beyond software, Meia is very interested in software-hardware interfacing and control systems. She has taken electives in power engineering and control systems and will be working closely with the electrical engineering team to design the system and develop the signal processing necessary to control the electrical and mechanical components. Having the most industry experience in the group, she is also taking on a leadership position and will be acting as project manager.	ECOR 1010 – Intro. To Engineering ELEC 2507 – Electronics I ELEC 3105 – Basic EM and Power Engineering SYSC 3600 – Systems and Simulation SYSC 3010 – Computer Systems Development Project SYSC 4805 – Computer Systems Design Lab SYSC 4505 – Automatic Control Systems I
Shawaiz Khan	Shawaiz Khan is a fourth year Computer Systems Engineering student. Working on previous and current projects during his studies, he acquired knowledge and skills in both hardware and software. Having a bit of experience in dealing with this before, he will mainly be working on	ELEC 2507 – Electronics I SYSC 2004 – OO Software Development SYSC 3010 – Computer Systems Development Project

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After, a full section on how the team as a whole has the skills to do the project

Commented [MC11R10]: Team as a whole section is still needed

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	setting up the database, as well as assisting in setting up the temperature and humidity sensors. Interested in learning more and gaining experience with front-end development, he will be assisting with the UI framework as well.	SYSC 3020 – Intro. To Software Engineering SYSC 4805 – Computer Systems Design Lab
Talal Jaber	Talal is a fourth year Electrical Engineering Student. Having developed most of his hardware experience from his co-op term where he worked in a power step-down transformer station. Talal had a lot of hands-on experience with motors and circuits throughout his studies and work term. Talal will be mostly responsible about the electrical design and the hardware design of the project.	ELEC 2501 – Circuits and Signals ELEC 3105 – Basic EM and Power Engineering ELEC 3907 – Engineering Project ELEC 3509 – Electronics II
Marwan Zeyada	Marwan is a fourth year Computer Systems Engineering student. He always had a passion for computers and anything tech related. Throughout his study years, he acquired a lot of technical skills in both hardware and software. Having worked on a lot of UIs and software in his projects, he will be working mainly on the graphical interface and the software side while also working on hardware to gain more experience.	SYSC 2004 – OO Software Development SYSC 3010 – Computer Systems Development Project SYSC 4805 – Computer Systems Design Lab ELEC 2501 – Circuits and Signals ELEC 2507 – Electronics I
Ranishka Fernando	Ranishka Fernando is a fourth year Electrical Engineering student. Throughout the time at Carleton, he had the pleasure of not only gaining the academic knowledge required to move on past university years, but the soft skills required to be a successful member of the work force with more than 3 years of experience in the industry through various CO-OP positions related to research, hardware, software, construction, and project management. Ranishka will be mainly working on the electrical design of the project including integration and debugging of hardware and software.	

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Commented [MP14]: @Marwan Zeyada please add a description of expertise & interests, and add relevant courses

Commented [MP15]: @Ranishka Fernando please add relevant courses

4.1.1 Roles and Tasks



Team Member	Tasks	Justification
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Commented [MP16]: There was a comment about creating a break-down of work done by each person on each document. Would this just be for the proposal this time around?

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Meia Copeland	Linear Actuator Design	CAD experience from ECOR 1010 and personal projects
	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	Databasing	Experience in projects in SYSC 3010
	User Interface	Experience in projects in SYSC 3010 and minor intro in SYSC 2004
	Hardware-Software Interfacing	Experience in multiple hardware-software projects in SYSC 3010 and SYSC 4805
Talal Jaber	Electrical design	Designing required PCB for the system.
	Hardware integration	Choosing the right motor and driver for the project. Elec 3907
	Simulation	Using ANSYS to simulate the flexure displacement. SYSC 3501
Marwan Zeyada	User Interface	Experience in projects in SYSC 3010 and SYSC 2004.
	Hardware Integration	Experience in projects where hardware is the focus: SYSC 3010
	Databasing	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 design	
	Hardware integration	
	Debugging	

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Commented [MP18]: @Talal Jaber please fill out this section

Commented [MP19]: @Marwan Zeyada please fill out this section

Commented [MP20]: @Ranishka Fernando please add justifications

WIND TURBINE GROUND VIBRATION SIMULATOR

4.1.2 Collaboration

The team has leveraged multiple collaboration tools to keep each other, supervisors, and the Davy lab up to date with progress. Microsoft Teams is used for communication and document sharing. GitHub is used as a code, document, and design repository. The repository will be an open source for all work done, so that other labs can use the work for research in the future. Progress meetings are held every Monday at 2:30 pm, and include the team members, supervisors, and Dr. Davy. Further client meetings with Dr. Davy are scheduled on an as-needed basis to go over user interface and hardware designs such that they fulfill the Davy lab's requirements.

The team is also collaborating with Jelena Nikolic-Popovic, a Senior Member of Technical Staff at Texas Instruments Canada (TI). She is providing the team with expertise on TI hardware being used for the project and donating some hardware. Communications with Jelena are conducted through email.

4.2 Project Milestones

Milestone	Completed	Description
Hardware Design	Oct. 21	Research will be used to come up with final designs for the vibration mechanism and measurement to be implemented.
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.
Finalize Part Orders	Oct. 21	Parts required for the final designs can be ordered to enable development as soon as possible.
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 amplitudes.
Software Development	Feb. 1	Various components will be implemented such as GUI, database, communication protocols, custom libraries to retrieve data, and signals to control vibration mechanism.

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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.
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.
Integration Testing	Feb. 15	Final integrations between the hardware and software will be thoroughly tested.
Acceptance Testing	Feb. 28	Tests will be conducted to ensure the project works as is required by the Davy lab.

4.3 Schedule of Activities

Task	Begin	Draft	Completed
Kickoff meeting between engineering team and lab	-	-	Aug. 26
Research	Summer	Sept. 7	Sept. 30
Proposal	Sept. 7	Sept. 30	Oct. 21
Hardware & Software Designs	Sept. 7	Oct. 8	Oct. 21
Finalize Part Orders	-	-	Sept. 30
Hardware Test Phase	Oct. 1	-	Dec. 10
Test Plan	Oct. 31	-	Dec. 10
Development – Software & Hardware	Sept. 30	Jan. 1	Feb. 1
Software-Hardware Integration	Feb. 2	-	Feb. 15
Progress Report	Nov. 1	Nov. 18	Dec. 9
Oral Presentations	Jan. 9	Form – Dec. 9	Jan. 23-27
Integration Testing	Feb. 15	-	Feb. 28
Acceptance Testing	Feb. 28	-	March 10
Poster Fair	March 1	-	March 17
Final Report and Video	Jan. 15	1 st – Feb. 17 2 nd – March 24	April 12

Commented [MP21]: More specific on when certain tasks will be completed. Now that we have a better idea of the solution, we can split it into tasks

Commented [MC22R21]: This can be used as 'sections' on gantt chart, and we can come up with more granular tasks to be 'sub-sections'

Optional: provide a Gantt chart showing what each team member will be working on in each week of the project.



4.4 Risks and Mitigation Strategies

Risks with this project are mostly related to the execution and scheduling of the tasks, as well as some external factors regarding sourcing of components.

The biggest risk involves the execution of the vibration mechanism, since the success of the entire project hinges on this one component. Not being able to generate the correct frequency is the most important aspect, and creating the correct displacement is a close second. To mitigate this risk, a significant amount of time went into researching how this mechanism

would be designed. Many options were looked at, and elements from each option are still being considered. Further mitigation will come from thorough testing of the current design, through simulated and physical testing.

Another crucial risk involves sourcing of some components. While some components can be 3D printed, therefore allowing for infinite customizability, other components cannot. Parts such as the motor shaft and camshaft are custom designs that will need to be manufactured in extremely durable material, preferably metal. Other parts such as gears are also extremely expensive and time consuming to have milled. To mitigate these risks, out-of-box components will be used as much as possible. In the case of gears, differential gear trains for RC cars can be utilized as their size and ratio can be leveraged. Mounting of these gears can be compensated for in 3D printed designs. Regarding more custom elements, alternate materials will be examined for the motor shaft and camshaft. Design aspects will also be considered, to eliminate the need for especially durable components. For example, reducing the amount of torque needed to create vibrations could allow for a 3D resin-printed shaft to be durable enough for long-term use.

Sourcing also involves risk regarding the supply chain. Issues have been rampant in the last few years, especially in semiconductors. This project requires the sourcing of many electrical components that rely on semiconductors, such as sensors, microcontrollers, and single-board computers. The team will use caution when finalizing a parts list and will try to find alternatives when possible. For example, the Raspberry Pi computer is a very useful and commonly used computer in projects like this. However, getting a Raspberry Pi is incredibly difficult. Instead, the team has partnered with Texas Instruments and will be using their widely available BeagleBoard. Just like the Raspberry Pi, the BeagleBoard is compatible with many Linux distributions, has pins for connecting sensors and powering components.

Due to all team members being in many other classes during the school year, difficulty in following the project schedule may arise. By carefully determining a timeline and tasks, these risks can be mitigated. Well-described tasks eliminate any confusion as to success criteria that could cause a loss of productivity. Well-planned tasks with the appropriate amount of time allocated to them will allow for team members to schedule their time accordingly and understand their responsibilities.



5 Project Requirements Checklist

Requirement	Description
5.8 Hz Frequency in vertical direction	Achieve using a stepper motor or brushless DC motor 3D printed design used to convert motion to linear motion
Low-weight flat surface	Flat, light-weight acrylic sheet

Commented [MP23]: @Shawaiz_Khan and @Marwan Zeyada, software requirements should be added

WIND TURBINE GROUND VIBRATION SIMULATOR

Power to drive the stepper motor	Achieved using the VCC pin of the BeagleBoard and driver or direct power
Measure vertical displacement	Slider Potentiometer or linear position sensor
Measure frequency	Accelerometer
Suspend surface and be able to move it	Use of stiff springs
Control speed and RPM of the motor	Use of shaft and gears
Keep gears and shaft in place and provide ability to move	Use of bearings to keep gears and shaft in place and have smooth motion. 3D printed frame to fasten everything together.
Data collection	Every specified interval, the details of various sensors should be saved in a database file successfully.



5.1 Stretch Goals

WEB PORTAL – Access databases from device through a web portal. View and download data from portal.

MODULAR LINEAR ACTUATOR DESIGN – Design multiple flexures with different displacement capabilities and allow for swapping of flexures to customize experiments further. Could also implement a swappable camshaft instead.

CLOUD DATABASE USING GRAPHQL – Store and access data remotely, as well as the possibility to control the system using mutations through GraphQL.

Commented [MC24]: @Shawaiz Khan, maybe add some research about this to your research section? Otherwise it kind of comes out of no where

6 Budget Breakdown

6.1 Hardware

Note, hardware does not include 3D-printed components or manufactured items, as costs for those items have not yet been finalized.

Item	Source	Price
NEMA 17 Stepper Motor	Amazon.ca	\$18.99
DC Brushless motor		
Motor driver		
MC3479 Accelerometer	Digikey.ca	\$21.47
LMC8 Linear Motion POT	P3America.com	\$50
Differential Gears 64T, 17T, 21T, 26T, 29T	Amazon.ca	\$16.29

Commented [MP25]: Need to source

Commented [MP26R25]: @Talal Jaber and @Ranishka Fernando can you guys find a placeholder for this one?

Commented [MP27]: Need to figure out a placeholder or finalized motor driver. Preferably from TI

WIND TURBINE GROUND VIBRATION SIMULATOR

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	FREE
BeagleBone Black	Digikey.ca	\$106
Temperature & Humidity sensor	Amazon.ca	\$16
Touch screen for interface	Amazon.ca	\$80
	Total	\$425.16

Commented [MP28]: Another option: https://www.amazon.ca/Prime-Line-Products-SP-9706-Compression/dp/B008RG3P7E/ref=asc_df_B008RG3P7E/?tag=googleshopc0c-20&linkCode=df0&hvadid=346147627168&hvpos=&hvnetw=g&hvrnd=2314713433565455132&hvpone=&hvtwo=&hvm=mt=&hvdev=c&hvdvcm=dl=&hvlocint=&hvlocphy=9000681&hvtargid=pla-335274182084&psc=1

Commented [MP29]: Needs to be updated when dc motor and driver prices added.

Commented [MP30]: Need to hear back from library about request

Commented [MP31]: Waiting to hear back from SID about whether we can use their services. They have also have other services available

6.2 Services

During the testing phase, access to 3D printers (extrusion and resin) will be required. 3D extrusion printing services are offered for free by the library, with a lead time of about [redacted]. 3D printing services (extrusion and resin) are also provided at a cost by the School of Industrial Design, with a lead time of [redacted].

Over the course of the project, laboratory space will be needed to assemble and test components. The team has been given access to the fourth-year project lab and will be looking into getting storage there.

Some manufacturing capability may be needed when the final design is ready. These services involve PCB printing and shaft manufacturing. Materials for the shaft manufacturing will be examined to determine the most cost-effective solution. The final frame and flexure will be 3D printed using high-quality filament.



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Appendices

You may wish to include appendices. For example, detailed circuit diagrams, detailed wireframes, data sheets for special components, etc.