

## **Abstract**

Shoe companies strive to invent technology that can better their models with regards to comfort, style, and support. While the arch support of current athletic shoe models could be greatly improved, companies are reluctant to address this issue due to the difficulty in accommodating various arch heights. In my senior IP project I designed an adjustable arch support that can be easily modified to fit anyone from a person with a low arch or a person with a high arch. Providing a person with the proper arch support will result in numerous health related benefits.

## **Introduction**

My IP project is a direct reaction to the millions of people who experience chronic foot and body pain resulting from diabetes, plantar fasciitis, fallen arches and body misalignment due to inadequate arch support. This pain is often mistakenly associated with physical activity and can deter people from being physically active. For most, this pain can be reduced and prevented through proper arch support.

During this two-term period I designed ArchFlux Technology, a built-in adjustable arch support system within athletic shoes. It can accommodate those with low to high arches without impeding the design aesthetic. The design is adjusted to fit a given activity or surface. The emphasis of my project pertains to the support structure of the shoe. Some concepts considered for arch adjustability are a strap system, interchangeable plates, and a bladder system in which air or fluid can be added or

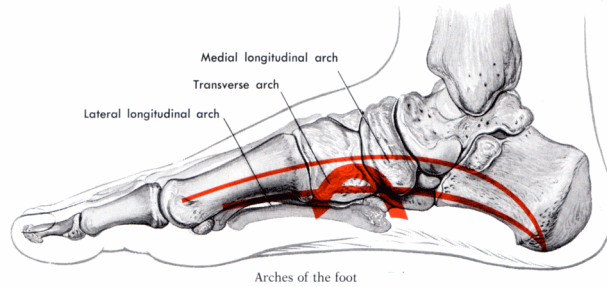
subtracted. I most intensely explored the bladder concept with the use of air due to potential ease and accessibility.

ArchFlux is targeted to both men and women who participate in any sort of physical exercise, from intense running to leisurely walking (women will receive greater benefits, as their foot and arch shapes are prone to biological changes). Arch support has rarely been explored in conjunction with shoes of any kind and has tremendous market potential in both athletic and medical fields, as both areas are multi-billion dollar a year industries.

The ultimate goal of this project is to help educate people about their feet and propose a cause of their discomfort. As a result, knowledge and my system will allow people to maintain physical activity without pain.

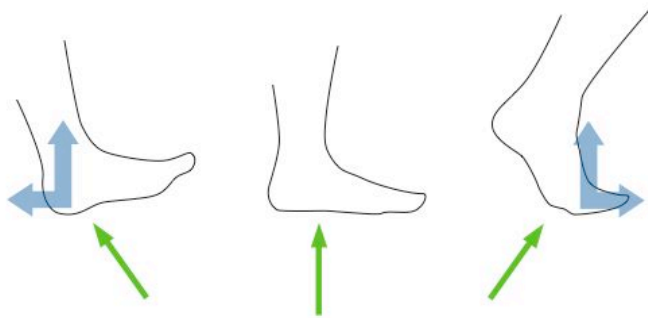
## **Research**

In order to effectively design for the foot, I had to become well versed in foot anatomy and function. The foot has two primary functions: weight bearing and propulsion. The arch plays a pivotal role in both of these functions. Multiple bones and joints give the foot flexibility, and in order to support maximum weight, an arch must be formed. The shapes of the bones and the ligaments in the foot maintain the arch. There are three arches of the foot: the medial longitudinal, the lateral longitudinal, and the transverse (shown in figure 1). The medial longitudinal arch is the highest and most important arch of the foot. The lateral longitudinal and the transverse arch are contained within the medial longitudinal arch. Arches are unique to each person, but can be classified as either medium, low, or high, based on the height of the arch.



*Figure 1 shows the arches of the foot*

After gaining knowledge about the anatomy of the foot, I focused on foot motion characteristics. One of the most important movements of the foot is that of the Gait Cycle (see figure 2). The Gait Cycle involves two movement periods: swing and stance. The swing is the movement of one leg while its foot is in the air. The stance is the movement of the leg and foot while the foot is in contact with the ground. There are three phases of the stance. The first phase is the impact, also known as the heel-strike, which occurs when the foot makes contact with the surface. At this moment, forces of two to three times the person's body weight is imparted on the body. The second phase is the support or mid-stance. During mid-stance the foot supports the body as the foot transitions from heel to toe. During this phase the arch will elongate as maximum pressure is placed on the arch. Proper arch support during this time will allow for proper running mechanics; inadequate support will yield improper running motion. The third and final phase is propulsion. During propulsion forces are distributed across the forefoot and the arch stiffens as the foot prepares to leave the ground (RunningWarehouse.com 2009).



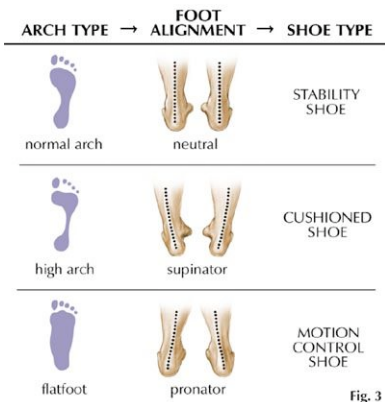
*Figure 2 shows the heel-strike, mid-stance, and propulsion of the Gait Cycle*

Throughout the research process, I interviewed Dr. Crystal Holmes, a podiatrist at the University of Michigan. Dr. Holmes expanded my understanding of the foot and foot problems. Most importantly, Dr. Holmes told me to not just look at the problems that are typically associated with inadequate arch support, but also to look at the absence of problems. Just because a person has a high or a low arch does not necessarily mean that they will have major foot pain or discomfort; contrastingly, just because a person has a medium arch does not mean they will be free of problems.

After interviewing Dr. Holmes, I met with Ammenath Peethambaran (an orthotist) and Jody LeCursi (a pedorthist) at the University of Michigan Orthotics and Prosthetics Department. Ammenath and Jody individually gave me guided tours of their facilities and described the process of designing custom orthotics. From these meetings I was able to get a detailed understanding of how foot scans are used to diagnose and treat foot problems, as well as what type of materials are used, given a patient's specific needs.

In addition to interviewing medical professionals, I thought that it would be important to get some insight from someone in the footwear industry. I interviewed Sarah Brewer, an employee of Tortoise and Hare, a local Ann Arbor running store, and

the president of the University of Michigan Running Club. Sarah explained to me that running shoes in particular were designed to promote proper running techniques through heel stabilization. Heel stabilization helps to promote proper running mechanics for those who over pronate (excessive inward rolling, typical of those with low arches), those who supinate (excessive outward rolling, typical of those with high arches), and those who already run neutrally or correctly (slight pronation, more common among those with medium arches). In order to compensate for these various running forms, running shoes come in three forms: motion control (for over pronation), cushioned (for supination), and neutral stability (for neutral running) (see figure 3). These differences among running shoes are effective in reducing pain and fatigue that can result from improper running mechanics; however, as I found in my research they do nothing for arch support.



*Figure 3 shows a running classification and shoe type chart for give arch types (Injuredrunner.com 2009)*

Arch pain is the result of structural imbalance and can come in many forms. A common cause is plantar fasciitis. The fascia is a broad band of tissue along the bottom surface of the foot from the heel to the forefoot. The excessive stretching of the tissue, usually due to over pronation by flat-footed people, causes plantar fasciitis. This problem

can be relieved with proper arch support. When walking on cement surfaces, three times a person's body weight is imposed on their feet with each step. The arch is supposed to support this weight; however it needs support itself. This problem becomes more severe with the continual increase of body weight within the population. A weight gain as little as ten pounds can trigger multiple orthopedic issues. While walking up stairs or an incline, the foot carries four to six times a person's body weight and this pressure will constantly flatten out the arches and stretch the tendons over time unless the arch is supported.

### **Users and Stakeholders**

The footwear industry is a multi-billion dollar industry that caters to millions of users from every background and demographic. In 2004 more than 493 million pairs of athletic shoes were sold in the United States. Athletic shoes are not just for athletes anymore; they are for anyone seeking a comfortable and supportive footwear option. Nurses, factory workers, and various other employees spend much of the workday on their feet. It is important that they receive adequate support for optimal work productivity and health. Both men and women could use increased arch support throughout the day; however, women would benefit more from this product. Due to hormonal changes, pregnancy, and other biological factors, the female foot is periodically changing shape. Since the shape of the foot is changing, it is necessary that women have a support mechanism that can change with them and their needs.

This product is also of great interest to the serious athlete. Plantar fasciitis is becoming more and more prevalent in athletes and there is a dramatic increase in injury

rates because if it. Because their shoes do not provide enough support to stabilize the foot during their active motions, athletes are experiencing many other foot injuries through improper bending and rolling of the foot. In a 2008 weekly injury report of NCAA men's basketball players, nearly 10% of the player injuries were the result of ailments that could have been prevented with proper foot support.

ArchFlux Technology carries many implications for diabetics and those who suffer from other medical conditions. The diabetic foot is extremely sensitive. It is prone to ulcers caused by friction within shoes; this friction can be reduced when the foot is cradled in the proper position. Many people who suffer from back and joint pain can also experience relief from adequate arch support as their body will be properly aligned and their body weight will be distributed evenly. Research studies have proven that using arch supports by diabetics and at-risk patients results in a significant change in balance, functional mobility, pain, and self-reported benefits (Mulford 2004).

The majority of footwear support is focused around the concept of heel stabilization within running shoes. Most athletic shoes give the sensations of an arch support, but this lies within the shape of the sock liner insert (Foot.com 2009). These liners, however, are flimsy and provide no support whatsoever (see figure 4). Heel stabilization without arch support is counterproductive. Footwear companies would have a much more effective product if they were to provide the user with arch support. The reason companies do not consider the arch as much as they should is because of the difficulty in allowing the support to accommodate the greatest number of users without adding to manufacturing costs and efforts. ArchFlux Technology would provide a way

for shoe companies to provide consumers with arch support by only adding one extra component to a shoe that would accommodate the majority of users.



*Figure 4 shows the lack of support of shoe sock liners, which give the illusion of arch support*

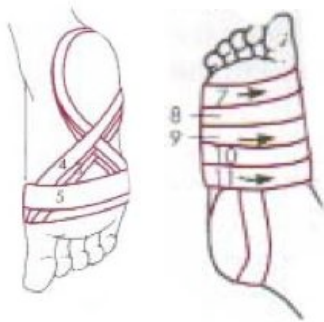
### **Market Products**

There are many different kinds of over-the-counter and custom orthotic insert options that people purchase to alleviate their nagging foot pain. An orthotic is a device worn inside the shoe. A custom functional foot orthotic is made from either a digital or physical mold of the foot. It is designed to control alignment and function of the foot in order to treat or prevent injury-causing force on the bones, joints, tendons and ligaments by redistributing pressure on the bottom of the foot (Huppin). Custom orthotics, like those that Ammenath Peethambaran and Jody LeCursi make, are usually very effective for the patient. Custom orthotics, however, cost hundreds of dollars, need to be replaced yearly, and can typically only be used in one pair of shoes. Over-the-counter orthotics provide gentle support to the foot and spread the weight more evenly along the bottom of the foot (Bumgardner 2007). The problem with these inserts is that often the arch support is not rigid enough, and provides more cushion rather than support. Over-the-counter inserts rely on the user to know what they need for their foot, which is information that



most consumers lack. Often, consumers need to buy countless pairs to find one that they find comfortable or moderately effective; while this is great for the manufacture, it puts a major strain on the wallet of the user. In 2008 alone, Dr. Scholl's foot care products achieved sales of over 18.5 million dollars.

An inexpensive way to support the arch is arch strapping or taping. Strapping procedures are utilized as temporary treatment because there is concern over the duration of the effectiveness (Ator 1991). It is quick and inexpensive, as only a roll of medical tape is required. The tape provides a lift on the arch when configured in a particular way (shown in figure 5) (Coolrunning.com 2009).



*Figure 5 shows two arch strapping methods*

The Nike® LunarGlide+™ (shown in figure 6) was introduced to the footwear market in August 2009. The LunarGlide+™ generated a great amount of buzz because it offers an arch strap (Nikebiz.com 2009). The arch strap is made of soft microfiber and provides added support around the medial side of the foot and can be slightly tightened or loosened (shown in figure 7).



*Figure 6 shows the Nike® LunarGlide+™ arch strap*

*Figure 7 details the LunarGlide+™*

In the early 1990s the Reebok® Pump™ was introduced (shown in figure 8). The Pump™ was the first shoe to have an internal inflation mechanism that regulated a fitting cushion in the upper tongue. In 2005, Reebok® introduced a pump shoe without laces. The pump lay within the heel of the shoe so that there is no manual pumping required. Every time the user takes a step, air is pumped into the shoe (which also contains a release button so that the pressure does not exceed five pounds per square inch). The Reebok® Pump™ was crucial to my project when examining how air can be used within the shoe for support.



*Figure 8 shows an early version of the Reebok® Pump™*

In 2001 Spaulding® revolutionized the way air is added to athletic balls by introducing the Infusion™. The Spaulding® Infusion™ contains a dual-action built-in

micro-pump™ that can add or release air from the ball (shown in figure 9)(Spalding.com 2009). The Spaulding® Infusion™ line of products detailed the need for air to be added or subtracted without inconveniencing the user by requiring them to secure an additional device component, such as a standard air pump, much like the Reebok® Pump™ .



*Figure 9 details the Spaulding® Infusion micro-pump™*

In December of 1997 Mizuno® introduced their new Wave® technology. Mizuno Wave® technology incorporates a thermoplastic wave plate into the midsole heel area of running shoes to provide various levels of cushioning and support (Kaneko). The wave shape itself allows for increased shock absorption and compression and disperses impact forces uniformly over the length and width of the midsole. The Mizuno Wave® resists over-pronation and minimizes excessive midsole collapse, resulting in proper motion control (Mizunousa.com 2010). The Mizuno Wave® comes in six different shapes and sizes (shown in figure 10), each having a different function ranging from cushioning to stability.

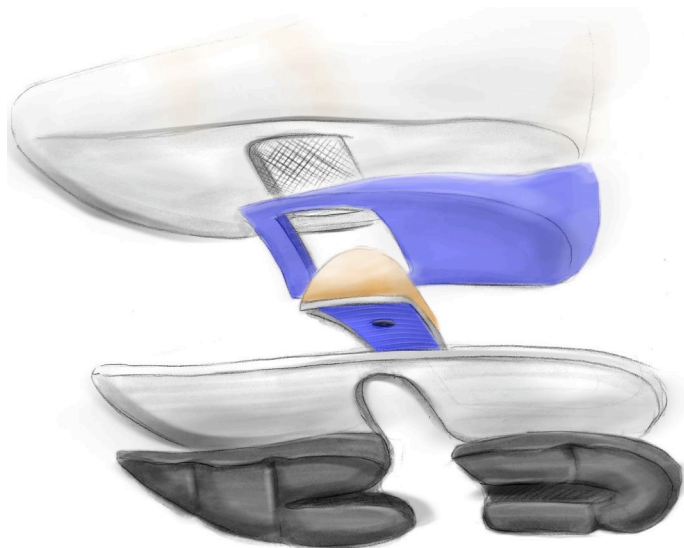




*Figure 10 shows A. Double Wave, B. Fan Wave, C. Parallel Wave, D. Composite Wave, E. Skeleton Wave, and F. Zigzag Wave*

### **Concept Generation, Processes, Testing, Experimentation**

The concept generation for my adjustable arch support began in August with a preliminary design bladder concept (shown in figure 11).



*Figure 11 shows an exploded rendering of my initial bladder concept*

In my design the arch rubber bladder is located in between the upper portion of the shoe (the lining, overlay, collar, and toe box of the shoe) and the midsole (connects the upper to the outsole of the shoe). The midsole and outsole (rubber traction) of the shoe is designed so that the bottom of the bladder frame is accessible from the bottom of the shoe for adjustability. Within this design concept I worked with various air valves that could

be used to add and subtract air. Three valves I considered were a standard sport ball valve, a bike tire valve, and the infusion™ pump valve (shown in figure 12).



*Figure 12 from top to bottom shows sport ball valve concept, bike valve concept, and infusion pump concept*

Throughout my concept generation I brainstormed particular specifications that I should consider while designing the adjustable bladder. Foremost, the bladder material needs to be able to adjust to conform a low arch and a high arch without compromising rigidity. The bladder also needs to be comprised of a material or material covering that can wick away moisture from the foot so that blisters do not form. The bladder needs to conform to the various geometries of the foot throughout the Gait Cycle movement. Also the design itself should be intuitive and not complicated to use. The user must know what he/she is adjusting and how these adjustments impact their support and fit. Since orthotics are not considered “cool” shoe accessories, I am intending on seamlessly integrating the bladder into the shoe, so that it does not draw attention to itself; however,

I will keep in mind that this accessory has the potential to be one of interest and therefore should be highlighted to a certain degree. Finally, it is vital that adjustable support be effective and require minimal effort. If it requires a lot of adjustment, people will not think that it is worth the hassle.

In order to calculate appropriate measurements, I created plaster foot casts of high, medium, and low arch people with roughly the same foot length of 25-27cm (shown in figure 13). I filled the negative casts with a silicone rubber to create a positive, with which I could work with the shape and measurements of the arch.



*Figure 13 shows plaster foot casts*

I filled the rubber foot mold arches with air-drying clay (shown in figure 14) so that I could calculate the specific measurements of the arches.



*Figure 14 shows clay filled arches*

In order to gain a greater understanding of shoe construction, I reverse engineered multiple pairs of athletic shoes (shown in figure 15 and 16). I examined the difference between different types of running shoes and found that typically neutral shoes had a solid rubber midsole, whereas a stability or motion control shoe contained dual-density foams and rigid plastic counters to reduce torque.



*Figures 15 and 16 respectively show the difference between a neutral Nike® shoe and stability New Balance® shoe*

To visually depict the lack of adequate arch support, I used my positive rubber foot molds (shown in figure 17). When pressure is applied to the foot the arch completely collapses and elongates in an uncomfortable and unnatural way (shown in figure 18).



*Figure 17 shows a low arch foot without pressure on a stability shoe sole*



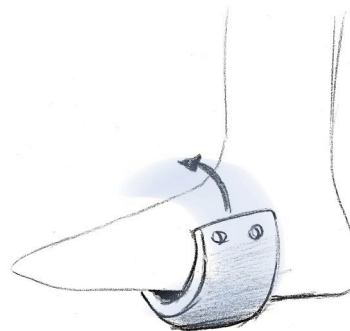
*Figure 18 shows a low arch foot with simulated pressure on a stability shoe sole*

The lack of support is evident in the low arch foot, but is even more drastic with other arch sizes.

In the fall of 2009 I took a multi-disciplinary mechanical engineering course called Analytical Product Design. Other members of my team were an undergraduate ME student, a graduate ME student, and a design science PhD candidate. We worked on designing a winter performance running shoe called “CoolRunning.” While our project focused on the upper construction of a running shoe, I used this opportunity to work with the medial side support of the arch. In our design I created a side arch lift, similar to the Nike® LunarGlide+™ (shown in figure 19). The design, however, differed from the LunarGlide+™ because the arch strap went slightly under the medial arch, whereas the LunarGlide+™ is completely on the side of the foot (shown in figure 20).



*Figure 19 shows medial view of*



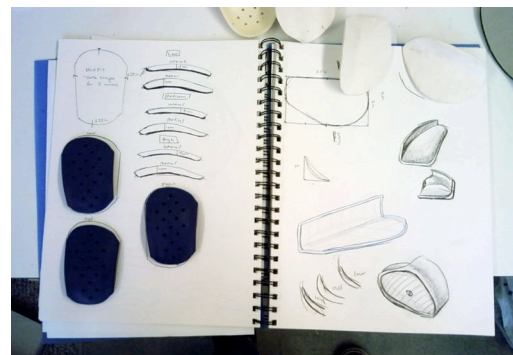
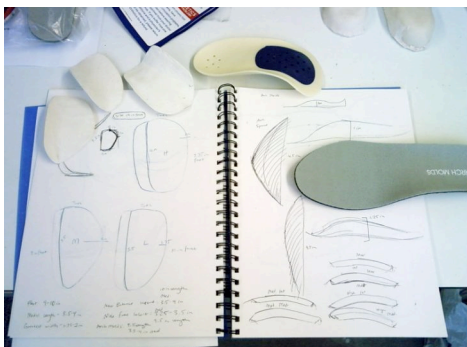
*Figure 20 shows slight cradling of arch strap*



## *CoolRunning shoe*

After completing the CoolRunning arch strap design, I realized the importance of side arch support to keep the arch from falling. In my initial design concept, this area was completely neglected. With this new revelation, I began a new bladder concept generation that provided more medial support. I explored the idea of adding an external strap that would stem from the bladder to the shoe, but instead settled on redesigning the shape of the rigid bladder frame.

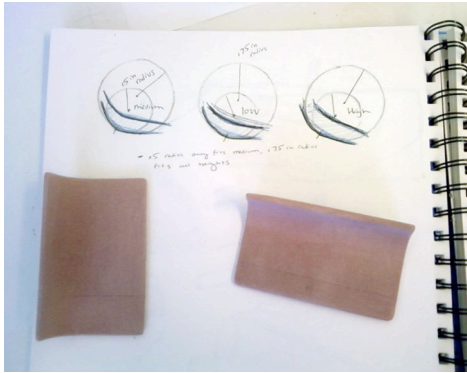
Before I could work on constructing the bladder frame, I had to use my positive arch molds to figure out the proper measurements and curves. I also looked at orthotic products that I had purchased to compare their dimensions with my measurements and thus create what seems to be the optimal shape (shown in figures 21 and 22). In doing so, I found that bottom support frame should be 3.5 inches in length and 1.75 inches at its greatest width. The shape itself resembles a slightly distorted “D”.



*Figures 21 and 22 detail arch measurement process*

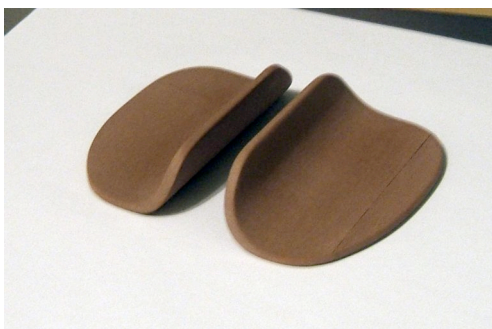
After deciding on the basic footprint of the bladder frame, I compared the medial outside radii curvature of the arch molds on each foot to find a radius that would accommodate each foot (shown in figure 23). I found that each mold nearly perfectly

matched a .75 inch radius. Using this measurement, I began to carve two identical bladder frames out of Ren Shape.



*Figure 23 shows medial radii calculation with Ren Shape forms*

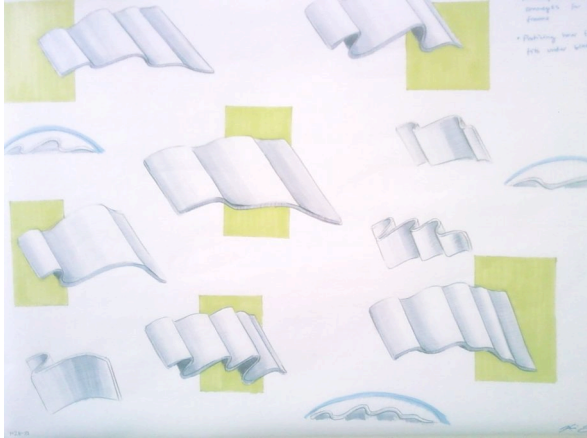
With the standard common measurements calculated and carved in Ren Shape, I used similar methods to decide on the top side medial curvature and used my calculated footprint to create two anatomically correct bladder frames (shown in figure 24). I found that the angles at which the medial arch was formed were within a few degrees among the arch molds. The radii along the top were also shared among the molds. Using the data I had collected, I was able to determine that the medial frame support should have a lower (towards the heel) angle of 56 degrees and upper radius of 1 inch, and an upper (towards the toe) angle of 65 degrees and upper radius of .5 inch. These frames serve as the basic outlining footprint and size of the frame.



*Figure 24 shows anatomically correct Ren Shape bladder frames*

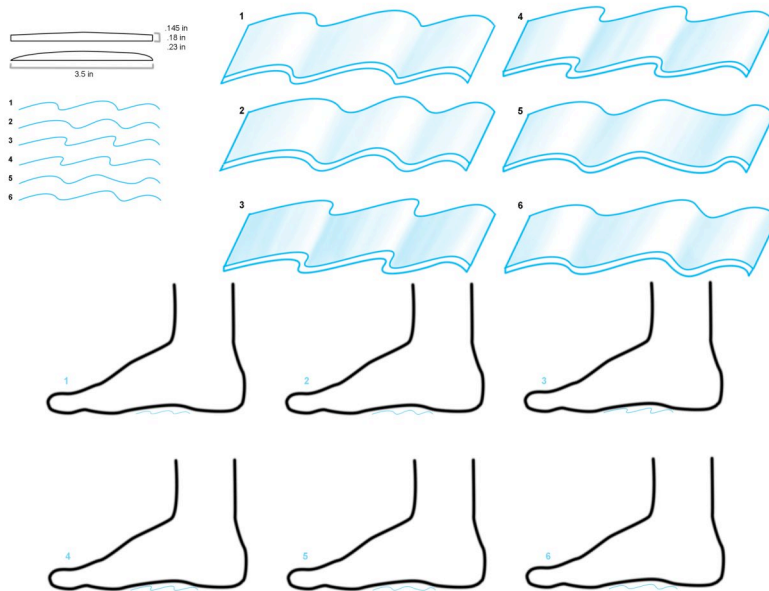
With the bladder frame footprint decided, I began to consider different variables that may come into play while a person is actively moving. I categorized these variables into environmental and personal. Some environmental variables include but are not limited to: temperature and weather conditions, running surface (pavement, artificial, soft natural), and surface condition (ice and snow, uneven, cracking, debris). Some personal variables include but are not limited to: running motion characteristics (over-pronation to supination), water retention and inflammation (among both men and women), foot sensitivity, and weight. All of these variables could have the potential to cause enough stress on the bladder system so that over time with wear and tear, the bladder itself could break or rupture. I then decided that a safety system should be put in place so that the foot would not experience a great amount of trauma should it go from being supported to completely unsupported. I felt the best way to provide a “safety net” was to have an internal structure that was slightly lower than my desired low arch height, this way it would not interrupt the desired function of the bladder system, but could still catch the foot if the bladder failed. After juxtaposing the measurements of my arch molds with that of other products I had purchased, I decided that the safety support should range from .145 inches in the lower (heel) end to a high point in the middle of .23 inches while gradually tapering off to .145 inches near the upper (toe) end. While brainstorming the most efficient and beneficial way to model this support, I turned back to the Mizuno Wave® concept. The wave shape would provide desirable attributes of compression and shock absorption that would be crucial during the gait cycle. The wave amplitudes themselves could fill the safety support space and follow along my predetermined bladder frame footprint. I researched more in depth the frequency, amplitude, and angles of the

various Mizuno® waves, all the while comparing how the shapes and sizes would react when applied to the arch versus the heel. I explored the impact of the number of waves optimal for the arch before finally deciding on the three waves (shown in figure 25).



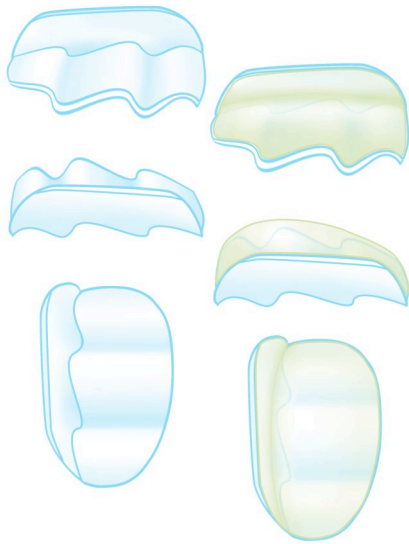
*Figure 25 details the wave number decision-making process*

After I determined that three wavelengths were optimal, I worked digitally in creating multiple possible wave shapes that fit within my support criteria and compared how they would accommodate the movement of the foot (shown in figure 26).



*Figure 26 shows 6 possible wave shapes and how they would fit within the arch*

After experimenting with various wave shapes, I came to the conclusion that a combination of my first and sixth wave shape would be optimal for foot movement and for the safety support. I then created some Photoshop renderings of what the new bladder frame and full bladder system would look like (shown in figure 27).



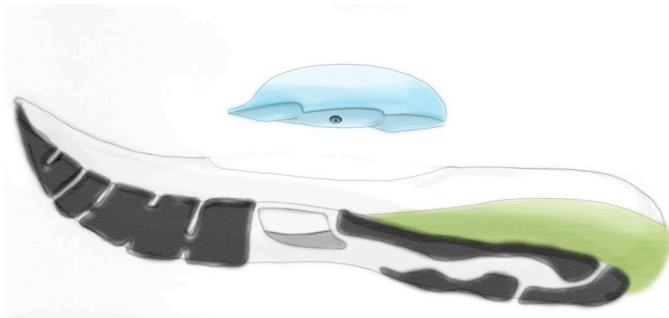
*Figure 27 shows in the left column the wave bladder plate (top to bottom) lateral view, medial view, and aerial view; and in the right column the entire bladder support system (top to bottom) lateral view, medial view, and aerial view*

It was at this point that I officially decided on the name ArchFlux Technology. The term flux itself means the act of flowing in and out or continuous change. Flux relates to the wave shape of the plate, the action of adjusting the bladder, and the change in the arch itself.

In the shoe, ArchFlux is secured in the midsole and also functions as the shank of the shoe by aiding in torque prevention (shown in figure 28). The midsole and the outsole contain an opening in the bottom of the shoe for adjustment (shown in figure 29).



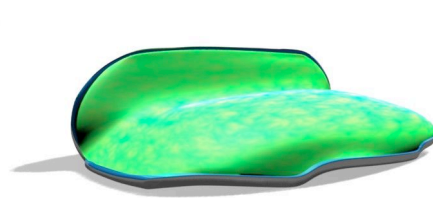
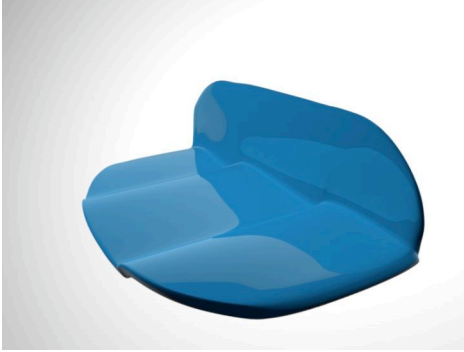
*Figure 28 shows an exploded view of the shoe sole, ArchFlux frame, and ArchFlux bladder*



*Figure 29 shows a bottom exploded view of the midsole and outsole opening allowing adjustment through the bottom of the ArchFlux frame*

I purchased four pairs of athletic shoes to deconstruct and use the soles for housing my ArchFlux models. I cut away the upper portion of the shoe, carved a space for the ArchFlux plate to fit into the midsole, and opened up the outsole to allow access to the adjustment valve. I had considered modeling and making my own soles for the project so that the model fit would be seamless, but decided that it was not worth the additional cost and effort. The shoes I purchased had a midsole and outsole that was completely made of rubber, so they lent themselves well to my project because there was no existing shank or form of support and stability.

Throughout this process, I worked on a 3D model of the bladder frame for 3D printing (shown in figure 30) and a completed ArchFlux model (shown in figure 31).



*Figure 30 shows completed frame model      Figure 31 shows complete ArchFlux model*

The right and left foot models were printed in ABS plastic material (shown in figure 32). Once sanded and smoothed, I used the models to create a silicone rubber mold. The molds were filled with plastic resin and dye to create multiple sets.



*Figure 32 shows printed ABS plate models*

Nearly twenty pairs of ArchFlux model plates were cast. I used some of the sets for construction and material practice and exploration before picking the five best looking sets to use for exhibition display. The plates had valve holes drilled, were sanded, and then covered with polyurethane for additional shine (shown in figure 33).



*Figure 33 shows ArchFlux plates being coated in polyurethane*

Using a template that I created based on the plate dimensions, I cut .032” general-purpose buytl rubber pieces and covered them with a moisture wicking fabric. The rubber was attached to the plates using industrial strength adhesive and then sealed using a silicone sealant.

While looking at various one-way and two-way valves, I realized that finding a valve that met the design criteria I set for the model—allows for air addition and subtraction, is small, and does not require extra component—was a design problem in itself. So I applied two different valve options to the plates for consideration: a two-way twist valve and a one-way rubber valve. The two-way twist valve allows the opportunity to inflate and deflate the bladder without the need for an extra outside component (aside from a blowing tube that would be housed in the inner sole of the shoe). The valve that is applied to the display models is slightly bigger than what I had ideally envisioned and is also fairly expensive at \$8 per valve. The rubber valve, similar to those found in athletic balls, is small and inexpensive at only \$.70 per valve; however, it does require the use of a manual air pump. Both valve variations were applied to the plastic plate frames and sealed. With the valves attached, I could inflate the ArchFlux models and check for any



air leaks. With any found leaks repaired, I applied a final layer of polyurethane and installed the ArchFlux models into the altered shoe soles.

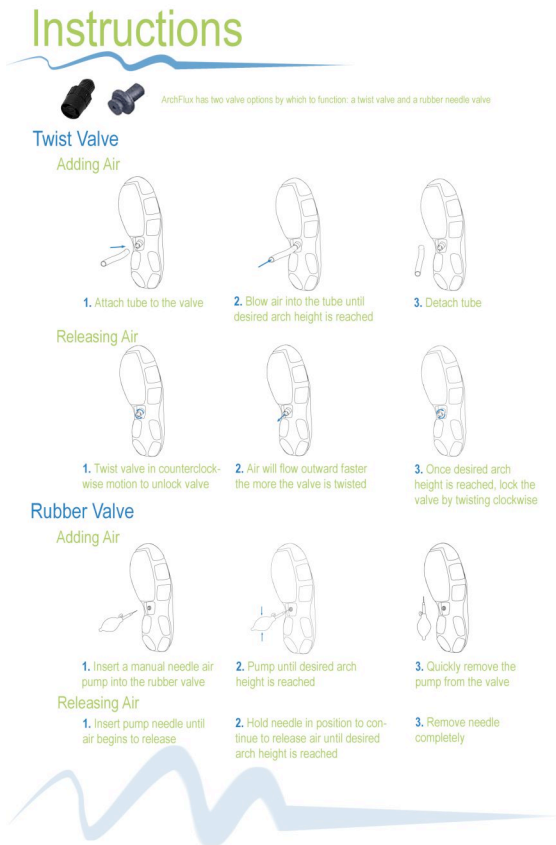
### **Exhibition and Reflection**

In my exhibition setup (shown in figure 34), one pair of soles with ArchFlux models containing the twist valve option were set on a pedestal so that viewers could see how ArchFlux Technology would be incorporated into a midsole and outsole of the shoe. Also on the pedestal was a separate set of ArchFlux models with the rubber valve and a hand pump for the viewers to use and adjust the models. I felt that a project like this really could not be fully understood or appreciated unless the viewer could test the efficacy of the models. On three floor platforms, I adhered the remaining three pairs of alter shoe soles with the ArchFlux models. Each set had different high adjustments so that viewers could stand on all three and feel first hand the difference.



*Figure 34 shows Wanderlust exhibition set-up*

Finally I created poster visuals depicting the arch, market analysis, ArchFlux Technology, and instructions for use (shown in figure 35). The posters were intended to help the audience understand the full scope of the project.



*Figure 35 shows the instructional poster hung at the exhibition*

Throughout the exhibition opening night, lots of viewers commented that either they or someone they knew had foot problems and could really benefit from this product. Everyone who stood on the models commented that they could feel the support and it felt very comfortable. Some were astonished to hear that all the models were of the same exact mechanism, just adjusted to different levels.

During the exhibition I realized that I should have done some things differently. Allowing my project to be interactive was a very important aspect to me; however, I should have been more exact in my signs that told the viewer to test the models. In labeling each test model's height, I said to feel free to step on the model. It seemed obvious to me that a person would first take off the pair of shoes he or she was wearing

before doing so, but I found that this was not always the case. Fairly early on in the night I saw two people standing on my models with their shoes still on. Before I could ask them to remove their shoes, they cracked and broke the medial side of two ArchFlux plates. As the night wore on, I also became aware that my rubber adhesion and sealing process was not durable enough to withstand a lot of wear and tear. During my research phase I found that the best way to provide an airtight seal with rubber is through a process called “vulcanization.” During this process, high temperatures, pressure and sometimes chemicals are used to form crosslinks between individual polymer chains. Since I did not properly replicate this process, the ArchFlux bladders began to slowly release air throughout the night. The seal was strong enough to allow the bladder to be inflated and tested immediately, but over few minute spans the bladder would completely deflate in nearly all the models.

## **Business Plan**

My business plan is to obtain a patent on ArchFlux Technology. Since there is a high cost of entry into the athletic shoe industry market and a great sense of brand loyalty, the design would be best suited to be licensed to an existing shoe manufacture at a conservative 10% royalty rate. If ArchFlux were introduced through a currently known shoe company, it would be able to leverage the existing marketing, distribution, and production channels as well as benefit from the company’s expertise.

Figure 36 shows the material cost to produce one ArchFlux model. The twist valve option would cost \$19.64 to produce per set while the rubber valve option would cost \$5.04 to produce per set. Both of these figures would be dramatically reduced with

large-scale production efforts. Shoes with ArchFlux Technology could be priced at a \$15-\$25 premium over traditional shoes (depending on the valve option). This price points allows for optimal shoes sales because the price difference between a pair with ArchFlux Technology and a pair without does not appear substantial to the consumer, yet would yield additional profits.

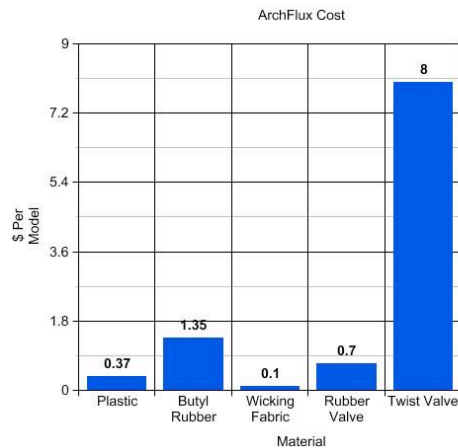


Figure 36 shows ArchFlux material cost breakdown

## Conclusion

I spent this year researching and meeting with a certified podiatrist and the University of Michigan Orthotics and Prosthetics Department to gain a detailed understanding of the foot, as well as a local shoe store employee and avid runner to better understand shoe structure and technology. I worked on concept generation, dimensions, compliance mechanisms, and 3D modeling. For the Wanderlust exhibition I displayed three fully functional ArchFlux models set in shoe soles for viewers to test, as well as two display models detailing the different valve options.

I plan to continue working on this project because it has such great market potential as well as medical and athletic implications. I will explore more valve options and learn to create a tighter rubber seal so that the models will be more durable. I hope to

refine this project to a point where I could eventually present ArchFlux to a shoe company for production.

Arch support importance is a relatively new concept. While it's been known that arch support is beneficial, only over the last fifteen years have research studies been done to prove the importance and health benefits. This area of study has been applied minimally within shoes themselves; however, interest has grown as the need has grown.

Millions of people suffer from foot, body, and joint pain as a result of inadequate arch support. With proper arch support people will be able to live healthier and more active lives. ArchFlux Technology will help to educate users about their foot and will make relief more accessible.

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