uOttawa

GNG1103: Deliverable D

Group C12

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1.0 Introduction

The students of the Engineering Design have been tasked with constructing a practical design solution to a climate sensor for JAMZ's food delivery drone. The rise in food delivery due to the COVID 19 pandemic and limited coverage within rural communities means a drone operated delivery service could be feasible. Less human resources will be needed to deliver to regions with low profit margins, and delivery labourers can be redirected to reduce bottlenecking.

The climate sensor is a necessary component which will relay the temperature and humidity of the compartment which holds food and drinks. A series of subsystems have been defined to construct a fully functioning and balanced climate sensor.

The first subsystem is the data processor, which is to smoothen the digital output from the Arduino. This system will take the data that is fed by the sensor and will deconstruct it to form a signal which can be read as temperature and humidity. The data processor is supplemented by a visual feedback system. This data is taken from the Arduino and is displayed visually to be easily interpreted by a drone operator.

The whole system must be protected from the elements in the protection subsystem, which covers the Arduino and all necessary electrical components. The positioning of the climate sensor on the drone is also determined in this step. To protect the box from debris and foreign items from entering inside, a sealing subsystem is also defined to ensure that the box does not lose insulation capability despite their being wires inside that extend to the exterior of the box.

2.0 Subsystem Definition

The climate sensor system consists of 4 subsystems. These subsystems are: Sensor climate/delivery content protection, data processing, Arduino protection, and hole debris protection. Most of these subsystems focus on protecting the components that are crucial to the functionality of the climate monitor to provide the user with reliable and accurate data.

First, the climate/delivery content protection is required to protect the sensor while it is inside the box and exposed to the environment. When the box is retracted and attached to the drone, the sensor will have access to the internal space of the box and may need protection from water and other miscellaneous objects due to shaking or condensation formation with humidity. When the box is lowered, the sensor will be exposed to the outside environment which faces similar issues as the previous case where water from rain, or other debris flying in the air may damage the sensor.

Next, the data processing subsystem attempts to remove random noise from the sensor output to provide a stable and accurate data. This is done in software as it is a digital signal.

Third, the Arduino protection is required to protect the main control board from damage. It will be placed on the drone but needs protection from the environment as debris and water could damage the board and stop proper data transfer/processing from the sensor to the flight computer.

Lastly, the hole debris protection aims to prevent foreign materials from entering the inside of the box. This hole is required for the sensor to access the inside condition of the box but introduces a point of entry for water and other materials.

3.0 Concept designs

3.1 Sensor climate/delivery content protection

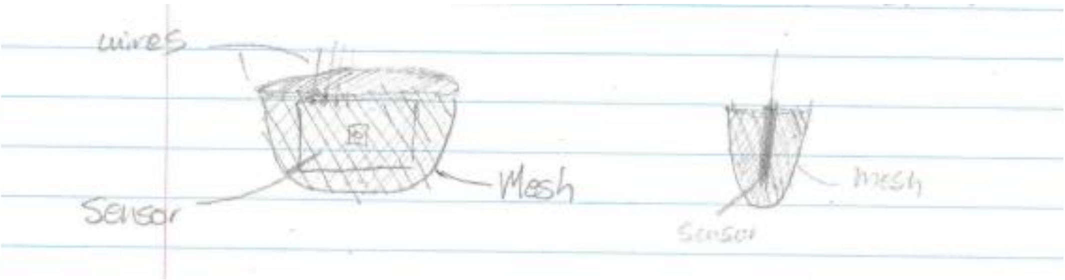


Figure 1.1 Mesh Design

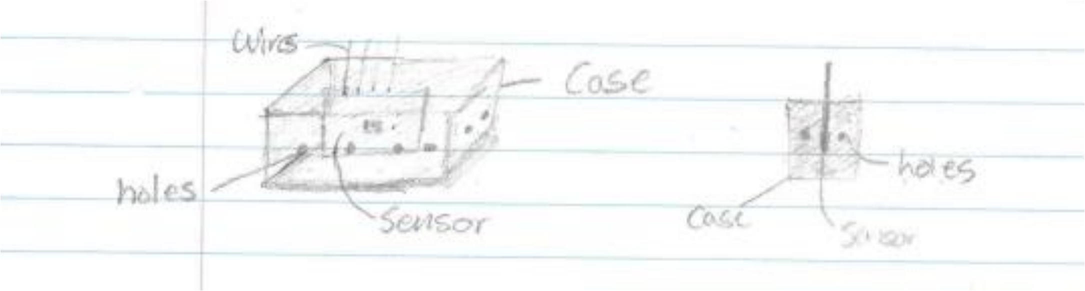


Figure 1.2: Solid Case Design

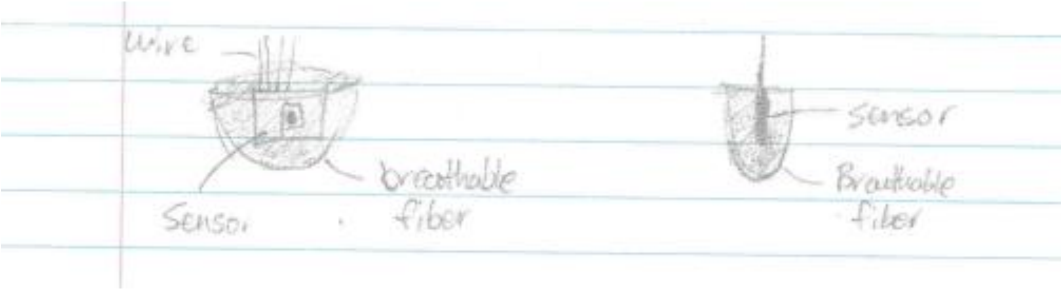


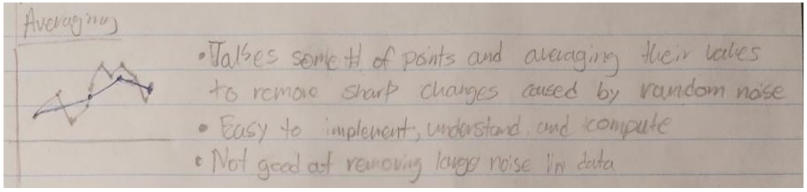
Figure 1.3: Breathable fiber design

Figure 1.1 shows a mesh that could be out of metal or other materials that surrounds the sensor to protect against debris and some water protection as the mesh catches/slows down of the water droplets that may fly towards the sensor. This does not take up a lot of space and relatively light. The downside of this method is the weak water protection as it relies on water tension on the fine mesh to stop water from coming in which is not very effective for water with speed.

Figure 1.2 shows a case that closes in the sensor with some holes for air to pass the sensor. This would prevent most of substances from damaging the sensor. It is safer compared to the other designs in terms of water and debris resistance. The size could be cut down to fit the sensor perfectly and have the hole directly on the chip component that measures the humidity/ temperature, slightly different from the sketch.

Figure 1.3 shows a similar concept to the mesh idea, but instead a breathable fiber is used to provide a barrier. This would be more effective at blocking water compared to the mesh and it very light. A disadvantage is that it may affect the reading on the humidity sensor for a while if liquid is absorbed to the fiber as the liquid evaporates near the sensor. It also lacks structural rigidity.

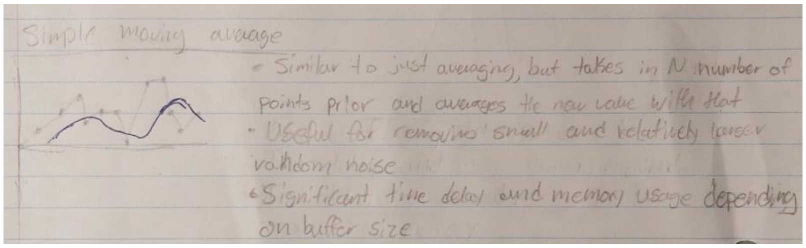
3.2 Data processing



Averaging

- Takes some # of points and averaging their values to remove sharp changes caused by random noise
- Easy to implement, understand, and compute
- Not good at removing large noise in data

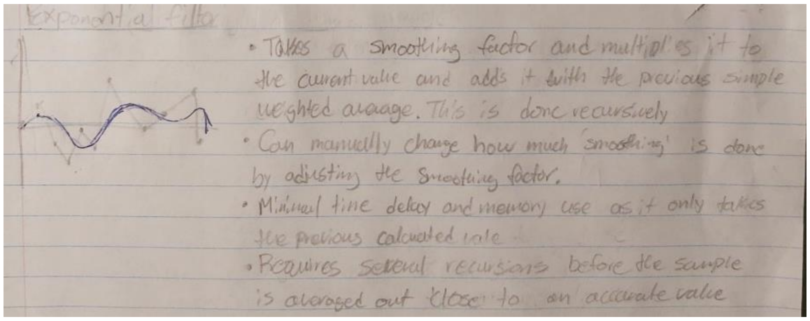
Figure 2.1: Averaging Method



Simple moving average

- Similar to just averaging, but takes in N number of points prior and averages the new value with that
- Useful for removing small and relatively larger random noise
- Significant time delay and memory usage depending on buffer size

Figure 2.2: Simple Moving Average Method



Exponential filter

- Takes a smoothing factor and multiplies it to the current value and adds it with the previous simple weighted average. This is done recursively
- Can manually change how much 'smoothing' is done by adjusting the smoothing factor.
- Minimal time delay and memory use as it only takes the previous calculated value
- Requires several recursions before the sample is averaged out close to an accurate value

Figure 2.3: Exponential Filter Method

From the digital output from the sensor, there may be some random variation in the reading. To smooth out the output values and remove sudden spikes, 3 possible solutions have been proposed.

First is averaging where it takes the average of N number of values from the sensor to remove some noise. This method is very easy to implement and good for removing small noise in the data, depending on the N value. Depending on the N value, it may require a lot of memory.

The second is the simple moving average where it takes the average of n number of values and with each new value, it is added to the previous n number of values and averaged with that. This is useful for removing small to relatively larger random noise. However, it has significant time delay and requires a lot more memory depending on the buffer size.

Last is the exponential filter where it weights the current reading and previous smoothed value to calculate the current smoothed value. This recursive filter can be adjusted to change how much the data is smoothed out by adjusting the weighting factor in the program. There is minimal time delay and memory. The method does require several recursions before the sample is averaged out close to the accurate value.

3.3 Arduino Protection System

The Arduino Protection System is intended to prevent damage to the microcontroller. Some criteria considered for designing the subsystem include minimizing damage from a low-impact crash, protection from common weather elements, and Arduino accessibility. The system must also be fixed onto the drone, whether permanently or semi-permanently (attachment styles).

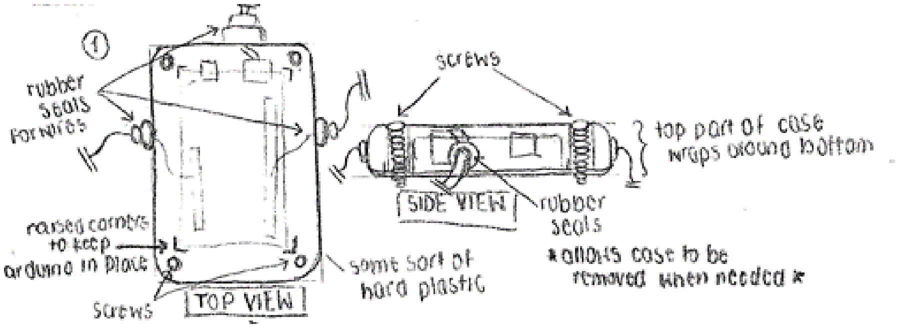

①
rubber seals for wires
raised corners to keep arduino in place
screws
TOP VIEW
some sort of hard plastic
screws
top part of case wraps around bottom
SIDE VIEW
rubber seals
allows case to be removed when needed

Figure 3.1:Screws are contained within the Arduino protective case to hold the system in place

Two designs fall under the semi-permanent, screw attachment style. Both contain similar features but differ in the screw placement and dimensions. The first design has screws contained within the case. This will require larger screws that exceed the height of the case to make contact with the surface of the drone. The second design contains screw holes extending out from the top and bottom portions of the case. This reduces the surface area of the case itself and will require smaller screws to fix the case onto the drone. Consequently, the small extensions may increase the likelihood of a failure along their stress points. Other features are outlined in Figure 3.1 and Figure 3.2.

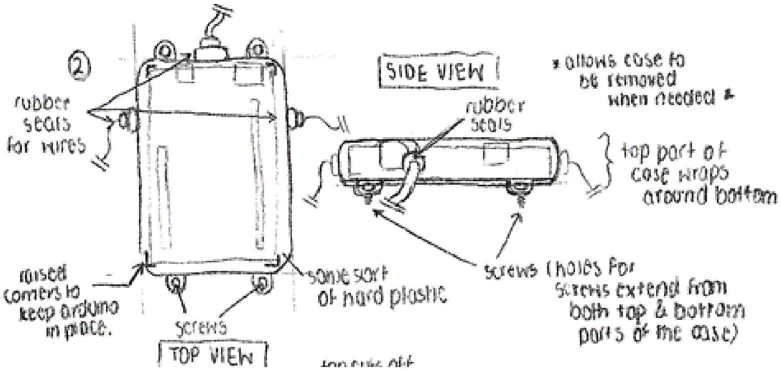

②
rubber seals for wires
raised corners to keep arduino in place.
screws
TOP VIEW
some sort of hard plastic
SIDE VIEW
* allows case to be removed when needed *
rubber seals
top part of case wraps around bottom
screws (holes for screws extend from both top & bottom parts of the case)

Figure 3.2: Screws extend out from the Arduino protective case to hold the system in place.

The third design falls under the permanent, glue attachment style. The case features a sliding top to access the Arduino, while the case itself remains fixed on the surface of the drone. The weakness of the design is its exposure to wear-and-tear due to moving parts. Its permanency on the drone can also be a disadvantage – the design feature does not allow the case to be easily removed for repairs or relocation. Other features are outlined in Figure 3.3.

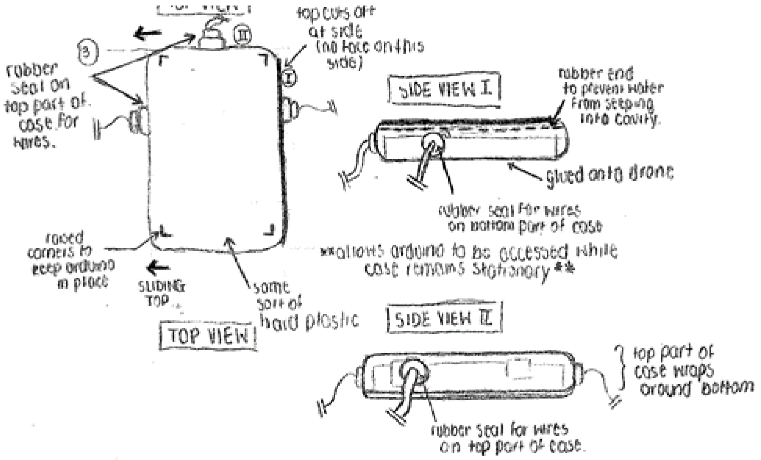

③
II
I
top cuts off at side (no face on this side)
rubber seal on top part of case for wires.
raised corners to keep arduino in place
SLIDING TOP
some sort of hard plastic
TOP VIEW
SIDE VIEW I
rubber end to prevent water from seeping into cavity.
glued onto drone
rubber seal for wires on bottom part of case
allows arduino to be accessed while case remains stationary
SIDE VIEW II
top part of case wraps around bottom
rubber seal for wires on top part of case.

Figure 3.3: Glue holds Arduino protective case in place while sliding top allows access to the microcontroller.

Design criteria such as a cooling mechanism for the microprocessor were not considered during the design process of this subsystem. The group came to an understanding to wait for feedback from JAMZ. If concerns for a cooling mechanism were raised, the team will re-evaluate their designs and make the appropriate changes.

4.0 Analysis and Evaluation

4.1 Climate/Delivery content protection

After consideration of the three basic systems as shown in figure 1.1-1.3, a fourth concept was created where a combination of both mesh and breathable fiber is used to protect the sensor. The mesh will provide structure and support the water/debris protection of the breathable fiber.

The concepts were compared with the set of criteria as shown in the table below. The water protection weighted heavily as this could take out the sensor and the debris protection following behind as it would be less likely to cause damage to the sensor but could potentially cause issues. The size was also weighted heavily as a large sensor case will require a large hole in the box which is undesirable. Durability was another key criterion as this would have to be strong enough to protect the sensor while it is exposed to the outside environment during the box descent and any other unforeseen events to meet the clients need of reliability.

Criteria	**Weight (1-5)**	**Concept 1**	**Concept 2**	**Concept 3**	**Concept 4**
Water protection	5	1	4	2	3
Debris protection	4	4	4	4	4
Mass	2	3	1	3	2
Size	5	1	4	4	3
Cost	2	3	1	4	2
Durability	4	4	4	1	4
		54	**76**	**61**	**70**

Table 1: Comparison table for climate/delivery content protection

Out of these concepts, concept 2 shown in figure 1.2 was determined to be the best solution. The case provides good water and debris protection with a small size which is vital. The casing for this system will most likely be plastic printed from a 3D printer, but further research into the type of materials that could be used will be conducted.

4.2 Data processing

For data processing, the exponential filter was selected to be the best candidate for this system. However, the moving average is still under consideration as it could be modified to a weighted moving average and exponential moving average.

For the selection criteria, flexibility, time delay, and memory were selected. Accuracy was not included in this section as that would depend on the sensor itself. If accuracy was defined as how much noise these methods can handle, it would depend on the what the values used in the equation for each individual methods are and is impossible to compare directly. The flexibility criterion in this table is defined as the ability to change the amount of filtering without negatively affecting other factors like time delay and memory. The time delay and memory criteria are based on the theoretical best case for each method.

Table 2. Comparison table for data processing solutions

Criteria	**Weight (1-5)**	**Concept 1**	**Concept 2**	**Concept 3**
Flexibility	5	1	3	1
Time delay	3	3	2	1
Memory	2	1	3	1
		16	**27**	**10**

Table 2: Comparison table for data processing solutions

The exponential filter was found the be the best option due to its flexibility and general lack of disadvantages compared to the other two methods in this use case. By modifying the weight constant in the equation, the amount of smoothing done can be adjusted making this the ideal method without negatively affecting other factors. During testing, it may discovered that the sensor is more prone to noise so having the option to adjust the filtering without needing to use more processing power, memory, or time delay is a major benefit.

4.3 Arduino Protection System

A set of criteria were established for the design of an Arduino protective case. In the event a JAMZ delivery drone launches their parachute, the protective case must be able to withstand a low-impact crash. Here, the number of stress points and moving parts were considered in the weighing. All concepts shared a similar feature of raised corners to keep the Arduino in place, therefore the feature did not affect weighing. For protection from common weather elements, minimal cavities and rust prevention were considered. All concepts shared similar materials and wires seals. These features did not affect weighing. For Arduino accessibility, the sliding mechanism in concept three may cause issues if not enough space is allowed for the door to move. This was also a consideration in weighing the size criteria for concept three. Lastly, the durability of each concept was weighed by considering features like their minimal stress points, wear-and-tear from moving parts, as well as rust prevention.

Criteria	Weight (1-5)	Concept 1	Concept 2	Concept 3
Protection Against Low-Impact Crash	**4**	5	3	2
Protection from Common Weather Elements	**5**	4	4	3
Arduino Accessibility	**3**	5	5	4
Relocation/Removal	**2**	5	5	2
Durability	**4**	4	3	2
Size	**1**	3	5	1
Cost	**2**	3	4	4
		90	**82**	**55**

Table 3: Comparison table for Arduino protection system

From Table 3, criteria were weighed, and the first concept held the highest score overall. In weeks to follow, small adjustments to the design can be added to improve its overall durability and protection from common weather elements. Some sort of rubber covering to slow the process of oxidation on the screws will be considered before prototyping, or a stainless-steel material.

4.4 Hole debris protection

For hole sealing, a system which allows the wire and sensor to enter and exit the box upon its release is designed. Three designs are conceptualized as recommended.

The first design is seen below in Figure _. It consists of a round plastic construction with four slits cut into it similar to the lids from a drinking cup from a fast food restaurant. When the cable is lowered to enter the box to begin taking climate measurements, it will pass through the slit and secure in place.

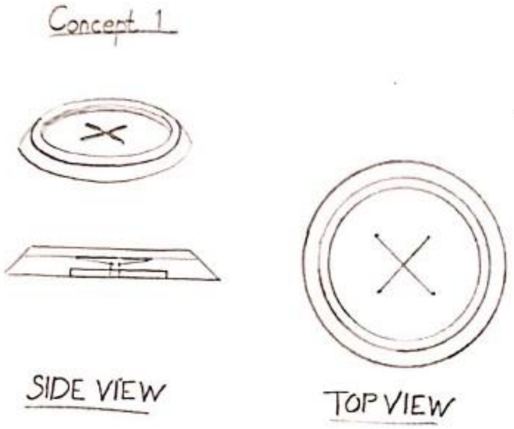


Figure 4.1: First concept for Sealing

This design is the most economical of the three generated concepts. It uses the least materials and the least space. However, due to the slit it may still allow water droplets and exterior moisture to enter which could potentially reduce the box's insulating capability. The risk of droplets could also lead to more water on the sensor which could lead to faulty readings and skewed data.

The second design concept, seen below in Figure _ is constructed out of rubber and has a conical profile. Instead of using a slit, a hole is drilled through the middle which is wide enough to fit the wire and sensor. The wire passes through and is locked in place by a rubber stop the same width as the hole in the sealing. The sealing is attached to the box by the means of an adhesive.

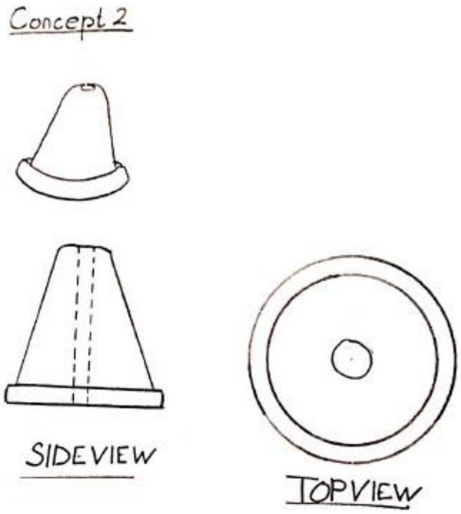


Figure 4.1: Second Concept for Sealing

This design has good sealing capabilities as it is constructed out an impermeable material and because it is small will only slightly increase the cost of production. The main drawback of this design is the dependence of an adhesive which could potentially wear down with time and cause leaks and loss of insulation. The adhesive will also make repair and maintenance more complicated as the adhesive will have to be removed prior to removing the seal.

The final concept is seen below in Figure _ also constructed out of rubber and plastic. This design consists of two rubber rectangles which are sandwiched in between a cylindrical cross section. One of the rectangles is threaded and can be screwed or unscrewed from the cross section which makes attaching the seal simple. There is a hole in the middle of the seal which is where the wire can be placed, and a rubber stop connected to the wire can seal the hole.

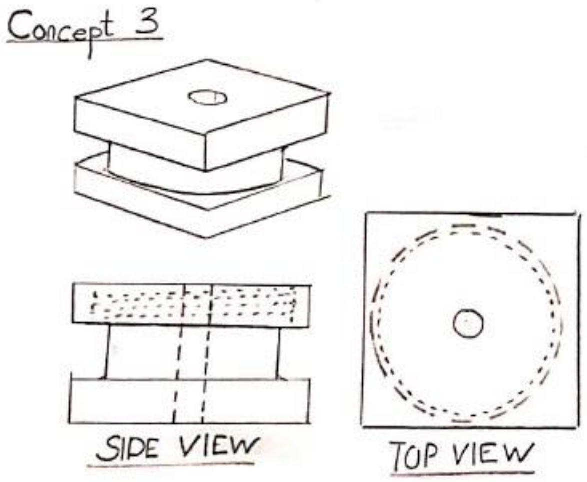


Figure 4.2: Third Concept for Sealing

This design is the costliest to manufacture, as it requires two pieces of different material and it requires threading which increases manufacturing time and cost. However, in terms of insulation this design is the best as there are no permeable surfaces which can attract moisture and affect the insulating capability of the box.

Criteria	**Weight**	**Concept 1**	**Concept 2**	**Concept 3**
Water Protection	5	2	4	5
Debris Protection	5	2	4	5
Size	1	5	2	2
Cost	2	5	3	2
		40	**48**	**56**

Table 4:Comparison table for hole debris protection

As seen in Table 4, Concept 3 has the highest score, therefore it is selected for the given application.

5.0 Conclusion

The purpose of this project is to design a climate sensor system to relay temperature and humidity data to the drone's operator. The system will consist of four subsystems which are: sensor climate/delivery content protection, data processing, Arduino protection, and hole debris protection. These subsystems will help ensure that our climate sensor system is both functional and protected while in use.

It is concluded that the best concept for the sensor climate/delivery content protection was a rigid case. This concept allows for good protection for the sensor while also being compact in size. For the data processing subsystem, the exponential filter was chosen as the best choice since it provides flexibility and smooth data while also lacking disadvantages. The best concept for the Arduino protection system was determined to be the first concept with screws found inside the protective case. This case provides protection and easy accessibility for the Arduino while also being very durable. Lastly, the best concept for the hole debris protection was concluded to be the third idea. This concept is more expensive but allows for the most protection against debris and moisture entering the hole in the top of the box.

The four subsystems are key components to the climate sensor system. Each of the determined concept designs for the subsystems will continue to be developed and researched on before the prototyping stage begins. This will allow continued expansion and improvements on existing design ideas and before settling on a final concept.

6.0 Future work

Moving forward, more research on the products will be needed to understand finer details such as the type of material for the case, exact dimensions, etc for prototyping. With the upcoming client meeting this Wednesday, the placement and space of the components will be discussed, and any misconceptions and uncertainties will be cleared as much as possible before proceeding with any purchase.