Conceptual Design

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1. Introduction:

In order to create a conceptual design for the project, different subsystems are required to be identified in order to create a variety of ideas that can be interchanged with each other. From there, initial ideas for each subsystem can be created before being subjected to previously identified benchmarking criteria. Then the best ideas will become apparent and the separate subsystems can be combined in order to identify the initial concept design.

2. Subsystems:

To generate a wide variety of ideas, the project is split down into three subsystems so that each group member can independently generate different ideas for different parts of the design. The benefit to this is that it allows you to think of the project at a smaller scale, concentrating on the smaller aspects, rather than the entire design as a whole which can become overwhelming. The identified subsystems are the following:

-Dust detection (method of detecting dust)

-HMI communication (method of communicating dust data to the HMI system)

-Device mounting (method of attaching/integrating the device into the existing infrastructure)

3. Ideas:

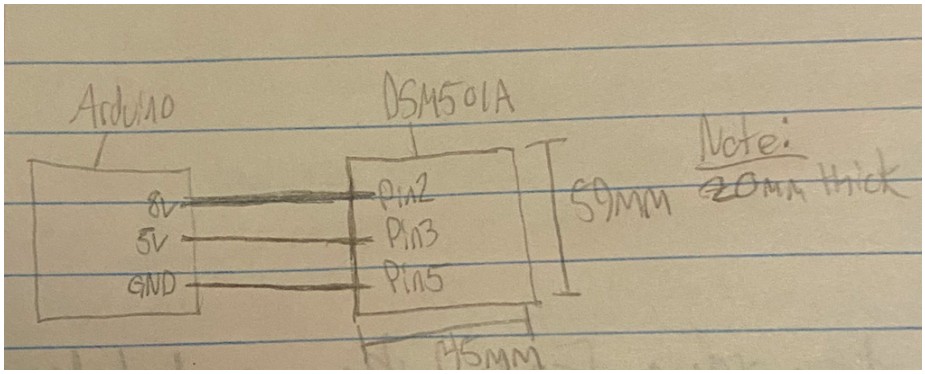
Each group member comes up with an initial idea for each subsystem of the design. This results in 15 smaller designs, rather than 5 big designs for the whole system which helps to break the project down into smaller pieces.

Cameron:

Dust detection:

DMS501A Dust Sensor:

- >1 micron sensitivity; can detect particles smaller than 2.5 μm
- Size: 59 x 45 x 20 mm
- Operating Range: -10-65 °C
- Cost: ~$20 including shipping on Amazon if arriving by March 16-28th; fastest shipping is February 16-23, but it would be more expensive
- Connects to Arduino

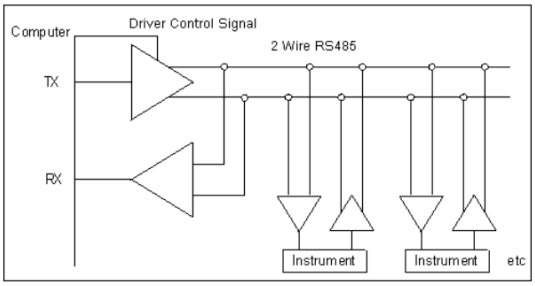


More info: https://www.elecrow.com/wiki/index.php?title=Dust_Sensor-_DSM501A

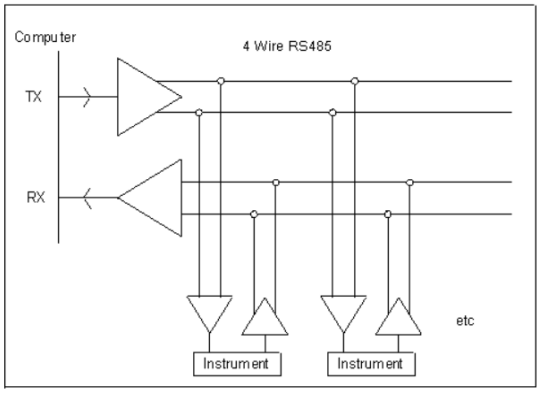
HMI communication:

- RS485 connection https://www.seeedstudio.com/blog/2021/03/18/how-rs485-works-and-how-to-implement-rs485-into-industrial-control-systems/
- Connects to HMI and Arduino via an adapter
- Maximum Operational Distance: 1,200ft
- ~$10
- Dimensions not listed
- Can work with 2 wires or 4 wires (4 lets it transmit data in both directions simultaneously)

2 Wire Half Duplex System

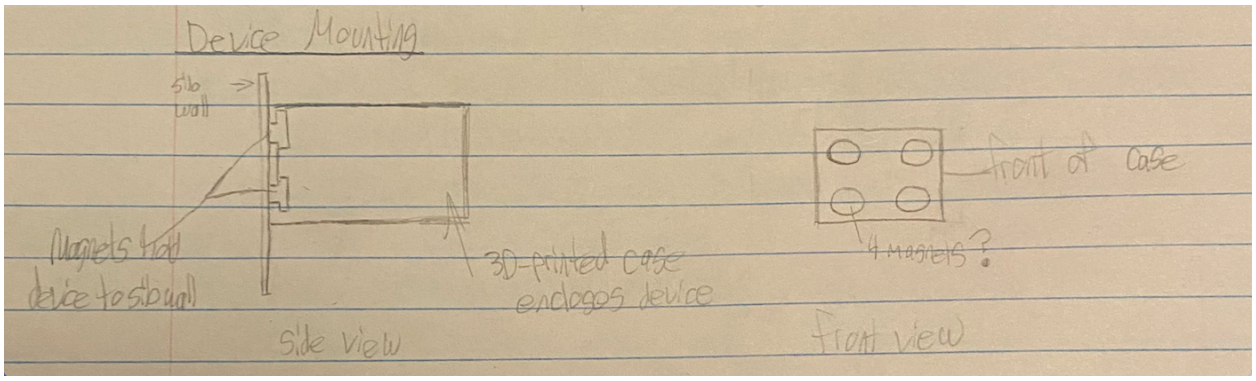


4 Wire Full Duplex System



Device mounting:

- 3D printed case enclosing the device with room for magnets to be embedded (silo material permitting)
- Magnet strength required would depend on a few factors, namely weight
- Potential complication: could magnetism interfere with our device?



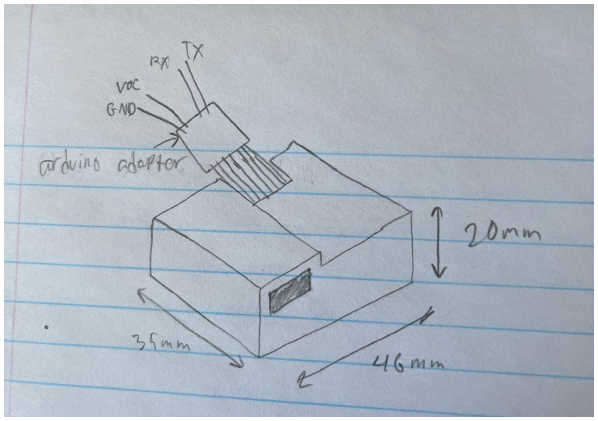
Ben:

Dust detection:

PMI 2.5 Laser Dust Sensor:

- Detects particles in the air with 0.3-10 micron accuracy
- Has an adapter to attach to an Arduino unit (code available in link below)
- 65x42x23 mm including wiring
- Under 10-second response time
- -20 to 50 °C operating range
- Unsure of the range of the laser (could limit the placement of the device)
- $46.90, 2-3 business day shipping

More info: https://wiki.dfrobot.com/PM2.5_laser_dust_sensor_SKU_SEN0177



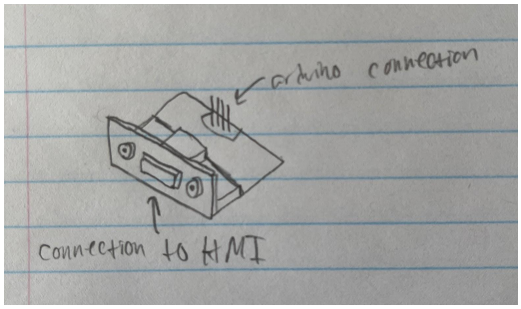
HMI communication:

RS232 Arduino Adapter:

- Compatible with industrial HMI systems

- Has RX/TX serial communication with the Arduino, which is the same as the laser sensor. Would have to code extra serial ports but it is possible (see links below)
- Couldn't find the size, but appears to be quite small based on the overall size compared to the pins
- 15 m range but can go further by slowing down data rate
- ~$2-3 depending on the source

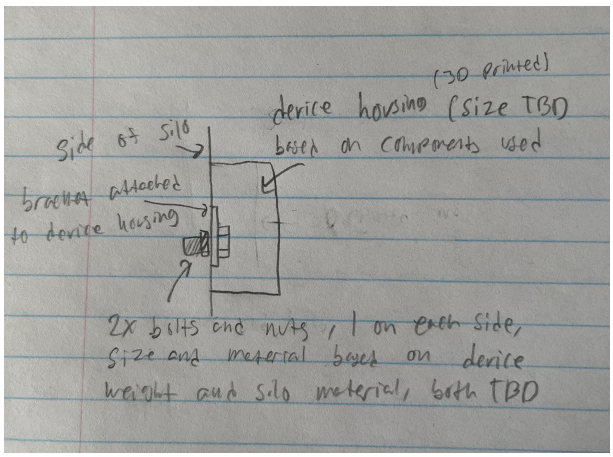
https://forum.arduino.cc/t/how-to-use-multiple-rx-and-tx/462066
https://www.quora.com/Can-we-do-the-communication-of-Arduino-and-HMI



Device mounting:

Side-mounted housing:

- 3D printed device housing (lightweight, fairly strong, easy to manipulate)
- Attached to the side of the silo with a bolt and nut on each side
- Size of bolts and housing variable depending on other components used (sizing, weight, etc.)
- Can probably be adapted to be moved to the top of the silo or to the side of a pipe elsewhere



Hung:

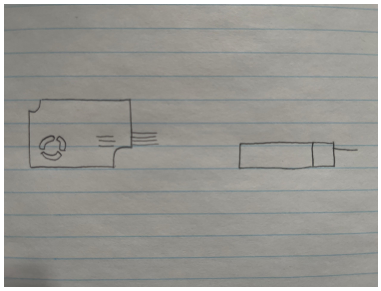
Dust detection:

ZH07 PM2.5 Laser Dust Sensor:

- Detectable particle diameter: 0.3-10 μm
- Effective range: 1000μg/m³
- Detection Interval: 1s

- Working current: ＜120mA
- Response time: T90＜30s (90% of final output in less than 30s)
- Dimension: 48×40×12.5mm(L×W×H)
- Weight: ＜30g
- Working temp: －10～60℃
- Unsure If it can connect to Arduino, probably can
- 13$ on Aliexpress

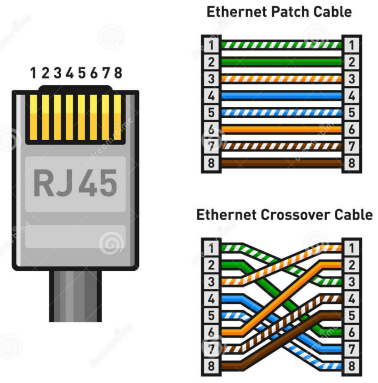
More info: https://www.aliexpress.com/item/4001211956649.html



HMI communication:

RJ45 cable:

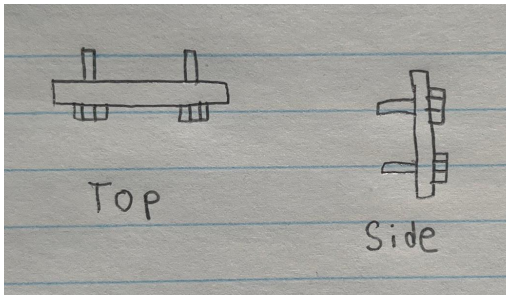
- Requires adapter to connect to the Arduino
- Can be connected to most HMI systems
- 328 ft range
- ~$10



Device mounting:

- 3D printed housing

- 4x stainless steel bolts on each side attached to silo



Jason:

Dust detecting and HMI communication:

BinMaster NCR80:

- Radar sensor/Weight Sensor that can detect the mass and volume of the silo and detect when the mass of the contents in the silo is abnormally low/high compared to its volume
- This is assuming that data can be found on the density of malt dust and malt and find a notable difference such that the system can reliably differentiate between the mass of a batch of malt with normal dust conditions compared to the mass of a batch of malt with increased dust
- The device has its own app that can be integrated into the HMI system to transfer information

More info: https://www.binmaster.com/products/product/80-ghz-non-contact-radar-for-solids

Device mounting:

- Pulley/rail system where the sensor can be attached outside of the silo (at the roof)
- A handle can be used to slowly move the sensor into position.

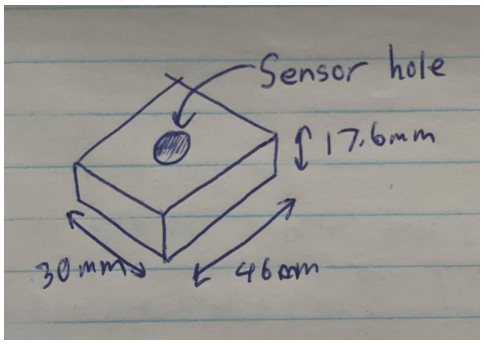
JC:

Dust detection:

GP2Y1010AU0F:

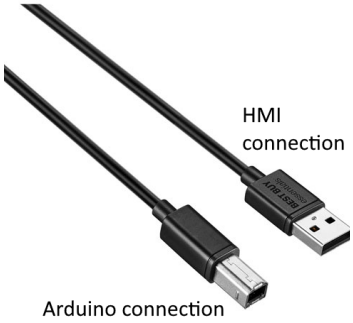
- Detects the reflected light of dust in the air
- Detects particles larger than 0.8μm in diameter
- Can connect to an Arduino
- Very low current consumption (20mA max, 11mA typical)
- Operating temperature: -10 to 65 degrees celsius
- Weight: 0.04 kg
- Dimensions: 63.2mm×41.3mm×21.1mm
- Estimated 5 years lifetime
- Can be attached to an Arduino unit

More info: https://global.sharp/products/device/lineup/data/pdf/datasheet/gp2y1010au_e.pdf



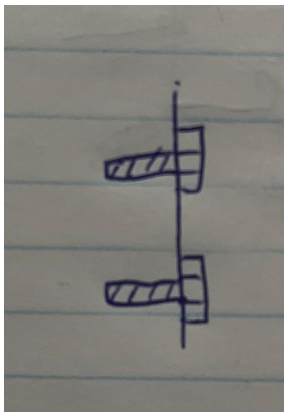
HMI communication:

- USB cable type A to B
- Connects to arduino
- Around $5



Device Mounting:

- 2 steel bolts attached to the side of the silo



4. Idea Comparison:

Dust detection	Cameron	Ben	Hung	Jason	JC
Concept:	DSM501A Laser Dust Sensor	PM2.5 Laser Dust Sensor	ZH07 PM2.5 Laser sensor	BinMaster NCR80	GP2Y1010AU0F light reflector
Accurately measures dust	>1 micron, but can detect particles under 2.5 µm	0.3-10 µm accuracy	0.3-10 µm accuracy	0.2 inch accuracy, 393 ft distance range	Detects particles larger than 0.8µm in diameter
Detects incoming dust in advance	Possible if installed in silo	Possible if installed in silo	Possible if Installed in silo	Possible	Possible if installed in silo
Make recommendations	Arduino code	Arduino code	Unsure if it can	Coding can	Arduino code can

based on info	can recommend things	can recommend things	connect to Arduino	calculate % of dust and recommend things	recommend things
Operate under different conditions	-10-65 °C	-20-50°C	-10-60°C	-30 to 120	-10 to 65°C
Cost	~$20	$46.90	13$ not included shipping	Not Sure (probable expensive as a quote is required)	Around $15 to $20

HMI communication	Cameron	Ben	Hung	Jason	JC
Concept:	RS485 connection	RS232 cable + Arduino adaptor	RJ45 cable	NCR80(Built in communication device)	USB Cable Type A to B connection
Can communicate with the HMI system	Yes (wired) Max Range: 1,200m	Yes via cable, 15m range	Yes, 328 ft range	Yes (Remote), can be integrated to the plant's PLC	Don't know
Make recommendations based on info	Yes via arduino code	Yes via arduino code	Yes via arduino code	Can send data remotely to existing desktop	Yes via arduino code
Cost	~$10 + adapter	~$3 adapter + ~$15 cable	~$10 + adapter	Not Sure (probable expensive as a quote is required)	~$5

Device mounting	Cameron	Ben	Hung	Jason	JC
Concept:	3D printed case enclosing the device with room for 2 25lb	2x steel bolts on side of silo attached to device housing	4x stainless steel bolts to device case	Rail/Pully System	Screw with zinc plated steel bolt and nut from the case

	magnets to be embedded				
Easy to install	Yes; non-invasive	Requires drilling into silo, but fairly simple	Requires drilling into silo, but fairly simple	Somewhat complex installation(installing rails & chain)	Requires drilling into silo, but fairly simple
Size/Fits where it's meant to be installed	Variable size; likely fits in silo, holds up to 50 lbs	Variable size but should easily fit on the side of the silo	Side or top of the silo	Under the roof of Silo(should fit)	Yes
Accessibility	Could be removed from the inside	Can be unscrewed for maintenance	Can be unscrewed for maintenance	Can be easily accessed using a level & hatch	Can be unscrewed for maintenance
Operates under different conditions	Magnets could likely withstand the expected temperature range	Steel bolts work well under many temperatures, may rust if exposed to water	Stainless Steel bolts that are rust resistant	Completely protected by the silo	Steel is zinc plated for protection against rust.
Cost	$10-15	$0.77/bolt at Home Depot	$1.94/bolt at Home Depot	Home Depot ~$40 for 2 rails + ~$3 per foot for steel chain + ~$10 for pulley	$0.87/bolt at Home Depot

Using our previously-defined criteria/desired specs, we compared the concepts that each of the five members came up with for each of the 3 subsystems and rated them by colour. By rating them in this way, we were able to visualize which of the ideas were better or worse overall based on how much red/green/yellow they contained. Generally, the highest priority was to avoid as much red as possible because we do not want to design something with glaring problems. Once we discussed as a group what we thought of each of these ideas, we took components from some of the preferred subsystem ideas to form 3 group ideas within the next stage.

5. Group Ideas:

1:

Dust detection: GP2Y1010AU0F light reflector

HMI: RS485 cable + adaptor

Mounting: 4x stainless steel bolts connected to the side of the silo

2:

Dust detection: BinMaster NCR80

HMI: BinMaster NCR80

Mounting: Rail and pulley system

3:

Dust detection: PM2.5 Laser Dust Sensor

HMI: RS232 cable + adaptor

Mounting: 2x 25 lb magnets

	Idea 1	Idea 2	Idea 3
Accurately measures dust	Detects particles larger than 0.8µm in diameter	0.2 inch accuracy, 393 ft distance range	0.3-10 µm accuracy
Detects incoming dust in advance	Possible if installed in silo	Possible if installed in silo	Possible if Installed in silo
Makes recommendations based off information	Yes via arduino code	Can send data remotely to existing desktop	Yes via arduino code
Operate under different conditions	-10 to 65°C Stainless Steel bolts that are rust resistant	-30 to 120 Completely protected by the silo	-20-50°C Magnets could likely withstand the expected temperature range
Easy to install	Requires drilling into the silo, but fairly simple	Somewhat complex installation(installing rails & chain)	Yes; non-invasive
Size/fits where it's meant to be installed	Side or top of the silo	Under the roof of Silo(should fit)	Variable size; likely fits in silo, holds up to 50 lbs
Accessibility	Can be unscrewed for maintenance	Can be easily accessed using a level & hatch	Could be removed from the inside

Cost	Detection: $15-$20 HMI: $10 + a few dollars for adapter Mounting: 4x $1.94 bolt Total: ~$40	Price largely unknown, but we suspect that this option is very expensive Total: way too much	Detection: $46.90 HMI: $15 + $3 Mounting: ~$10-$15 Total: ~$78

We took the combined ideas using different subsystem concepts and compared them using the same criteria as before, but now as whole systems. Using the same colour-coding technique as before, we determined that we did not like idea 2, and we were not going to move forward with it (red in multiple areas). We liked the precision of idea 3, the HMI communication of 1, and preferred the reliable bolts in 1 compared to a large number of unknowns with the magnets in 3. We took this feedback and combined ideas 1 and 3 to create our initial “best” design: the PM2.5 Laser Dust Sensor, the RS485 cable + adapter, and the 4 stainless steel bolts.

6. Combined Idea:

Criteria	**Combined Idea**
Accurately measures dust	0.3-10 µm accuracy
Detects incoming dust in advance	Possible if Installed in silo
Makes recommendations based off information	Yes via Arduino code
Operate under different conditions	-20-50°C, stainless steel bolts are rust resistant
Easy to install	Requires drilling into the silo, but fairly simple
Size/fits where it’s meant to be installed	Will easily fit on the side or top of the silo (size likely under 30x30x30 cm considering components used)
Accessibility	Can be unscrewed for maintenance
Cost	Detection: $46.90 HMI: $10 + a few dollars for adapter Mounting: 4x $1.94 bolt Total: ~$68 (+~$30 for an Arduino UNO)

In the end, we decided that we liked our design best if it incorporated the PM2.5 Laser Dust Sensor for the greatest accuracy, the RS485 cable and adapter for greatest range and convenience, and the four stainless steel bolts for reliability, durability, and ease of installation. This combination provided us with the most appealing solution we had seen yet.

7. Reasoning:

Dust detection:

Accuracy was one of the most important criteria based on what was said during the zoom call with Mill Street Brewery. Because of this, we chose the idea that yielded the most accuracy. The dust collection device could also detect incoming dust in advance if placed in the silo, as it could measure the dust levels in there before it reaches the air filter. Out of all the options, we believe that an operating temperature between -20-50°C was the best choice because it could operate in a colder climate. The cost is $46.90, and although it was the most expensive option out of the small sensors, we chose this because it gives better accuracy than the other options and we know that it can connect to an Arduino.

HMI communication:

For HMI connection, one of our top priorities was Arduino compatibility, since we want our solution to be primarily Arduino-based. Once we narrowed down our ideas to the ones we were 100% certain could communicate with HMI and Arduino, we were down to two frontrunners: the RS485, and the RS232. Both of these concepts were used in one of our main ideas once we combined different concepts for each of the subsystems. In the end, we decided to go with the RS485 as the RS232 had a much shorter transmitting range and both cables and adaptors were pretty much the same prices.

Device Mounting:

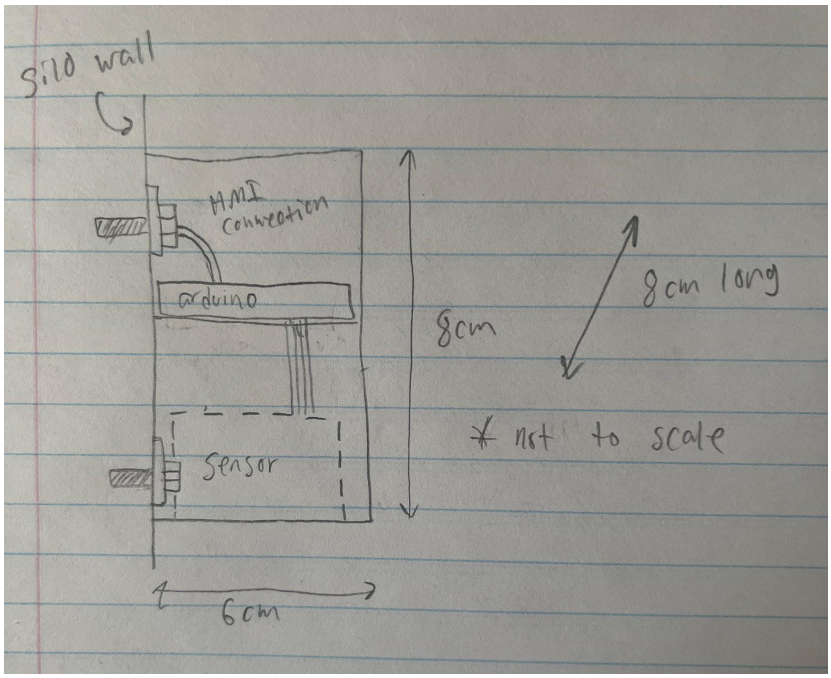
Multiple group members thought from the start that attaching our device to the silo via bolts was the ideal approach to mounting. Still, there were two other ideas we strongly considered: a magnet-attached system and a rail and pulley system. These more unique ideas each had some clear pros such as the magnet system’s installation being very non-invasive and the pulley system making it very easy to remove the device for maintenance. In the end, however, it was determined that the pulley system would be too complex to install and that the magnet solution left a lot of room for uncertainty, so it was decided that the best route was to choose one of our bolt ideas. In the end, we went with the slightly-more-expensive stainless

steel bolts (4 of them) because the material will not rust very easily and should last for longer. This solution of the mounting component seems appropriate because we trust that it can securely hold up our device without a very taxing installation process, as well as the fact that it's very inexpensive even with the more costly stainless steel bolts.

8. Conclusion:

By going through the process of identifying subsystems, creating ideas for them, and comparing them, we were able to eliminate some ideas and figure out the best combination of the remaining ideas in order to develop the best overall global design, which can be seen below in a rough sketch featuring the combined ideas.

Potential design:



Wrike snapshot:
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=tJImRFw22WMg7Gu9YXmzn3d2w2pGTFAe%7CIE2DSNZVHA2DELSTGIYA