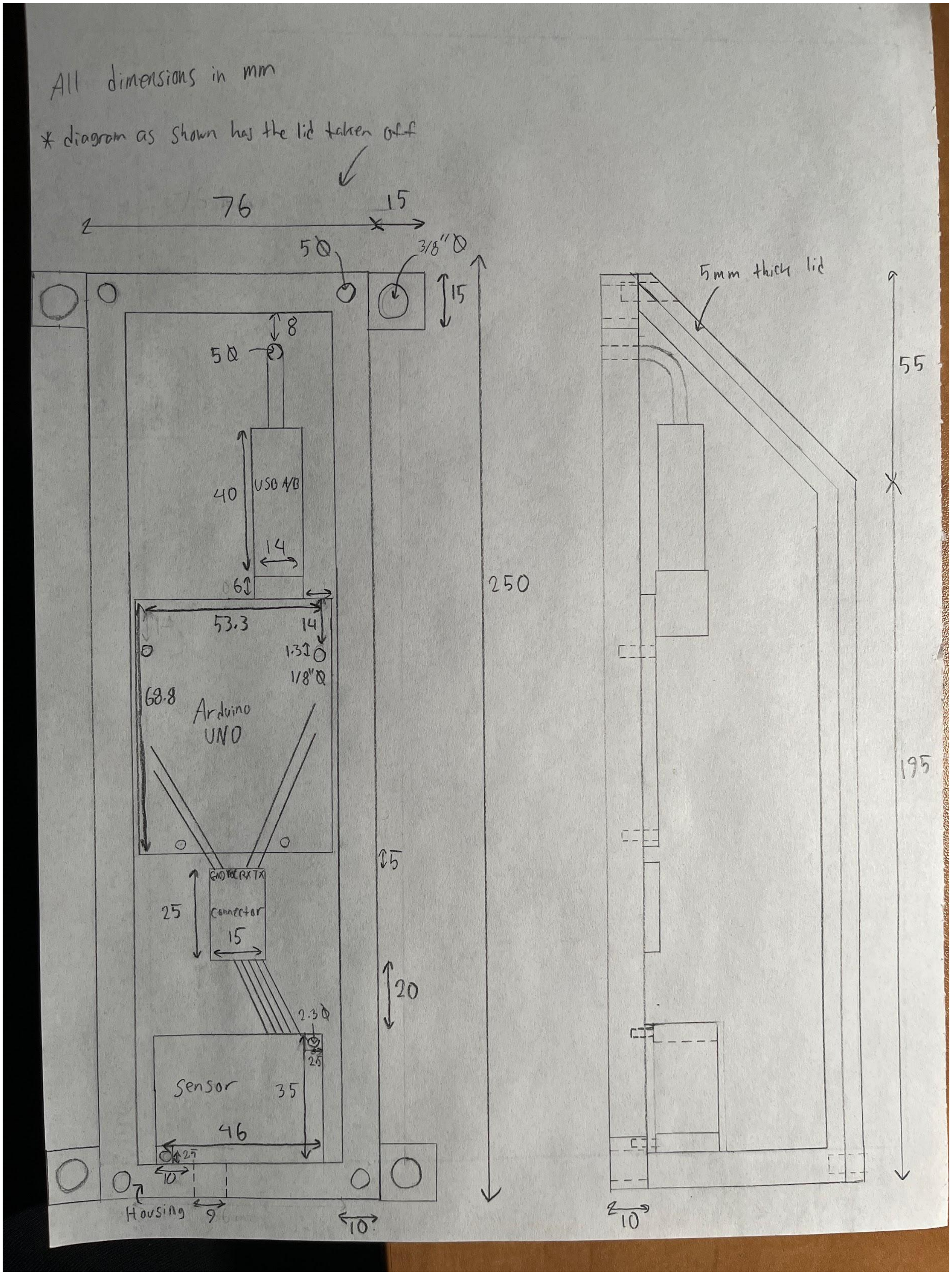
Detailed Design:



Components:
-PM2.5 laser sensor
-Arduino connector
-Connector cable
-Superglue
-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

Starting off with the interior components, the PM2.5 sensor is located at the bottom of the device and is used to detect dust in the air by shooting a small laser beam and measuring how much the beam is refracted by the dust in the air, therefore finding the dust concentration. It's screwed into the side of the device and faces downwards towards the malt as that's where the dust will be originating from. Dust concentrations in the air will be at the highest when the malt is moving, so placing the device near the bottom of the silo would lead to quick notice of increased dust concentrations when the malt is in motion.

Moving upwards, the sensor is connected by a cable to an Arduino adapter that comes with the sensor, along with the cable. The adapter will be fastened to the side of the housing with superglue as there are no screw holes on the component. It should be noted that the exact size of the adaptor couldn't be found on the product site, so the dimensions were roughly measured based on images on the site which had the adapter positioned beside the sensor.

On to the Arduino itself, which will process the data from the sensor to do the calculations of the dust concentrations, as well as alert when the levels become too high. It's connected to the side of the housing with 4 screws, which are inserted through the pre-drilled holes on the device. It should be noted that extra space was made inside the housing to ensure that there was enough space to insert the wiring into the Arduino ports, as the solid parts of the wires stick up above the maximum height of the Arduino itself. Exact figures on how far the wires stick up could not be found, so extra space was allocated just to be safe.

Concluding the interior components, the Arduino is connected to the HMI system via a 4.8 m USB-A/B cable. This cable was selected as it's more than capable of transmitting the required amounts of data between the device and the HMI system, as well as the fact that it can plug directly into the Arduino without any adaptors. The cable will exit the device through the side and wall of the silo, and should be long enough to reach an HMI connection, although extension cables can be purchased if this isn't the case.

Moving on to the device housing itself, it's a 3D-printed box with a removable lid. The lid was added to allow the components to be accessed for maintenance, as well as so that the entire device doesn't have to be taken off the silo wall for maintenance, as doing so requires draining the entire silo to reduce the risk of an explosion. The walls of the device are 1 cm thick which should be strong enough to withstand the force of the malt entering the silo. The lid is 0.5 cm thick, but will be attached to points on the main housing that are also 0.5 cm thick to result in the total thickness being 1 cm. The lid will be screwed onto the main housing to ensure that it doesn't just come off on its own, as a snap-on version could possibly be removed by the force of the malt entering the silo.

Finally, the housing will be connected to the silo via 4 ⅜" thick bolts. This size of bolt was chosen as they were small enough to be incorporated into the design without too much additional modification, but are also more than strong enough to withstand the forces that will be acting on the box. On the outside of the silo, they will be secured using a simple washer and nut system that's easy to both install and remove.

Bill of Materials:

Item	Quantity	Cost/Unit	Total Cost	Justification
PM2.5 Laser Sensor	1	$46.90	$46.90	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	Needed to fasten adapter to side of housing
M2-0.4 x 6 mm screw (10 pack)	1	$3.99	$3.99	Needed to attach sensor to the side of housing
Arduino Uno Rev3	1	$27.60	$27.60	Uses our code to interpret data

Arduino jumper wire pack	1	$9.40	$9.40	Needed to connect the adapter to the Arduino
4.8 m USB-A/B cable	1	$8.11	$8.11	Arduino connected to HMI via USB-A/B cable
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	$5.97	To simulate filling silos with malt for testing
16 oz ¾”	1	$9.61	$9.61	Used for pouring

opening funnel				the malt for test 1, the malt rubbing against it should increase dust levels for testing verification
Garbage bag	1	Already acquired	Already acquired	Needed to contain the malt dust during prototype 1
Tape	1	Already acquired	Already acquired	Used to hold the housing and lid together for prototype 2
Total			$133.54 Note: may be slightly higher with additional shipping and taxes	

List of Equipment:

Equipment	Justification
Arduino IDE	Used for writing all the code and for testing the dust sensor during prototyping (raw dust concentrations will display within the IDE)
3D Printer	Used for printing the housing and lid, as well as the scaled-down version for prototyping
Phillips Screwdriver	Used for tightening the screws that hold the internal components and lid in place
Adjustable Wrench	Used for tightening the bolts that hold the device housing in place
Fusion360	Used for designing the housing and lid which will then be 3D printed

Significant Project Risks:

Risk	Associated Contingency
Material may not be food safe	Make sure all equipment (both the sensor casing as well as any tools used to install the sensor) are sanitized and meet all Foods Canada or any other food safe organization requirements.
Materials do not come in time or websites are not reliable	We can check stocks of local stores to find replacements/alternatives for materials we order
Mounting system could damage the silo	In a prototype wherein we simulate silo conditions, if we find that our “silo” may be damaged, we can use one of the other concepts we came up with for device mounting subsection, or we could develop a new one tailored more to our new needs if none fit.
Mounting fails due to harsh conditions Mounting cannot withstand silo pressures Flow of malt could be too strong	Once again if we notice issues with mounting reliability in our prototyping, we could consider one of our other concepts. Alternatively, we could choose a new, more rigid material to comprise our casing, such as a metal.
Sensor doesn’t work as intended	If the sensor does not work to accomplish our needs in prototyping, we could consider one of the many other sensors on the market that our group has researched and discussed.
Code does not run properly	If the code does not run properly at first, we will simply have to work rigorously to find the problem and solve it. A common way to do this is to isolate the components of our code and test them individually until we determine which part is causing the problems. Next, we rework that section until achieving success.
Incorrect measurements	If we find our chosen measurements either do not fit the silo or work together in our design, we can use our current design as a baseline and adjust it as we see fit. Prototyping should quickly reveal this.
Outdated drivers (occurs when the Arduino drivers present in the computer aren’t automatically updated, and the computer doesn’t recognize the Arduino board).	If our computer does not recognize the Arduino, we will know that this is a likely cause, and we will ensure to update the Arduino.

Other unpredictable challenges/roadblocks that may show up during testing.	We will work prudently and meticulously in order to spot any unforeseen roadblocks well ahead, and we will need to come together as a group to tackle any such problems.

Prototyping Plan:

Test #	Test objective	Prototype and test method	Expected results and how they'll be used	Test duration and start date
1	PM2.5 sensor can detect dust.	PM2.5 sensor attached to the Arduino with the default given code, pour grain malt through a funnel into a bag to simulate filling silos with malt, have the sensor in the bag during this process.	Dust concentrations should be displayed on the screen. This will also give us a rough idea of the dust concentration in the silo and what could be considered too much dust. The test will be concluded once the dust concentration either displayed or not displayed on the IDE after the malt has been poured.	The test should only take a few minutes, but creating the prototype and setting up the test may take 1-2 hours. The test will be completed as soon as all required materials arrive (~March 1).
2	Device housing will work.	Scaled-down (⅓ size) device housing and lid, 3D print them, and hold the housing and lid together with tape.	Check to see if the device housing and lid fit seamlessly together and that all of the holes line up. If they don't, this will tell us that one or both parts need to be re-designed to ensure that they do fit well together. The test will be concluded when the parts have been observed to either fit together or not fit together.	The housing and lid will be printed on March 9 and the test will occur whenever the parts finish printing. It should only take a couple of minutes to verify that they fit well together. If the prototype fails the test, repeat it with the re-designed parts until it passes.
3	Device attachments will work.	3D print to-scale models of the attachment points (housing to silo, housing to lid) and insert the	Check to see if the bolts and screws will securely hold the required parts in place. If they don't the parts must be	Assuming the previous prototype goes as planned, this will also be completed on March 9. It should also only take a

		bolts/screws into the holes. Also shake the parts around a bit, more than what would be expected within the silo.	re-designed to ensure that the device doesn't fall apart. Testing will be concluded if the parts withstand 15 seconds of shaking without falling apart, or whenever they fall apart if that happens.	couple of minutes to verify that the parts are working as intended. If the prototype fails the test, repeat it with the re-designed parts until it passes.
4	The final solution works.	Assemble all components as outlined in the detailed design. Repeat the grain malt test from prototype 1.	The device should alert when the concentration of dust exceeds the threshold. The threshold in this test will probably be lower than the threshold in the actual silo. This will verify if the device is working as intended. The test will be concluded when the device displays the correct information as intended, or whenever it fails a part of the test.	This prototype will be built on March 12 and will probably take a couple of hours to assemble. Because of this, the test will likely have to be performed on the weekend, but the test itself should only take a couple of minutes. It will be repeated multiple times and for multiple concentration thresholds to ensure that it's working properly.

Wrike snapshot:
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=1cEfMyU3mAOh7ZWD6W1CmgOGPiI1Cstu%7CIE2DSNZVHA2DELSTGIYA