University of Calgary

ENEL 300

ELECTRICAL ENGINEERING DESIGN

FINAL TECHNICAL REPORT

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[redacted]

April 21st, 2023

1 Introduction

Many people suffer from lung and breathing conditions that hinder their ability to perform certain tasks or simply enjoy the outdoors under circumstances of poor air quality. It is becoming increasingly common for places around the world to experience weeks of smoke polluted air in the hotter months due to growing numbers of forest fires. For people with good lung health, it can be difficult to be outdoors in these conditions, however, for people with issues relating to lungs and breathing it is often detrimental to their health to be outdoors.

The purpose of this report is to present a solution to these issues of breathing and lung health in polluted air conditions. The solution being presented is an assisted breathing mask which intends to allow respiratory compromised people to be outside their homes in polluted air quality conditions. The mask uses a combination of electrical and passive components to filter out polluted air and provide clean breathing air.

The 9 parts of this report discuss (2.1) the people who will benefit from this solution, (2.2) the product that will provide the solution, (2.3) the product's sustainability, (3) a technical description of the product and how it works, (4) how we went above and beyond the technical requirements, (5) testing the products functionality, (6) the process of designing the product including teamwork aspects, (7) future work to improve the product further, (A) a user manual/instruction set and code, and (B) a discussion of intellectual property when coming up with names and designs.

2 Persona and Product

This product is aimed towards people with lung conditions and those who worry about their lung health. When creating the product we also took time to consider how different conditions would affect how users interact with the product. Meaning that, although we aimed it towards those with lung problems, we also considered those with vision and/or hearing issues in order to try to make it accessible and easy to use for everyone.

2.1 Persona

Three personas were created during this process.

Persona 1: Adriel Uther.

Adriel Uther is a young adult with Cystic Fibrosis, a condition which has a severe effect on lung functioning. Although she likes to be able to exercise and do activities outside she finds it very difficult to do this safely with the ever decreasing air quality levels. Normal masks are not enough to filter bad particles, such as smoke, out of the air and they make it more difficult for her to breathe, therefore she is looking for something that acts as a better filter while also keeping easy airflow.

Figure 1: Persona 1 User Profile Canvas.

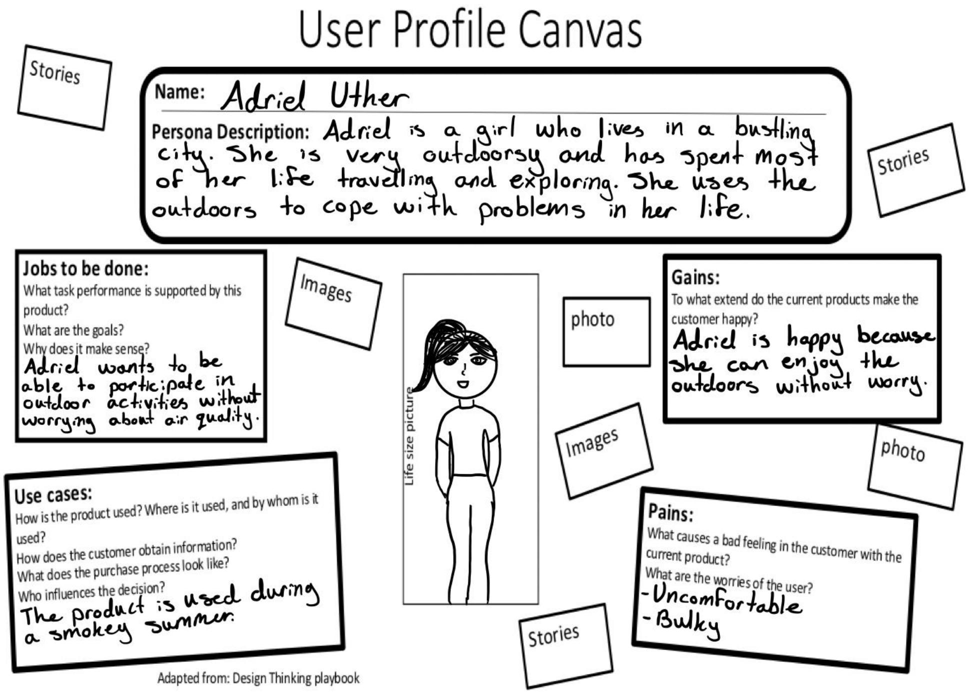


Figure 1 was created during the development of the Adriel Uther user persona. The user profile canvas showcases who she is, why she uses our product and then pains and gains it gives her.

Figure 2: Persona 1 Empathy Map

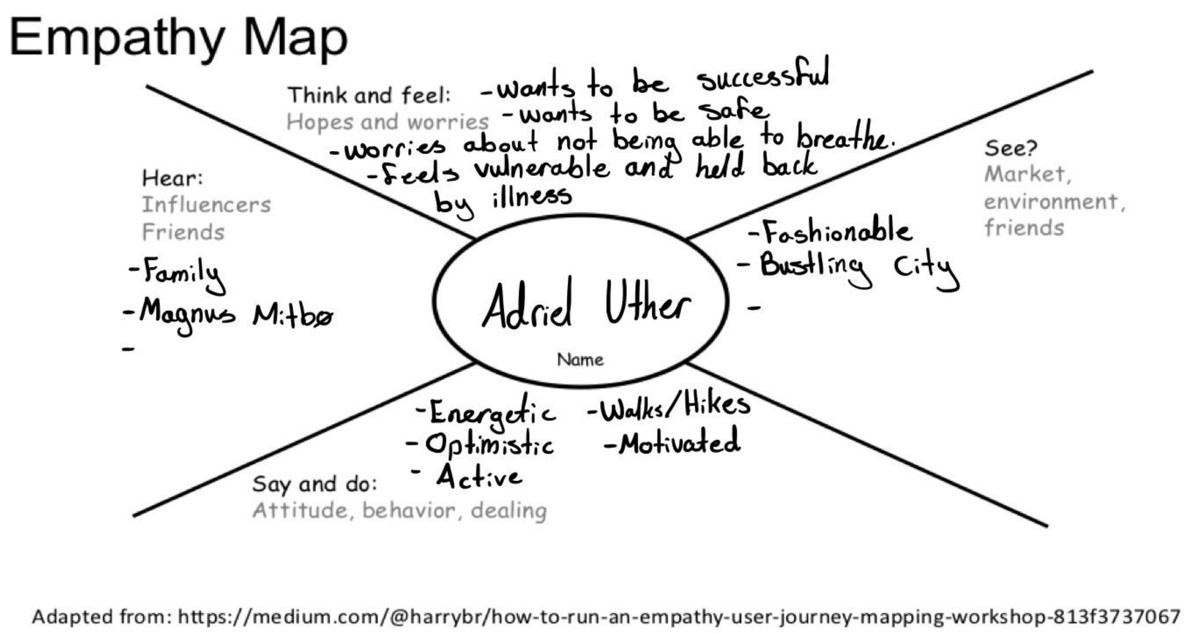


Figure 2 is an empathy map created while creating Adrial Uther's persona. It gives more insight into the thoughts and feelings of the persona.

Figure 3: Persona 1 User Canvas from Mural

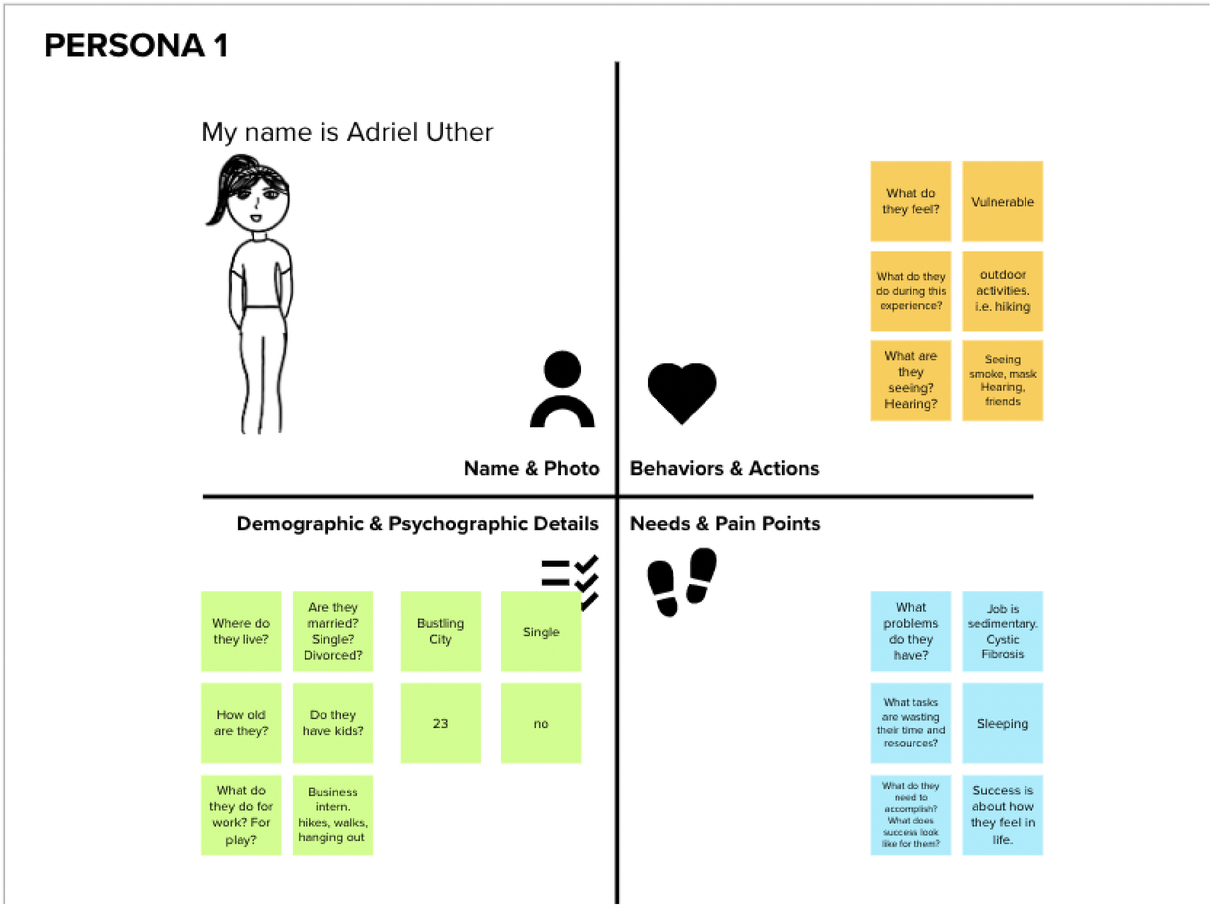


Figure 3 showcases a different user canvas than Figure 1. This was the final step in creating the Adriel Uther user persona. It brings together the ideas from the previous two figures while adding some more specific details about age and job.

Persona 2: Josiah Marco

Josiah Marco is a visually impaired man with asthma. He lives in one of the most polluted cities on Earth, New Delhi, India.[1] While Josiah loves to walk when doing errands around the city he finds it difficult to feel safe while doing so as he does not know the air quality around him. He is looking for a product which indicates how poor the quality of the air around him is and that helps to filter out bad particles to prevent him from suffering from asthma attacks.

Figure 4: Persona 2 User Profile Canvas

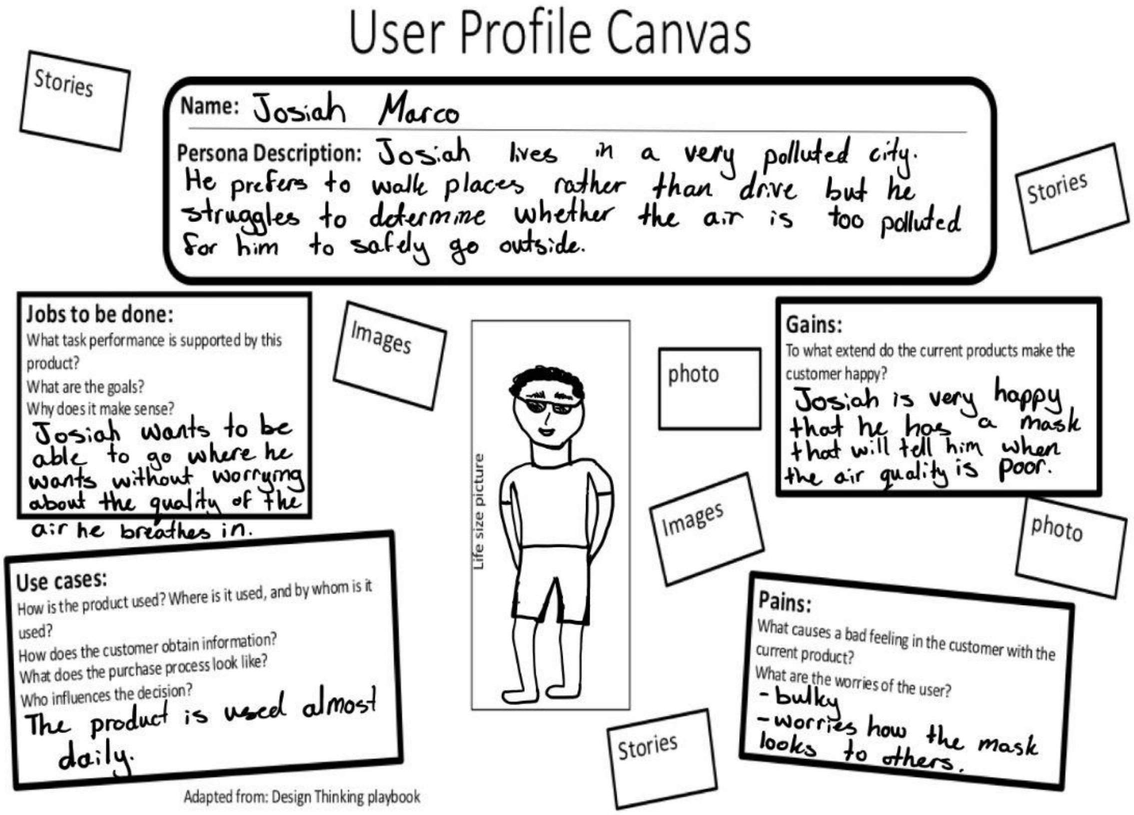


Figure 4 outlines who Josiah Marco is and indicates the pains and gains he will get from our product.

Figure 5: Persona 2 User Canvas from Mural

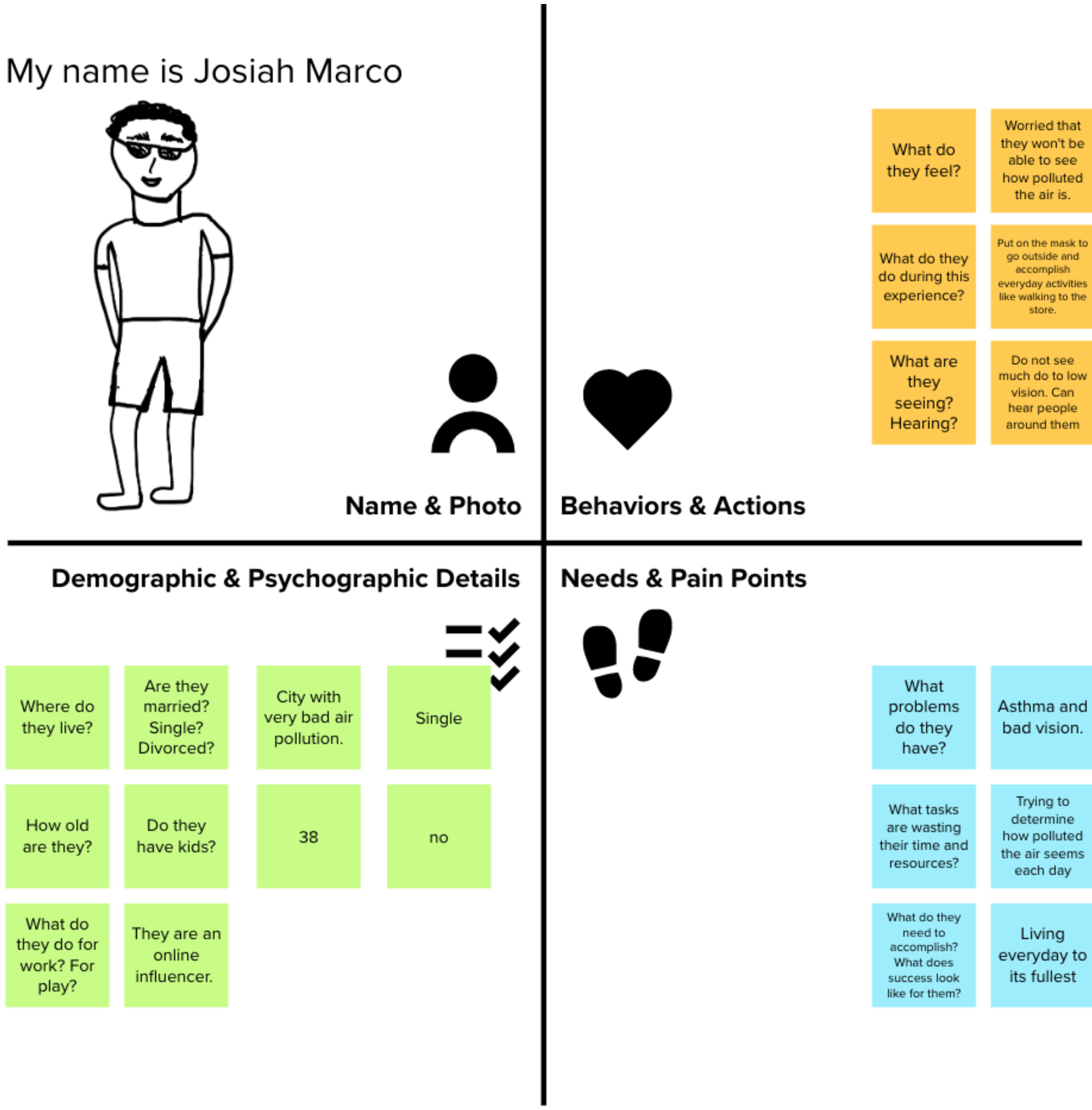


Figure 5 completes the Josiah Marco persona by adding more specific details and fully outlining the struggles Josiah goes through which can be helped by our product.

Persona 3: Landebert Adelina

Landebert Adelina is a construction worker who also does odd jobs every now and again. He spends his summers working in Washington, US which he has noticed is becoming increasingly affected by wildfire smoke. He has started to worry that his exposure to the air pollutants at work and the smoke during the summer will start to affect his lung health. Landebert has been working non-stop since he graduated high school to try to get enough money saved to not have to work for his whole life but he is now worried that by the time he has enough money saved, his lungs will be too damaged to do all of the things he wants to do. In order to fully create this user persona, the profile canvases in Figure 6 and Figure 7 were created.

Figure 6: Persona 3 User Profile Canvas

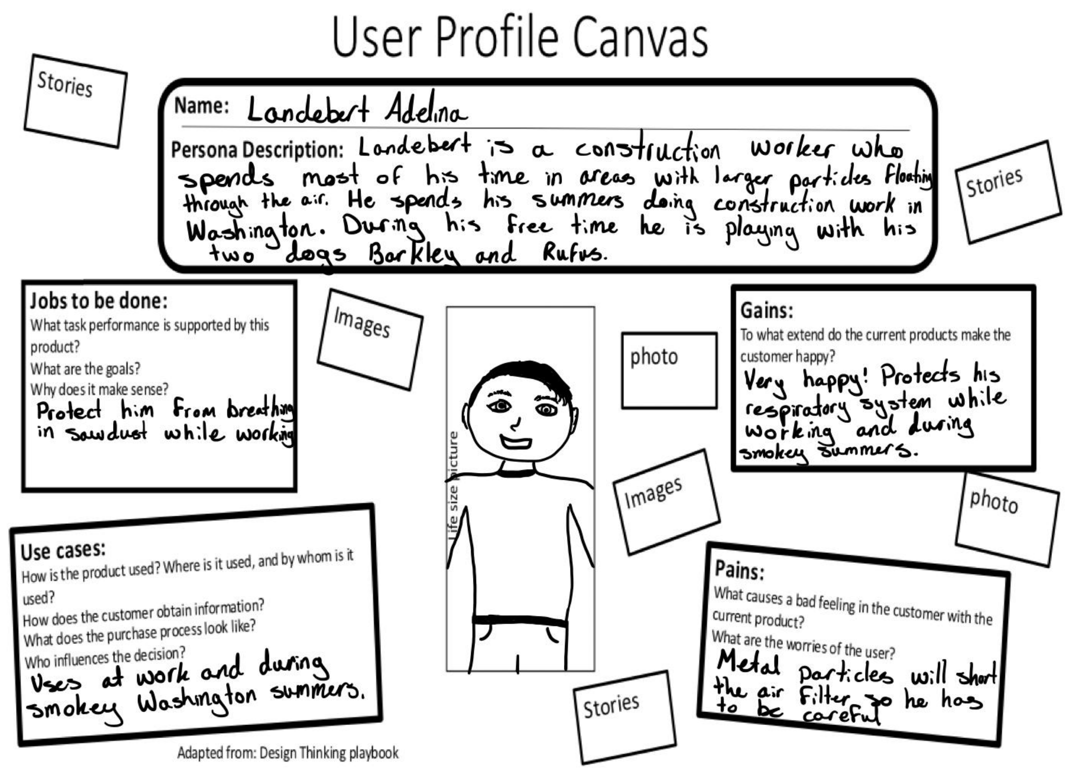


Figure 6 outlines who Landebert Adelina is and indicates the pains and gains he will get from our product.

Figure 7: Persona 3 User Canvas from Mural

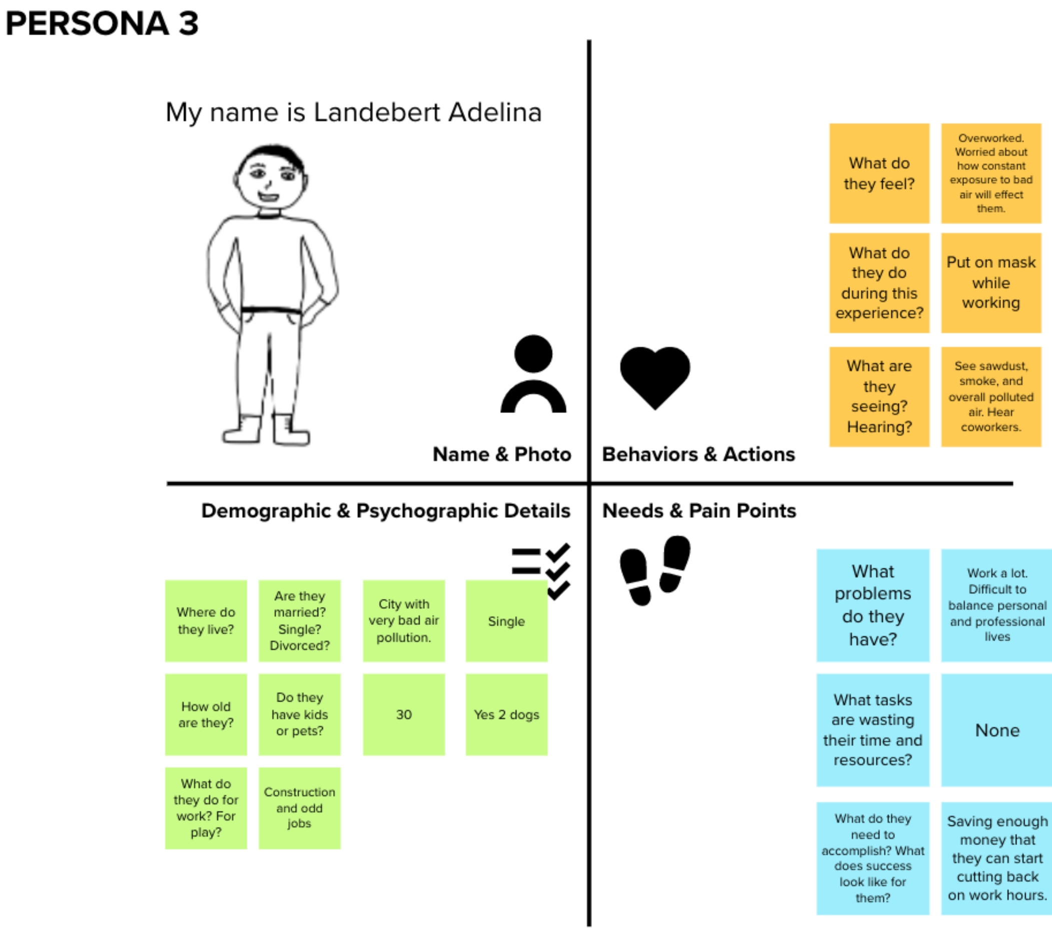


Figure 7 completes Landebert Adelina's persona. Adds more specific details to fully outline who Landebert is and how our product can benefit him.

In addition to the user personas, we also created a survey which was sent to the general public to gain their feedback on the product and to gain insight on how the public feels about the things we assumed when creating our personas. While questions like "Would access to an active filtration mask increase the amount of time you spend outside?," and "To what extent do you worry about your lung health?" had somewhat mixed responses, shown in Figure 8, two things were clear from the results of the survey:

1. Smoke and high air pollution contribute to a decreased amount of time spent outside. While most responders indicated that they often exercised outside during the summer, over 70% also indicated that large amounts of smoke and/or high air pollution prevent them from exercising outside as much as they hope to.

2. People want to know the quality of the air around them and be alerted when it is poor. Figure 8, **c)** below shows the result from a question on our survey which directly ties to this issue.

Figure 8: User Survey Response Graphs

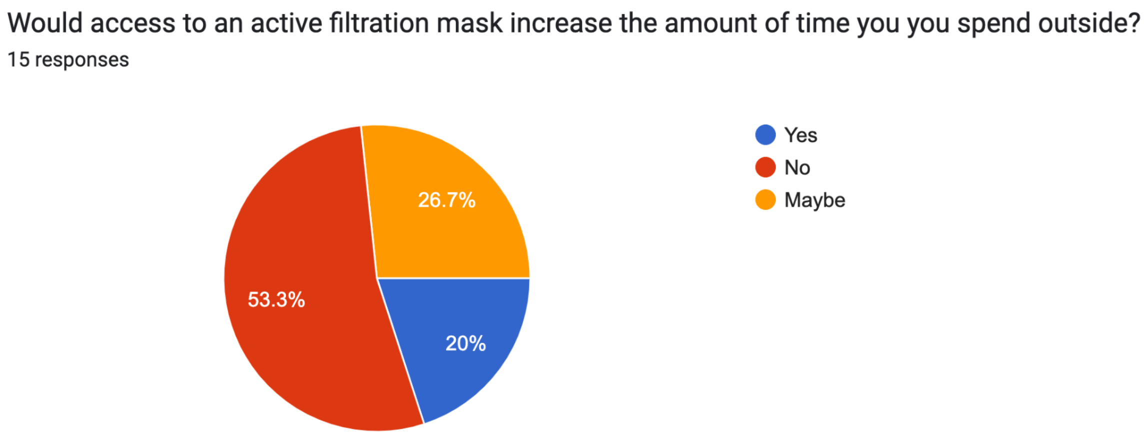


Figure 8, **a)** Image from user survey. Indicates that most responders do not believe a filtration mask will increase the amount of time they spend outside.

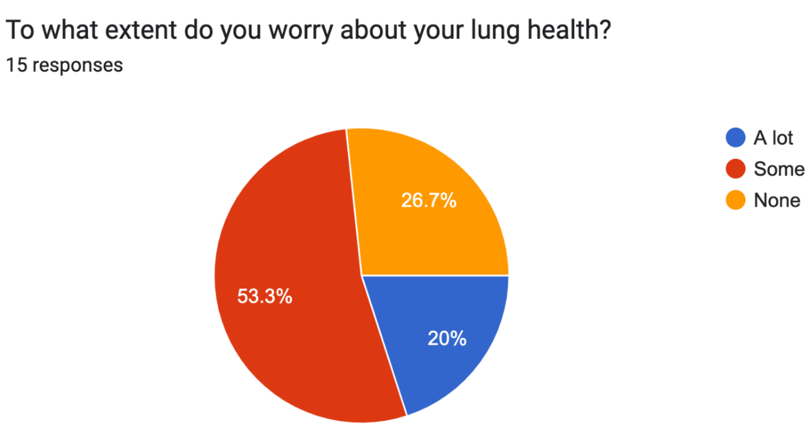


Figure 8, **b)** Image from user survey. Indicates that more people have some worries regarding the health of their lungs.

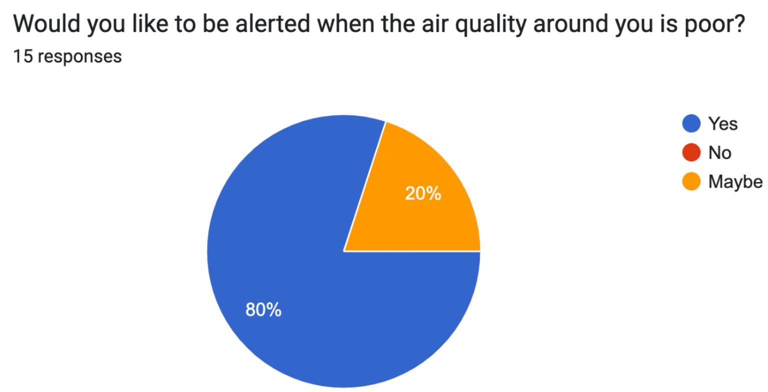


Figure 8, **c)** Demonstrates that the majority of people would like to be indicated when air quality around them is low with 80% of responses being "Yes" and the other 20% being "Maybe".

2.2 Product

Figure 9: The Ion-Man 369

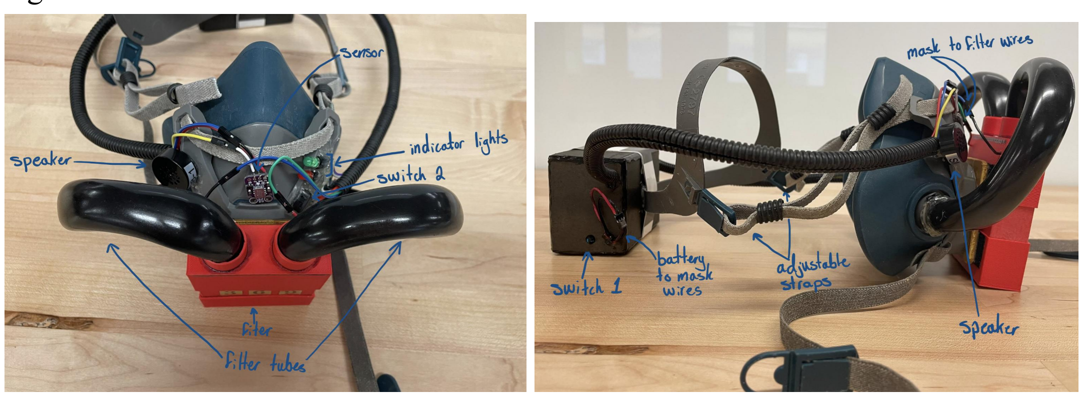


Figure 9 shows labeled images of the final Ion-Man 369 series mask.

The users of the product have been considered at every stage of development from idea creation, to testing, to building. Our product, the Ion-Man 369, is an electronic mask which uses ionization of particles to filter the air the user will inhale. It comes equipped with an air quality sensor and audible alert system which indicate to the user approximately how poor the air quality is. In order to keep the mask simple and easy to use we tried to limit the amount of maintenance it required, therefore, the user only needs to clean the filter plates with a brush or cloth and recharge the mask after use.

Impact and feasibility were two things we took into great consideration during the early development of our idea. The main impact of our product comes from the benefits it brings to users. It will allow those with lung conditions, or who worry about their lungs being damaged, to be outside without worrying as much. It also indicates when air quality is poor which will allow people to better gauge the quality of the air they are intaking and thus better judge whether being in that area, at that time, is worth it. When looking at impact we took into consideration the sustainability goals that the UN is working towards. Our product is especially geared towards the Good Health and Well Being goal as the product protects the physical health of its users, with the added possibility of increasing their mental health as it allows them to get outside and be more active. However, it also works towards the Responsible Consumption and Production goal as it will be made from sustainable, cleanable, and rechargeable components. This means that instead of using the disposable, one to two time use masks, our users will have a mask that lasts for much longer only requiring a small amount of maintenance. Finally, the mask works towards reducing inequalities between those with and without respiratory conditions. By decreasing the amount that those with poor respiratory health have to worry, while increasing their ability to be safe in areas with poor air quality, the Ion-Man 369 aims to shorten the gap between what those with and without respiratory conditions can accomplish. Additionally, we aim to make our product with recycled materials such as scrap aluminum plates for the filters and old construction masks for the body. Overall, after analyzing the information presented above we found that our product would have a high impact. The feasibility of our product was more simple to analyze. The audible alert system and sensor are fairly simple to implement as they just require a small circuit for the speaker, a sensor, and some code for sensor readings and audio output. However, the ionization filtration system has been much more difficult to implement than expected. It requires a much more developed circuit and a higher understanding of circuit elements to understand how they will interact, use current and voltage, and much more. Finally, the development of the body of the mask could present some issues as our team is not specialized in monitoring airflow capabilities or designing something that will fit well around a person's face. Although some elements of our product are more difficult to create than others, we feel that with the time given for the creation of the product as well as making use of testing the product is very feasible.

Some changes we made to our product throughout its creation were:

1. The type of sensor used. The initial plan was to use a carbon monoxide detector as that is an invisible gas which is present in smoke and something our filter design would struggle to filter from the air[2]. However, this was changed to a general air quality detection sensor to increase the impact and versatility of our product.
2. The air filter circuit/filter plate design. The air filter circuit has been redesigned many times throughout the development of our sprint. It started as a small voltage amplifier and has evolved into a much more complex circuit, outlined later in the

report. This new circuit allows us to decrease the amount of plates used in the air filter which in turn decreases the bulkiness of the mask.

These changes were made in order to make our product more manageable, impactful, and overall more feasible as a product that people would want to purchase and wear.

Value proposition, shown in Figure 10, is something we considered farther into the design process. While we had been considering how our users would be impacted by our product most of this consideration had gone to our specific user personas. Adriel Uther wanted to be able to breathe easily while outdoors so we created an active filtration system so that the mask was less airflow restrictive than the traditional masks. Josiah Marco wanted to be alerted about the air quality around him so our product includes a system which alerts its wearers of the air quality conditions around them. Value proposition analysis gave us broader indication of the impact the product will have on a more broad target audience.

Figure 10: Value Proposition Analysis

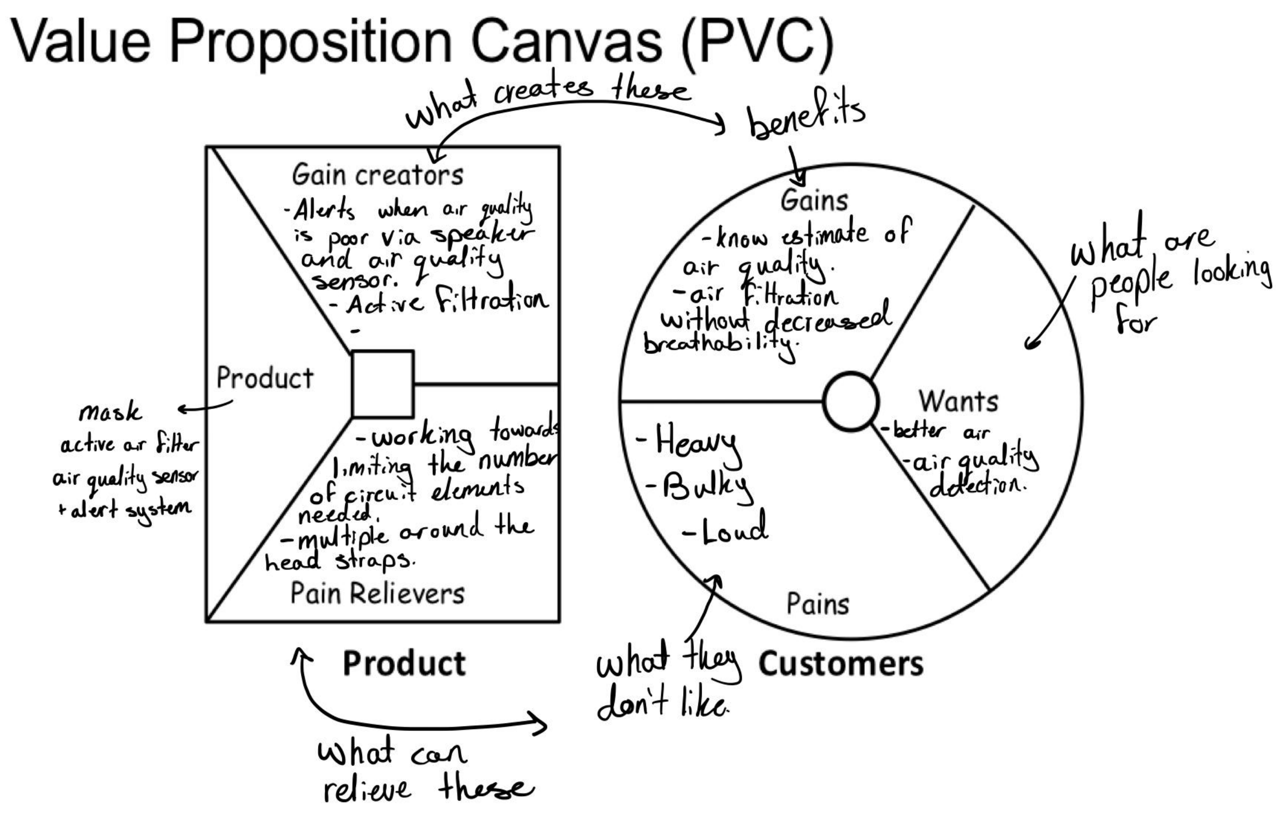


Figure 10 shows what our product provides to customers and what those customers could like/dislike about the product. This information tells us how valuable the product is to its users/to our customers.

2.3 Sustainability Plan

Sustainability for our project was considered for three different stages of its life.

The first stage was product creation. The Ion-Man 369 was created using mostly scrap parts such as scrap aluminum plates for the filter, an old construction mask, and other parts found laying around our houses like MOSFETS from an old television circuit. The filter and circuit casings were 3D printed which is a sustainable and ethical way to produce a product and source material.

Moving onto the second stage, the mask while in use. Our product contributes no waste or negative emissions when in use. Instead, it works towards multiple of the UN sustainability goals. Due to one of the Ion-Man 369's main target groups being those who are respiratory compromised, it has a large contribution to the *Good Health and Well Being* UN sustainability goal. The Good Health and Well Being goal is working to improve everyone's well being no matter their age or any medical conditions they may have. By providing a portable, active air filter to those with respiratory issues, we provide many more opportunities for these people to participate in physical activities outside. This not only improves physical well being, but also has the potential to improve mental well being as users can get outside, interact with other people, and get some exercise. The product can also promote better well being for those who worry about damaging their lungs, getting carbon monoxide poisoning, or a multitude of other things. For example, Canada and the United States are often heavily impacted by wildfire smoke in the summer/fall. Our mask will filter the air so that when breathing a reduced quantity of the damaging particles are inhaled thus protecting the user's respiratory health and ability to breathe. This helps those with respiratory issues as well as those who worry about their lung health. Furthermore, the Ion-Man 369's audible alert system which indicates decreasing air quality conditions as well as increasing levels of toxic gasses promotes better health and well being for those who work in industrial environments as they will be alerted right away when a toxic gas is in the air rather than having to rely on the detection systems of the building/area they work in. Additionally, when coming up with the concept for the product we worked to make it reusable and made of lasting materials so that it complies with the UN's goal of *Responsible Consumption and Production*. The battery in the mask is rechargeable, similar to a phone's battery, to limit battery waste. The mask was also built to be reusable with a cleanable filter which will make it a lasting purchase. The combination of a rechargeable battery and a cleanable filter allow the mask to last for a long time, limiting not only user consumption but mask production as well. As well, the aspects discussed for stage one contribute to responsible production of the mask.

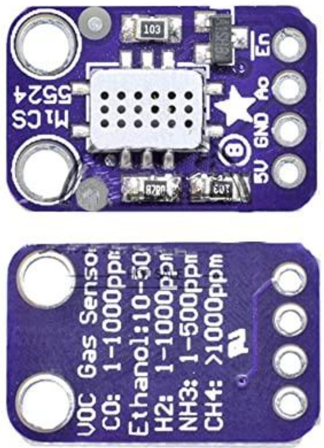
Stage three is the mask's end of life. The hope is that the mask does not have an end of life. The battery can be recharged and the filter can be easily cleaned which only leaves accessory elements to cause the mask to reach its end of life. These accessory elements include our two indicator LEDs and our air quality/gas sensor. In order to increase the amount of use the mask could get before its end of life we made these components completely replaceable. If damaged the LEDs or sensor can easily and quickly be removed and replaced by ordering new ones. Along with trying to extend the time before the end of life of our product, we made it modular so that components can be disposed of properly. The circuit boards and battery located in a box at the back of the mask can be detached and placed into electronic recycling. The filter, tubes, and sensor are all fully detachable from the mask and the filter can be further deconstructed so that each part of the mask can be disposed of in its proper place rather than throwing the whole thing into the garbage.

3 Technical Description

Sensor

The sensor detects various polluting gasses including smoke, carbon monoxide, ethanol, ammonia and methane. It is powered by 5V and produces a varying output voltage based on the amount of gas in the reading up to 5V. There are 4 pins on the sensor: input 5V, input GND, output, and an enable pin. The sensor output pin will be programmed to the AVR128DB28 microcontroller (AVR) as the input that drives the speaker, LED and mask function. The AVR will be programmed to produce different outputs to the speaker based on the reading from the sensor (varying voltage), as well as turn on the mask above a certain threshold voltage. A simple smoothing circuit (a resistor and capacitor) with a time constant of 1ms was used between the sensor and the AVR to eliminate some of the noise in the sensor readings sent to the AVR.

Figure 11: Gas Sensor[3]



Speaker Alert System

The audible alert system consists of a variable input voltage implemented with code on an AVR being sent to a transistor circuit attached to a speaker.

The circuit was designed with both a PNP and NPN bipolar junction transistor, an n-channel MOSFET, resistors, and a mini speaker with an internal resistance of 8Ω. The circuit was designed following the schematic in Figure 12 with the Vin term coming from the AVR.

Figure 12: Speaker Circuit

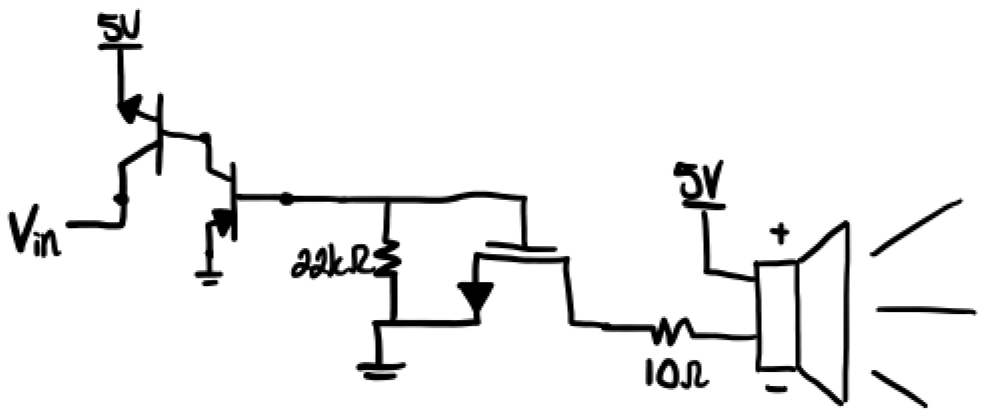


Figure 12 is the schematic used when creating the circuit used to connect the speaker to the AVR128DB28 microcontroller.

After testing what Vin peak-to-peak voltages and frequencies were the easiest for people with hearing impairments to hear it was determined that a variable input signal with a voltage of about

5Vpp, offset of 2.5V, and 1kHz frequency was the best to use with this circuit. Therefore, a voltage signal approximately matching these constraints (5Vpp but with a frequency of 909Hz) was coded into the AVR using its built in digital to analog converter. This was done using a 5V reference voltage and the following formula:

$$V_o = \frac{D}{2^n} V_{ref} \quad {}^{4}$$

Where V_o is the analog voltage wanted, D is a digital value for that voltage, V_{ref} is the reference voltage (set in the code to be Vcc which in our case is 5V), and n is the number of bits used in the conversion (n = 8 in this design)[4].

Using this equation, digital values for voltages from 0V to 5V were found at even intervals of 0.25V giving a total of 21 different digital samples. When calculating D for V_o = 5v, D ends up being 256, this is out of range for an 8 bit converter therefore the value 255 must be used instead. As well, to get a full waveform when implementing it in the code it is important to include values from 0V to 5V and back to 0V. This method created a triangle wave from 0V-5V.

The input wave was used along with different voltage thresholds (correlating to readings that the AVR gets from the sensor) in order to code the speaker to beep once for 0.35seconds when the voltage reading is between 1V and 3V, twice for 0.35seconds each with a 0.35second pause in between at voltages between 3V and 5V, and three times when the sensor reads 5V or higher.

Filter

The filter system consists exclusively of a solid state static electricity generator in conjunction with the use of various aluminum plates. The working principle behind this filter is to charge micro particles in the air with a net negative static charge while simultaneously charging the aluminum plates with a net positive static charge. The oppositely charged particles and plates will then attract one another, causing the microparticles (such as smoke, pollen, dust, etc.) to precipitate out of the air and condense onto the plates. They will then lose their charge but have accumulated together in large enough quantities to safely remain attached to the plates. In this way, the air is cleaned of pollutants in a reusable and sustainable manner.

Taking a closer look at the static generator design itself, it consists of two main stages; the voltage step up stage, and the voltage multiplication stage. The voltage step up stage consists of a center tapped step up transformer powered by two mosfet transistors. These are connected as shown in the diagram below:

Figure 13: Voltage Step Up Circuit

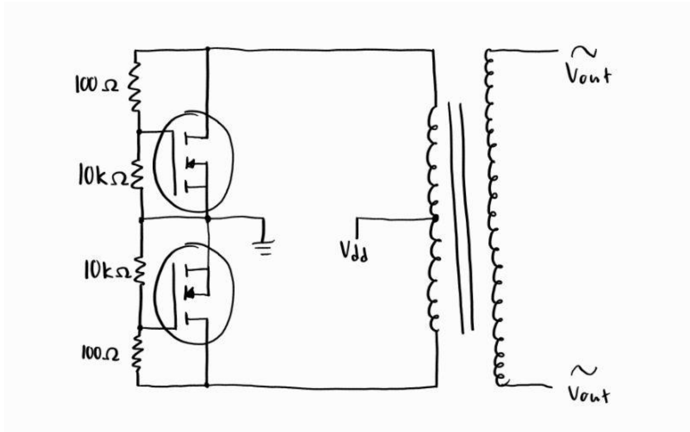


Figure 13 is the schematic describing the transformer driver circuit using 2 N-channel MOSFETS. This circuit was designed in class

The gates of the mosfets are driven by the feedback generated by the primary coil in the transformer. In the circuit above, one mosfet turns on initially (could be either one as components are not built equal and will never start at the exact same instant) and induces a magnetic field within one half of the primary coil. As a result, the secondary coil produces a high voltage output as it has many more turns than the primary, but at the same time the second half of the primary is energized, delaying the turn on time for the second mosfet by opposing the initially supplied voltage. However, this effect only lasts as long as there is a change in magnetic field and so is temporary. After a delay the second mosfet turns high and energizes the second coil. This again energizes the secondary winding which generates high voltage but at the same time energizes the first half of the primary coil, this time driving it low. This will turn off the first mosfet for a period of time before allowing it to turn on again as the induced voltage on the second half of the primary coil drops to zero. The mosfet then turns on again and the cycle repeats, creating an oscillation dependent on the inductive properties of the primary coil of the transformer while driving the secondary coil in turn.

The second half of the circuit deals with the high voltage output of the transformer in the first part outlined above. In order to statically charge dust particles, a high voltage DC output is required, however the transformer only provides AC. This means the transformer output has to be rectified, and further multiplied to even higher magnitudes to achieve effective filtering. This is done using a Cockroft Walton multiplier. The circuit schematic of such a multiplier is detailed in Figure 14.

Figure 14: Cockroft Walton Multiplier Circuit[5]

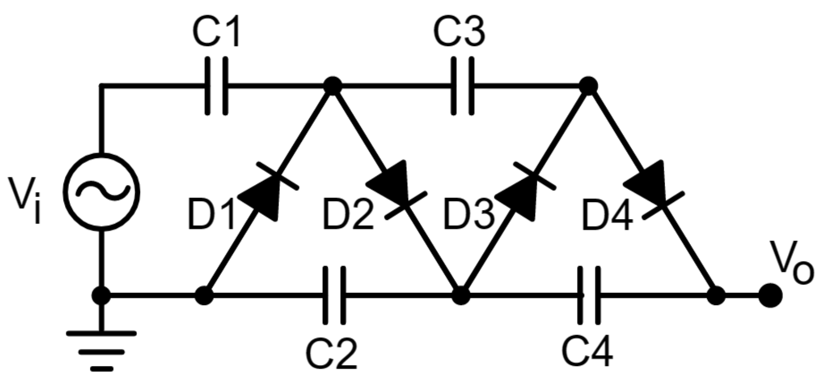


Figure 14 is the schematic describing the Cockroft Walton multiplier circuit.[5]

This multiplier works only with an AC power source, as it uses the positive cycle of the AC wave to charge one set of capacitors, and the negative cycle to charge a second set. The two sets of charged capacitors exist in series with one another which results in a multiplication of the input voltage while also rectifying it. In other words this multiplier is perfect for rectifying and multiplying the AC voltage produced by the first part of the static generator circuit.

The mechanical aspect of the filter hinges on many sets of charged plates. One set is positively charged relative to the other set. Most commonly in filters of this sort the positively charged plates are considered to be grounded and the negatively charged plates are simply at a negative potential relative to ground. These plates are arranged in a way that allows unpurified air to enter between a small gap, about 3mm, between a set of oppositely charged plates. The electric field generated between these plates statically charges the dust particles and pushes them to condense onto the surface of the nearest plate. These particles are held to the plate by the continuous generation of charge by the static generator circuit, as well as the continuous precipitation of more particles falling on top of them which mechanically fixes them into place, not allowing them to rise back into the air.

<u>Integrating The Circuits and Sensor.</u>

The AVR was used to integrate all of the above components. As discussed above the sensor readings control the audible alert system through the AVR. The AVR also controls automatic mode for the air filter. The filter has a MOSFET and a physical switch between it and the Ion-Man 369's power source. This physical switch is used to operate manual mode to turn on and off the filter. However, the MOSFET and AVR are used to control automatic mode which turns the Ion-Man 369's filter on whenever the sensor reads a voltage of 3V or higher. When the AVR sees that 3V has been read from the sensor it sets an output pin to high which turns on the MOSFET thus completing the connection between the filter and the power souce and turning on the filter. The connection between the circuits is shown in Figure 15.

Figure 15: Circuit Integration

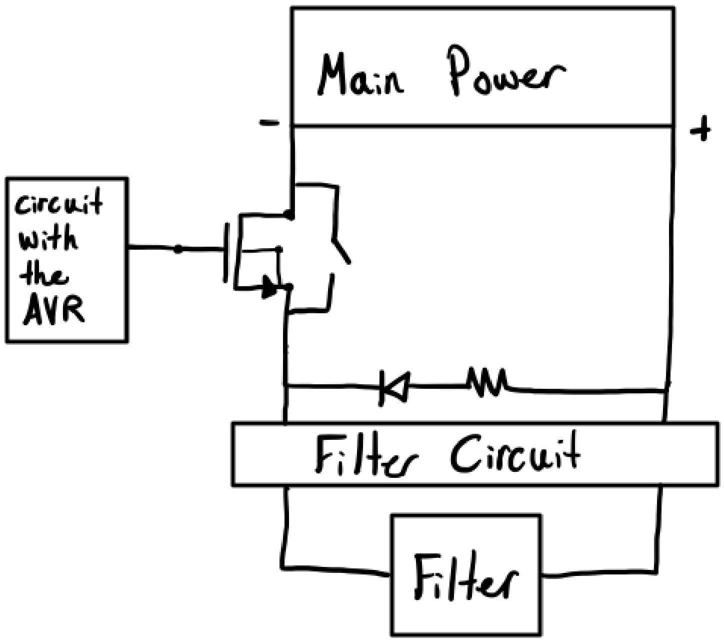


Figure 15 shows how the two circuits, that for the speaker and that for the filter, are connected to each other. And how the filter circuit is connected to the power source.

Table 1: Technical Components

Component	Uses	How did we learn to use it?	Where did we get the component?
AVR128DB28	Reads sensor, controls speaker, controls automatic filtration mode.	ENCM 369	From ENCM 369 class
MOSFET	Increase current going to the speaker and air filter.	ENEL 361 and additional research for implementation in complex circuits.	From a recycled TV power supply board
Bipolar Junction	Increase	ENEL 361 and	Available to use in

Transistors	voltage/current going to the MOSFET.	additional research for implementation in complex circuits.	the Maker Space
Smoothing Circuit	Smooths sensor readings going into the AVR.	ENEL 343	Capacitors and resistors available in the Maker Space
Cockroft Walton Multiplier	Used to rectify and step up the voltage generated by the transformer in order to create a high enough potential for static filtering.	Did research online, going above and beyond class material to understand and design a circuit with properly sized components.	The Capacitors and Diodes required were ordered online through Amazon.ca
Transformer	Used to step up the battery voltage from 5VDC up to 1kV AC in order to properly feed the Cockroft Walton multiplier circuit and limit required stages of said multiplier circuit	Did research online. This is beyond the scope of any of the classes taken so far and was done solely through research and testing	The transformer was recycled from an old bug zapping racket
LEDs	Used to indicate power levels	ENEL 361	The LEDs were given through ENCM 369 Labs and ADALM kit
Switches	Used to turn power and manually turn the filter on and off.	Research about different types of switches.	Switches were recycled off of an old power supply board
Sensor	Air quality sensor to monitor air quality.	Research. We learned how the sensor worked and how to interface with it.	The air quality sensor was ordered online through Amazon.ca

4 Above and Beyond

This project went above and beyond course material mainly through its use of the Cockroft Walton multiplier, transformer driver circuit, and use of multiple N-channel MOSFETS. The transformer driver was researched by team members and designed from scratch. This meant learning about AC to DC conversion, transformer theory relating the number of input turns to output turns of wire, feedback through inductive loads and corresponding magnitude and current capabilities of said feedback, as well as overall bi-stable circuit design theory as well (a circuit that will oscillate between 2 ‘stable’ states such as the one used to drive the transformer). The circuit was thought of and constructed originally through many iterations, firstly using BJT transistors which burnt out due to high collector emitter current, and were eventually replaced by MOSFETS which could handle a lot more power as shown in the final schematic. The use of MOSFETS to convert DC to AC in order to drive a transformer is well beyond the scope of any class taken in second year electrical engineering. Furthermore, the Cockroft Walton multiplier circuit was constructed based on the provided schematic seen previously, however the components were sized based on calculated output from the transformer driver circuit. This meant sizing capacitors with a large enough Farad rating to store charge but at the same time small enough to charge to max capacity given the time frame in which they are charged (depending on the frequency of the transformer output). The diodes were also sized based on voltage and current requirements. In addition to the filter circuitry, the speaker amplifier was also designed by team members. It was shown in class to use OP amps to drive the speaker but an OP amp was found to not provide enough power to bring the speaker to an alert level volume. Therefore, 2 BJT transistors in conjunction with an N-channel MOSFET were used to design and create an original speaker amplifier circuit that worked to drive the speaker to louder volumes. This was again outside of class material. Overall the speaker amplifier circuits and the static generator circuits are both designed and built on knowledge and skill that exceeds the level of second year electrical engineering courses.

5 Testing the Product

Testing the Sensor

Testing the sensor for the Ion-Man 369 was a fairly simple process consisting of placing it in a jar with different gasses, such as smoke, and seeing how its voltage changed with varying quantities of these gasses. The findings of this testing were that the voltage reading of the sensor increased with the worsening of air quality conditions.

Testing the Alert System

The alert system was tested many different times at many different stages. Many circuit iterations were created to ensure the alert system was consistent and at a good volume. Each of these circuits were tested with a voltage divider circuit to simulate sensor readings to verify the qualities listed above. Once volume and consistency were verified they would be tested while connected to the sensor to see if the code written for the AVR128DB28 microcontroller worked with the circuit.

Testing the Filter

Most of the testing done for the Ion-Man 369 was performed on the filter. It was tested for circuit functionality, plate distance, and filter efficiency. Functionality of the circuit was done many times as different iterations of the filter circuit were created in order to get enough power into the filter to charge its plates. These tests were simple tests run by connecting the circuit to a power and seeing if the wires that would end up connected to the filter plates would spark. Following this, metal plates were connected to these wires to see if the circuit provided enough voltage to charge the plates. This was the stage that most of our circuit iterations failed at. Once the final circuit was created in a way that provided enough voltage to charge the plates, the ideal distance that should be between the plates was tested by finding the smallest distance apart the plates could be without sparking. This was done as a smaller distance would create a stronger magnetic field but sparking between the plates could be unsafe for the users so we had to find a balance between them. Finally the effectiveness and efficiency of the filter was tested. This was done in two ways. The salt test, and the smoke in a jar test.

The salt test represented an extreme, and fairly unrealistic scenario, where salt (a reasonably large particle) was poured through our final filter design while it was off (a control test) and while it was on. The mass of the salt was measured before and after it was poured through the filter, and the amount of salt that was caught by the filter was also measured. After a few trials we found that the filter was about 50% efficient in this scenario. Images of one of the salt test trials can be found in Figures 16-19.

Figure 16: Control Salt Test

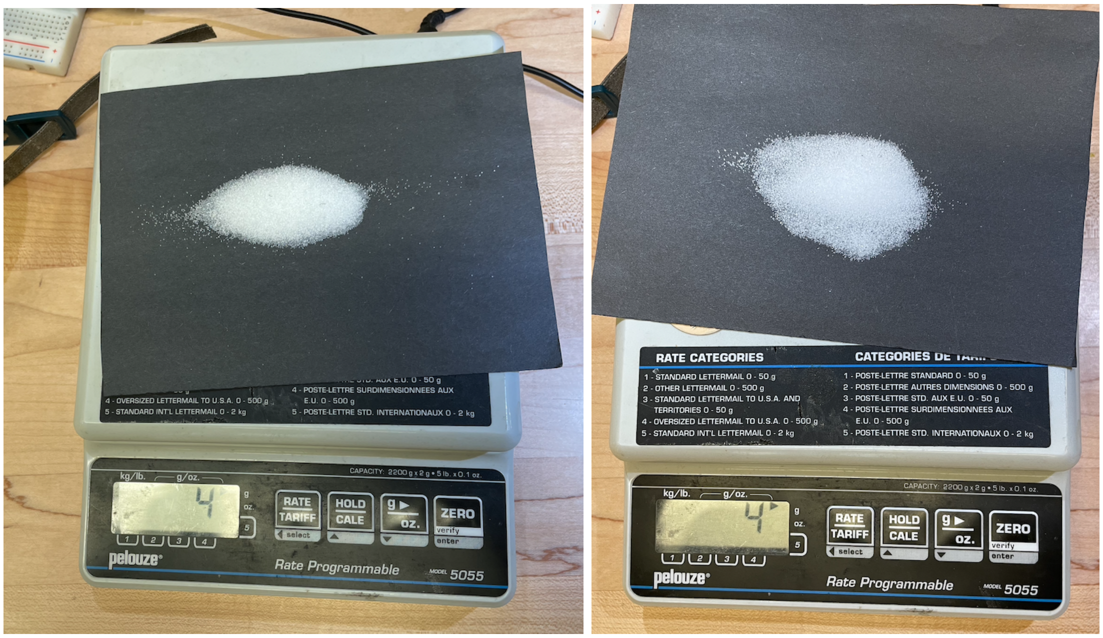


Figure 16 shows the mass of the salt that was poured through the filter while it was turned off (left) and the mass of the salt that fell through the bottom of the filter (right).

Figure 17: Control Salt Test Filter

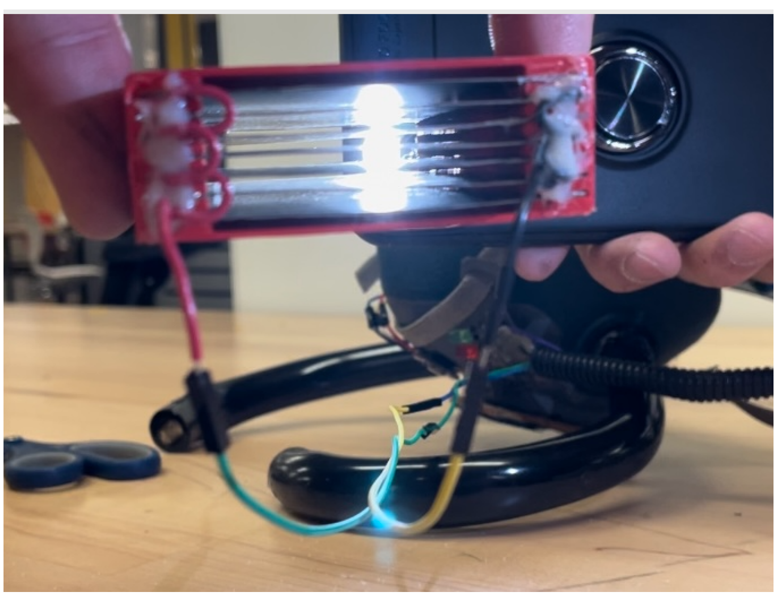


Figure 17 shows the filter after performing the salt test with the filter off.

Figure 18: Salt Test

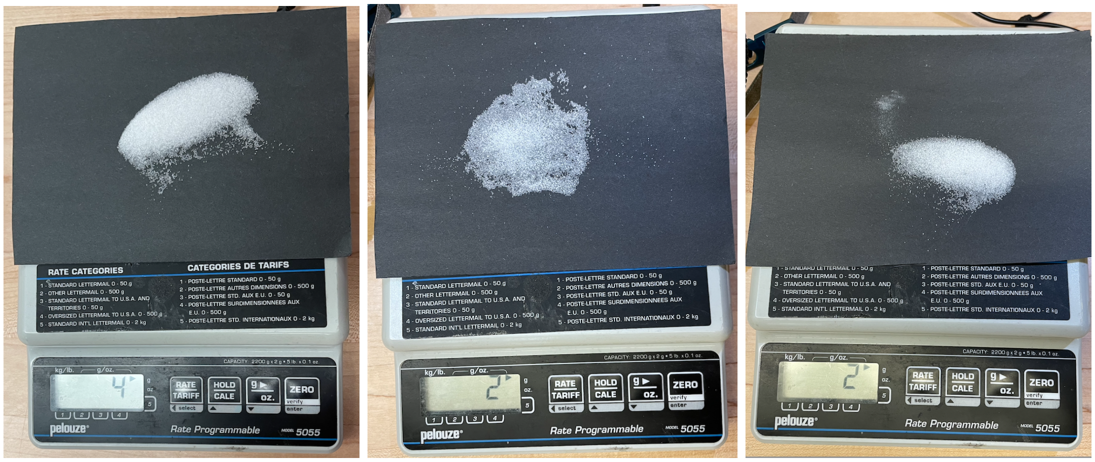


Figure 18 shows the mass of the salt before it was poured through the turned on filter (left), the mass of the salt that fell through the bottom of the filter (middle), and the mass of the salt that was caught by the filter (right).

Figure 19: Salt Test Filter

Figure 19 shows the filter after salt was poured through it (while the filter was on) but before the plates were discharged causing the salt to fall off of the plates.

The smoke in a jar test was done by attaching two plates to the filter circuit and placing them as well as the sensor into a closed jar with a burning/smoking piece of paper. The voltage the sensor was reading was monitored before and after the filter was turned on to see how the voltage reading changed when the filter was turned on. In all of our tests the sensor reading would drop very quickly showing that the filter truly was removing smoke from the air in the jar. In order to further prove this we wiped the plates after each smoke test and found that they always came out dirty meaning that they had picked up some smoke particles. Figure 19 - 20 show voltage readings from a couple of our smoke in a jar tests.

Figure 20: Smoke in a Jar Test One

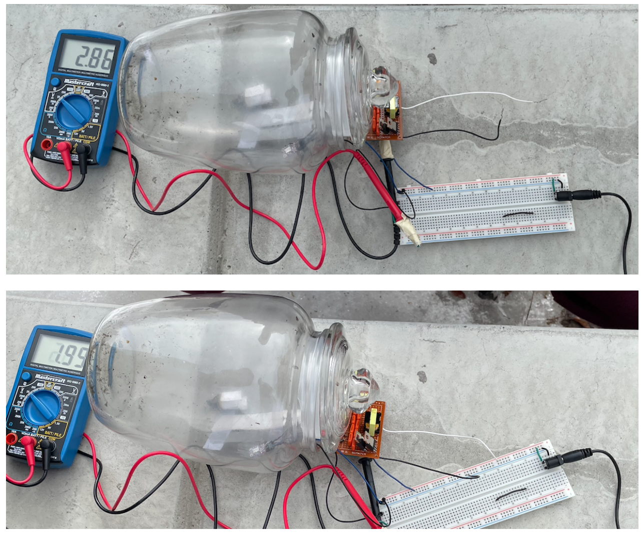


Figure 20 shows the voltage reading before (top) and after (bottom) the filter was turned on.

Figure 21: Smoke in a Jar Test Two

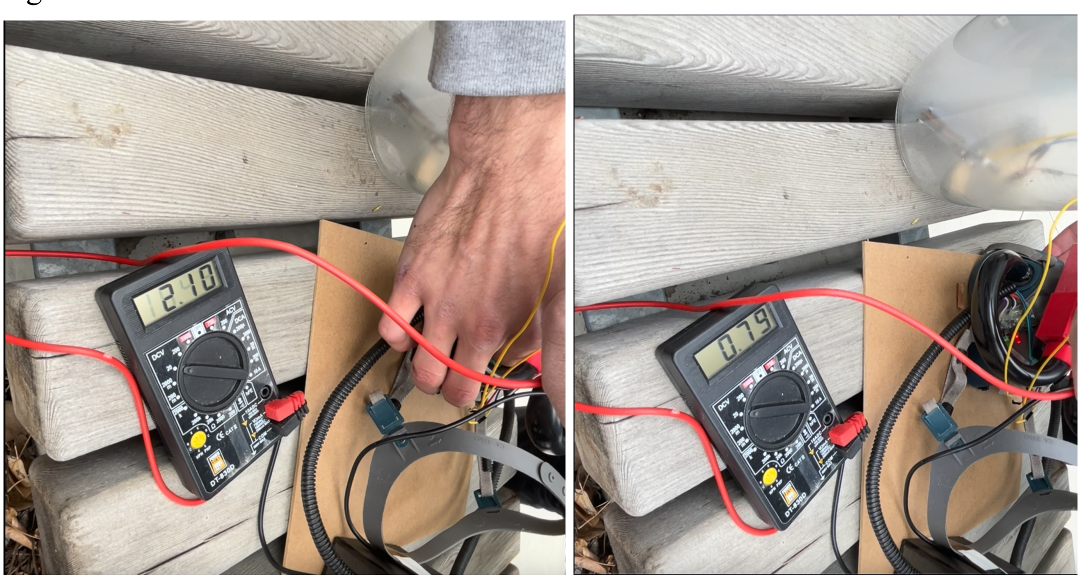


Figure 21 shows the voltage reading before (left) and after (right) the filter was turned on. In this case the voltage drop from 2.10V to 0.79V was also caught on camera and was found to have occurred in just 8 seconds.

Testing the functionality of all mask components (the sensor, alert system, indicator lights, and filter) together was done using this smoke in the jar test and by using the voltage divider set up to simulate sensor readings.

6 Teamwork and Agile Project Management

Agile project development is a way to break the process of creating a product down into several phases and allows one to work in iterations. The process is split into a number of sprints depending on time constraints and work required. Before each sprint began, we underwent a brief planning phase to outline what we intended to accomplish by the end of the sprint. Tasks were decided on and assigned to a group member based on interests and strengths.

The Agile method allowed us to develop iterations of the final product and test it in smaller phases. This way, a final product wasn't created in full only to find out it doesn't work. Developing iterations makes for easier tests and potential fixes on smaller parts. As a team, we developed great partnerships that allowed us to accomplish quality work. The strong relationships amongst team members provided an encouraging and respectful work space which resulted in more efficient work. Encouragement and offering help was key to this project. Many parts of the project required multiple members to complete and all group members were more than willing to assist.

The method of using sprints to break up product development was very beneficial. At the beginning of each sprint, we would plan what we intended to complete by the end of it. This was determined by deciding on a minimum viable product that we wanted by the end of the sprint and then breaking the MVP into smaller tasks to be completed. At the end of each sprint, we did a retrospective, which was essentially an analysis of what went well, what went poorly and what can be improved. Using these retrospectives, we were able to create a plan for the next sprint that considered these points. This was very helpful in creating a more tailored plan specific to our strengths and weaknesses for each sprint. We were able to identify the things that we did well and did poorly as a group and individually and assign tasks accordingly.

7 Future Work

The future of the designed product lies within its size, reliability, affordability, and renewability. One of the main factors described above is the product's size. The product is currently reasonably large and heavy, but investing in more research and development towards sourcing smaller components and designing more efficient geometries will allow for the future designs of the product to progress to sleeker and more user friendly categories. Furthermore, minimizing the size of the product will allow for the use of cheaper components as well, further reducing the production and use cost, and at the same time allowing for the use of less un-sustainable materials leading to a more positive impact on the environment as a whole. Both of these aspects align with UN goals of sustainability and human development, and with more investment into the possibilities of where this mask technology can be applied, the better a world will be created through the use and invention of this product.

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A User Manual, Instructions and Code

The user manual and instructions for how to use this product can be found by following the link below.
https://docs.google.com/document/d/1RQVuRel9uzle78XkqxkH8LQPt4JljWUboi6MXkQEi1Y/edit?usp=sharing

The code used for this product can be found by using the following link:
https://github.com/Brighton-McKibbon/ENEL300/tree/main

B Intellectual Property

When looking for patents of products similar to the one described in this report we used patents.google.com. By looking up keywords such as “mask”, “ionic filtration”, “electrostatic filter”, “active filter”, “air”, “electronic”, and many more, we were able to look through many patents to see if there was any patented product similar to our own. Some patents had components similar to the product we have created, however, we found only one which was very close to our design. The following patent is for a mask which, like ours, intended to use an ionization technique to filter air before it is inhaled. This patent has been abandoned.
https://patents.google.com/patent/US20220062664A1/en?q=(%22electronic+air+filter%22+%22mask%22)&oq=%22electronic+air+filter%22+%22mask%22

When deciding on a name for our product we looked into whether there were any trademarks/names similar to ones we were considering. This was done using the Global Brand Database. Our first name choice was The Ion-Man 369 which had 0 matches in the database. While IonMan by itself had 17 matches, this number was small enough for us to feel that the name choice of Ion-Man 369 was unique enough to be easily marketed and searched.