
AIRBENDER

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THESIS PAPER

2020/06/09

PART 1

HISTORY

Although the history of endurance running goes back over 2 million years to the evolution of the homo genus[1], to study the origins of the sport in its modern state, surprisingly one needs to only go back as far as 1896 when the first marathon was run as part of the inaugural Olympics in Athens, Greece.[2] Following that historic event, participation in the sport grew slowly, and it was not until the 1970's that the first significant spike in its popularity can be observed. It was due in large part to three factors which happened within relative proximity to each other, both in time and space, which would break through the cachet of running as an activity for elite athletes and celebrities.

The first factor was the publication of a book by the University of Oregon's track coach Bill Bowerman. Entitled, "Jogging: A Physical Fitness Program for All Ages", it used science to show that jogging did not just help the waistline, but that it could also be used to improve cardiovascular health.[3] Bowerman, alongside Phil Knight, would also become co-founder of Blue Ribbon Sports, or as it would later become known, Nike, which began to gain national recognition in the 70's for the quality and style of its athletic shoes. To complete the trifecta, one of Nike's athletes, Steve Prefontaine, who was coached by Bill, was becoming a superstar for his heroic performances. As former US record holder, Alberto Salazar put it, "Pre inspired a whole generation of American distance runners to excel. He made running cool."[4]

Following the first running boom, there would be two more significant participation spikes in the coming decades. One in the 80's after the official inclusion of women in the marathon where Joan Benoit became the first female champion, winning on home soil in Los Angeles in 1984. The other came in the 90's when health and wellness trends saw participation rates in the marathon grow by almost 50%, a trend that would carry on into the early 2000's as well.[5]

Looking at the current state of distance running in the United States, it appears to have plateaued over recent years and it is hard to predict how or when this will change. However, what is clear is that the sport is now experiencing a boom internationally, with participation growth rates from 2008 to 2018 including 505% in Africa, 262% in Asia, and 42% in Europe.[6] Although the reasons for this influx of runners varies, a growing middle class in developing countries which has a disposable income and a willingness to prioritize healthy living is assumed to be a key driver.

SPORT ENVIRONMENT

There are two distinct environments that endurance runners experience, the one in which they are training and the one in which they are racing. Depending on the level of athlete and where in the world they live, training typically occurs 4 to 6 days a week in a spectrum of climates ranging from a humid 40°C [104°F] down to a windy -30°C [-22°F]. Training occurs over the span of a year and typically builds up to one or two

major long distance races throughout the year where the athlete's goal is to be at the peak of their performance. For those reasons, participants are doing the majority of their running in direct vicinity of their homes or work since they are required to fit training into their day around commuting and other errands. On the other hand, when it comes to their races, runners are increasingly choosing destination races over local ones[7], presumably as a form of vacation and sight seeing. This observation is important to note because it allows us to deduce that although major cities may not be ideal for running due to their density and high rate of emissions, anyone training is still required to use their immediate urban environment out of necessity.

Combining the mask's inherent purpose of protecting athletes from air pollution and the aforementioned circumstance faced by runners living in the city, it is also reasonable to assume that large cities in countries with under developed environmental policies are going to be the most in need of air filtration masks. With that in mind, it becomes easier to narrow down specific countries and cities the mask will need to be designed for, taking into consideration everything from climate to cultural stigmas which could impact a runners decision to wear the mask. Using a global air quality index, it quickly becomes apparent that a concentration of both highly populated and polluted regions are found in central and eastern Asia. In order to create a manageable strategy, I have decided to focus my research primarily on Beijing, China. On top of checking all of the boxes listed above, it is also preparing to host the 2022 Olympic games, which is sure to drive participation across a wide range of sports.

PM2.5 Legend ⓘ | WHO target | Good | Moderate | Unhealthy for sensitive groups | Unhealthy | Very unhealthy | Hazardous | Unit: µg/m³

Beijing, China YEAR	Annual AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2008	81.5				103.9	98.4	99.8	89.7	65.4	59.3	84.2	73.1	
2009	101.8		65.4	80.4	87.1	84.0	96.8	105.8	107.4	108.7	92.8	155.1	109.0
2010	104.0	90.4	97.2	94.1	80.1	87.1	109.0	123.4	97.7	122.8	118.8	138.4	97.1
2011	99.1	44.9	150.3	57.5	91.7	65.1	108.8	107.4	103.7	95.0	145.6	109.4	108.7
2012	90.5	118.9	84.4	96.5	87.8	91.0	96.6	80.6	81.2	59.8	95.0	87.4	109.2
2013	101.7	193.4	123.6	123.4	65.8	85.2	111.5	68.8	61.9	90.9	106.6	90.7	98.5
2014	97.7	118.8	174.6	110.5	95.1	72.2	59.0	89.6	62.8	70.3	140.7	104.2	78.6
2015	82.7	107.9	96.7	89.1	78.9	60.1	54.4	55.1	44.6	47.1	72.8	124.8	162.0
2016	73.1	71.2	44.2	93.0	65.1	53.5	59.3	67.1	46.2	54.4	82.5	101.1	136.8
2017	58.9	120.2	73.1	64.4	53.3	59.0	42.3	51.1	37.3	56.8	56.6	46.5	45.8
2018	50.9	36.0	51.6	90.4	63.0	54.5	46.7	47.2	33.3	28.0	44.6	74.4	41.5
2019	42.6	54.1	55.8	51.4	47.6	36.8	38.4	35.8	22.1				

Taking a closer look at the environment specific to Beijing. The city, which is the capital of China, has an urban footprint of 4,144 km/sq [3,400 mi/sq] is home to a population of approximately 21,450,000. Although the air quality has dramatically improved over recent years, as of 2019 it still ranks in the top 200 most polluted cities. It is expect to average 42.6 micrograms per cubic meter of the smallest lung damaging particulate, PM2.5 by the end of the year. That is four times higher than WHO's annual concentration guidelines.[8] According to first hand account as well as the chart below provided by AirVisual, pollution tends to rise during colder months when heating buildings increases energy consumption.[9] Looking more specifically at weather, theirs "features four distinct seasons - short windy spring, long hot summer, cool pleasant autumn, and long chilly winter. July and August are the hottest months with the highest temperature around 37ºC [99ºF], while January is the coldest time with the lowest temperature around -15ºC [5ºF]."[10]

CONSUMER DATA

The starting target market for the Airbender is both males and females between the ages of 20 - 30. It is targeted at endurance athletes, but more specifically sub-elite distance runners who train 4-6 times a week primarily for personal wellness. In major cities across the world, and more notably in developing countries with poor environmental regulations, air pollution is considered a major risk to health, responsible for as many as 8 million deaths per year worldwide[11] and a decrease in life expectancy of 2 years[12]. "To put this into perspective, this means that air pollution causes more extra deaths a year than tobacco smoking, which the World Health Organization estimates was responsible for an extra 7.2 million deaths in 2015. Smoking is avoidable but air pollution is not."[11] Although there are various industrial and recreational air filtration masks available, there are no options designed specifically for athletes where fit and air flow rate are the most important features.

As it relates to China and Beijing in particular, studies by Greenpeace have found that “the capital’s smog is laced with a range of heavy metals, the worst being arsenic, which reaches six times the Chinese and European limits on heavily polluted days.”[13] In the same study the researcher commented, “even running on lightly polluted days a lot of people will think, ‘Oh, the AQI is only 100 so I can go for a jog. What many of people don’t know is that jogging when the AQI is 100 is the same as walking when the AQI is 250. If you wouldn’t walk without a mask on such a heavily polluted day, then don’t go running when it’s lightly polluted out.”[13] All of this is to say that quite simply, exercising in city with air as polluted as Beijing’s can have serious implications on your health. Currently, aside from industrial and various lifestyle masks, there is nothing geared towards athletes who are most in need of protection from pollution.

China as a whole has seen unbelievable growth in running participation, reflected by the number of marathons in the country which went from 22 in 2011 up to 400 by 2017. More broadly, “race organizers from Sanfo, the Chinese equivalent of REI, estimate that there were 20 million people running recreationally as of 2018, and Yu Lanjiang, the founder of Zuiku, China’s most widely used race registration app, said there were more than 800 road races that he knew of in 2017, along with at least 450 trail traces. This year, he expects the total to climb to more than 1,500. Sanfo put the number even higher, at more than 2,000.”[15] Although it is very difficult to place an exact number on running participation in Beijing alone, without question running is booming in popularity across the country.

The profile of our target consumer is best reflected by Pengchao Zhao, a friend of Shawn’s who lives in Beijing. As a former collegiate sprinter, he is now a personal trainer and part of the city’s growing middle class. In his pursuit to stay active and live a healthy lifestyle, Pengchao runs or bikes roughly 15km daily and wears either a 3M or surgical mask the majority of the time, even being forced to wear them indoors when air pollution is at its worst. Having interviewed him through a video call, Pengchao commented that his biggest complaints about the masks he currently wears are that

they have poor air flow, he experiences a lot of moisture buildup as well as discomfort from the straps, which he wishes were adjustable.

SPORT RULES

Beyond staying within a marked course to be the first to cross a finish line, there are very few rules when it comes to the sport of running, and even less referring to training. Aside from the usual ban of performance enhancing drugs, there is nothing which prohibits athletes from using specialized equipment for training purposes. In fact as it relates to the mask specifically, under the IAAF's Competition Rules document, under "Section II - General Competition Rules", Rule 144.4.C states that:

> "Any kind of personal safeguard (e.g. bandage, tape, belt, support, wrist cooler, *breathing aid* etc.) for protection and/or medical purposes. The Referee, in conjunction with the Medical Delegate, shall have the authority to verify any case should he judge that to be desirable."[16]

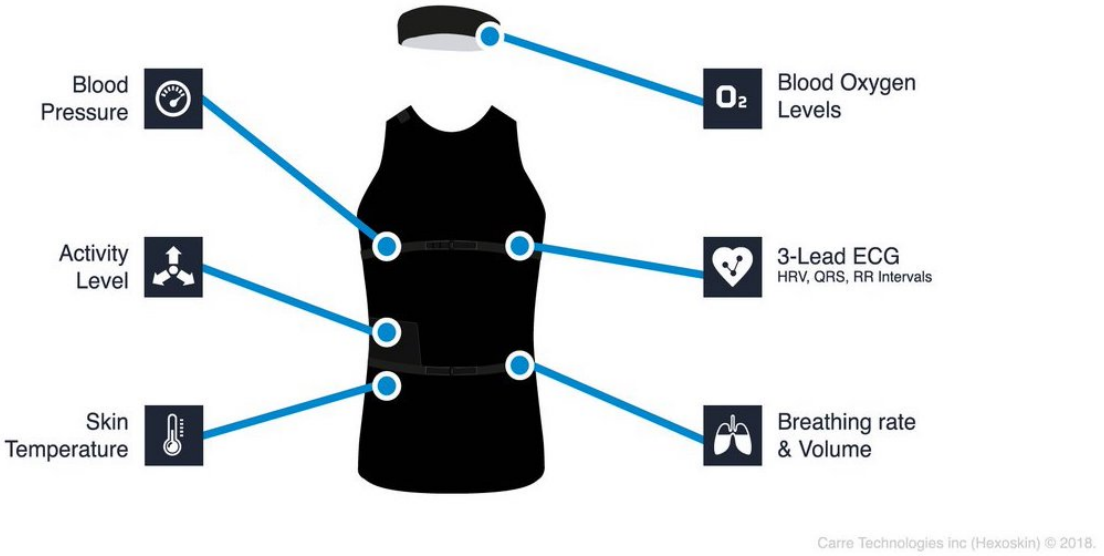
Given the inclusion of "breathing aid" with the scope of allowed assistance, it is entirely reasonable to assume an air filtration mask would be permissible even in the context of a race. With that said, the target market for the Airbender is not world class runners who will move to other countries for environments more conducive to their training. Instead, this mask is primarily for those who are not professional athletes but enjoy running and want to stay healthy. For that reason there should be no risk of masks being banned from use, aside from a decision by the government unrelated to sport.

PHYSIOLOGY

The most critical aspect of the mask in relation to a runner's performance is the ability to supply enough oxygen during the peak of their aerobic capacity. In other words, the

mask must not negatively impact the runners performance due to a shortage of oxygen which they would otherwise have access to without the mask. There are two key factors which impact this: 1] the ability for air to flow through the filters at a rate which allows the athlete to attain their VO2 max and 2] the ability for air which is exhaled to escape efficiently so that it does not create a high pressure zone within the mask that would prevent fresh air from flowing in.

One of the tools I will be using help me determine if the mask is having a positive or negative effect on its users is Hexoskin, a biometric t-shirt and headband that are used to provide precise health monitoring. Used by the Canadian Space Agency [CSA], these wearables have been tested against the "gold standard" of laboratory equipment to compare respiratory rates, tidal volume, minute ventilation and heart rate, and the results have been found to be acceptable for field use.[17]



Directly related to this dimension of the mask is what sort of filters air will be passing through, their permeability, and the harmful particles chosen to be removed from the air breathed in by the runner. These factors are described in more detail under the “materials” heading.

Aside from the masks air flow rate, there are several other important ways it interacts with the body and can have impact on an athlete performance and experience with the product. For example, the ratio of oxygen that is inhaled and/or exhaled through the mouth and nose can have a significant impact on performance. “Studies have shown that the change from nasal to oro-nasal breathing occurs between 30-40 L/min. Amis states that approximately 80% of the breathing at rest occurs via the nasal route, O’Kroy states that 80% of the breathing during exercise occurs via the oro-nasal route.”[18]

There are other smaller and unexpected physiological factors which may play a larger or smaller role depending on the design’s evolution. The use of a mouthpiece to keep the mask in place, could play a role in the ability to breathe, but it may also have other positive ramifications. In one study on the effects of mouth guards on agility, power and vertical jump, it was concluded that, "significant improvements were found in all vertical jump protocols using the mouthguard when compared to the no mouthguard conditions.”[19] Even though no significant differences were found between the two conditions in agility and power, it is an interesting example of the wide range of factors that need to be taken into consideration.

MARKET LANDSAPE

Currently if athletes are looking for a mask which offers both performance and style there are no existing solutions. Industrial masks provide great air filtration but are very bulky and look like they belong on a construction site. On the other hand, there are some lifestyle masks which are customizable and contemporary to today’s fashion trends, however they do not provide the same quality of fit or air filtration as the

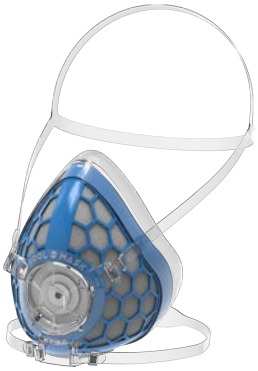
industrial mask. In addition, both of these styles of masks place very little importance on the rate of airflow because they are not designed to be used during highly aerobic activity. Airbender will differentiate itself from all of these air filtration masks by combining style with performance.

The one mask currently available which is closest to matching the needs of athletes is called Koolmask, made by a startup based out of Seattle, Washington. With a retail price of $159.00 USD, their mask includes 2 two turbo fans, a silicone seal, air quality sensor, adjustable straps, modular design, and a patented air valve. With that said, although they do suggest it would work well during exercise, their target market seems to be individuals with severe allergies and serious breathing problems. Besides that, their mask also does not look very aesthetically pleasing, looking more like something which you would find people wearing in a hospital, and it also has a cable running to a battery pack which would be very distracting when running.

Aside from Koolmask, the only other options athletes have are a variation of lifestyle and industrial masks previously mentioned, very few of which contain features or aesthetics specific to athletes. Price points for these masks typically fall below $100 but range from as low as $10 for 3M dust masks to as much as $372.00 for full faced industrial masks. Provided below are examples of a basic SWOT analysis, as well as a market map which help to visually layout the market landscape.

KOOL MASK

$159.00 US



Features	Benefits
Two built in turbo fans.	Supply up to 150 L of air per minute.
Patent pending exhale valve.	Maintains cool, dry interior.
Honeycomb structure.	Provides extra airflow and helps with heat dissipation.
Monitors air quality.	Sends real-time air quality notifications.
Fan speed control.	Adjustable to users activity needs.
Positive air pressure.	Prevents air leakage.
Silicone seal.	Fits various facial characteristics and minimizes leaks.

SWOT	
STRENGTHS + wide range of product features + highly transparent about science + well organized and experienced team	WEAKNESSES - mask is bulky and requires batteries - cable can easily get tangled when exercising - not appealing to style minded audience - team lacks diversity, particularly in age - seems targeted at white Americans
OPPORTUNITIES + updated form would appeal to wider demographic, particularly athletes + advanced features can be easily removed to reduce complexity and lower price	THREATS - turbo fans can not be patented - no clear target market - premium pricing may deter adoption

WAIR

€54.90 [$61.19 USD]

Features	Benefits
Anatomical Silicone Seal	Maximizes filtration effectiveness.
Necktube Attachment	Conceals masks under fashionable accessory.

SWOT	
STRENGTHS + stylish and customizable + strong focus on science + easy to assemble	WEAKNESSES - designed to be concealed - targets commuters, not athletes - poor harness design - designed for white European population - no exhaust valve
OPPORTUNITIES + may capitalize on future fashion trends + expansion of product line or addition of features with future iterations of mask	THREATS - only 2 distinguishable features - easily replicated design

RZMask

$34.95 USD

Features	Benefits
Dual Exhaust ValveS	Prevent moisture buildup.
Adjustable Straps	Help ensure proper fit and improve comfort.
Adjustable Nose Clip	Reduces fogging when wearing lenses.

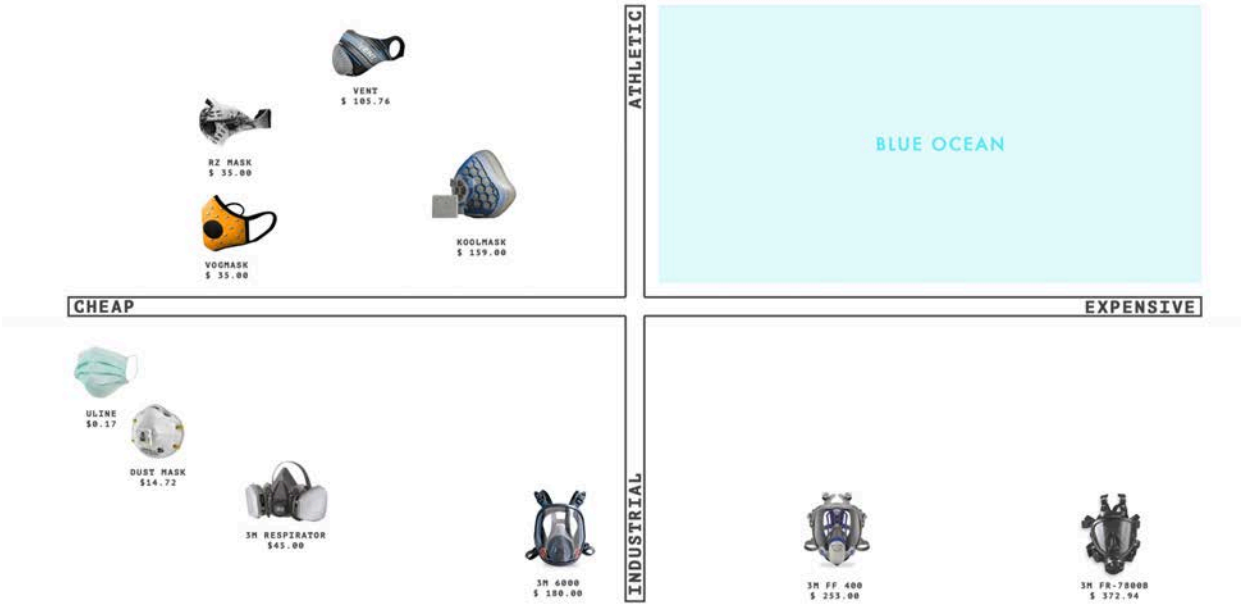
SWOT	
STRENGTHS + ranks very well on search engine results + used across multiple industries + simple, low cost design + easily decorated with colours & graphics	WEAKNESSES - lacks distinguishable silhouette - primitive seal which can easily allow leaks
OPPORTUNITIES + expansion of product line to masks with more advanced seal & features	THREATS - only 2 distinguishable features - easily replicated design - no patented technologies

Vent

$79.99 USD

Features	Benefits
Resistance Training Mode	Adjustable airflow to simulate exhaustion.
2 Point Harness	Wraps back and top of head for added stability.
Pressure Valve	Stabilizes pressure in mask for easier breathing.

SWOT	
STRENGTHS + strong brand recognition + athlete specific marketing + own proprietary technologies + unique training features	WEAKNESSES - targeted towards weight training and high intensity routines. - aggressive silhouette/profile and thick straps make it hard to conceal -
OPPORTUNITIES + adding products for endurance athletes + refined harness and silhouette	THREATS - strong association with power lifting and training, not for competitive use



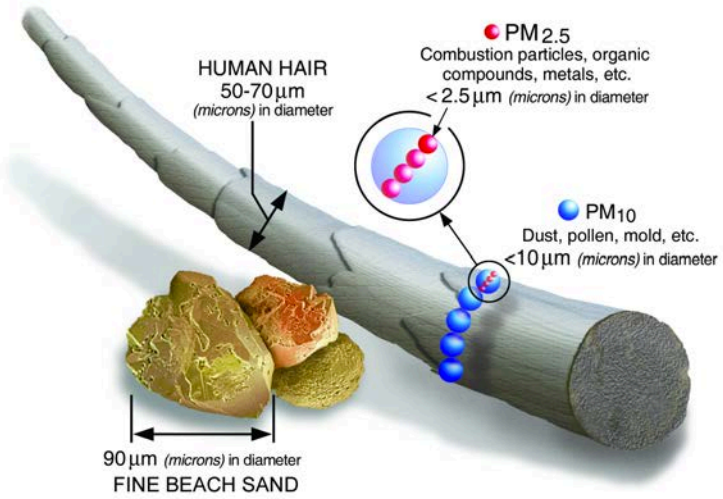
PRODUCT ANATOMY

Looking at the previous examples, it becomes clear that current masks can be separated into two categories based on their construction, one containing a hard frame/chassis like structure made from plastic, or another featuring a soft “outer sleeve” using non-woven textiles. Those made from plastic are injection molded using common thermoplastics such as Acrylonitrile Butadiene Styrene [ABS], Polyurethane [PU], or PA Nylon, depending on the required properties. 1.3 Alternatively, the soft masks are most likely to be made of neoprene or mesh spacer. In both cases, beyond the frame or sleeve there are 4 key components which make up a respirator and ultimately distinguish one from the other in function and form, they are listed below along with descriptions on their materials and manufacturing:

Filter

The importance and purpose of the air filter in a respirator goes without saying, but there are many combinations of materials and finishes which can be used to determine exactly the type of particles being filtered, as well as what level of air flow you are looking to achieve. However before going into how they are made, it is important to understand more about the pollution prevented from being breathed in.

Particle matter is often divided into two main groups, “coarse fraction which contains the larger particles with a size ranging from 2.5 to 10 µm (PM_{10} - $PM_{2.5}$),and fine fraction which contains the smaller ones with a size up to 2.5 µm ($PM_{2.5}$). The particles in the fine fraction which are smaller than 0.1 µm are called ultrafine particles.”1.7 Coarse particles are produced by the mechanical break-up of larger solid particles, for including dust from various industrial activities, non-combustible materials released when burning fossil fuels, as well as pollen and mold spores. 1.7 Fine particles on the other hand are mostly composed of gases, which also includes odours. 1.7



With all of that in mind, there are two common air purifiers which can be used to remove some or all of these particulates from the air: mechanical filters and electrostatic precipitators. Mechanical filters are made using very fine [less then 1 micron in diameter] borosilicate glass fibers or plastic fibers (e.g., polypropylene) which are tangled together and compressed to form a filter mat. 1.6 “Electrostatic precipitators rely on electrostatic forces to remove particles from the air. They work by creating a cloud of free electrons through which dust particles are forced to pass. As the dust particles pass through the plasma, they become charged, making them easy to collect. Electrostatic precipitators can collect particles down to a diameter of 0.01 microns (0.00001 mm)”.1.6

In addition to these two filter types, activated carbon is used to remove volatile organic compounds and odours.1.6 “Activated carbon is produced by heating a carbon source (coconut shells, old tires, bones, etc.) at very high temperatures in the absence of oxygen, a process also known as pyrolysis or destructive distillation. Pyrolysis separates the pure carbon from the other materials contained in the raw material. The pure carbon is then exposed to steam at 1,500°F(800°C). The high temperature steam activates the carbon. The activation process forms millions of cracks in the carbon grains. These cracks have diameters of about 0.002 microns (0.000002 mm). Because there are so many cracks, the activation process provides the carbon with an enormous surface area per weight—about 6.5 acres/oz (1,000 m 2 /g). The millions of cracks provide locations where organic compounds can be adsorbed.” 1.6

While the manufacturing of these non-woven textiles is extremely complex, once they are in sheets the process of assembly is paradoxically simple needing only to be die cut and potentially finished with lamination, bonding, printing and/or sewing before being ready for use. 1.8

Seal

Seals play an important role in the effectiveness of a mask because they determine whether or not dangerous particles are actually prevented from being breathed in. One of the biggest current problems, and therefore biggest opportunities moving into the future, is that they do not address the large variations in bone structure which can be found between ethnicities. Having an adjustable or customizable feature which conforms to each wearer's anatomical needs would greatly decrease the risk of an air leak, as well as enhance overall comfort.

The most premium material currently used for seals is silicone due to a number of valued qualities including its durability, temperature and chemical resistance, flexibility, tensile strength, and natural transparency which allows it to be easily coloured. 1.4 This type of seal is used with the rigid mask frame, and like the plastics used for that, it is also injection molded. In the case of a soft mask, it is the material itself being held onto the head with tension that creates the seal. In many cases a small piece of foam or a metal clip which can be bent will be inserted around the upper cartilage of the nose to create a better fit.

Air Valve

A one direction exhaust air valve is another essential component which determines how easily air is leaves from the athletes mouth, passes through the mask and returns to the external environment. Air valves are one of the components most likely to be patented due to their ability to create a true performance advantage, product differentiation, and therefore a strong selling point.

Regardless if the mask is of the hard or soft variety, the air valve is one component which does not vary as far as how it is made. In every case it is injection molded as small individual parts using the full range of plastics mentioned earlier [with exception of the rubber flapper which can be die cut], then assembled to create a mechanical working air valve.

Harness

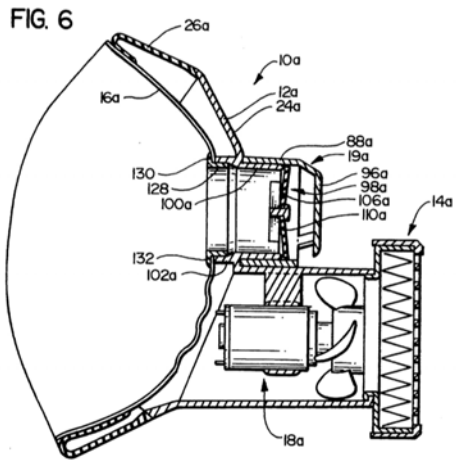
The fourth key component involved with a face mask is the set of straps which rap around the back, top of the head or ears, in order to keep it affixed to the head. The harness plays a large roll in the comfort of a mask because any sort of abrasion or protrusion against the head will be highly noticeable, especially when it is intended for

use over runs that are more than an hour long. It can also create pressure if it is on too tight, or on the other hand, a feeling that the mask is too loose and may fall off.

The main characteristic of the harness straps is that they need to have stretch in order to help conform over various sizes of heads and to create higher tension. For those reasons one popular option is an elastane band similar to those used for ski goggles. In this case the premium option would be to blend it with nylon for exceptional durability as well as a soft hand. Another option is rubber or silicone bands, which do not provide has much stretch but provide just enough still provide good elongation and recovery.
1.4

PATENTS

As mentioned earlier, patents in the respirator space are primarily focused on how air is draw into or out of the mask. Of specific interest to me was the ability to use a fan in order increase the rate of air flow into the mask. US patent 5372130 for doing exactly that has expired .



Another very simple and relevant valve I was interested in was the one used by 3M in their disposable dust masks. Covered by US patent 6460539, this one belongs to 3M and unfortunately is still active.

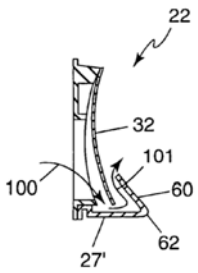


Fig. 9

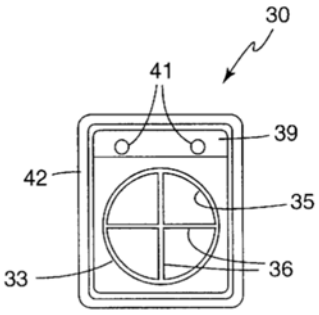
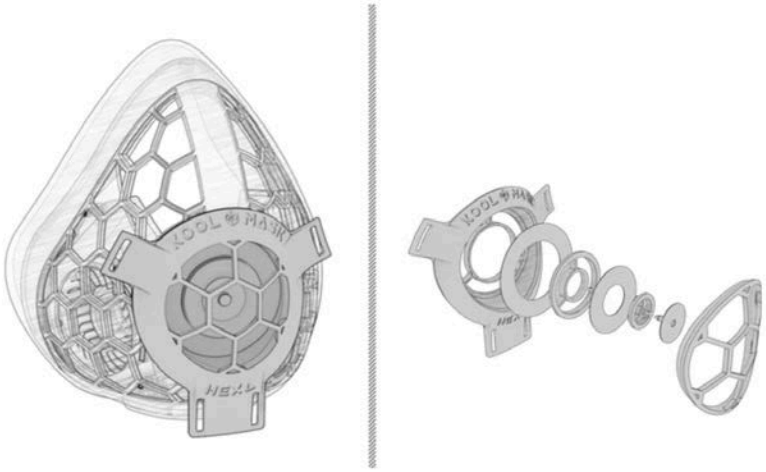


Fig. 3
(Prior Art)

With that said there is still a lot of room for innovation in this space, as demonstrated by Koolmask. According to their Kickstarter page, they have applied for a patent on their air valve which is suppose to reduce moisture buildup inside the mask.



TRENDS

Due to the historical levels of air pollution in Beijing as well as other parts of China and Eastern Asia, wearing a mask has long been accepted as normal, unlike in North America or Europe where there are still stigmas associated with them. So although the market is relatively mature, there really has not been much progress in terms of technology or trends. However, in recent times there has been a slow shift towards mask customization due to artists like Zhijun Wang, who makes functional air filtration masks using repurposed shoes. In fact, his masks which are valued as art are known to sell for as much as $15,000 USD. However this is an extreme, and on the other end of the spectrum everyday men and women are also customizing their masks, predictably to avoid how depressive they look and feel. Going forward with Airbender, an emphasis will be placed on the ability to creatively customize while taking into consideration anatomical fit.

RESEARCH TRAVEL

In order to gain better insight on the use and landscape of masks, as well as to better understand the running culture that exists in my target market, this past February I traveled to Asia. My trip took me to 3 capital cities: Seoul, Hong Kong and Tokyo, each chosen for a distinct reason. Seoul has recently seen an explosion in the number of running crews, so my goal there was to connect with as many as I could to learn more about the movement. My visit to Hong Kong on the other hand was about experiencing a city that is know to be polluted, but at the same time has a relatively wealthy, well educated population. The last city I visited was Tokyo. Known for being at the forefront of technology, product quality, and culture, among the things, in Japan my goal was to observe the selection and branding of masks, along with the overall retail landscape.

In addition to the aforementioned, in each city I was looking to connect with as many running crews as possible to learn about their experiences with masks, as well as to

collected face scans that I could later analyze to ensure accurate mask sizing. Below is an account of my key takeaways from each city.

SEOUL

My general takeaway from Seoul was that although pollution is not as bad as other major Asian cities, its citizens are very aware of PM levels. Along with apps available on everyone's phone, there are also public notifications displayed using lit up billboards. In addition to this, it is well know that during spring months there is a very heavy yellow dust which covers the city and causes many breathing problems. Although some debate the cause of this influx, it is generally accepted that it is blown over from the dry deserts of China. Ranging in size from 1μm to 10μm, these "dust storms" are reported to be intensifying over recent years, now beginning to occur in Fall and Winter rather than the usual Spring season. [24]

With that said, pollution levels do still get dangerous, and when this is the case, athletes have developed various ways to cope. For example, they may train indoors by swimming or using the gym. Another strategy is to avoid the polluted air by adjusting running routes to the pathways along the river which lay 10-20 meters below city streets, offering slightly cleaner air. Aside from these strategies however, runners do wear masks as well but do not have any options available to them besides the standard dust mask which is what I saw every single person wearing.

Along with general observations on pollution I was also able to learn more about the growing movement surrounding running crew culture, which has spread to all parts of the world but particularly across North America, Europe and Asia. Having met with and ran alongside the founders of Private Road Running Club [PRRC], I was able to learn more about their origins. Turns out that they were heavily influenced by The Bridge Runners which is a crew still running out of New York City, known by some as the starting point of the run crew movement.

This turned out to be a part of a consistent theme in Seoul, all the runners I met seemed very polite, educated, trendy and sensitive to cultural trends, which is due in part to the fact they often travel to Japan but also North America. With all of that taken into consideration along with the lack of stigma surrounding wearing face masks and its proximity to other nations that experience major air pollution, Korea certainly seems like it would be an important strategic point for the launch of Airbender.

HONG KONG

Having landed in Hong Kong on February 1st, I had arrived at a very interesting moment just after Chinese New Year, during ongoing political protests, and right as the COVID-19 was beginning to gain steam, the result of which was that my observations were strongly skewed. With factories closing down, employees working at home, and tourism coming to a halt, pollution was at an all time low. Simultaneously because of

the virus, nearly every single person in public was wearing a mask. This also meant that masks were completely sold out wherever I went.

However, one advantage of arriving in Hong Kong at this time was that I was able to see all of the masks that people had available to them. To my surprise there was not a single moment where I saw a mask that I had not researched. In fact I can hardly remember seeing any alternatives period to the standard dust or surgical masks. It was also interesting to note how many times I heard comments on the sky being clear and sunny because of the drop in pollution. This was also shocking to me because I still had never seen a city with such poor air quality in my life, which leaves me wondering how bad normal days are, never mind the days when it gets really bad.

Due to social distancing practices already taking effect as I visited, I was unable to meet with one of the largest running crews that I had hoped to while in Hong Kong. However I was still able to meet and run with one of its founders, Nigel, as well as with a girl named Barbara after finding a running tour she had posted on Airbnb. In both cases when I brought up air quality and air filtration masks there was unanimous agreement that it was a major problem and that some sort of mask would be very helpful. Both of them also mentioned that airflow was one of the primary reasons why they did not run with any masks, as much as they wanted to and have tried in the past, current masks are simply too uncomfortable.

TOKYO

The last stop on my trip was for a short 2 day stay in Tokyo in one of the busiest and most well know neighbourhoods, Shibuya. Once again I was able to use Airbnb to find running tours which allowed me to learn more about their running culture, the use of masks, and to collect more face scans. One thing which became immediately clear to me was that the air was much cleaner in Tokyo then it was in Hong Kong or even Seoul. Although there are some days which are guaranteed to be worse then others, overall the runners agreed that I was not a major issue. However, one of my guides did

mentioned that he can be prohibited at times from running in Spring because of the large amount of pollen which creates allergy problems for many people. This, in addition to the common courtesy of wearing masks when you are not feeling well, could mean that there is still a small niche demand for Airbender in Japan.

As far as options currently available to them, the most prominent mask I saw was one made from a sponge-like material. Stretchy and capable of withstanding a couple of washes, this mask was certainly the most comfortable that I have experienced and also looks the most aesthetically pleasing. With that said, it still wraps around the ears and does not do a good job sealing off the face, which means that like a surgical mask it most likely does a better job of spreading contagions then actually filtering air. Before leaving I did also visit an athletic store which was primarily oriented towards runners. I was surprised to find that on the counter at checkout they actually had a small box of face masks available for sale. I purchased one, and the mask turned out to be terrible, worse fitting and less effective then even a surgical mask I believe, but it does highlight an idea I have which is that Airbender could be a good point of sale product that can be sold in athletic stores.

TRIP SUMMARY

In all of these places I visited wearing a mask is more than just a prevention method, it also serves as a common courtesy if you believe you are sick and capable of getting others infected, or even if you feel you have a weak immune system and do not want to burden others with worry. It’s important to note that many of these masks were not even designed to filter air, rather they are used to help prevent the spread of bacteria and viruses. With that said, approximately half the runners I saw with masks were using masks with no filtration capabilities, while the other half used standard dust masks. I did not discover any new masks that I was not aware of previously, and certainly nothing designed specifically for endurance athletes.

As it relates to masks, in a role of reversal, Asia may now unintentionally be having its first major impact on Western culture in the form of the stigma and norms for wearing a mask. Why there is such a difference in how North Americans and Europeans view and wear masks is a long conversation which leads to many cultural nuances, however one thing which I believe cannot be disputed is that the COVID-19 pandemic has brought greater awareness to the world of our global connectedness, as well as the importance of understanding what we are breathing in. Along those lines, although masks are currently being linked directly to the virus, it seems safe to assume that it will help normalize the idea of wearing a mask to protect yourself from air pollution in the future as well.

On a final note, I did also ask everyone I could where they would buy masks if they needed one, and if they have ever heard of a mask specifically for runners. In all cases the answer was that they would probably buy it at a pharmacy or online, and that they have not seen any for athletes.

DESIGN

Based on all of my research which explored the performance requirements of endurance athletes, filtration technologies and the current landscape of masks, I am confident in saying that there is a clear need for a mask which can protect runners from poor air quality while offering a more visually appealing and better fitting alternative. Combining all of these variables has shaped the design brief as seen below.

BRIEF

Design an affordable, reusable mask with replaceable filters that protects endurance athletes from PM 2.5. Its airflow rate should allow for an oxygen uptake of 6.5L/min, while the attachment point, seal, and exhaust must prevent abrasion, overheating or moisture buildup. It must also remain effective across gender and ethnicity, as well as evoke a feeling of confidence and speed through its aesthetic.

ENVIRONMENT

Airbender is primarily intended for use by endurance athletes, specifically runners and cyclists, who live and train in major urban centres with dangerous levels of air pollution. It is designed to be used by sub-elite and amateur athletes who run or bike 4-6 times a week in a wide range of climates, from hot and humid to freezing and windy. Elite athletes are not a priority due to the fact that they tend to relocate to areas specific to their training needs, often in smaller towns at high elevation where air quality is not as much of an issue. With that said, the mask could ideally be used in race situations when air quality is poor as well.

RETAIL

A soft launch of Airbender masks will begin as early as Summer 2020 upon my graduation from the Sports Product Design program with an official launch planned for Winter 2020. The goal in respect to pricing and profit margins is $20.00 USD FOB and an MSRP of $80.00 USD.

VALUE PROPOSITION

Airbender is a lightweight, packable air filtration mask for endurance athletes living in the world's most polluted urban centres. It eliminates the bulk and clinical aesthetic of other masks by focusing purely on the essentials of performance such as airflow, moisture management, stability and field of view.

KEY SOLVES

1] Airflow

The ability to create a mask which allows athletes to breathe as naturally as possible without the feeling of constriction has been cited numerous times through my interactions as the most important feature they are looking for. The most reliable way to accomplish this is by maximizing the surface area of the filter. Aside from simply expanding the size of the filter, one other technique I will be experimenting with in order to create this effect is vacuum forming. In theory I should be able to create a texture in the filtration media similar to folds seen in automotive filters to increase surface area.

2] Moisture Management

The human face plays a key role in our perception of comfort and therefore needs to be carefully considered when designing a face mask. [25, 26] Particularly while exercising it is very important to keep the face well ventilated and to manage moisture caused by perspiration. Preventing moisture buildup by using materials that can soak up, transport, and evaporate liquids can make a dramatic difference in overall perceived comfort.

3] Field of View

Being able to keep as much of an individuals natural field of view is essential for two important reasons. First, it can be a major safety hazard to have your sight blocked off, especially in urban environments where athletes are often crossing roads or running up, over and around obstacles like stairs and sidewalks. Secondly, some individuals report that wearing a mask can make them feel constricted and claustrophobic. Keeping it as low profile as possible and reducing weight can once again have a major impact on the overall perceived comfort in relation to other masks.

4] Filtration

Although it may be counter intuitive, filtration is not ranked as the highest priority solve for a reason. The logic is that because the majority of athletes are currently using masks which offer little to no protection and are simultaneously uncomfortable and aesthetically unattractive, being able to offer them a product which matches current filtration rates but will be used more often will have a greater overall impact then one which filters 99.99% of particulates but is bulky and uncomfortable.

MATERIALS & MANUFACTURING

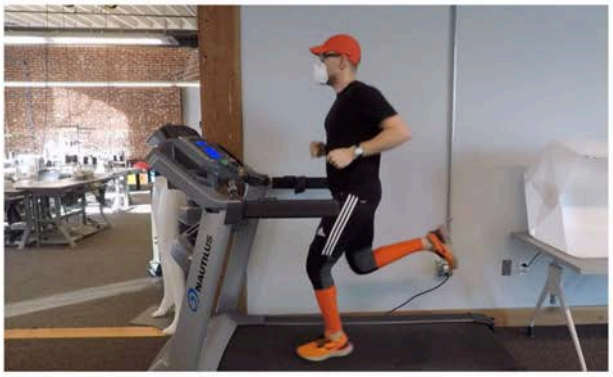
The goal for the making of this air filtration mask is to keep constructions as simple as possible in order to minimize costs as well as the carbon footprint. This is particularly relevant for the filtration media itself which will need to be disposed of regularly once it has been loaded with particulates. For that reason, one of the environmental benchmarks will be finding or helping to develop a bio-degradable filtration media which can be safely thrown away at its end life. According to a researcher from HKRITA that I spoke to while in Hong Kong, this should be made possible by using bio-based PLA plastics. There is also a research paper that describes a new process of spinning silk to create a nano fibre which has already proven to be effective at filtering air while simultaneously reducing resistance, which is also bio-degradable. [27]

AESTHETIC

As mentioned previously, the mask will be completely useless if no one wants to wear it. For this reason it must touch on all of the performance features previously mentioned while also being visually appealing. Athletes should look and feel fast while wearing it, and most importantly not be embarrassed to go out in public. Although this is a barrier which is much easier to overcome in Asia, in North America and Europe it is still a major challenge.

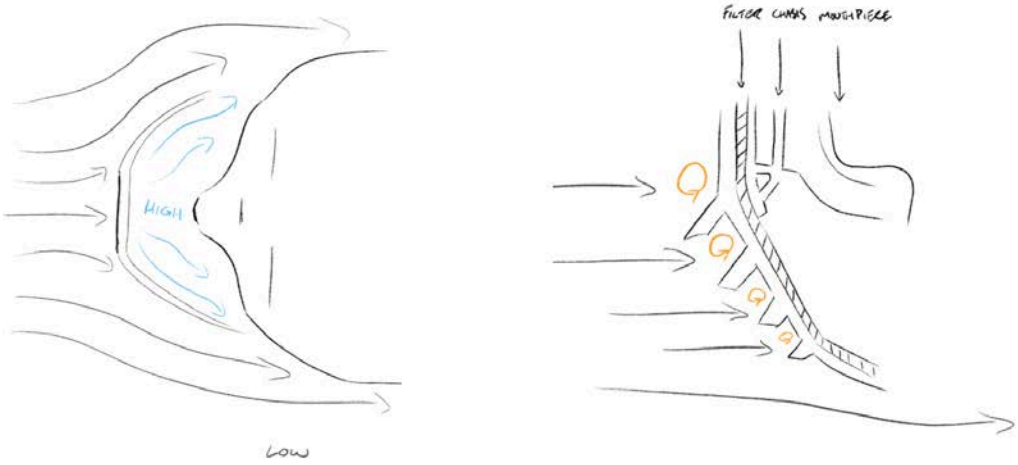
IDEATION

My process for ideation began with sketching masks, starting with an exploration of how I could avoid the mask wrapping around the ears. Using inspiration such as biking and paintball masks, I eventually ended with a concept where the mask would be attached by having the user biting on a mouthpiece which was connected to a chassis that held the filter and a shield in place. Using this as a starting point I created my first prototype by gluing a snorkelling mouthpiece into a standard 3M respirator as seen below. Even though I could not breath in through the mouth and could only breath in through the nose, I found this prototype to be quite successful. It felt more comfortable to me then having the mask attached using straps, and when I took it for a run on a treadmill I did not experience any issues at 10 km/h. This test did however bring to light a potential problem which I had anticipated, which was the tendency for the mouth piece to make the user drool even though the mind adapts with reoccurring use to understand that it is not food, slowly decreasing the amount of saliva generated.

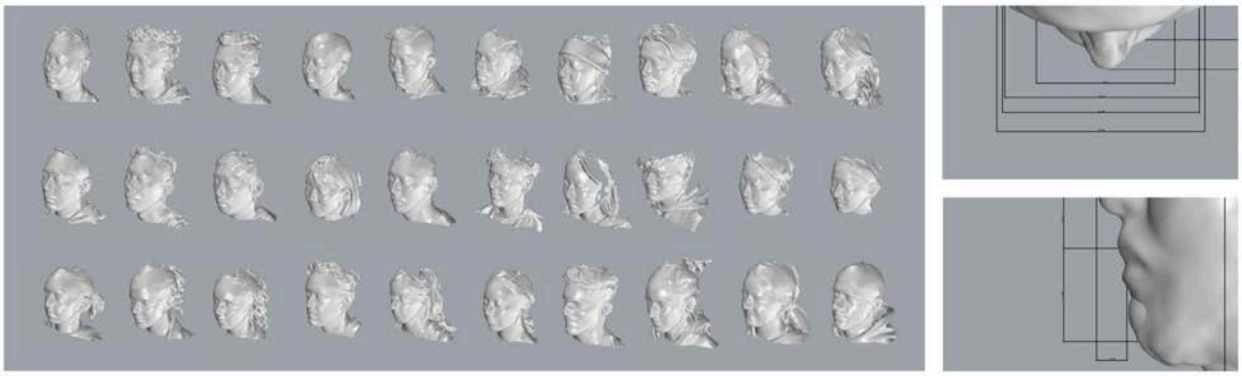


Following this prototype I began to iterate the mask concept using more sketching. My focus was now on determining the construction logic of the mask and its materiality. In addition, having learned about new concepts and extended my research to explore air vortices, air pressure, and various aerodynamics structures used on cars and planes, I began to imagine a mask with two unique features: 1] an invisible pressure seal which is created when the athlete is moving due to the positive pressure zone created inside

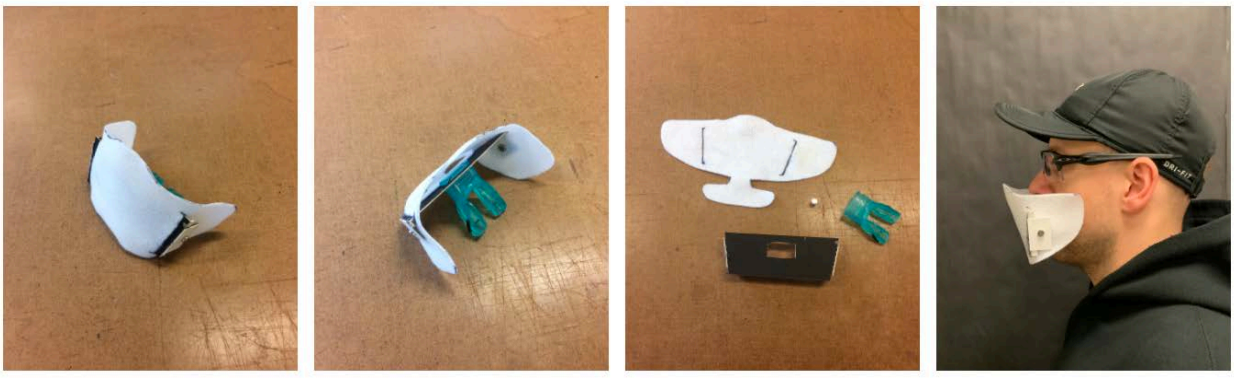
the mask, as seen in the left hand sketch below and 2] small structures which generate vortices in order to boost the rate of airflow into the mask at a rate that is proportional to the velocity of the runner, as demonstrated in the right hand sketch below.



Around the same time, having come back from my research trip to Asia with 30 scans split between gender and ethnicities, I began to take measurements which could be applied to future prototypes. The result was a spreadsheet which allowed me to compare certain dimensions across Korean, Chinese, Japanese and American faces for both men and women. My focus when taking these measurements was on the width of the face, as well as the distance from those same points to the mouth, nose and chin. Although it was a relatively small sample size, the scans have provided me with an effective starting point for mask dimensions.

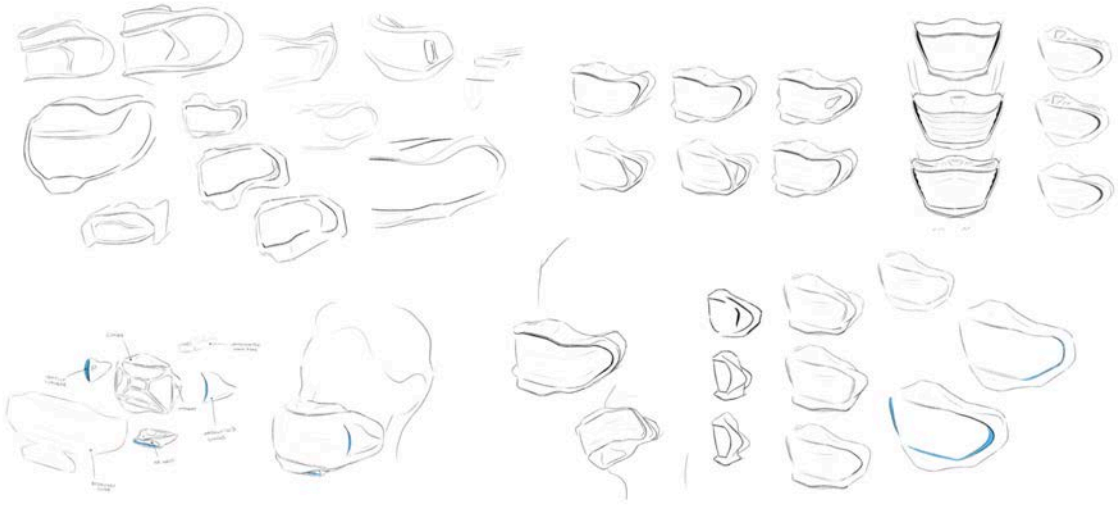


Following the analysis of the 3D scans I then began to create paper models of the mask filter in order to explore form, function, and scale. I feel that this medium turned out to be quite effective as it allowed me to work out some small details and verify my measurements by placing the models around various classmates faces. This in turn would also inform my drawings which I was expecting to turn into a CAD model. After more iterations and some abstract drawing exercises designed to explore potential lines, my next step was to make a second prototype using some thick, rigid paper, a felt to simulate the materiality of a filter, a snorkelling mouthpiece and 4 magnets.

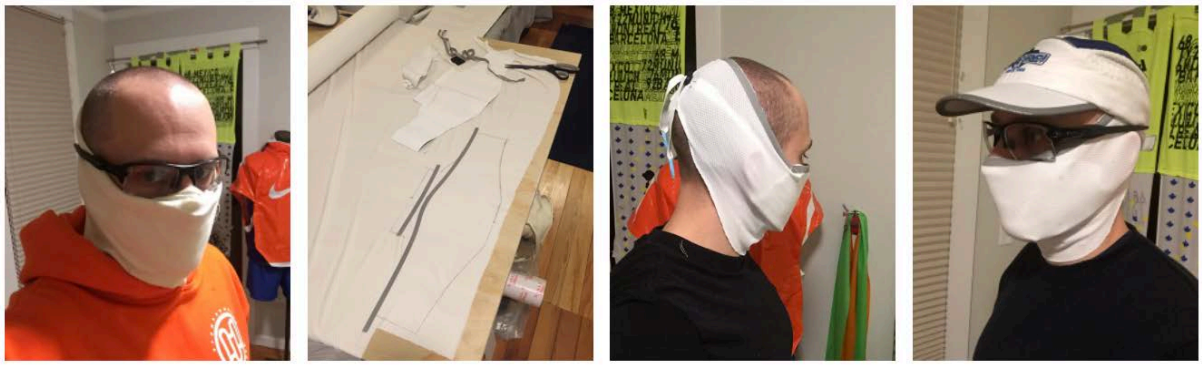


Once again this method proved to be quite effective as it allowed me to not only better visualize the scale and form, but it also allowed me to dawn the mask in a sense and experience things like the field of view I would have. More importantly however, this

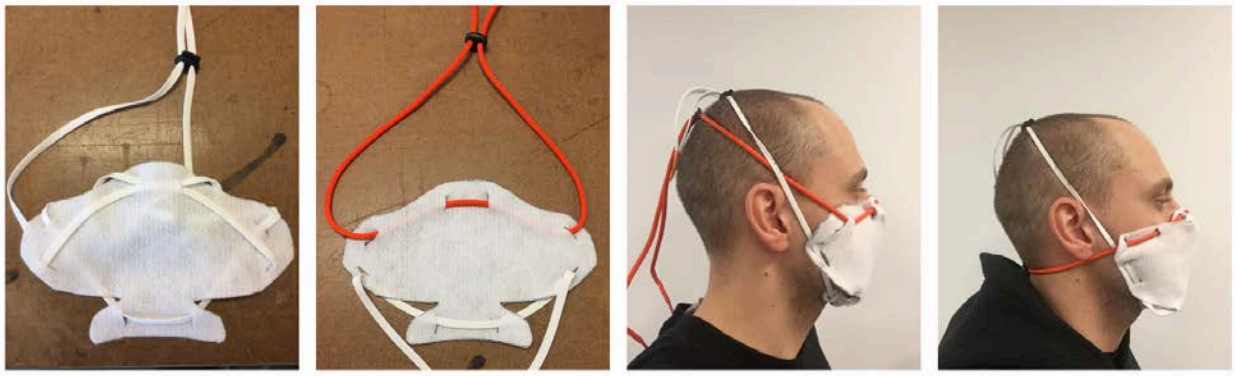
prototype inspired me to rethink how the final mask could function and be assembled. In addition to goals of making the mask lightweight and low profile, I also wanted to make it as accessible and affordable as possible. Having a simple design which could be easily assembled, disassembled, stored away or shipped was very appealing and would not be possible with larger 3D printed or injection molded masks.



I continued with iteration headed towards the concept seen in the drawings above, however there would turn out to be a third prototype in a completely new direction. Inspired by feedback I was receiving from various sources, I decided to try a style of mask that would wrap around the head, much like a bandana or scarf, with a built in filter. Using the felt pattern I had already developed, I made a quick first sample using scraps of fabric and quickly followed it up with a more precise version as seen below.



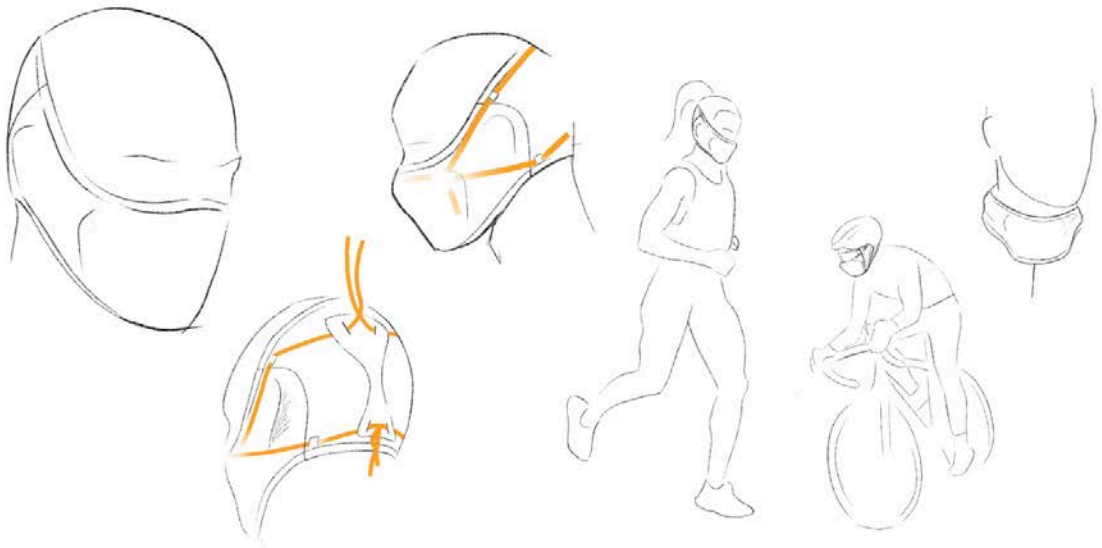
My next step was to determine how I could integrate a replaceable filter in a way that would be user friendly and create a reliable, stable fit. My first instinct was to connect the filter and the shell by weaving through an elastic or lace which would secure and adjust at the back of the head. After some initial tests which showed that this system should work, I began to rapidly iterate on the exact placement of the straps with a focus on how comfortable and secure it felt on the head. The next step was to integrate the filter which added the element of weaving it in a way that ensures a proper seal, while also considering its shape and dimensions for sizing purposes. Finally once I had those elements worked out I began working on how it would integrate into the mask, taking into consideration how intuitively the filter could be replaced, how consistent the experience was of dawning the mask and securing so that it looks and feels the same every time, as well as the overall form and closure mechanism at the back of the head.



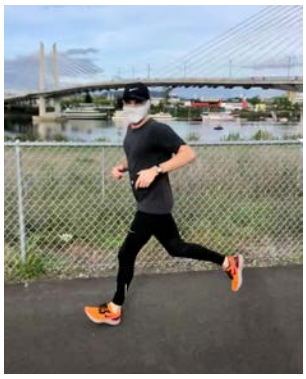
By removing the carbon filter used in many masks for gasses, selecting filtration media which loads faster but has lower air resistance, and combining that with strategic sizing and vacuum forming to increase surface area, it is possible to significantly increase the airflow rate the mask is capable of. In regards to moisture management, the fabric used on this prototype was developed by Polartec with a 3D plaited mesh that combines hydrophobic and hydrophilic fibres to create a unique, lightweight anti-cling knit. Using advanced textiles such as this will allow the mask to prevent moisture buildup and potentially even help create a cooling effect. Moving on to field of view, the advantage of this mask is quite obvious as it sits right against the skin and has a very low profile. Finally, while the filtration capabilities will need to be investigated further, the closest comparison that can be made might be a surgical mask due to how close it sits to the mouth. The major difference however is that surgical masks are intended to help prevent the spreading of contagion rather than filtering air. Therefore this level of protection would already be more effective for individuals using surgical masks while training.

In addition to these primary features, the design also has some unexpected secondary benefits that I realized once I started to wear it. For example, given rising global temperatures this design can also be used to protect users from the sun in hot weather, or with some material adjustments, used to protect them from the cold during winter months. It is also very easy to pack, can be worn with hats, helmets and glasses, and it may even prove to create a tighter seal then some masks currently do thanks to the lacing system which helps the filter securely conform to the users face.

The next step was to do more sketching to help me refine the overall aesthetic. The largest change would be how far back the front panel stretched, moving back past the ears in order to prevent heat build up. The change also have the mask more stretch and therefore flexibility in sizing.



Based on the drawings I continued to prototype, which eventually lead me to a proof of concept which I was able to take on over a dozen runs. I started with short runs of roughly 20 minutes and slowly increased them until I was running as much 50 minutes, with elevation in 29˚C [84˚F]. During and after these runs I would assess the mask's performance in a number of areas including how secure it felt on the head and where it was creating pressure points. Overall the experience was very comfortable from the very start, however making small changes along the way, such as softening the foam used and adjusting the lacing, helped improve it even more so.

Although the version seen above would be used for validation testing, it would go through one more major change which would prove to be the final direction. The change stemmed from feedback received during my midterm review which suggested I open up the back of the mask to allow for long hair to pass through more easily. The results was rather then using a mesh knit as the back panel, I enlarged the TPU hotmelt panel that I was originally using to create anchor point, and included added openings for hair. The unique construction of the panel also causes it roll at the top, allowing it to wrap the top of the head which not only prevents slippage, but also helps to let the user know if they are wearing the mask correctly.

To summarize the final design, here is a list of the features and benefits:

Universal Fit - Although there is a need to create sizes both smaller and larger to improve comfort and fit for certain individuals. Due to its high stretch soft shell, the Airbender is able to fit over a wide range of head shapes and sizes across all ethnicities and genders.

3D Mesh Shell - By using a combination of hydrophobic and hydrophilic fibres that are knit into a 3 dimensional structure, Airbender’s mesh shell plays an important roll in the overall comfort of the mask. This unique combination is designed to help manage moisture by wicking it off the skin, however unlike most performance fabrics which aim only to have it evaporate, by retaining some of the moisture this knit also aims to cool

the skin by preventing it from being completely dried out. Meanwhile, because of the structure which creates standoff, it also helps to prevent any fabric cling. The result of all of this is an extremely lightweight shell which is able to comfortably protect the athlete from both heat and cold.

Flex-Foam Seal - A key to the comfort of the mask is a medium density, soft open celled foam which is layered with the filtered, next to the skin. The foam performs several functions starting with creating volume to ensure a better seal. It also serves as padding to reduce pressure points caused the lacing, as well as to absorb and distribute moisture caused by perspiration.

Replaceable Filter - Adding to the functionality of the mask is a replaceable filter that is affixed to the interior using a lacing system, which first and foremost extends the lifespan of the mask by ensuring that it does not have to be thrown away once a filter is no longer effective. Depending on the filtration technology used in the final product, it will allows users to remove filters to be thrown away, or to be washed separately from the mask, dried, and then put back in. It could also add a dimension of modularity to the mask in the future by allowing users to insert various filters depending on their needs as it relates to air quality levels specific to the city and time of year.

Adjustable Straps - The lacing system that runs through the mask serves multiple purposes. It’s core function is to attach the filter and seal combination to the interior of the mask and keep them in place. In addition to this, once tightened it also helps secure the mask to the users head, promoting a better fit while also ensuring better stability. Another very important function that comes with tightening is that it forces the flex seal to conform to the facial features of the wearer to create a customized seal.

Gaiter Functionality - A small but convenient feature of the Airbender is the ability to dawn it as a gaiter around the neck after it has been placed over the head. This allows the mask to be taken off and put back on very quickly when resting or travelling due to the lack of it being needed to be taken off entirely.

Peripheral Cutout - Patterned and integrated as one unit, the shell, lacing system and filter work together to flow around the eye, helping to avoid obstructing the athlete's line of sight and maximize field of view.

Sewfree Construction - Extremely low profile, Airbender's construction minimizes the need for stitching or seam lines which may cause any abrasion on the face or head.

Reflective Detailing - Accents of reflective trim on the font and back of the mask improve visibility in low light conditions for added safety.

Customization - Another small but important feature of the mask is the easily customizable soft shell which adds an element of personalization and scarcity.

FILTRATION MEDIA

The exact filtration materials and technology to be used are still to be determined and based largely on the access and capacity of suppliers, which means there is a wide range of possibilities for what may be used in the final product. With that said, as my testing has shown, it is possible to find a balance between air flow and protection in order to optimize a filter for the oxygen uptake requirements of athletes.

In ideal circumstances, the filter would be able to trap particles up to .01 microns using nano fibre technology that is washable, as well as biodegradable at the end of its life span. To my knowledge, these technologies all currently exist on their own but have not been combined. By doing so, I believe you it would be possible to create a high

performing filter which minimizes the pressure drop experienced by athletes while also minimizing the environmental impact of manufacturing and disposing filters. As such, it will be my goal moving forward to help develop this technology for use in the Airbender

VALIDATION

CONTROLLED TESTING

In order to create a controlled environment that I could easily access to test prototypes and various masks, I built a wind tunnel with specific considerations for the scale of models and sensors I would need to place inside. I began by making a CAD model but soon after made a very rough prototype using cardboard in order to help me determine the most optimal construction. Once some wrinkles in the design had been ironed out, I proceeded to make an improved version using foam board as seen below.

The wind tunnel is important for multiple reasons. On the most fundamental level, it allows me to simulate an athlete in motion and to closely observe the effects directly surrounding a mask on a model head. More importantly though, it creates a controlled environment where I can adjust variables such as the wind speed or, to an extent, the volume of particulates. With lots of trial and error, I was ultimately able to configure the tunnel to perform two different controlled tests:

1] AIR FLOW

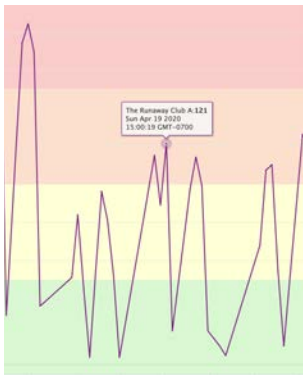
By placing a panel in the middle of the box with a cut out that forced all the air to move through a sample of material, the first test gave me a very simple measure of how much air resistance a textile or combination of layers, would create. This was a very important test for my design because as stated earlier, my most important solve was to ensure a high rate of air flow into the mask. By placing an anemometer up against the sample of fabric, I was able to test how well air was moving through a wide range materials. Although this test is not upheld by any industry standard, it did give me a reliable, repeatable method that I could at least use for my own records.

2] FILTRATION

The next test involved directing particulates at the masks while they were in the wind tunnel worn by a mannequin head in order to test each mask's ability to protect the wearer. The particulates were generated by incense placed at the front which were drawn into the tunnel by a fan at the rear. The level of PM2.5 was measured by a sensor which I placed in the styrofoam mannequin head by carving out a hole where the mouth is just below the nose. The sensor, which connects to wifi, would then provide me with real time data.

Although this test did provide me with a controlled, stable environment where I could test masks relative to one another, there were also many more variables which could have effected the results that will need to be better understood and controlled in future testing. For example, the size of the mannequin heads was quite a bit smaller then the average human head, which is likely to have a major impact on the effectiveness of each seal. There was also the issue of the quality of construction of the wind tunnel itself, which was not completely air tight. The result is the possibility that particulates where reaching the sensor not directly by going through the filter or around the seal, but through small cracks in the testing section which could allow polluted air to reach the sensor. Ultimately it did offer a good starting point for testing, and all masks were tested in equal circumstances, however more work is needed to create a more controlled environment.



COMBINED RESULTS

Taking a look at the results of both tests, there was a clear reduction in Max PM 2.5 levels recorded with the masks on, however none of the masks were able to reduce levels by more then 50%. This may be a bigger reflection of potential issues with the testing equipment and setup that were mentioned previously, however there is also an added element of moving air which can be expected to reduce a masks efficiency. Along those lines there does seem to be a correlation between air speed & max PM 2.5

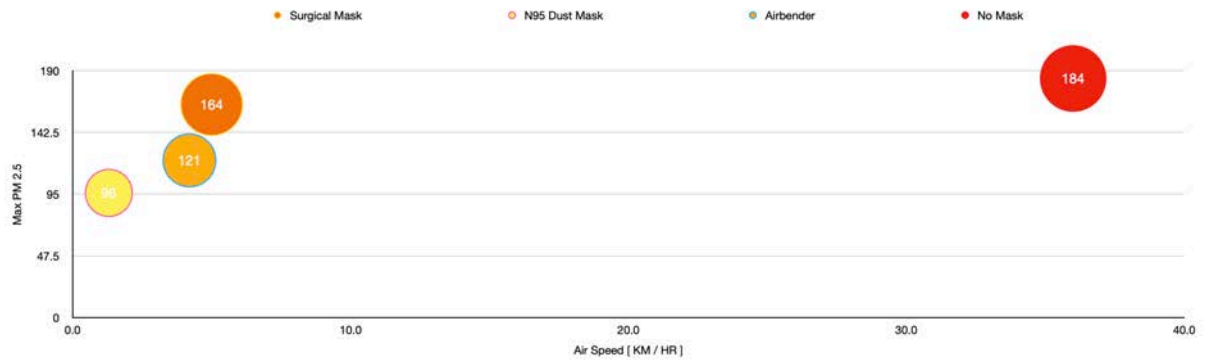
levels, which is logical because the faster air moves through a filter, the less resistance, and therefore the more likely some particles will get through. Exact results of both tests look as follows:

AIR SPEED [KM/HR]

NO MASK	..... 36.0
SURGICAL	..... 5.0
N95 DUST MASK	..... 1.3
AIRBENDER	..... 4.2

MAX PM 2.5

NO MASK	 184
SURGICAL	 160
N95 DUST MASK	 96
AIRBENDER	 121



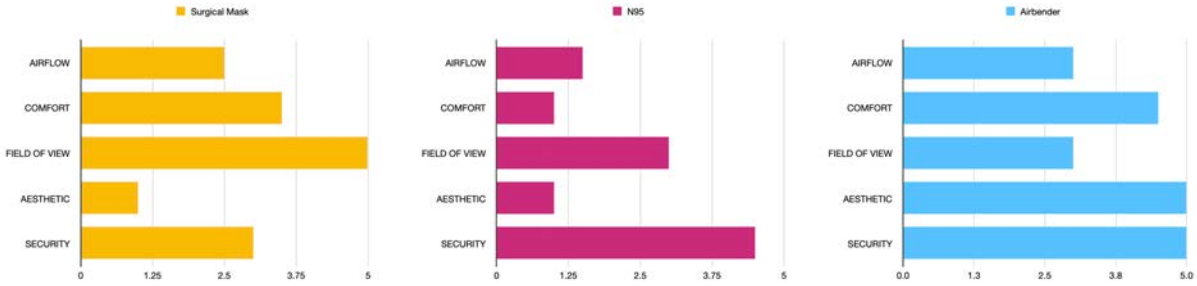
Breaking it down, the N95 did the best job of filtering, however the rate at which air passed through it hardly registered on the anemometer. On the other hand, the surgical mask recorded the highest air speed at 5.0 KM/HR, but did the worst job of protecting the mannequin.

Airbender on the other hand, using the optimized combination of materials mentioned earlier, registered an air speed just below the surgical mask at 4.2 KM/HR, however its maximum PM2.5 levels also measured 40 points lower.

SUBJECT TESTING

The next phase of testing involved having athletes physically try on and test the masks. Before the COVID outbreak, the testing plan was to have multiple subjects run on a treadmill at a controlled speed with a fan pointed at them blowing air that matched their running speed in order to simulate an outdoor environment. Instead I was restricted to one runner, and testing outdoors where I had much less control over certain variables like the runner's speed. With that said, given the limited number of test subjects and lack of a controlled environment, there was unfortunately too much variability in the heart rate, breathing rate and volume to extrapolate any definitive results using the biometric shirt.

The testing did however still allow me to conduct a survey to assess the perceptions associated with the mask. Using the same masks as those used in the controlled testing, I had my athlete run a one kilometre loop and then followed each lap by asking him to rate the masks on a scale of 1 to 5 to gauge: airflow, comfort, field of view, aesthetic and security. Based on his responses, Airbender ranked highest with a total score of 20.5/25, falling short in only the field of view category where the surgical mask was rated the highest. Where Airbender separated itself was in the categories of airflow, comfort, security, but especially aesthetic, where it scored a full 4 points over both of the other masks. Overall, the surgical mask came in second with 15/25 points and the N95 Dust Mask scored the lowest with 11/25.



Asked to comment further on the Airbender after our testing, my athlete Jon Haley said, “It feels comfortable and it doesn’t feel constraining, but you definitely feel a whole head presence versus, like a mask. So you have this whole sensory thing here which adds like a layer of security to it.”

As with all the other testing done so far, the survey was a good start, however a larger population size is going to be required in order to draw out more significant, reliable feedback that can help to drive the design forward.

MARKETING

NEXT STEPS

My immediate focus following graduation will be to contact the necessary suppliers to procure samples and place orders for materials so that I can begin to produce the Airbender in small batches. Once the masks are ready, the fastest and most direct sales channel will be a website which I plan to develop myself, allowing me to reach a global audience with a direct to consumer strategy.

PROMOTION

As far as the larger marketing and promotion strategy, companies like GoPro, or more recently paper mask company, Wintercroft, offer great case studies on the power of user generated content where the product essentially promotes itself when users post and share themselves using it across various social media channels. That content can then be reposted and shared, significantly reducing the cost producing marketing media, and helping to promote the product through word of mouth. In addition to developing a system for monitoring these interactions, another key strategy will be collaborating with various run crews around the world, but particularly those in East Asia, that have strong followings both in real life and online. By working with these crews to create custom designs that their members can wear, the goal is not only to generate exposure for the brand, but also to create unique mask designs which help distinguish the crews, become collectable, and also increase the chances of runners wanted to share their masks with followers.

PART 2

CORE STRENGTHS

I believe that my core strengths reside in my curiosity and the ability to draw on various interests for inspiration. Regardless of the field, whether it is music, biology, business, engineering or other, being open to learning new things and changing along with them has kept me growing as a designer and allows me to draw from a wide range of experiences. Another strength of mine which is closely tied to the other, is the ability to accept risk. By not being afraid to fail or being worried about what other may think, it allows me to try things which others might not be willing to. It allows me to push the boundaries of what is possible or expected.

INNOVATION

My strengths relate to innovation because in order to think outside the box and develop ground breaking ideas, it is critical to be able to see beyond your field and take calculated risks. In many ways this is exactly what the Medici Effect helps to explain, that the intersection of concepts from unrelated fields and the willingness to explore them is what is most likely to lead to exponential improvements.

CAREER

As someone who believes that everyone is born with the right to make a living doing what they love, I have always dreamed starting my own business so that I can control what I do and when I do it. I believe the Airbender respirator presents an opportunity for me attempt create a company with a very distinguishable product that aligns with my passions of running and sustainability, so it is something I plan to seriously pursue.

With that said, I also understand the risks and challenges involved with startups due to my background with entrepreneurship, so I am not naive enough to attempt it without a backup plan. The fallback goal of this capstone project is to have a project in my portfolio which demonstrates that I can work across categories, manage complex projects, as well as contribute to product innovation. In doing so, I hope to leverage my work on the Airbender to one day become a creative director for an established brand.

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AIRBENDER

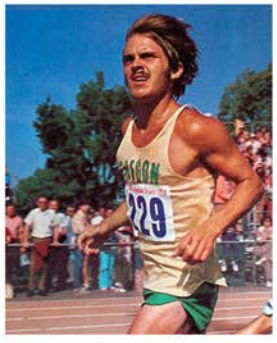
Capstone Project
by Oli Bartoszek

v 2.8

RUNNING HISTORY

1970's

1st Running Boom
Prefontaine & Bowerman



1980's

Femail Inclusion
Los Angeles Olympics

1990's

2nd Running Boom
Health and Wellness Trend

2000's

Global Running Boom
Growing Middle Class

INTRO

PARTICIPATION

GLOBAL INCREASES

300% Russia
259% China
161% Argentina
154% India

RACING IN CHINA

22 + Marathons in 2011
400 + Marathons in 2017
1500 + Road Events
450 + Trail Events

"Race organizers from Sanfo, the Chinese equivalent of REI, estimate that there were **20 million** people running recreationally in 2018"

- Runners World

POLLUTION

AIR QUALITY INDEX

000 - 050 Good
051 - 100 Moderate
101 - 150 Unhealthy
151 - 200 Dangerous
201 - 300 Hazardous

AVERAGE AQI

110..... Moscow
169..... Beijing
105..... Buenos Aires
169..... Delhi

"A lot of people will think, 'Oh, the AQI is only 100 so I can go for a jog. What many of people don't know is that jogging when the AQI is 100 is the same as walking when the AQI is 250."

- The Beijinger

PERSPECTIVE

CIGARETTE EQUIVELENT

LOCATION	PER DAY	LOCATION	PER DAY	LOCATION	PER DAY
United States	0.4	Beijing [Average]	4.0	Portland	0.2
Europe	1.6	Beijing [Bad Day]	25.0	Toronto	0.6
China	2.4	Shenyang [Worst Recorded]	63.0	Delhi	2.9

SH**T! I SMOKE

A mobile app inpsired by Berkley Earth's findings about the equivalence between air pollution and cigarette smoking. Once cigaraette per day is roughly equal to a PM2.5 level of 22 μg/m³.

ATHLETE PROBLEM

AIR POLLUTION

Endurance athletes training in major urban centers without protection are increasing their inhalation rate of already dangerous levels of pollution by ~3x, raising their probability of experiencing future strokes, brain cancer, miscarriages, and mental health issues.

Beijing, Marathon (2014)

Delhi, Half Marathon (2017)

ATHLETE INSIGHTS

PROFILE

NAME: Pengchao Zhao
JOB: Personal Trainer
CITY: Beijing

INTERVIEW

As a former collegiate sprinter that now runs or bikes daily, Pengchao informed me that he wears a surgical or 3M dust mask the majority of the time when exercising outdoors, and even requires one indoors when air quality is very poor. He also says pollution is worst in the winter, most likely due to everyone's heating being turned up.

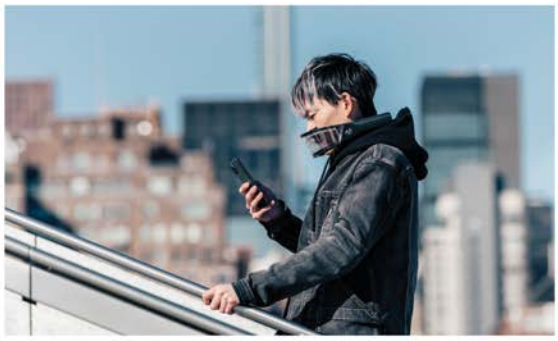
KEY TAKEAWAYS

- biggest complaint is poor air flow
- experiences a lot of moisture build up
- finds the straps very uncomfortable
- wished the straps could be adjusted

PROTECTION

LANDSCAPE

Although there is an increasing number of masks with varying features that help to distinguish them in regards to filtration and aesthetics, there are currently none that are specifically targeting athletes and the performance they require.



OPPORTUNITY

RESEARCH

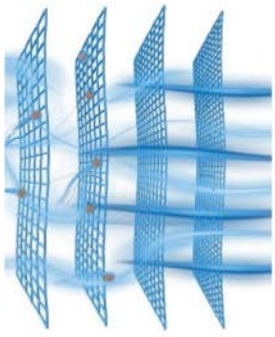
REQUIREMENTS

FILTRATION

// protects against PM 2.5
// replacable filter
  • easy to assemble
// prevents air leakage

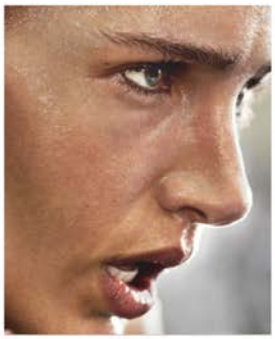
AIR FLOW

// enables VO_2max
  • max filter surface area
  • efficient exhaust



COMFORT

// prevents skin abrasion
// prevents over heating
// dissipates sweat



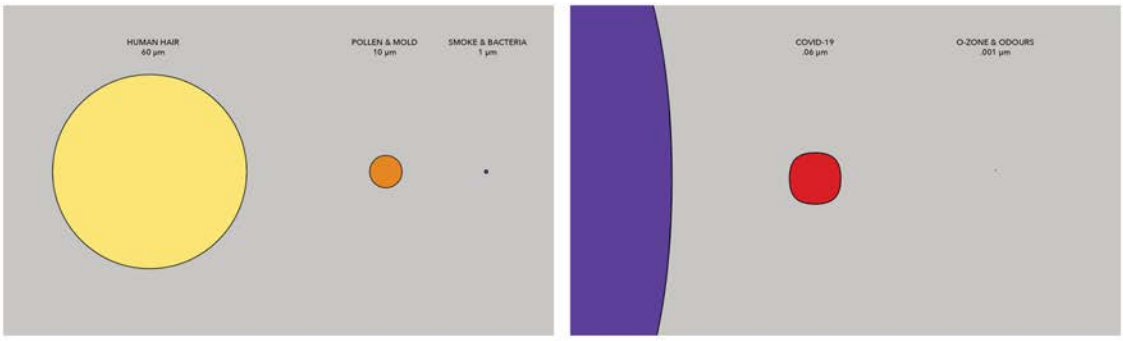
PERCEPTION

// creates confidence
  • looks & feels fast
  • contemporary aesthetic

PARTICULATES

SCALE

Particle matter is often divided into two main groups, coarse fraction ranging from 2.5 to 10 µm [ie. pollen & mold], and fine fraction with a size up to 2.5 µm [ie. smoke & viruses]. The particles in the fine fraction which are smaller than 0.1 µm are called ultrafine particles [ie. o-zone & odours].



FILTRATION MEDIA

MECHANICAL

Meltblown, or mechanical filters, typically remove particles up to 0.3 microns and can be used as the exterior most layer to filter larger particles to decrease loading time.

ACTIVATED CARBON

If required, activated carbon filters can be sandwiched between mechanical and electrostatic media to remove orders and harmful gasses such as O-zone.

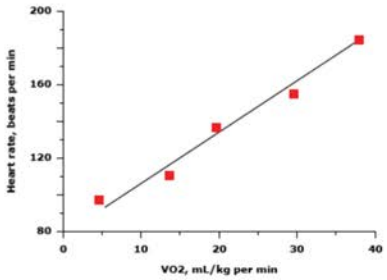
ELECTROSTATIC

Rely on electrostatic forces to remove particles from the air. Very effective but degrade over time. Typically remove particles up to 0.01 microns.

OXYGEN UPTAKE

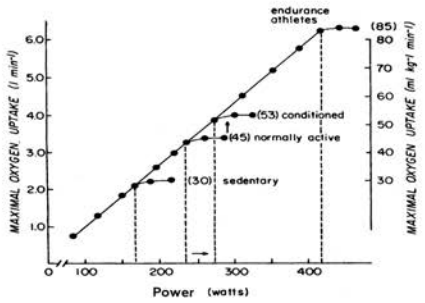
BEATS PER MINUTE

Oxygen consumption is relative due to fitness levels and genetic traits, however heart rate and oxygen uptake is linear up until a point of critical intensity.



AIRFLOW RATES

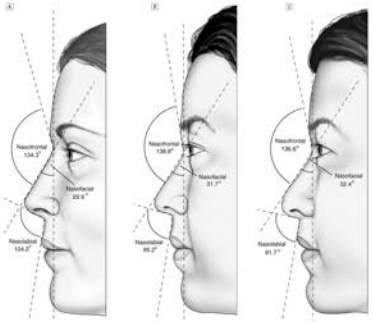
Based on an elite endirance athlete's requirement of approximately 6L of oxygen per minute, this allows us to set an initial target flow rate.

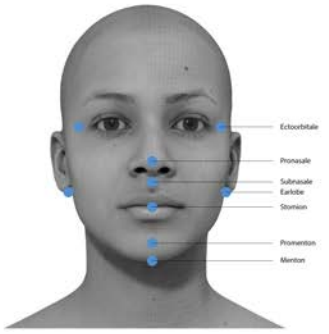


ANATOMICS

ETHNOGRAPHIC VARIANCE

Investigated the differences and similarities between various ethnicities to determine how it may impact the design of my mask. Noted landmarks on the face that I could use to conduct measurements and translate into product dimensions.





TRAVEL

SEOUL • CULTURE
[JAN 28 - FEB 1]

+ CVS Running Club
+ Private Road Runners Club
+ Good Runner Co.

HONG KONG • TECHNOLOGY
[FEB 1 - FEB 5]

+ Harbour Runners
+ HKRITA
+ The Mills

TOKYO • PRODUCT
[FEB 6 - FEB 9]

+ R&B Run Crew
+ Shibuya
+ Harajuku

EXHAUST VALVES

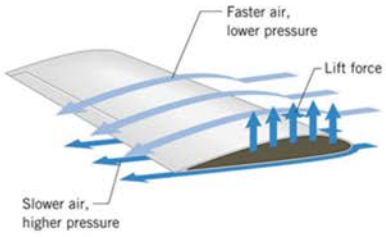
MOUTH PIECES

Looking at one study which measured the effect mouthguards had on an athletes cardio vascular system, and another which measured there performance with a series of physical tests, it was found that there was little to no impact. In once case the average high of a vertical jump increased with a mouthguard in.

PRESSURE ZONES

BERNOULLI'S PRINCIPLE

Air will always flow from a high pressure area to a low pressure area. By creating a high pressure zone around the mouth you could eliminate unfiltered air from being breathed in, and therefore remove the need for a seal.



VORTICES

BASKING SHARK

"Swimming with its mouth wide open, this fish catches plankton on the side of its gills. Water eddies around the gills, pushing the plankton back into the main flow, which sends suspended food toward its digestive system. The eddies create a self-cleaning effect like backwashing that turns this 'sluggish, inoffensive fish' into inspiration."

FUNCTION & FORM

BUGATTI DIVO

According to Bugatti, 60,000 litres of oxygen is sent through the engine per minute of operation at top speed. In addition to seperate intakes for 2 radiators, primary + secondary brake cooling, a front differential, and the engine, it must be aerodynamically stable at speeds over 375 kpm [233mph].

DESIGN

PRODUCT BRIEF

OBJECTIVE

Design an affordable, reusable mask with replacable filters that protects endurance athletes from PM 2.5. Its airflow rate should allow them to reach their VO_2max, while the attachment point, seal, and exhaust must prevent abrasion, overheating or moisture buildup. It must also remain effective across gender and ethnicity, as well as evoke a feeling of confidence and speed through its aesthetic.

ENVIRONMENT

- sub-elite & amateur training
- major urban centers
- wide ranging climates

RETAIL

NAME: AIRBENDER
LAUNCH: FALL 2021

FOB: $20.00 USD
MSRP: $80.00 USD

DESIGN DIRECTION

KEY SOLVES

1] AIRFLOW
2] MOISTURE MANAGEMENT
3] WEIGHT REDUCTION
4] FIELD OF VIEW
5] FILTRATION

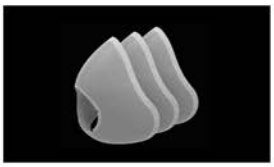
Maximize surface area of filtration media.
Efficiently exhaust CO_2 and vapour.
Minimize volume of material used.
Considered lines for low profile.
Limit exposure to PM 2.5.

MANUFACTURING

- Vacuum Formed Filter
- Biodegradable Materials

AESTHETIC

- Organic Lines
- Fast & Fresh
- Simplicity
- Personality



PROTOTYPING PLAN

METHODS

- Prototyping by Hand
- 3D Scanning
- CAD Modeling

MEDIUMS

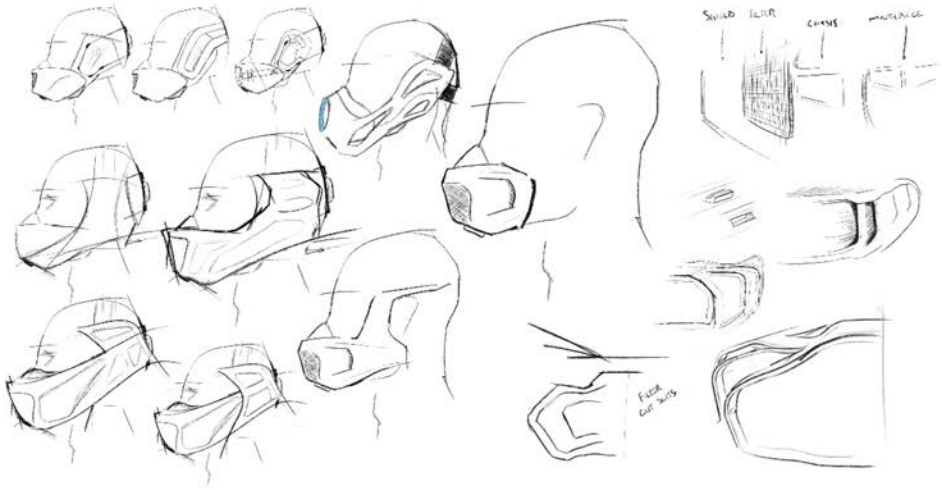
- Sketching
- Paper Models
- Clay Models
- 3D Printing

DELIVERABLES

- Data analysis of 30+ scans to determine mask sizing.

x 1 Miniature wind tunnel for mask testing.
x 3 Mask shield designs to be tested in wind tunnel and on subjets.

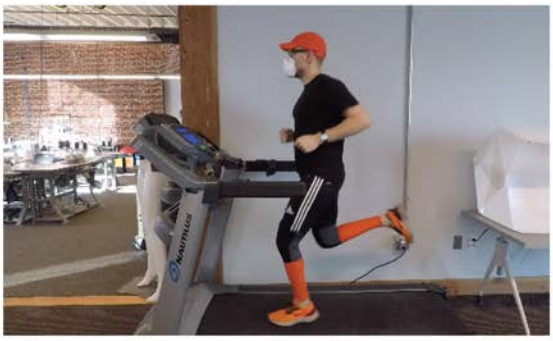
IDEATION



PROTOTYPE v1

BASELINE PERFORMANCE

As my initial proof of concept to determine design feasability, I glued a snorkling mouth piece into a standard 3M dust mask. Aside from a build up of saliva, I was able to jog comfortably at over 10km/hr.



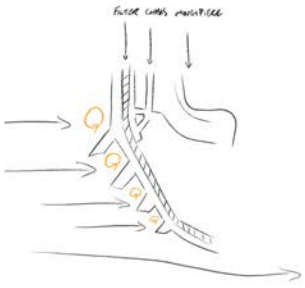
EVOLUTION

PRESSURE SEAL

Using Bernoulli's Principle, I developed the concept of using a runner's motion to create an invisible pressure seal. In short, when the athlete is in motion the resistance created by the filter creates a pocket of high pressure in the mask to keep out contaminated air.

VORTICE GENERATION

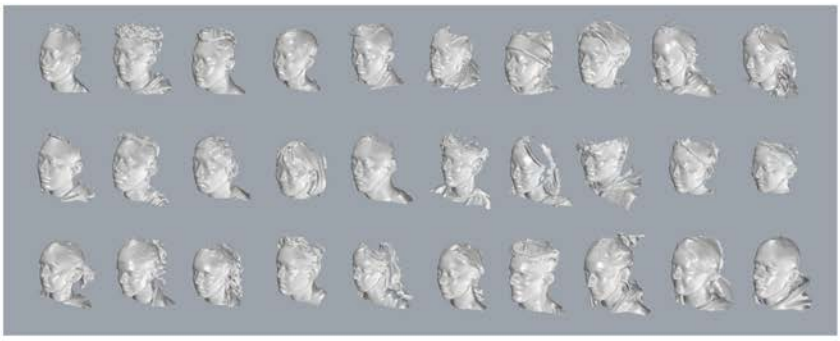
Prompted by an advisor and drawing from research done on the cross-vorticle filtration of Basking Sharks, I also imagined the possibility of using the mask's form to create vortices which increase the rate of air flow into the mask in proportion to the athlete's velocity.

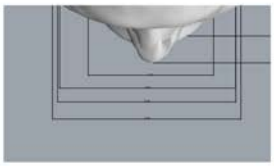


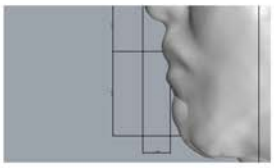
3D SCANNING

MASK SIZING

Using a portable scanner attached to an iPad, I scanned a total of 30 subjects: 10 Korean, 5 Japanese, 5 Chinese and 10 American split across males and females. Using the landmarks previously discussed, I analyzed these models to created an average for product sizing.



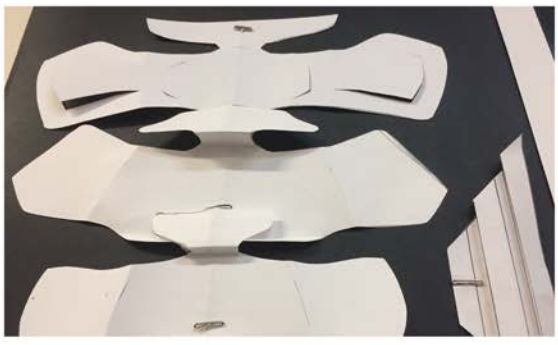




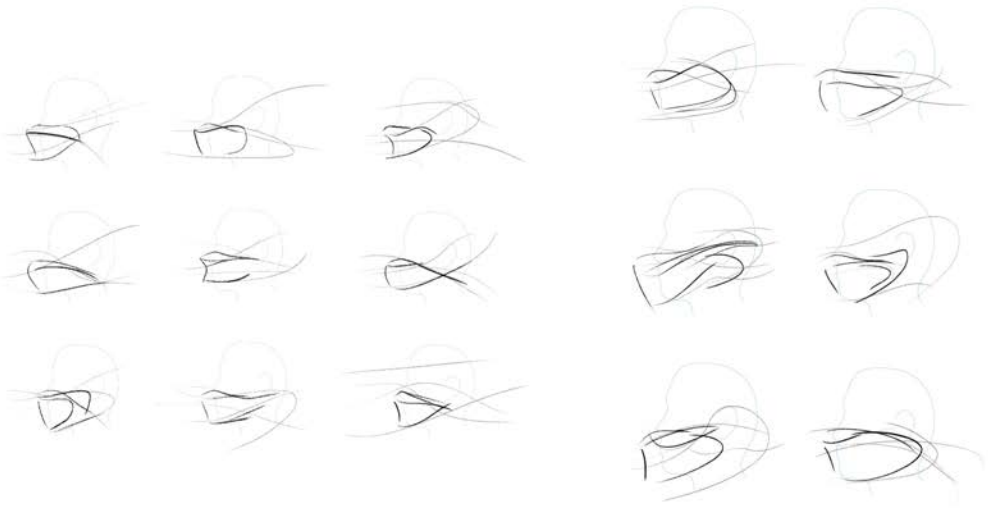
PAPER MODELS

POSSIBILITIES vs LIMITATIONS

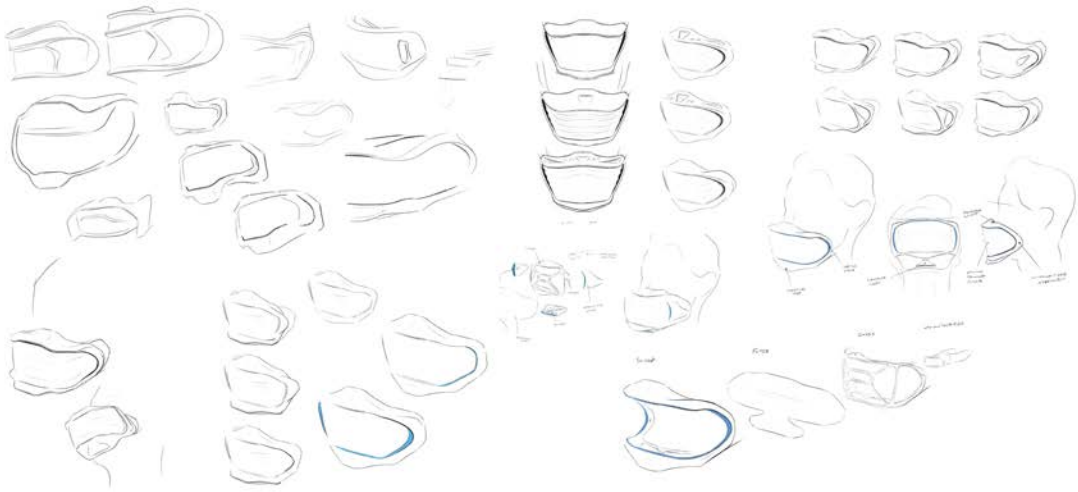
Working with paper models to explore the possibilities and limitations of form. This technique also allows me to use the anthropometric data I have collected to start modeling physically in true scale.



LINE EXPLORATION



ITERATION



PROTOTYPE v2

MASK ASSEMBLY

Using the measurments collected from my face scans, I made a mask to scale which can be easily assembled and taken apart to allow for simplified packaging and improved durability. This development had a major influence on my design moving forward.




VALIDATION

WIND TUNNEL v1

FLOW & FILTRATION

Started by prototyping and assembling a wind tunnel which will allow me to measure the effectiveness of my design theories by using sensors that measure air pressure and concentrations of PM2.5.



WIND TUNNEL v2

UPGRADES

Extended the tunnel for smoother transitions and added fins to reduce turbulance, creating laminar flow which is essential to take more precise measurments.

SECTIONS

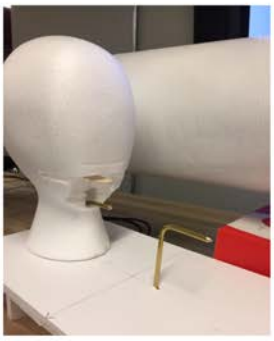
Divided into 3 sections measuring roughly 11 ft when combined, the win tunnel can be easily disassebled for transportation or rearrangement.

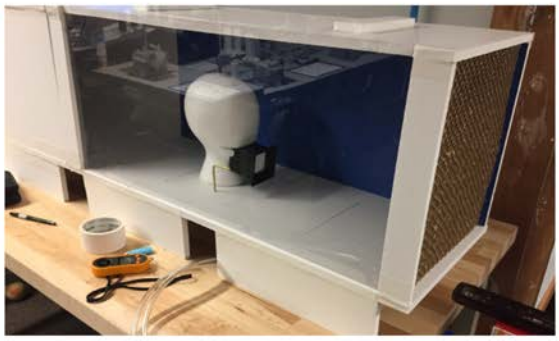


TEST SECTION

CONTROL ENVIRONMENT

Using a combination of instruments inluding pressure gauges, particulate counters, an anemometer and an ambu bag, the test section gives me a controlled environment where I can simulate a moving, breathing runner in order to determine the masks effectiveness.





SUBJECT TESTING

PERFORMANCE & PERCEPTION

In addition to a qualitative survey, I will use a sample size of roughly 10 participants and outfit them with a biometric shirt to analyze the impact on cardiovascular performance on a treadmill by monitoring their heart rates and tidal volumes.

DATA COLLECTION

PURPLE AIR

Measures the concentration of PM2.5 which canl be generated by lighting incents or cigarettes.

MANOMETER KIT

Can be placed inside and outside the mask to measure the pressure differential which allows comparison of air flow.

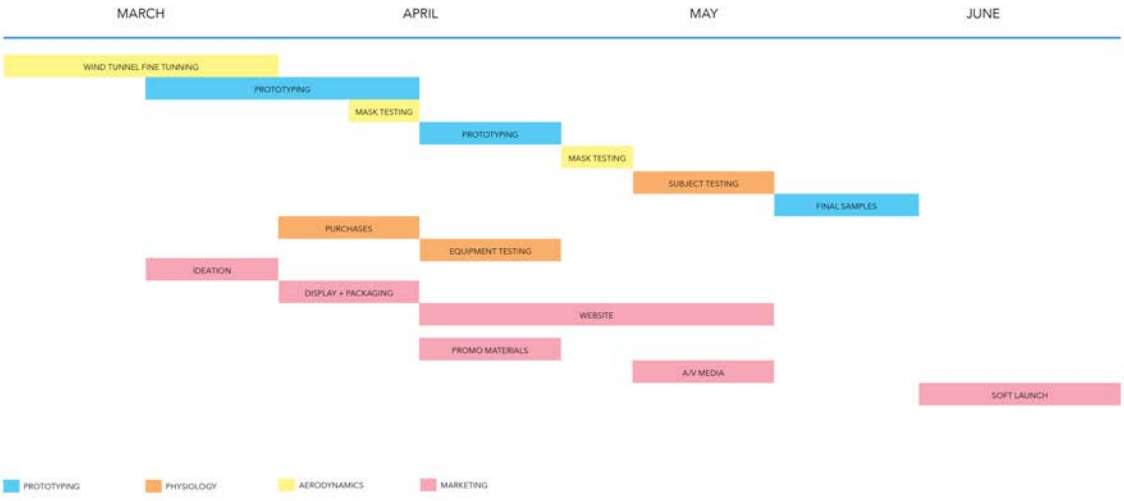
HEXOSKIN

A wide range of sensors which will allow the comparison of tidal volume, heart rate and blood oxygen levels across masks.

SURVEYS

Using an iPad to collect qualitative data from users about their use of masks and the perception of it while running.

CALENDAR



TO BE CONTINUED..

AIRBENDER

INSPIRED | PERFORMANCE | SECURITY

by Oli Bartoszek


AIR QUALITY EQUIVELENT [AVG/DAY]
UNITED STATES
x 0.2
EUROPE
x 1.6
CHINA
x 2.4
BEIJING
x 4.0


RUNNING PARTICIPATION

ATHLETE INSIGHTS

PROFILE

NAME: Pengchao Zhao
JOB: Personal Trainer
CITY: Beijing

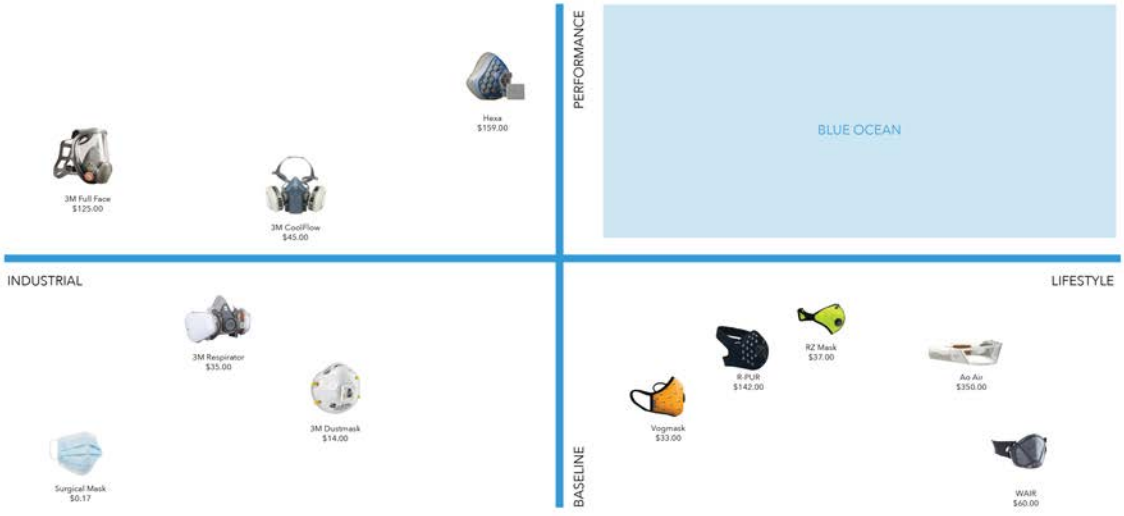
INTERVIEW

As a former collegiate sprinter that now runs or bikes daily, Pengchao informed me that he wears a surgical or 3M dust mask the majority of the time when exercising outdoors, and even requires one indoors when air quality is very poor. He also says pollution is worst in the winter, most likely due to everyone's heating being turned up.

KEY TAKEAWAYS

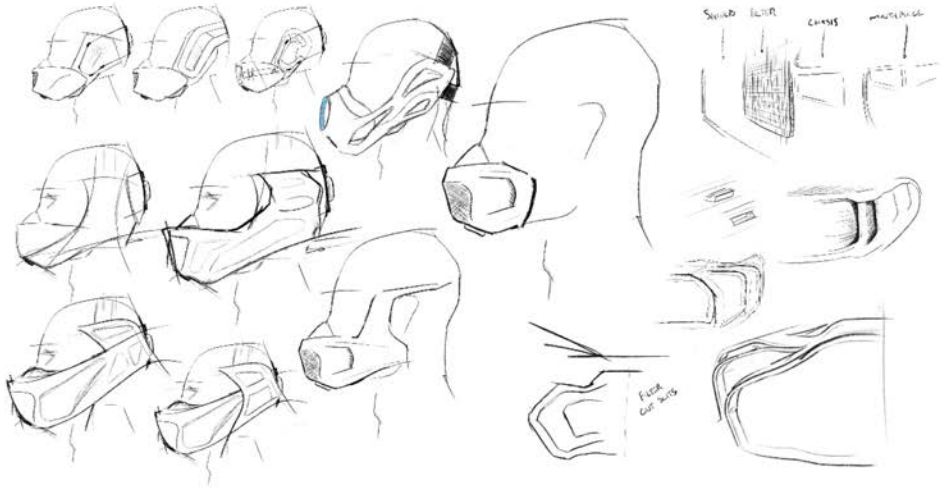
- biggest complaint is poor air flow
- experiences a lot of moisture build up
- finds the straps very uncomfortable
- wished the straps could be adjusted

OPPORTUNITY




ATHLETE PROBLEM
Current air filtration masks do not solve for athlete needs as it relates to airflow, moisture management, weight reduction, or aesthetic.

IDEATION




PROTOTYPING


TRAVEL & RESEARCH

INSPIRATION

PROTOTYPING

DESIGN PIVOT

New gaiter inspired direction resembling bandana or scarf with replaceable filter.

LACING IDEATION

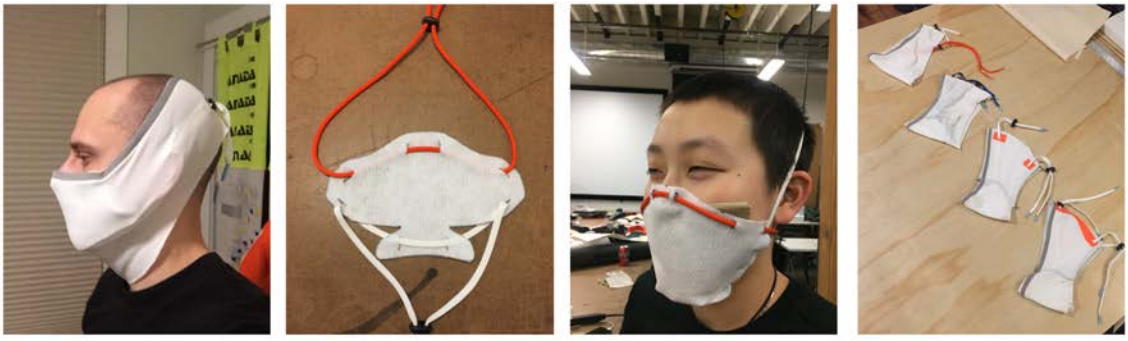
Explored configurations to keep the filter in place but allow it to be removed.

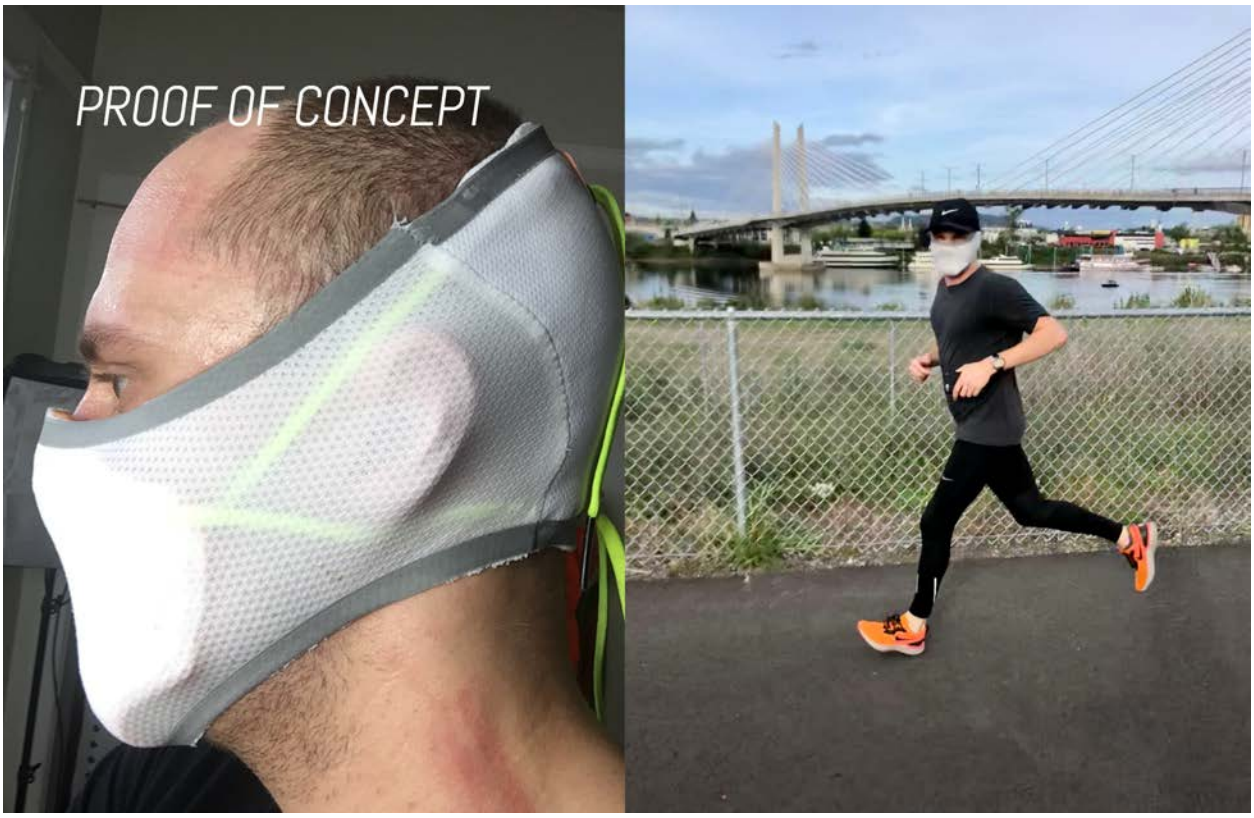
FIT TESTING

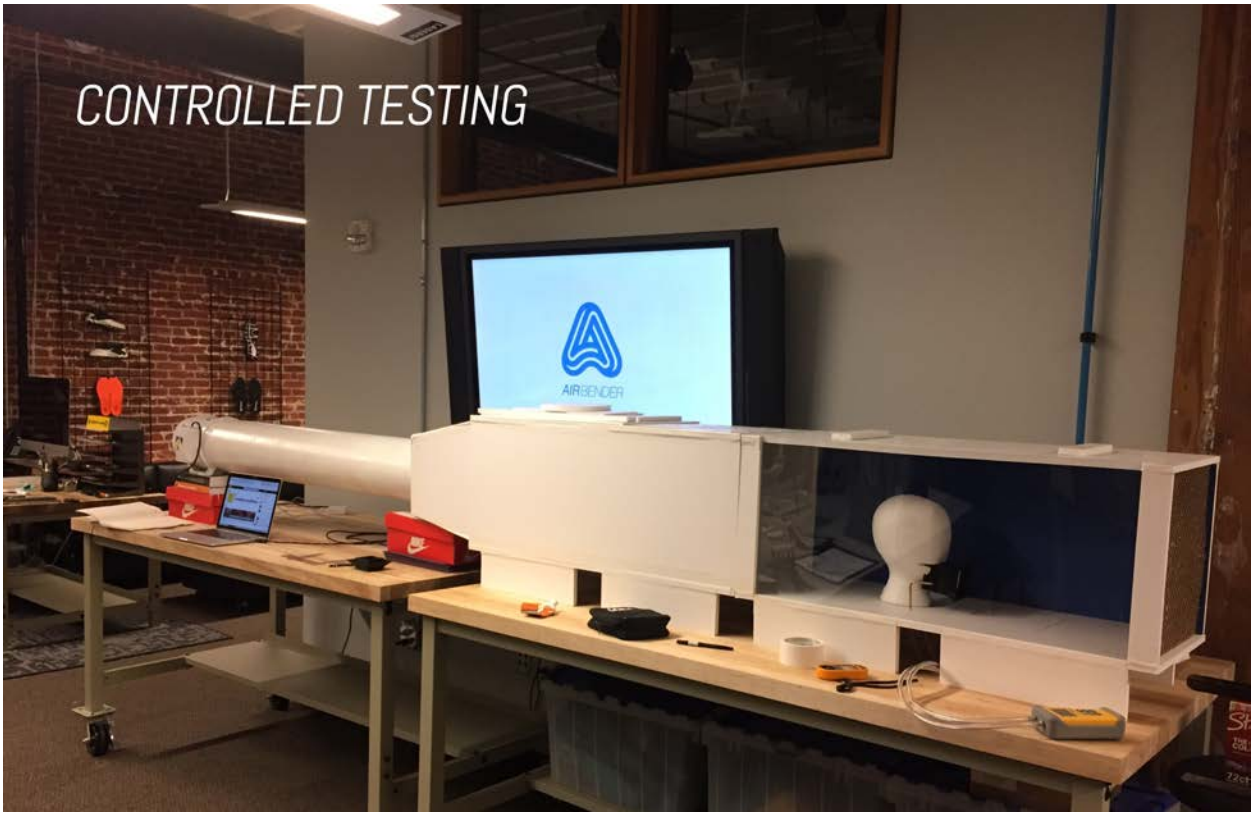
Tested variations of the straps, shape and weaving system to find an adaptive fit.

RAPID ITERATION

Continued work on fit & construction logic to ensure intuitive assembly and use.

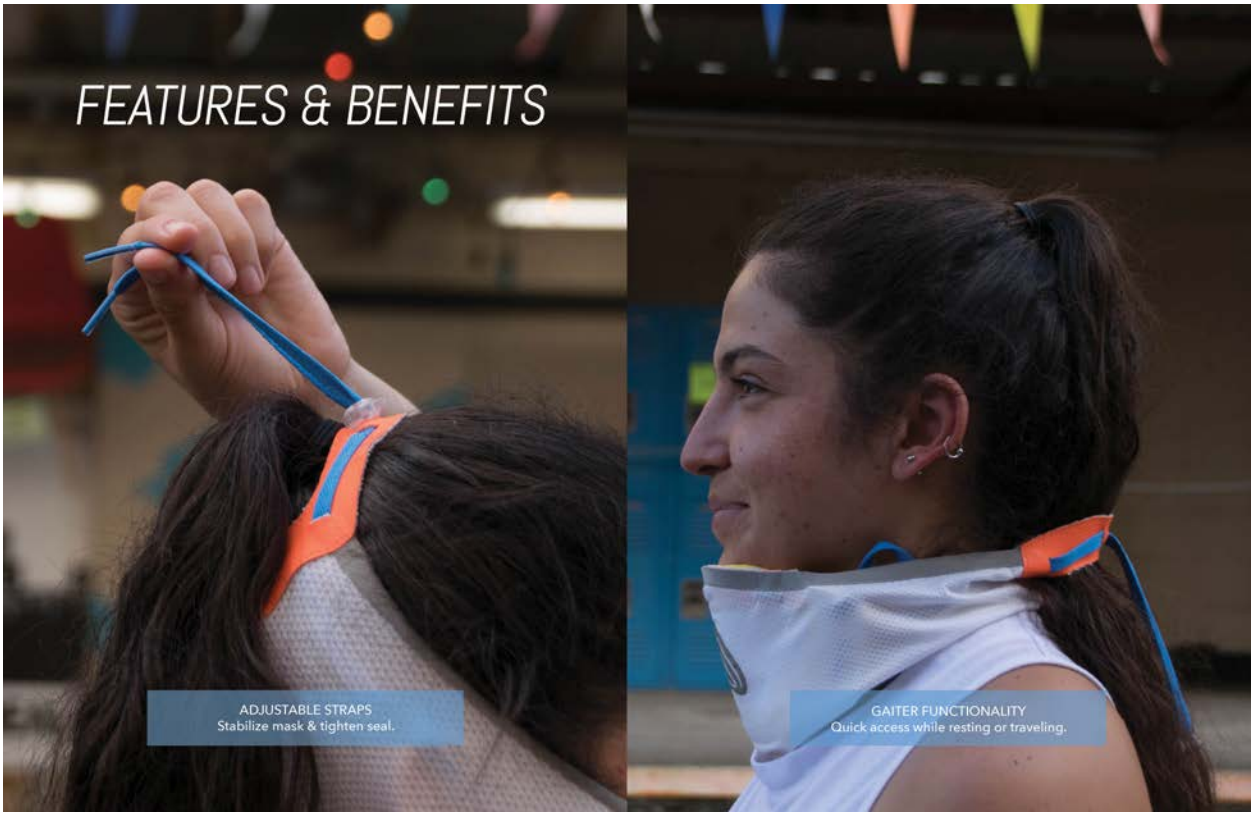



PROOF OF CONCEPT

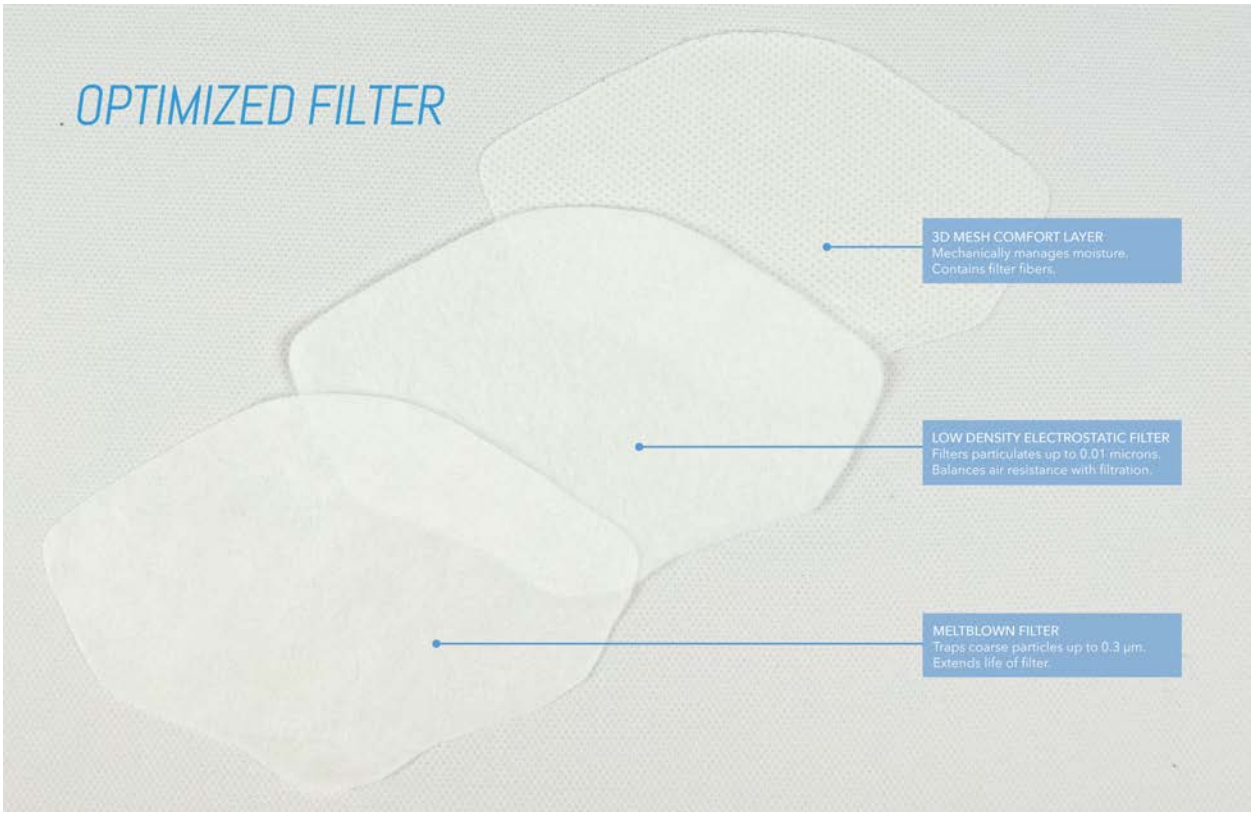

CONTROLLED TESTING
AIRBENDER

FLOW & FILTRATION


FEATURES & BENEFITS
SEWFREE TRIMS
Constructed to minimize abrasion.
PERIPHERAL CUT
Widens athlete's field of view.
REFLECTIVE DETAILING
Boosts visibility in low light.
UNIVERAL FIT
Accommodates all ethnicities & genders.
3D MESH SHELL
Manages moisture & shields face.
FLEX-FOAM SEAL
Conforms uniquely to facial features.
REPLACEABLE FILTER
Enables washable, reusable shell.

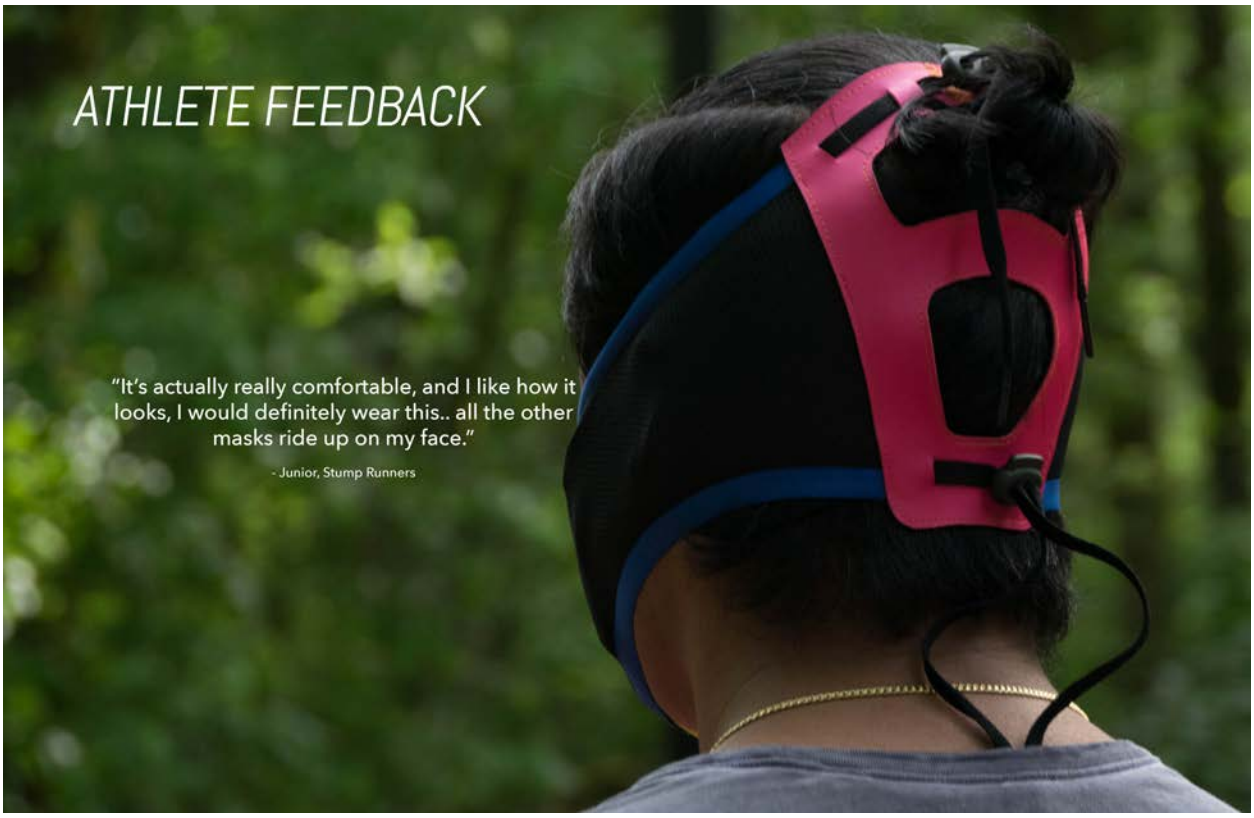

FEATURES & BENEFITS
ADJUSTABLE STRAPS
Stabilize mask & tighten seal.
GAITER FUNCTIONALITY
Quick access while resting or traveling.

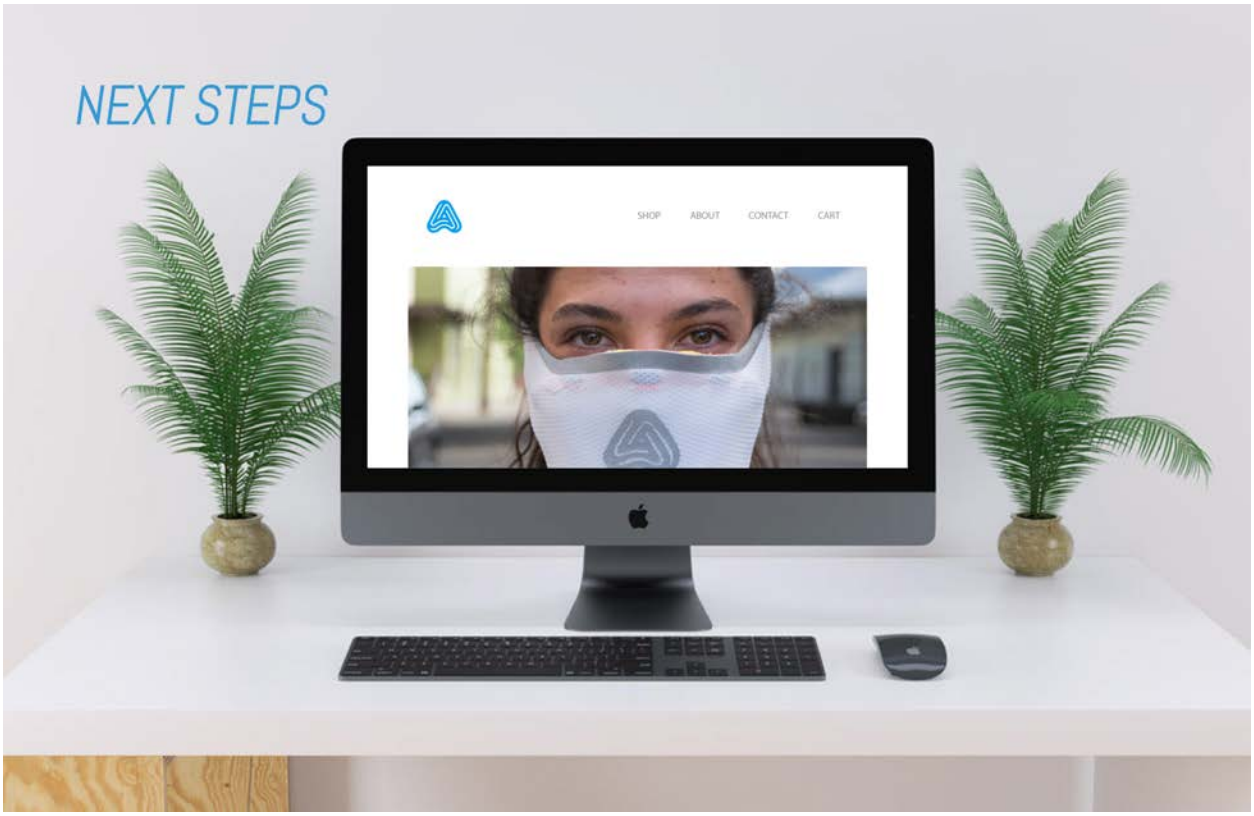

MECHANICS


OPTIMIZED FILTER
3D MESH COMFORT LAYER
Mechanically manages moisture.
Contains filter fibers.
LOW DENSITY ELECTROSTATIC FILTER
Filters particulates up to 0.01 microns.
Balances air resistance with filtration.
MELTBLOWN FILTER
Traps coarse particles up to 0.3 µm.
Extends life of filter.


CUSTOMIZATION


ATHLETE OUTCOMES
Combining comfort, security and aesthetic, Airbender increases the frequency of mask use to protect athletes and promote the power of sport when we need it most.


ATHLETE FEEDBACK
"It's actually really comfortable, and I like how it looks, I would definitely wear this.. all the other masks ride up on my face."
- Junior, Stump Runners


NEXT STEPS
SHOP
ABOUT
CONTACT
CART


WHAT'S NEEDED
3/8" PU FOAM
0.10G / cm3,15C
TPU HOTMELTS


THANK YOU.