GNG 1103 [F]

Engineering Design

Course Professor: **Rubina Lakhani**

Deliverable E - Project Schedule and Cost

Prepared by Group: # 4

Team Members:

Student Name:	Student ID:
Hiruni Senarath	300044216
Xiaoshuang Li	300109354
Arman Dhanjal	300111109
Paul MacIver	300116019
Stefan Ostojic	300208737

Date: February 28, 2021

Table of Contents

Introduction

The purpose of this deliverable was to create the general guidelines for each of the prototyping phases. In the first prototyping phase, the aim is to create a low fidelity prototype that will help the team understand subcomponents or assumptions we've previously made, in a low cost and quick manner. The second prototype is a medium fidelity prototype, that can potentially use components that will be used for the final product, to test more critical subsystems. Finally, the third prototype is a fully functional design that will be presented on Design Day. For each of these stages, an outline with the following elements was made: a list of material needed, the objects of each testing stage, and the subtasks needed to be done. This deliverable also includes a detailed BOM with all the components needed to create a fully functional design.

1.0 Detailed Concept Drawing and Explanation

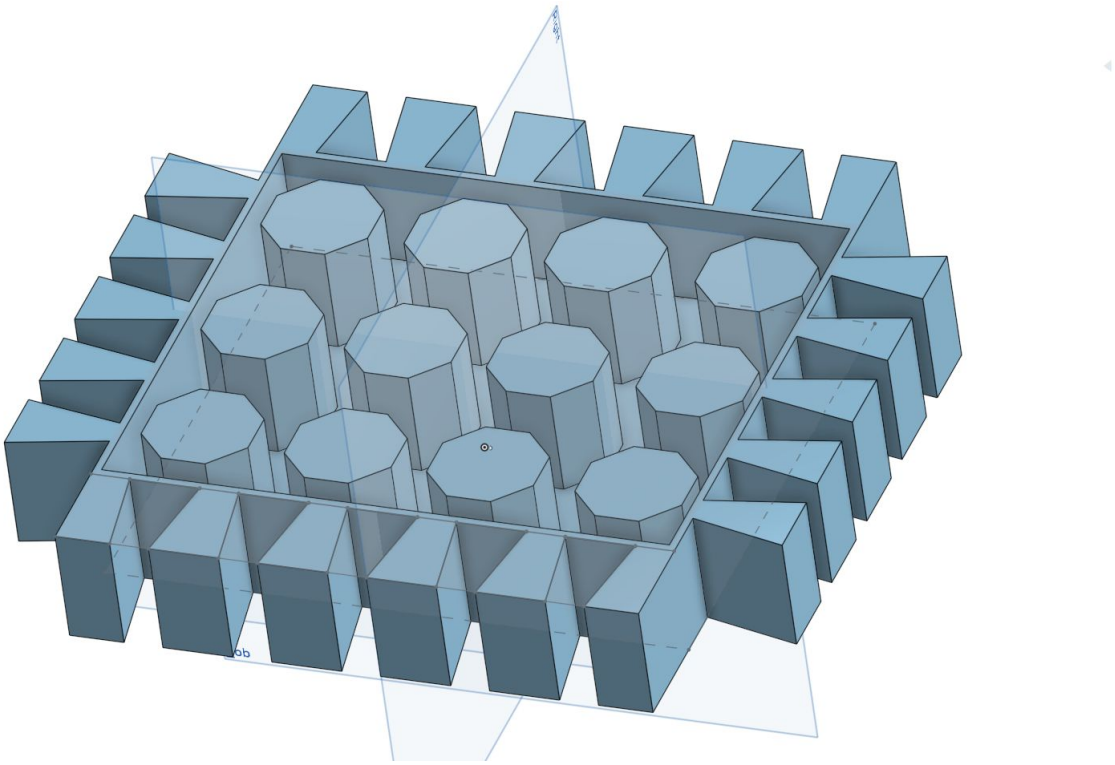

Figure 1. CAD model of column supports and connections

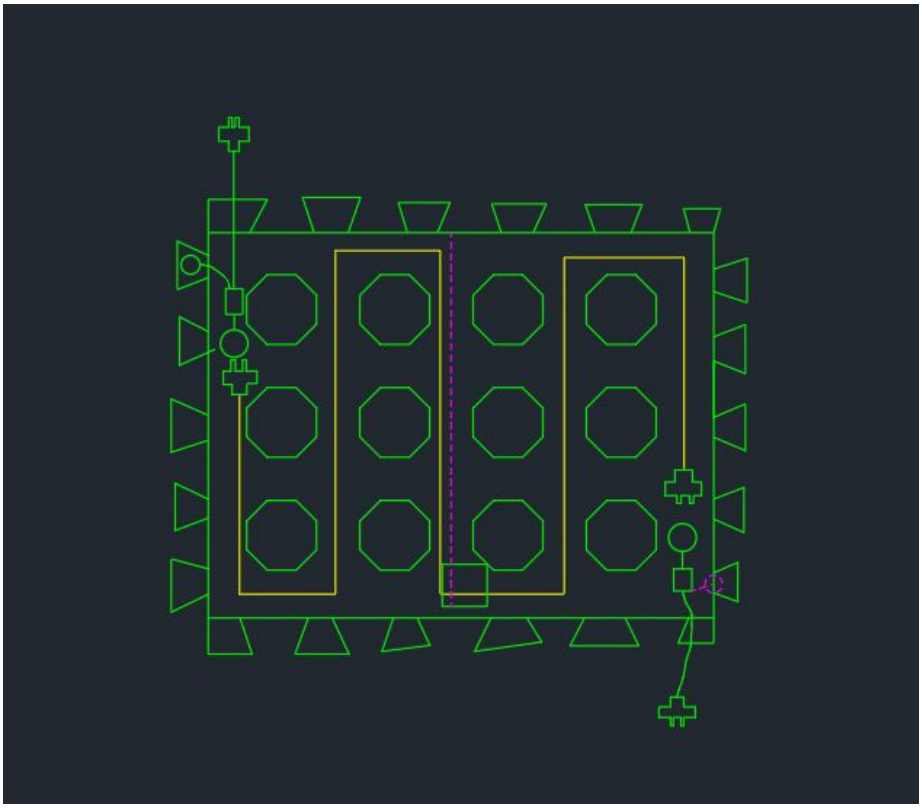

Figure 2. Sketch of internal components

The product uses electric heating cables as heating elements, and the double-ended spiral provides support, which achieves good load distribution and also provides great convenience for maintaining the designed system. Dovetail connections around the mat edge allow more pads to be connected, and adding a cable multiplier also greatly facilitates the ability to connect power to the next pad. The centerline on the cushion can be folded in half to reduce the floor area and make it convenient for storage. The connection point set near the centerline protects the wires, so there is no need to worry about the folding of the mat that will affect the circuit.

2.0 Prototype 1 (Low fidelity) Plan

For the low fidelity prototype, we will be focusing on figuring out the actual size of various subcomponents and testing how the folding mechanism and latches to open the mat will work. The following material will be needed for this phase:

- Access to Onshape or Solidworks
- Cardboard
- Tape
- Scissors

Onshape or Solidworks will be used to sketch some rough estimates of various sub components similar to how Figure 1 is a drawing of the internal component of the mat and the connections, so we can use this drawing to determine the size and amount of dovetail connections needed around the edge of the mat.

The cardboard, tape and scissors will be used to create a physical prototype and will focus mainly on the folding mechanism of the design and the ability to open the mat to do repairs. By building a physical prototype it'll allow us to test out various hinge mechanisms to open the mat and fold it for storage, so we can get feedback and decide which hinge to use. Using cardboard will also make this cheap and time efficient so we can test out multiple hinges.

The following subtasks will be added to Wrike to meet the goals for the first prototyping phase:

- Build the cardboard model of the exterior of the mat (one person)
- Model various hinges using cardboard (one person)
- Schedule group meeting to present the physical prototype
    - Discuss and document all feedback
    - Create another mini prototype out of cardboard (The person who built the prototype may need to construct something quick based on the feedback if time allows testing a new idea)
- Create a drawing of external components of the mat (the surface for walking, the connections are the edges, etc) in Onshape/Solidworks
- Create a drawing of internal components of the mat (the supports within the mat, the openings for the wires to connect to the next mat, etc) in Onshape/Solidworks
- Create a drawing of electrical components of the mat (the heated cable, the junction box, etc) in Onshape/Solidworks

3.0 Prototype 2 (Medium fidelity) Plan

At this stage of prototyping, all of the designs and modifications to the original design will come to life. Prototype two will be the production of each subsystem: the casing, the electronics, and the software to remotely control the modules. By building each subsystem separately, it will make testing each component easier by being able to isolate any problems and issues that arise for each system without having to diagnose where the problem lies. This would complete the groundwork for the final prototype as well by ensuring that the systems correctly function with minor tweaking needed, and leaving the final assembly to be finished.

For the body of the module, the general layout for all the supports and internals will be finalized. The size of the body will also be finalized so that by the end of the second prototyping phase so that all the subsystems can be put together for the final prototype after the final features have

been implemented. To aid in the construction of the body, a gym mat that utilizes dovetails will be used as a border and act as a general outline of the module. As for the bracing and supports, various materials will be sampled to minimize costs while maximizing materials knowledge and learning which material best suits the client's needs. This prototype would also include beginning to optimize the space available inside the module so that the most efficient pathway for the heating elements is outlined. Outside the module, the circuitry for the heating element will be organized to ensure that all the electronics function correctly. An insulator will also be investigated so that there will be no damage to the other materials used for the casing.

There are several different subtasks and goals that need to be met for this prototype to be completed, all of which can be found on the Wrike and are outlined as follows:

- Building the casing
    - Create the general frame
    - Creating the supports
    - Optimizing the space for the internals
- Electronics
    - Create the circuit for the heating element
    - Model junctions so that power can travel across one module to another
    - Make any necessary changes to the initial schematic
- Document all work done with photos and creating or editing sketches

4.0 Prototype 3 (Fully Functional Design) Plan

When designing prototype 3 based on the previous iterations of our product, it will be paramount that we have some pre-made equipment that will fit under the budget. For example, the filament heating system for the product, if included in the prototype, will have to be pre-constructed, since we do not have the capabilities to fully assemble a working heating system while each being based out of a different location. We will also need a watertight casing unit such that the electronics contained within the product will not be damaged due to the entrance of water into the unit. This casing has been discussed to be constructed of a variety of materials, which will need to be tested for both heat conductivity and high melting point such that the heat imparted by the filament will be transmitted to the snow and ice, while also not melting due to conducting the heat. Preliminary considerations for materials include aluminum and steel (specifics yet unknown), since they are both good heat conductors, and will not melt given the little amount of heat being applied. Also, if the heating level is low enough, we may be able to incorporate a high heat-capacity plastic material, which would be both cheaper and easier to obtain.

In terms of tests that can be performed for this prototype, it is intended to be as high-fidelity as possible, meaning it should perform similarly to the final product. Thus, some tests we can run

are strength and stability tests, as well as heating tests. The product should be able to support the weight of a minimum of 300 lb at once without sustaining any structural damage. This is a minimum estimate, since the final product is intended to last 10+ years, and the wearing out of the materials would likely reduce the maximum load capacity of the design. For heating tests, we can perform tests using ice cubes/compacted snow and determine whether the heating filament is strong enough to melt the cold substance, whether the selected material can conduct the heat effectively enough, and whether the surface temperature reaches the desired range we have specified.

Some subtasks we will need to add to our Wrike page so that we stay on time to meet our goals are as follows:

- Acquire materials based on the materials list (to be finalized later)
- Evaluate materials (if possible prior to building) to ensure their validity
    - Example: test conduction of heat through metal selected
- Research pre-constructed heating-cable builds to be used in the prototype
- Construct the prototype in as functional a manner as possible
- Test the prototype for strength and durability
- Test the prototype for heating ability (how much snow melted per minute)

Note that for a physical prototype, only one person will be gathering materials and assembling the prototype for testing due to the locational constraints of our team.

5.0 Preliminary BOM

Item Number	Part Name	Description	Quantity	Unit Cost (CAD$)	Extended Cost (CAD$)
1	Heat it HISD 9-feet Pipe Heating Cable	Heating cable to be used in the interior of the mat as the heating element [Link 1]	x1	28.79	28.79
2	Cable Matters 2-Pack 4 Outlet Power Splitter Cord (Power Cord Splitter) 1.5 Feet	2 pack of cable multiplier with 1 male plug and 3 female plugs to use in combination with the heating cable [Link 2]	x1	24.99	24.99
Total					53.78

Link 1:
https://www.amazon.ca/18-feet-Heating-Cable-Built-Thermostat/dp/B01GZJKOJQ/?_encoding=UTF8&pd_rd_w=MtkoY&pf_rd_p=3b81ae56-012f-4bd9-853e-4e9ac6ad5bfc&pf_rd_r=PX6MZ4705F52DDSMXYHB&pd_rd_r=6331d4bc-0e7f-4902-a85a-1cb03c442a9e&pd_rd_wg=2o6e5&ref_=pd_gw_ci_mcx_mr_hp_d&th=1

Link 2:
https://www.amazon.ca/Cable-Matters-2-Pack-Outlet-Splitter/dp/B01K3ADZ76/ref=sr_1_1?dchild=1&keywords=Cable+Matters+2-Pack+4+Outlet+Power+Splitter+Cord+%28Power+Cord+Splitter%29+1.5+Feet&qid=1614571304&s=hi&sr=1-1-catcorr

Conclusion

With this deliverable, we successfully displayed a more detailed rendering of the design that we decided to prototype. Using CAD to create a 3D rendition of the design to show off the support columns and the dovetail connections; with the more detailed 2D drawing to show the interior heating and electrical components of the design. We also went in over in detail what the 3 stages of prototyping will contain, with the first stage of prototyping we will use cardboard and basic tools such as scissors and tape to create a basic physical version of the design to model the structure of the final design and test the folding and connecting mechanism. The purpose of the second prototype will be to test each subsystem in its entirety, building each subsystem separately will allow us to run tests on their mechanisms and functions individually before the final assembly. Finally prototype 3 will be the final assembly of the design where all of the subsystems will come together to create a functional and operational prototype that we will be able to show off on Design Day. We also discussed the BOM in this deliverable where we go over some of the purchases that will have to be made for this design to be realized.