Prototype III and Customer Feedback

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1. Introduction:

After testing the functionality of some of the critical components of the design, it's now time to assemble the whole thing together. It is at this part of the project when all of the weeks of work that have been completed all come together to result in the final fully assembled project. It's important to test the entire product fully assembled, as even though some parts may work in isolation, that might not be the case when they're all put together. Despite this being the final product, it's still important to get feedback on it from users in order to identify room for improvement for both right now and in the future.

2. Prototype III Test Plan:

The third and final prototype will be a fully functional version of our design. It will be based on the detailed design, while also incorporating aspects that we've learned from previous prototypes. Although this prototype isn't supposed to be exactly like the version that we'd sell, it should fully satisfy the problem statement that was defined earlier in the design process. It's also important to test the functionality of the device fully assembled, as even though the subsystems have been tested individually, it's important to verify that they all work together as one when assembled.

Required materials:
-PM2.5 laser sensor
-Arduino connector
-Connector cable
-Superglue
-Electrical tape
-2x 2 mm screws (M2-0.4 x 6 mm)
-Arduino Uno Rev3
-Arduino wiring
-4.8 m USB-A/B cable
-4x ⅛" screws (M3-0.5 x 10 mm)
-3D printed sensor housing
-3D printed sensor lid
-4x 5 mm screws (M5 x 10 mm)
-4x ⅜" bolts (⅜" x 2")
-4x ⅜" nuts
-4x ⅜" washers
-Laptop with Ardino IDE installed
-Grain malt
-Plastic funnel
-Garbage bag

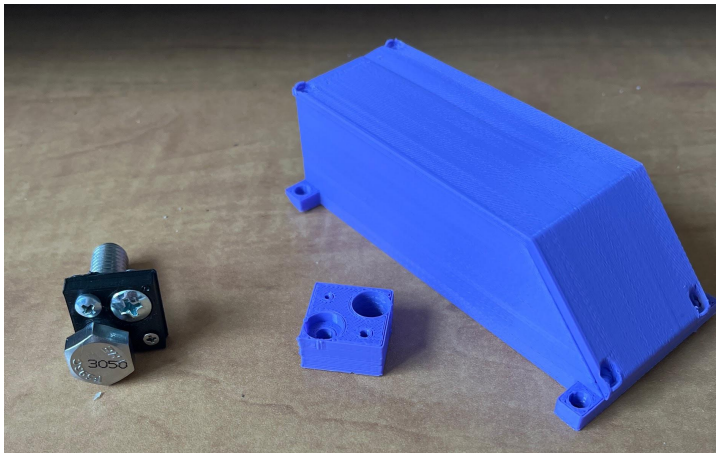
The prototype will consist of all the materials listed above assembled together as seen in the detailed design. Before this, however, all connection points (holes) will be 3D printed to scale, and then the bolts and screws will be inserted to ensure that they fit correctly. If they don't, they will be redesigned and the process will be repealed. The same will be done with the housing and the lid, although they will be scaled down when printed in over to save time. After this, the full-scale housing and lid will be printed out, then the components will be screwed or glued into place. Then, the test from prototype II will be redone with the fully assembled device and revised code to ensure that everything is working as intended.

Similarly to prototype II, the test will be completed once we observe dust concentrations appearing on our screen in the intended manner. The difference will be that we will continue to pour the malt in after we verify the data appearing on the screen in order to ensure that the device will work for longer periods of time. The test will be concluded once all of the malt has been emptied into the bag and dust levels have stabilized. In the event that the dust data doesn't display correctly or any other error occurs, we will stop the test in order to try to get an understanding of what went wrong and how to fix it. Since time will be limited until the deadline, we will likely have to consider how to fix things with our current resources rather than ordering new material to solve the problem.

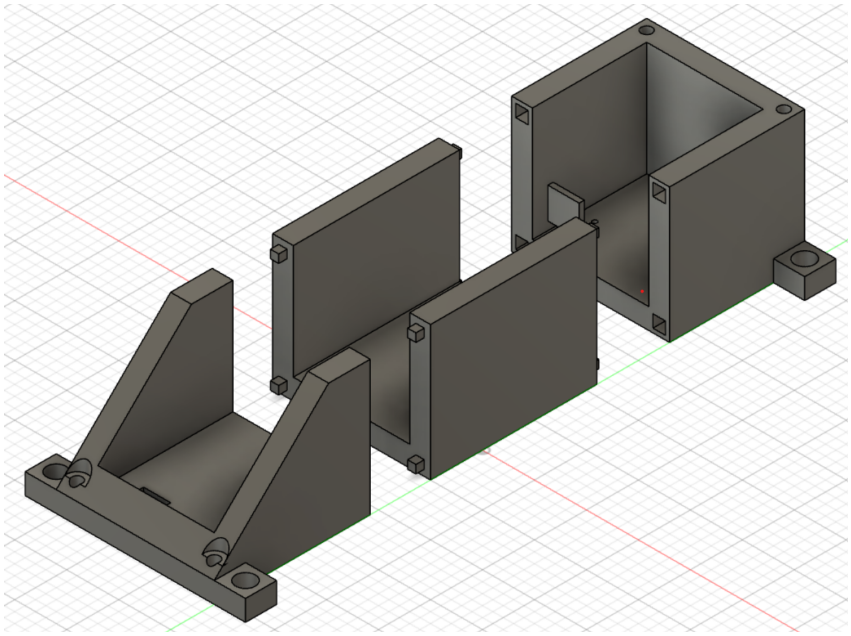
Printing out the connection points and scaled-down housing will be the first things completed, which will be on Tuesday. Once they have been printed and verified, the full-scaled housing will be printed on Wednesday, Thursday, and Friday. The lid will then be printed on Sunday. The housing sections will be assembled on Friday, the interior components will be assembled on Saturday, and then the final tests will be completed on Sunday.

3. Results:

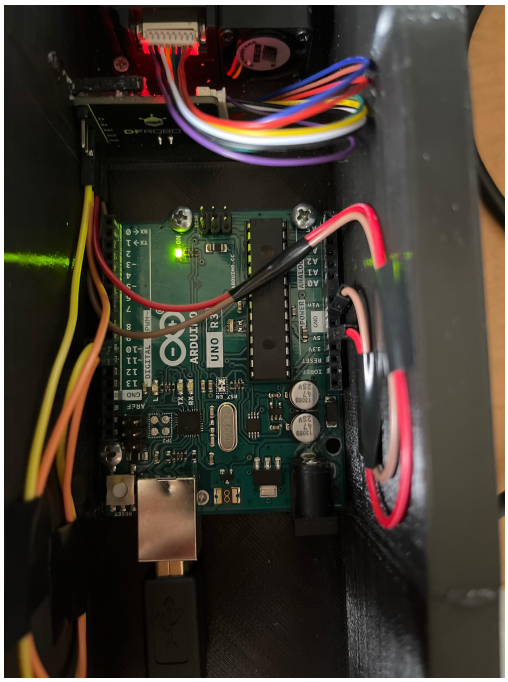
The printing of the scaled-down model of the sensor went exactly as planned, and it verified the fit of the main body of the casing and the lid together. However, the printing of the test holes showed us that they were slightly too small for the screws and bolts to fit in. To rectify this, the holes were slightly widened and the piece was reprinted. The screws and bolts fit in perfectly on the new piece, so we made those adjustments to our design accordingly.



When we went to print out the casing, we realized that it would take far longer to print than we initially anticipated. Because of this, we had to divide the body into 3 sections in order to print it within the hours of makerspace. To accomplish this, we created small slots on the pieces which would allow them to snap together, and then they will be glued together to keep them in place. For the lid, it would be able to be printed within makerspace hours without having to divide it. However, this required placing it on its side. Unfortunately, this meant that the printer had to go back and forth over a very small area very quickly, resulting in a lot of vibrations which caused the printer to pause the print. Because of this, the piece then had to be cut in two and placed flat to allow it to print. However, once this was done, the printer began to malfunction, first getting frozen at the same spot of the print multiple times (a simple 90° corner), then not extruding any material from the nozzle. At this point, all other printers were either taken or also broken, and there was not enough time left in the day to complete the print. As a result, we are not able to have the lid printed out for this prototype, although it will be printed out and assembled with the rest of the casing for design day.



When inserting the components into the casing, we noticed that the holes for the Arduino were slightly off. We looked back at the reference site that we used to design the holes and compared them to the actual measurements of the hole, and verified that they were the same measurements. The site said that the measurements were for the Arduino UNO, which is the board that we're using, but it's possible that the site was made for an older model of the board which had slightly different hole placements. The result of this is that we have 3 screws holding the board in place, although at a slight angle, but the fourth screw is unable to be inserted due to this slight discrepancy in measurement. The board is still securely in place, but not quite as secure as it could be.



As for the test itself, were able to get dust concentrations to display on the output screen on a couple of occasions, however we couldn't get the data to appear consistently or while conducting the actual test itself. We suspect that this is likely due to a voltage drop somewhere within the system, as the sensor requires 30 seconds of a 4.95-5V connection to transmit data. A sporadic voltage drop could explain this occurrence, as there is still power constantly flowing to the sensor, but just not enough to constantly transmit data. The cause of this drop may be due to our long USB cable that's required to reach the HMI system from the silo, or it may be due to something in the way the Arduino or sensor adapter transmits the signal, or maybe a combination of both.

```
31 ug/m3
33 ug/m3
28 ug/m3
29 ug/m3
27 ug/m3
30 ug/m3
33 ug/m3
31 ug/m3
28 ug/m3
28 ug/m3
30 ug/m3
32 ug/m3
```

```
28 ug/m3
30 ug/m3
32 ug/m3
WARNING, HIGH DUST CONCENTRATION
34 ug/m3
WARNING, HIGH DUST CONCENTRATION
31 ug/m3
WARNING, HIGH DUST CONCENTRATION
29 ug/m3
30 ug/m3
32 ug/m3
WARNING, HIGH DUST CONCENTRATION
```

Despite this, we were able to get valuable information from the test. We were able to get feedback on our brief data output from other users, which will be explained in the feedback section below, and we were also able to test how strong some of the seams were on the casing by finally conducting the malt pouring test that was intended for prototype II. We taped a piece of paper over the top of the casing since the lid unfortunately wasn't printed yet as stated earlier. Then, malt was poured through the funnel to simulate malt being poured into the silo. After this, we took the sheet of paper off and observed that there was no dust accumulation inside the silo. This indicated to us that all of our seams were sufficiently sealed, which is great as dust and electricity mixing is never a good thing.

4. <u>User Feedback:</u>

Despite not having any direct meetings with the client since the last prototype, we were still able to gather feedback on an aspect of our design, that being our data output. We showed 5 other students our data output (the screenshot below), which is the serial monitor window from the Arduino IDE. We asked them about how clear the message of the data was, and how well the organization was, the two most important aspects of the output. These 5 people are representative of users as if they can clearly identify what's being displayed and the meaning of it, then the trained employees at the brewery will also likely be able to do this.

```
28 ug/m3
30 ug/m3
32 ug/m3
WARNING, HIGH DUST CONCENTRATION
34 ug/m3
WARNING, HIGH DUST CONCENTRATION
31 ug/m3
WARNING, HIGH DUST CONCENTRATION
29 ug/m3
30 ug/m3
32 ug/m3
WARNING, HIGH DUST CONCENTRATION
```

User	Rating /10	General Feedback (unfiltered)
1	7	A bit boring, but it's clear and gets the point across. Could maybe add in a bit of colour somewhere
2	7	Looks good to me, numbers are a bit small on the screen but still good
3	8	I like it, everything is clear about what's being measured
4	8	Shows what needs to be shown I think. Not very fancy, but it's good
5	7	Kinda plain but it's all pretty clear

This feedback is very beneficial to us. All participants were able to immediately understand the context of the information and were able to understand its meaning. This means that our output is very understandable, and that it conveys the required information adequately. In terms of incorporating their feedback into our design in the future, there doesn't appear to be any simple way to change the colour of the text in the Arduino IDE serial monitor. To incorporate that, we'd have to find a way to export the data from the Arduino IDE to something else, which will likely be difficult to accomplish before design day, but it's definitely something that we could try. The same goes for the feedback about the number size. Other than they, everyone seemed pretty satisfied overall with the output, so we will stick with the same general output concept going forward.

5. Updated Materials:

Current BOM, items highlighted in red are items that are required if the device is installed in the silo, but had no purpose for this prototype so they weren't purchased.

Item	Quantity	Cost/Unit	Total Cost	Justification
PM2.5 Laser Sensor	1	Subtotal: $46.90 USD ≈ $63.77 CAD + Taxes and Duties (website does not specify); Shipping: $21.00 USD ≈ 28.55 CAD	$92.32 CAD ($28.55 of that is shipping)	Needed to sense dust
Arduino connector	1	Included w/ PM2.5	Included w/ PM2.5	Required to connect sensor

				to Arduino
Connector cable	1	Included w/ PM2.5	Included w/ PM2.5	Required to connect Arduino to HMI
Superglue	1	Already acquired	Already acquired (Would be about $3.72)	Needed to fasten adapter to side of housing
M2-0.4 x 6 mm screw (10 pack) https://www.amazon.ca/Prime-Line-9120609-Machine-Phillips-Stainless/dp/B07D5TLKHF	1	$3.99	$3.99	Needed to attach sensor to the side of housing
Arduino Uno Rev3	1	$48.16 CAD including everything (amazon)	$48.16 CAD	Uses our code to interpret data
Arduino jumper wire pack	1	$9.48	$9.48 CAD	Needed to connect the adapter to the Arduino
4.8 m USB-A/B cable	1	$8.11	$8.11 CAD	Arduino connected to HMI via USB-A/B cable
USB A-A adapter	1	$10.59	$10.59	For connecting USB cable to I2C adapter
USB-I2C Adapter	1	$14.99	$14.99	Connects USB A-B cable to I2C cable

2 m I2C cable	1	$6.95	$6.95	Connection to the HMI system
M3 x 10 mm screw (5 pack)	1	$5.29	$5.29	Needed to attach the Arduino to the side of the housing
Sensor housing material (Plastic/Resin)	1	Free in Makerspace	Free in Makerspace	Durable enough, light weight, easy to design with
3D printed sensor lid(Plastic/Resin)	1	Free in Makerspace	Free in Makerspace	To be attached on the main points in the housing
M5 x 10 mm screw (5 pack)	1	$5.29	$5.29	Needed to attach the lid to the housing
⅜ x 2” stainless steel bolt (5 pack)	1	$9.58	$9.58	Needed to connect the housing to the silo from the inside
⅜” nut	4	$0.24	$0.96	Needed to fasten the bolts in place from the outside
⅜” washer	4	$0.21	$0.84	Needed to fasten the bolts in place from the outside
2-row malt (1lb bag)	3	$1.99 x 3 + $14.41 Shipping	$20.38 CAD ($14.41 is shipping)	To simulate filling silos with malt for testing
16 oz ¾” opening funnel	1	$9.61 including everything	$9.61 CAD	Used for pouring the malt for test 1, the malt rubbing against it should

				increase dust levels for testing verification
Garbage bag	1	Already acquired	Already acquired (would be about $1.29)	Needed to contain the malt dust during prototype 1
Tape	1	Already acquired	Already acquired (would be about $1.72)	Used to hold the housing and lid together for prototype 2
Electrical Tape	1	$4.75	$4.75 CAD	Needed to hold loose-fitting electrical components together
Other Jumper Wires (Including M to F)	1	$9.99	$9.99 CAD	Needed to connect arduino to adapter
Duties	N/A	N/A	$28.08 CAD	Needed to pay for international shipping
Total			$275.61 ($71.04 of that is shipping and duties) Additionally, there is about $6.73 of material we already owned, not included in this total Note: may be slightly higher with additional shipping and taxes	

6. Conclusion:

We printed out test holes and a scaled-down casing to verify the fit of our design before moving on to the full-sized thing. We made adaptations to our design based on printing restrictions in order to proceed forwards, and also faced printing issues that prevented the printing of the lid currently. We then managed to briefly and sporadically get the dust concentrations to output while verifying the seal of the seams of the device. Lastly, we were able to get valuable feedback on our data output from representative users, despite the absence of a meeting with the actual client.

Wrike snapshot:
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=aBA2UFnmUPozvOZNWeqkacMOx1pkdgkC%7CIE2DSNZVHA2DELSTGIYA