ENGS 21 Winter 2016

Introduction to Engineering

Putting Ice Skates in Children's Own Hands:

Improving the Securing System of Ice Skates

Final Report

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I. Problem, Potential Users, Potential Purchasers

Ice skating is a popular winter pastime. People of all ages partake in both recreational skating and hockey, and last year over 533,000 children registered with USA Hockey.[1] In particular, children aged 5 to 12 cannot tie their own skates. Children learning to play hockey, for example, are often completely dependent on their parents and coaches to tie their skates – 92% of children under ten years old that we surveyed were. They lack the combination of strength and dexterity needed to tighten traditional laces properly. This is a problem that children face every time they prepare to go onto an ice rink. It not only limits the independence of young skaters, but also takes time away from the adults. Parents and coaches are, in fact, the most vocal about this problem.

Currently, the process of lacing skates requires people to pull on individual lace crossovers to get their skates tight, inching slowly from toe to ankle. Doing so requires a commitment of time and a fair amount of strength. In the end, people often do not get their laces tight enough. Loose skates can lead to injury, making skating painful and not enjoyable. More time spent outside of the rink fastening skates means less time on the ice doing what skaters want.

We spoke with and surveyed nearly 40 potential users – children ages 5 to 12 – and purchasers – their parents – about the issue. We saw several trends. Primarily, children either had difficulty tightening their skates properly by themselves or parents had to spend time helping them. One child remarked that, “I shouldn’t have to go to the gym when I’m nine years old to be strong enough to tie my own skate.” Professor Collier said that he has, on more than one occasion, spent twenty minutes doing up the skates of his child's entire hockey team. Further, some people mentioned having to leave the ice while skating to adjust the tightness of their skates. However, people did comment that they like the current style and aesthetic of hockey skates, among other qualities. Children told us that they wanted their skates to look like their parents and favorite hockey players, and parents told us they had trouble imagining skates looking any other way. The majority of our feedback came from families in the Learn-To-Skate and Mites hockey programs of the Hanover Hockey Association. We continued to survey these families, demonstrating prototypes, collecting feedback, and gathering testing data, nearly every weekend throughout the project.

II. Specifications

By working closely with our users and running preliminary tests, we were able to identify specifications that could drive the design toward a solution to our problem. We developed a weighted matrix of specifications which we referenced throughout our design iteration process. Eleven distinct specifications were identified. Three of them were particularly important to us. These three specifications were the time it took to secure the skate, the force it took to tighten the skate, and the resemblance to the laces on traditional hockey skates. Seeking to reduce the time it takes to put on ice skates, we used stop watches and determined that a user currently needed nearly a minute to put on one skate, but our goal was to be able to do it in under 30 seconds. For children to use our system independently, we needed the force to secure the system to be less than that which a child could pull up with one hand. We measured this force to be 100N.

We wanted our design to resemble the traditional aesthetic of a hockey skate because this would directly affect whether the parents would purchase our product or not. From our survey results, we had identified this feature as a primary focus in constructing our design. If the design was unattractive, it would not appeal to our users and purchasers. We used qualitative surveys to determine what both children and parents thought about the look of our system. We also considered the specifications of security, product cost, ease of assembly/repairability, “cool” look, originality, simplicity, variable tightness, and safety to put on. We developed quantifications and tests for these specifications, which can be seen in Appendix B.

III. Background and State of the Art

Figure 1 - Progression of Bauer Ice Skates

Securely tying ice skates has been a problem as long as the current design has existed. The parents we surveyed noted that their parents had to tie their laces just like they now have to tie their own child’s laces. In fact, we researched ice skate innovation and found that there have been no substantive changes in the past 50 years. This is shown above in Figure 1. The pictures show the evolution of Bauer ice skates from the 1960's to the present – or rather, the lack thereof. From youth skates to the top of the line skates used by professionals, the traditional look with the flat laces passing through alternating eyelets dominates the ice skate market. Although attempts have been made to change the ice skate securing mechanism, none have had widespread market success.

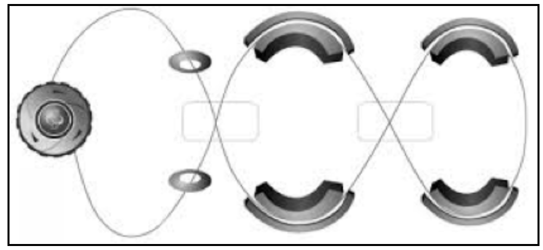


Figure 2- Boa-Closure System

One of the first state of the art systems we examined was the Boa Closure System, which has recently been implemented on a select number of skates.[2] This patented system, seen in Figure 2, relies on a steel wire that runs through eyelets, similar to normal laces.[3] Its main innovation is that the wire laces are tightened by turning a dial located at the top of the device. The laces are loosened all at once by pulling outward on the dial. This dial allows the user to easily and precisely tighten their footwear with a single hand.[4] However, the incorporation of the Boa System into hockey skates has not been widely adopted. A main reason for this is its appearance: it does not match the traditional aesthetic our users have grown to like. In addition, the system is susceptible to damage and not easily reparable, and it has not been shown to be easy to use by children. While CCM and K2, two major hockey equipment companies, offer the Boa system in hockey skates, it is not used at a competitive level. A CCM representative told us that he had used the Boa system with snowboard boots, but it broke easily and was very difficult to fix. He said CCM would never implement it in anything but beginner skates for this reason. The Boa system does present many positive aspects in lace tightening, and is probably the most progressive innovation currently in hockey skates.

Two other technologies that have been tried as alternatives to traditional laces, but have never been successfully established, are buckles and velcro. High performance buckles have been developed, as Figure 3 illustrates.[5] Although they are relatively simple and provide reliable tightness, they have limitations which have prevented their widespread success. In addition to their excess weight, buckles only tighten over the immediate area that they cover. They also do not allow the flexibility in the ankle that is important for skating. Velcro, although lighter than buckles, also has limitations. Similar to buckles, it only allows for tightening in the immediate area around the velcro. Additionally, people we surveyed were not sure a proper strength of velcro existed that would both stay closed during skating and not be too difficult to open off the ice. Velcro has been used in a design called Option B, shown in Figure 4, to entirely replace laces.[6] This system uses clips that are screwed into the eyelets of the skate, and the velcro straps are threaded through these clips. Although this option has certain advantages, such as retrofittability and the ability to tighten with one hand, it has many individual parts. Both Velcro and buckles also lack the

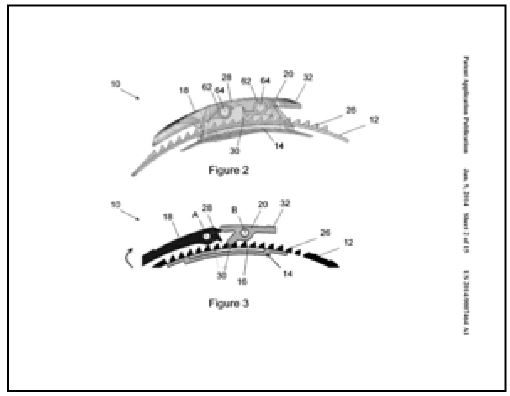


Figure 3- High Performance Sports Buckle

Figure 4 - Option B Velcro Laces

traditional hockey skate aesthetic of wide, flat laces that we found vital to creating a product that users would actually purchase.

We found an interesting concept for a multi-sport boot that incorporated a lace-like elastic tightening system with a buckle on the top during our patent search, as seen in figure 5.[7] Based on the patent sketch, this design has a few limitations. It would likely be difficult to securely tighten the bottom elastics just by pulling at the top due to friction, and similarly it would be difficult to loosen to remove the skate. Also, the elastic and buckle deviate too far from the traditional aesthetic. We have not seen this lacing system used in any widely manufactured boots. However, this model, especially the handle and use of elastic laces secured in one pull, is similar to performance water ski bindings, which were an early inspiration for our final product.

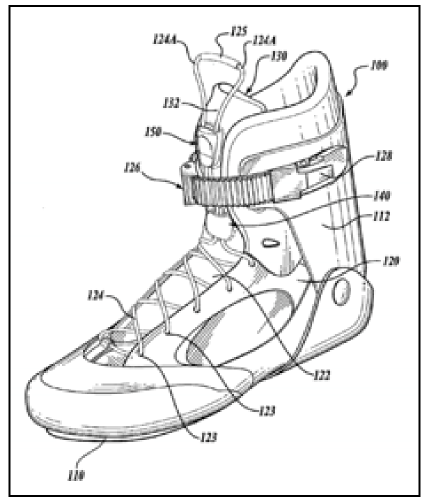


Figure 5 - Multi-sport Elastic Lacing System

Other lacing systems that represent the cutting edge of shoe lacing technology came up in our review of the state of the art. These technologies, meant primarily for running shoes, were developed with the same goal as ours: increase ease and decrease time to put on footwear. The first method, the Xpand lacing system, uses elastic laces that are fit to a standard tightness and then never have to be tightened again.[8] Some likely limitations include the ability to withstand the forces of skating without becoming stretched or loose, as well as the fact that the tightness is not adjustable. The second method is the Powerlace Auto-lacing System.[9] This system relies on the weight of the user stepping into the shoe to trigger mechanisms that tighten the shoe to a preset tightness. This product, as seen in Figure 6, is patented; however, it is not yet in production, so it remains difficult to judge its success or failure. Considering that skates are generally pulled on rather than stepped into, it is unlikely that this technology would function as well in skates. Additionally, the release for the laces is a tab at the heel, which need only be accidentally depressed during gameplay to cause serious issues for a hockey player. We concluded that while technology other than traditional laces exists for securing skates and other footwear, there is a niche for a product that not only resembles the traditional ice skate but also allows children to independently tighten their own skates.

Figure 6 - PowerLace Auto-lacing System

IV. Alternatives and Problem Solving

We considered a variety of options for developing a better method for securing skates. We created a matrix of alternatives, shown in Appendix B, in order to select the most promising direction. We ranked each alternative method for its effectiveness at addressing each of the specifications we identified. Out of all of these, the three most important ones were the time needed to secure the skate, the force needed to secure the skate, and the traditional aesthetic of the skate. We gave these an increased weight in the alternative matrix. The rest of the specifications are shown in Appendix A. Some of the alternatives that we brainstormed included changing the lacing pattern, putting new eyelets in the skate, implementing a new locking mechanism, changing the entry location of the skate, having multiple lock locations on the skate, and using a mechanical crank to tighten the skate. After running all of our ideas through the matrix, we concluded that changing the entry location of the skate was the most promising option, with changing the eyelets and developing a new locking mechanism also receiving high scores. We started working on both a rear-entry skate and a new eyelet system simultaneously because both of those options scored highly. To us, changing the eyelets meant reducing the friction within them, so we imagined using pulleys and drew a few designs as shown in Appendix C.

First Prototype: Side-Hinge Rear-Entry Skate

We focused our first prototype on changing the entry location of the skate using a rear-entry design with a side-hinge. This prototype is pictured in Appendix C. This system used wax laces that would only need to be tied once, likely by a parent, and then would stay tight for a long time. Day to day, the child would be able to easily slide his or her foot in and out of the back of the skate. We decided on a side hinge first because we thought a rear hinge would not open enough for easy access due to the interference of the skate blade. We secured the hinge to the skate using clips attached to straps, which would have been very easy for a child to secure. There were problems with this design. It took a lot of force to actually get the foot into the skate – the tester had to kick the bottom of the boot into the ground to fully insert his or her foot. Additionally, lateral stability in the ankle was limited. Experts at Stateline Sports stated that heel security is the most important aspect of overall skate security, so we sought to fix this problem in future prototypes. Furthermore, the clips did not hold the straps tight during testing, and had to be tightened multiple times throughout.

Intermediate Designs

After receiving feedback on our first prototype, we tested some intermediate designs, shown in Appendix C. We designed a sliding baseplate in SolidWorks that would have two pieces slide out from each other and remain connected in order for the child to insert his or her foot into the skate. We imagined a ratchet system on the sliding pieces so that the rear could simply be pushed in once the foot was inserted. The dial would sit below the skate to be protected from damage. However, this baseplate would be very difficult to design, particularly with our proposed ratchet unlocking mechanism. Also, adding a secondary baseplate to a skate made securing the blade of the skate more difficult. Lateral stability without any pieces overlapping the cut along the back of the skate would still present a problem with this design. We designed a similar ratchet mechanism for the sides of the skate in which the skate would be tightened with a nut and pull the rear of the skate closed. We did not proceed with this idea because there were many small, difficult to design parts involved, it would have been fragile, and it would not necessarily have been easy for a child to operate.

Rethinking Heel Stability

To better address the lateral stability problems associated with rear-entry skates, we tried to develop a rear-hinged skate that would overlap on the sides of the existing skate. We used molds of the back of a skate to create plastic pieces that extended around the whole back of the skate and over closer to the front. We also tried to design a skate that hinged backwards. In order to do this, we needed to leave some of the existing heel attached. Leaving some of the heel cup would also contribute to lateral stability. These prototypes are shown in Appendix C. In order to test if this was possible, we cut the back of the skate at progressively lower points to see where our user could relatively easily insert their foot into the skate while still maintaining as much heel stability as possible. We discovered that it was very difficult for users to insert their foot into the skate unless the back of the skate was cut all the way down, and even then it did not solve the problem of the user needing to bang their foot into the front of the skate in order to have it be secure. All of these test results led us away from the rear-entry skate idea and towards modifying the eyelets with pulleys, which ended up being our final prototype.

V. Description of Prototype

Figure 7 - Final Prototype

Our final prototype skate, shown in Figure 7, is a lacing system that incorporates pulleys, cleats, and a handle. The laces can be quickly tightened in a single pull as the paracord laces slide smoothly over the pulleys securing the skate to the foot. Once the desired tightness is reached, the lace can be locked in place by being inserted into sailing-inspired cleats that lock in one direction. The handle offers a comfortable solution to pull the laces tight and store any excess lace. The entire design is retrofittable and may be attached to any skate through existing eyelets. With paracord laces, it maintains the look of a traditionally laced skate.

Pulleys

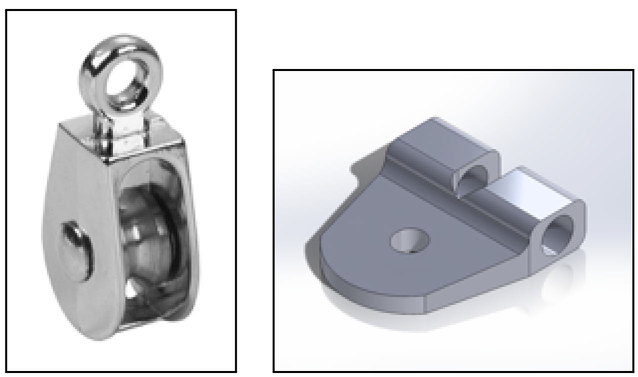


Figure 8 - Clip and Pulley

The pulleys are perhaps the key to our design. They reduce the amount of friction between the lace and skate, allowing it to slide to the proper tightness more easily. Ordinarily, the lace goes through the eyelets, where it does not slide smoothly. With the pulleys, it is possible to pull only from the top of the lacing and still achieve a comfortable fit all along the foot. Further, it requires much less effort to pull the lace than if it had been fed through the eyelets. Still using crisscrossed laces, our system resembles a traditional skate.

Using SolidWorks, we designed clips, shown in Figure 8, with which the pulleys are attached to the skate. We 3D-printed these clips and spray-painted them black to make them inconspicuous. The pulley is attached to the clip with a long screw that runs through the clip and is secured using a nut. The clip is fastened to the skate using another screw and a washer. The washer that we use to hold the clip in place neither protrudes nor causes discomfort. We incorporated user feedback and testing data by not placing pulleys at the bottom of the lacing system, realizing that most users only wanted to easily lace and unlace starting in the middle of the skate.

Cleats

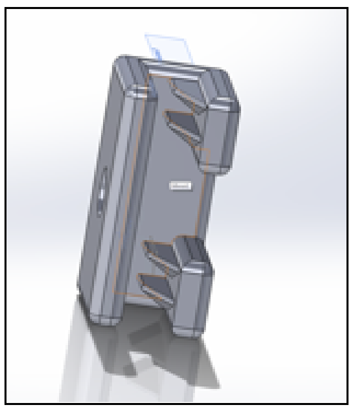


Figure 9 - Cleat

Cleats allow the user to lock the laces into place once the proper tightness is reached. Like we did for the pulley clips, we designed the cleats in SolidWorks, as shown in Figure 9, and 3D printed them. The design is based off of a cam cleat for a sailboat, which allows rope to be tightened in one direction without loosening in the other. This effect is achieved by the orientation of the triangle teeth on the inside of the cleat. We made the cleat as small as possible while maintaining effectiveness and made sure it did not protrude from above the edge of the skate, which might have affected comfort.

Handle

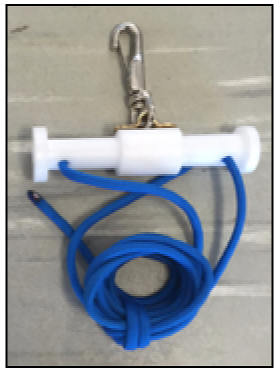


Figure 10 - Ergonomic Handle

We designed a handle, shown in Figure 10, to make pulling the laces more comfortable and easier for the user. The lace runs through the handle. Once the handle has been used to pull the skate secure, the excess lace may be rolled around it. When finished rolling the lace, the user may attach the handle to the top of the skate with a small clip. In the future, we would like to explore the option of a detachable handle, by which the lace can be tightened and then tied like normal laces.

Similar to the Option B Velcro system, our cleat and pulley method may be retrofitted to a skate, allowing a parent to transfer it to new skates as the child grows. Like the Boa Closure System, our design allows the user to easily tighten the laces, which resemble the traditional laces our users liked. Although the parts are now black, the color may be customized in the future if the user wishes. With our system, it is possible to secure the skate faster than most state of the art.

Our prototype performed well with user testing. We had Carter, a 9 year-old hockey player test our skate. He successfully performed hockey stops on both the inside and outside of the skate and was able to skate quickly and turn sharply without the skate becoming loose or causing him any discomfort. He tested one foot with our prototype and one foot in a normally laced skate, and was not able to tell the difference between the two or experience any discomfort.

VI. Testing of Prototype

We ran many tests on our prototype to compare it to the state of the art. The two most important tests that we conducted were timing how long it took to secure the prototype compared to the current state of the art, and how much force was needed to secure the prototype. With a stopwatch, we started measuring from when the foot was already in the loosened boot to the time when the laces were secured. As shown by the time graph in Appendix D, our prototype took less time to secure compared to other lacing systems. Our prototype took around 25 seconds *for a first-time-user child*, whereas traditional laces took around 50 seconds *for a parent* to secure, a significant improvement. Our lacing system was the second fastest system out of the benchmarks, only behind Option B, and was also below our specification time of 30 seconds.

Our force test measured how much force is required to tighten our lacing system until it feels secure to the user's foot. We had the tester attach force gauges to the handle of the skate and pull up until the skate felt secure. A graph of the results is shown in Appendix D. It took about 20 kg of force (100N of force per hand following Newton's Law of F=ma) to tighten our system, tested by our group, which is less force than the other state of the art that we tested. This was on the high end of the maximum force that children could pull, but based on watching a child put our prototype on, children are able to tighten the skate securely.

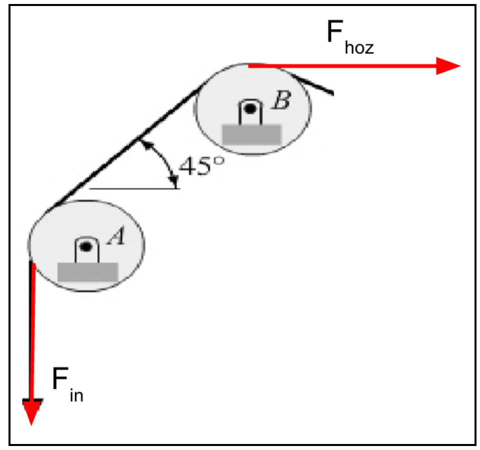
We also tested how many parts our design would add to the skate. We counted how many parts our design needed, and tried to lower that number as much as possible while maintaining our prototype's function. We originally did not want to have too many extra parts in order to keep the design as simple as possible, and to try to maintain the traditional aesthetic as much as possible. Our design ended up having more parts than some of the other options available, but after talking with parents and showing them our design, many of them did not care how many parts the system had, as long as it worked.

In terms of cost, we wanted to make a design that would not add much more cost to the standard hockey skate. We researched prices for our materials online and made a tentative cost for our prototype based off of those numbers. We found that our prototype would add around $25 to the total cost of the skate. Our price was comparable to Option B, the other retrofittable option on the market. We also tested how much weight our system added to the skate. We weighed each individual part of our prototype and calculated the percentage weight that our system added based on the weight of the regular hockey skate. We found a 15% increase in weight and about a 20% increase with the handle, which was a bit more than the other benchmarks.

However, we received almost no weight complaints from parents at the rink, and the children were only minimally concerned about the weight of the skate when we talked with them.

VII. Analysis of Prototype

For the final prototype analysis, we ran tests on how to optimize the design of the skate, using different numbers of clips and different materials for the laces. Our analysis was tested by our group members. In testing the time to secure and force necessary to tighten our prototype versus the number of clips, we found that having only two pulleys, one on each side near the top of the skate, was impractical. Our prototype took significantly longer to secure with two pulleys than with more, and the bottom laces did not tighten properly. We found that four pulleys was the most effective option. It took about the same amount of time to secure our prototype with four pulleys as with six, but the four pulley set took less force to secure than the six pulley set. Our testers reported that the feeling of security in the four pulley set was also comparable to that of a traditional ice skate. Using a set of four clips, we then decided to test what lace material would be most effective using the optimal number of clips. We tested paracord, shoelace, traditional laces, and waxed laces. The paracord was the quickest to secure, taking our tester about 16 seconds. This time, in addition to being faster than the other lace materials, was also only about a quarter of the time it took to secure the current state of the art.



We also analyzed how much friction the pulleys used. If the tension in the string was measured as 3 N, then the simple algebra $F_{Horizontal} = F_{in}\cos(\theta)$, where theta is equal to 45 degrees, tells us that the horizontal force on the pulleys from a 45 degree angle is about 2.1 N. We measured the horizontal force on the skate to be 2N. The lower theoretical value from the measured value results from the fact that there is friction in the pulleys. However, because the difference in derived horizontal force was so small it suggests that the friction in the pulleys is minimized.

We also analyzed the feedback we got from our users after we took our final prototype to a local ice rink and a local pond. People thought our skate was secure enough and was very easy to tighten. They also had positive opinions on our design. People had mixed opinions on the handle, however. Some people criticized it, saying it was simply too bulky and would get in the way. Despite this, most children were able to secure the skate properly, and most of the parents we interviewed said they would buy our prototype if it worked well enough for the child.

VIII. Ethics, Sustainability, and Liability

We wanted our design to be ethical, sustainable and legal. In terms of ethics, our design is intended to give children the autonomy they seek by allowing them to secure their own skates at a younger age than previously possible. Our design is sustainable in both an economically and environmentally friendly manner. Because our design can be retrofitted to any ice skate, purchasers must only buy the product once and then can transfer it to new skates as the child grows. This feature not only saves our users money in the long run, but it is also better for the environment since our design reuses material. Liability is an important concern with our device. Because our system will be securing a child's foot and ankle while skating, it is important that security and tightness are maintained throughout use. This means that our parts must not fail under the normal use. Specifically, this means performing more tests to ensure that our cleats hold in all scenarios. If we were careless in any aspect of our design and a user were to be injured, we could be held liable. Therefore, it is important that we test all aspects of our product's performance before marketing it.

IX. Economics and Business Plan

Industry: Sports & Hockey

Market Overview

U.S. hockey is a $260 million industry.[10] According to USA Hockey, the national governing body for the sport, a record 533,172 amateur players were registered across the country last season, eclipsing the previous high of 519,417 set in 2013-14.[1] Those numbers include youth and adult players. When adding in coaches and officials, the total membership exceeds 600,000. The organization also estimates that there are over one million Americans involved in amateur hockey in any capacity, whether as a volunteer, a parent or a manager. It is also noteworthy that these numbers do not include every single hockey player in the country as many leagues do not require players to be registered.

Our mechanism addresses all young ice skaters. Research indicates a potential market for our prototype of about 500,000 users, based on the number of children registered with USA Hockey. The number could be much larger, as our potential customers may also include children from other countries and children who are currently not registered with USA Hockey.

Product Overview

OneLace utilizes a pulley system to reduce friction between the laces and the eyelets to allow the users to more easily and efficiently tighten their skates with one pull. The unique handle design facilitates pulling and adds ergonomic benefits to the system. The price of the system is set to be $25. Because most parents spend around $75 per year on their child’s hockey equipment, we do not want our product adding significantly to this cost. In addition, our clips and handles could be color-customizable and size-customizable, so they will not look strange when retrofitted to either an old pair of skates from 10 years ago or a new pair that just came out.

Production and Sales

The final package, which is shown in Appendix F includes eight pulleys, two paracord laces, four cleats, two handles, the necessary eighteen screws and washers, and a few extra screws and washers. The retail price is $24.99. OneLace will produce small plastic parts (clips and handle) using injection molding in its factory in the US and purchase the rest of the parts (pulleys, paracord and screws) from suppliers in China. Once parts are packaged in OneLace's factory, the packages will be sold to different places, including sports equipment and hockey stores, famous hockey rinks, and online platforms such as Alibaba and Amazon. We will market at hockey trade shows and tournaments.

Costs, Funds and Cash Flow Models

The cost of our product is comprised of the variable cost and the fixed cost. Variable cost ($11.80 per package) includes direct material costs and direct labor costs associated with the packaging. The costs of paracord, pulleys and screw pairs are determined by the market prices on Alibaba. The costs of connectors and other parts produced by injection molding depends on the price of Delrin, also called polyoxymethylene (POM), which is the major thermoplastic used for injection-molding.

Fixed cost ($75,400) is a basic operational expense including rent, insurance premiums, salaries and marketing costs. House rent includes an annual payment to Brandt's parents for their basement, and will increase by 10% each year. Computers will be collected from donors, thus they will require no extra inputs. It is also noteworthy that those fixed costs will rise over time as our production increases as well as inflation. We believe a 10% increase in those costs every year will account for those changes.

Initially we will need a $105,000 investment to fund our cash-flow needs. The investment will come from two main sources: our five co-founders – each of us will invest $5,000 and will earn 20% of initial shares – and the capital market, where we will raise $80,000 from an angel investor, with an expected interest rate of 10% for 24 months.

Table III in Appendix F shows the sale projection. We expect to have 20 sales in the first month in 2017; we also expect that the sales will increases by 25% every month following. Since our market share is negligible, the marginal cost to increase one more sale is relatively low; we estimate our sales to grow quickly. In the second year, when the local market for our product is saturated and promotion in other cities is still efficient, we expect our market growth rate to decrease to 15%. In the third year, when our market share gets stable, both local and nonlocal sales become stagnant, our product sale will focus on foreign countries and remote areas, which is relatively costly and inefficient; we set our growth rate down to 5%.

Graphs in Appendix F show the estimated long-term and short-term cash flow model for OneLace. We consider the one year graph as short-term and three year graph as long-term. We project that cumulative profit will start negative and continue to decrease until February 2018, with a total net loss of $106,000. After that, monthly profit will become positive, and our investment will start to pay off. We expect to reach the breakeven point in May 2019, which is 29 months after we first started our business. The profit will continue to increase, and the cumulative profit in the last day of our 3 year cash flow model is estimated to be around $150,000.

X. Conclusion and Next Steps

We were able to create a successful and functional prototype. Our design meets all of our top specifications. We were also able to reduce the time it takes to secure skates from one minute *for an experienced parent* with the traditional lacing system to a mere 25.6 seconds *for a first-time-user child*. This time was below our goal time of 30 seconds. For force needed to tighten, we were able to create a prototype which children were able tighten securely without help from their parents. The force needed to secure our system was measured to be ~100N/hand, which is the maximum force a child can pull up with. For future prototypes, we would like to lower this force to continue making it easier for children to put on their own hockey skates. Finally, we wanted to maintain the traditional aesthetic that our users were so fond of. Positive initial user feedback suggests that we were successful in maintaining the traditional look of the skate. As one notable hockey 'purist' noted, "You haven't completely lost the look of the skate, which is the important thing."

Based on the positive user feedback we received on our prototype and the profitable business plan, we suggest that DCEF proceed with the development of our device. As we work to make this happen, there are a few areas of our design that we would like to improve. First, we would like to make the whole design sleeker and less conspicuous. This would involve making the clips, pulleys and handle smaller and a more streamlined part of the skate itself. This would also involve investigating different materials and methods of production. Ideally, we would make all the parts involved in our final product. To make the system easier for consumer use, we would integrate the pulleys and clips into one part. This would not only dramatically lower the number of parts in our system, but would also make it easier for the purchaser to quickly and easily install this system on their skates. We would also review the function and design of the handle. Currently, the handle is bulky compared to the rest of our system. However, it does make securing the skate significantly easier. For this reason, we would investigate either reducing the size of the handle or creating a detachable handle.

Every member of our group is excited to continue this venture and see where it takes us. We plan to pursue patents for various elements of the design.

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XII. Appendices

Appendix A: Specifications

Specification	Justification	Quantification	Test
Time to secure	Our project goal is to reduce the time it takes to put on skates	Time users (< 30 seconds)	Use stopwatch to time how long it took to put on skates
Force Needed to Tighten	Minimal force should be required to secure, so a child can do it themself	Measure how much force it takes to secure the alternatives (< 100 N)	Use force sensors to measure the force needed to secure at different points
Traditional Aesthetic	Our design should look like a traditional hockey skate	Does our design incorporate elements of a traditional skate? (y/n)	Acquire qualitative feedback from users
Security	It is imperative that skates are properly fastened to the foot	User “feel” test	Acquire qualitative feedback from users
Product Cost	Our technique will not be adopted if it increases the cost of skates significantly	Cost of materials (not much more expensive than current models)	Research how expensive each solution is
Ease of assembly/ repairability	Our technique will not be used if it is easily left at home or otherwise unaccessible	Time to assemble system from scratch (~ 2 minutes)	Use stopwatch to time how long it takes to assemble
“Cool” look	We want a design that children would want to wear	Are children willing to wear our skate? (y/n)	Acquire qualitative feedback from users

Originality	The project is uninteresting if solutions of that type already exist	Has our design been thought of before? (y/n)	Research state of the art
Simplicity	Our design should not be too complicated.	How many parts does our skate have, including eyelets, straps, etc? (< 25)	Quantify number of parts
Variable tightness	Users have stated that they often like to have different tightness at different points on their foot	Does the design allow the user to achieve the desired tightness at different points of the foot? (y/n)	Analyze different designs
Safe to put on	Our technique should not pose any risk of injury to the child	Is the design friendly for children between ages 5-10? (y/n)	Examine possible areas of danger

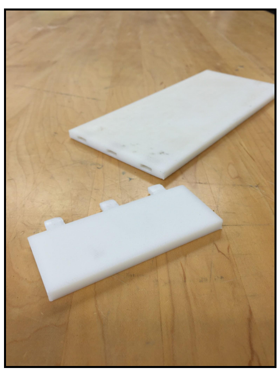
Appendix B: Matrix of Alternatives

Alternatives Matrix	Time to Secure (x3)	Security (x2)	Tightening Force (x3)	Product Cost	Repairability	Traditional Aesthetic (x2)	Looks cool (x2)	Simplicity	Originality	Variable Tightness	Safe to Put on	Ethical	Legal	Total
New Lacing Pattern	3	3	3	4	4	2	4	5	3	4	1	1	1	59
New Eyelets	4	3	3	4	3	4	4	4	3	4	1	1	1	64
New Locking Mechanism	4	3	3	4	4	3	3	4	4	4	1	1	1	62
Change Lace Material	3	3	2	5	3	3	2	5	2	4	1	1	1	53
Change Entry Location	5	3	3	2	2	5	4	2	5	4	1	1	1	66
Zipper	5	1	4	3	1	1	1	3	1	2	1	1	1	47
Velcro	4	2	4	4	2	1	2	4	2	3	1	1	1	52
Buckles	4	2	2	2	2	1	2	2	2	3	1	1	1	42
Torque System	4	3	2	2	3	2	3	2	3	2	1	1	1	49
Multiple Lock Locations	4	4	3	3	3	3	2	3	4	4	1	1	1	59
Mechanical Crank	4	4	4	3	2	3	3	3	4	3	1	1	1	61

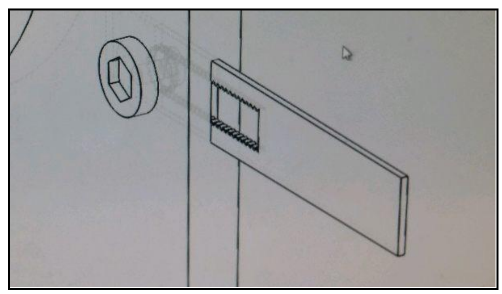
Appendix C: Prototypes

Rear-entry Skate

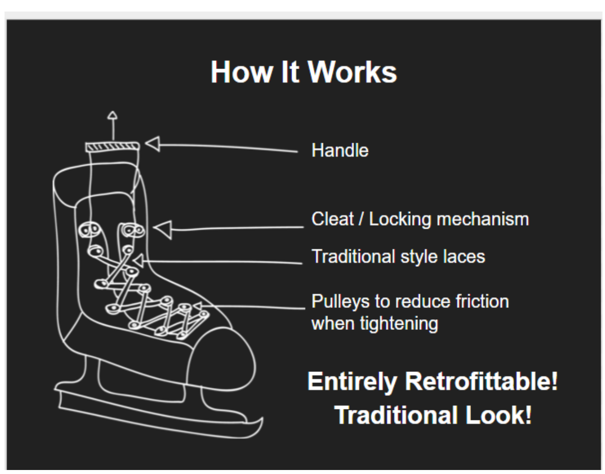
Rear hinge with overlap



Sliding baseplate

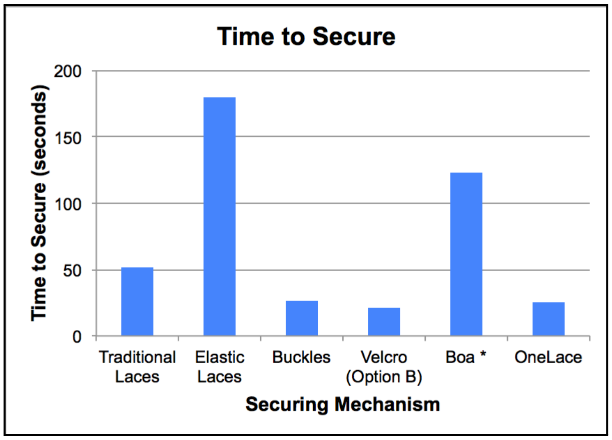


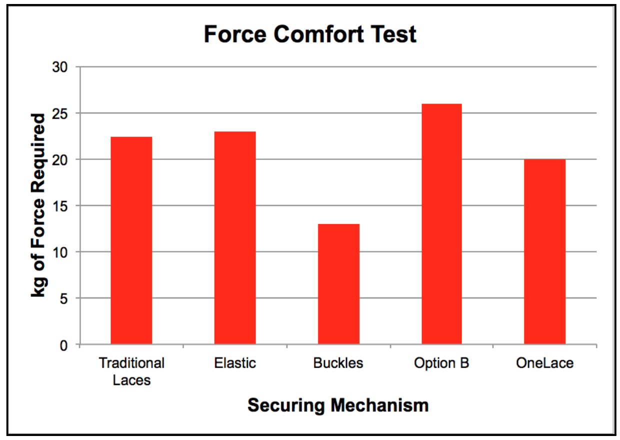
Ratchet

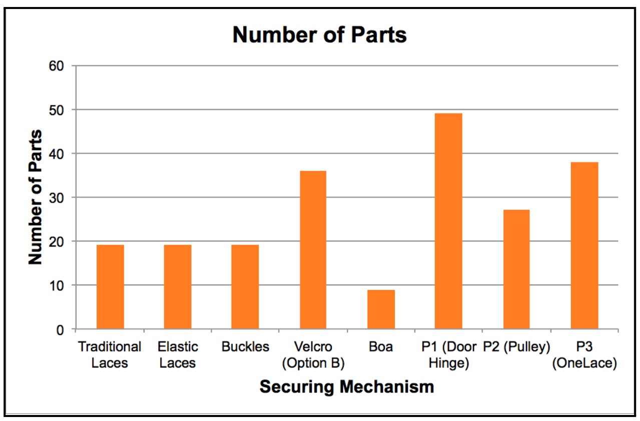


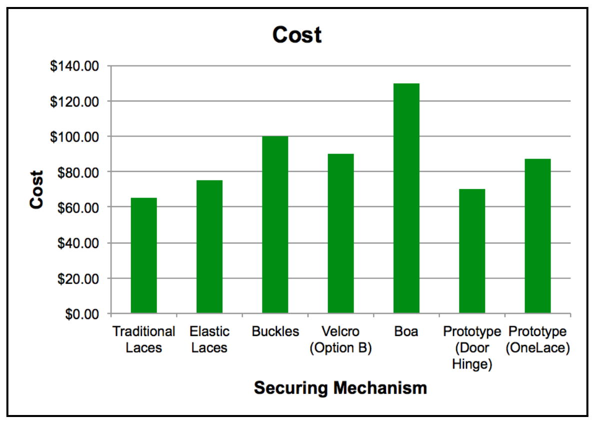
Pulley Prototype Drawing

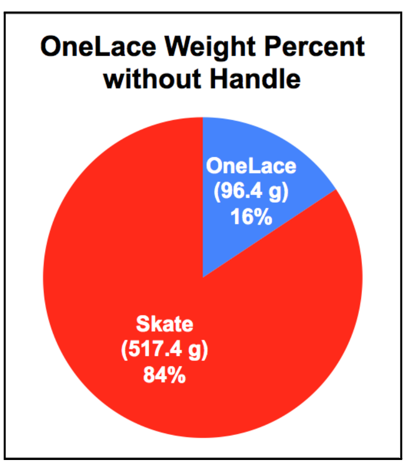
Appendix D: Test graphs

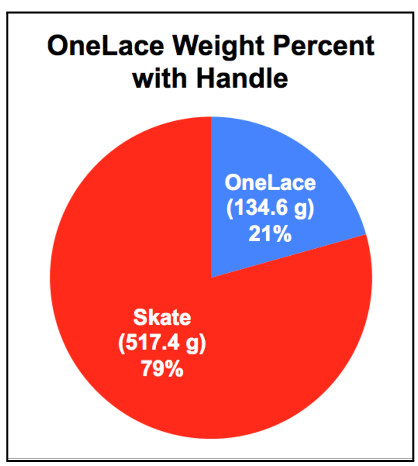




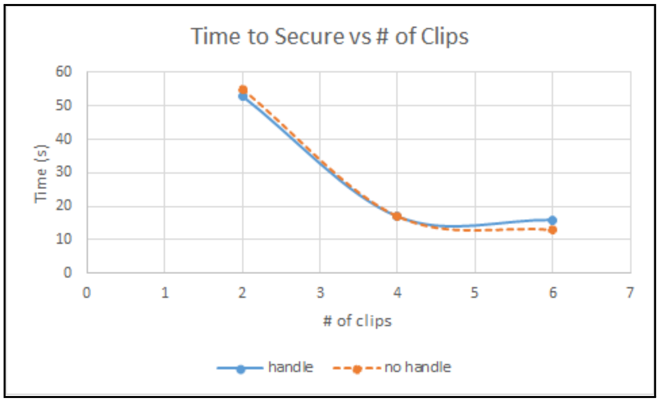


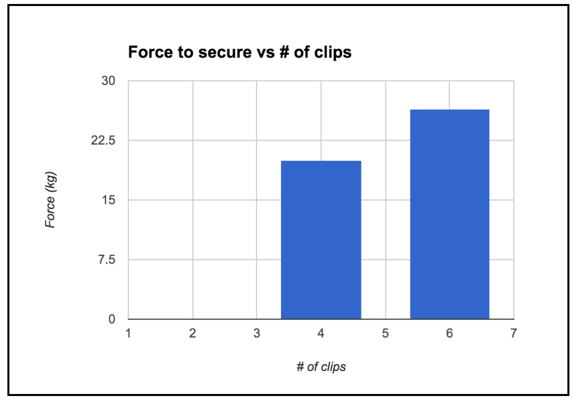


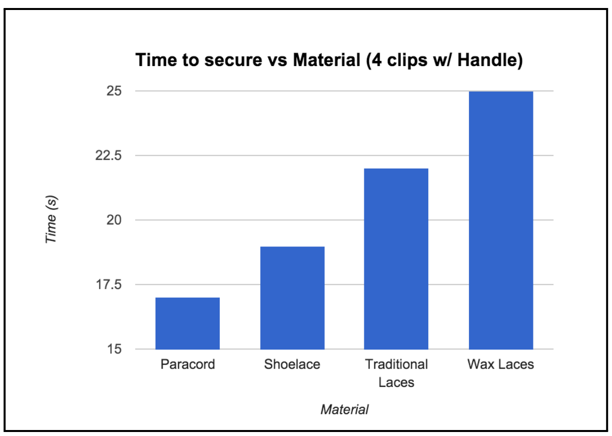


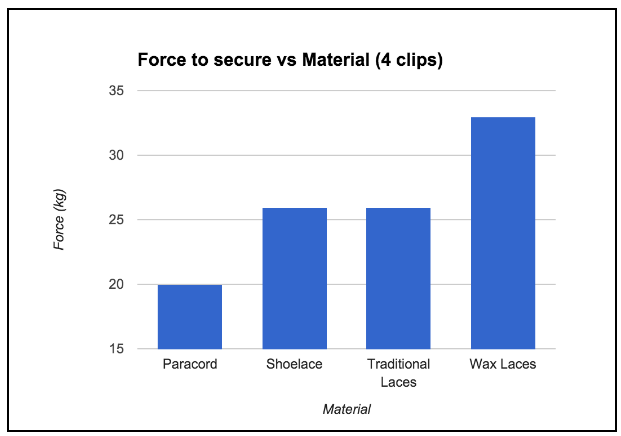


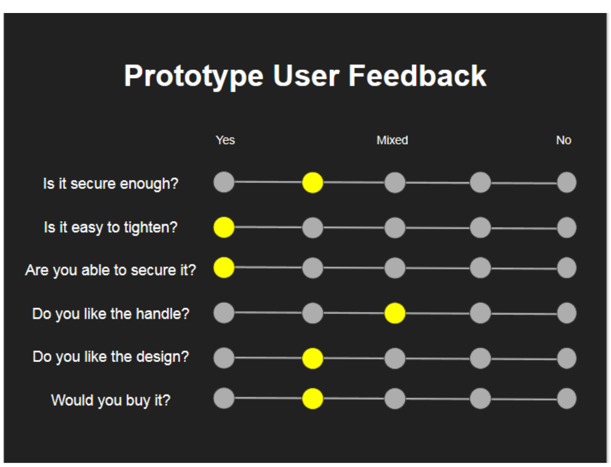
Appendix E: Analysis graphs

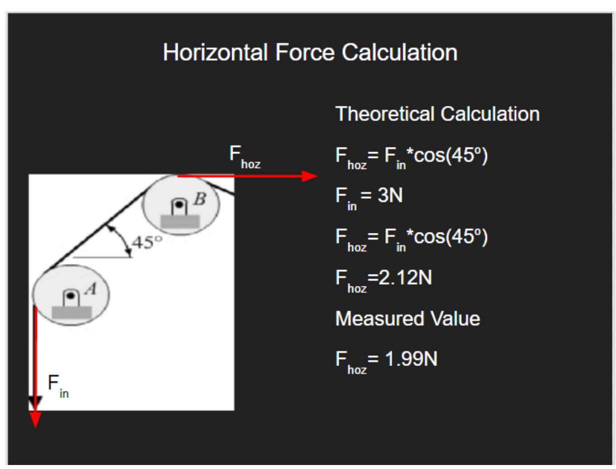












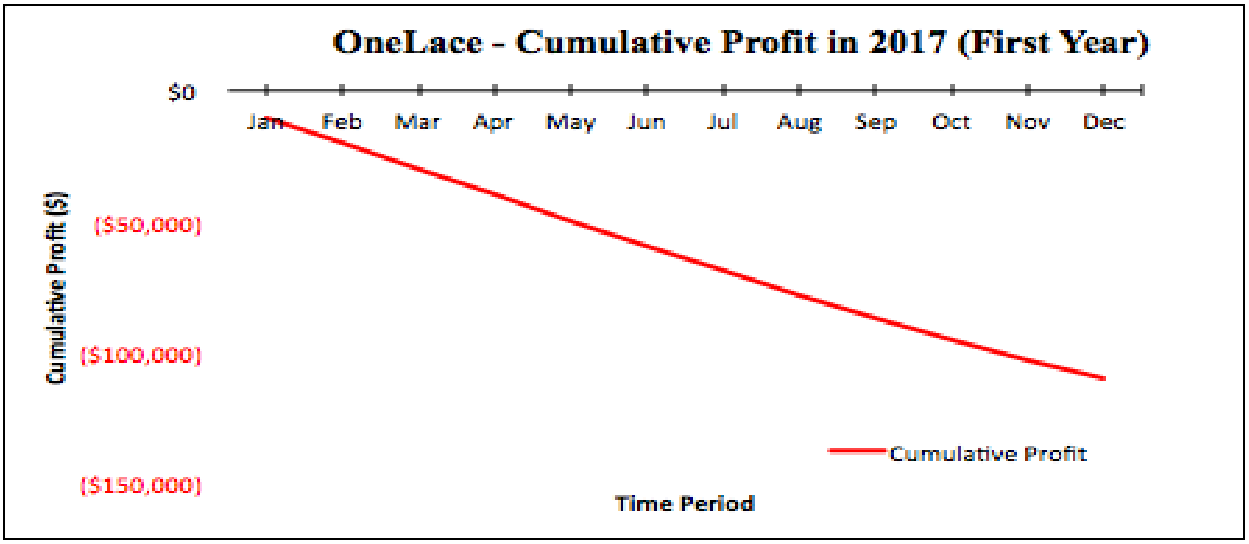
Appendix F: Business graphs and tables

TABLE 1: VARIABLE COST				
Parts	**Amt needed**		**Unit Price***	**Total**
Paracord	11.81	Ft.	$0.04	$0.47
Connector (4)	0.07	Kg.	$3.00	$0.20
Pulleys (8)	8	Ea.	$0.50	$4.00
Screws (18)	18	Ea.	$0.06	$1.08
Screw nuts (18)	18	Ea.	$0.07	$1.26
Screw washers (10)	10	Ea.	$0.08	$0.80
Cleats (4)	0.01	Kg	$3.00	$0.02
Handle (1)	0.04	Kg	$3.00	$0.11
Clip (1)	1.00	Ea.	$0.10	$0.10
Assembly	0.50	Hr.	$7.50	$3.75
Total Variable Costs				**$11.80**

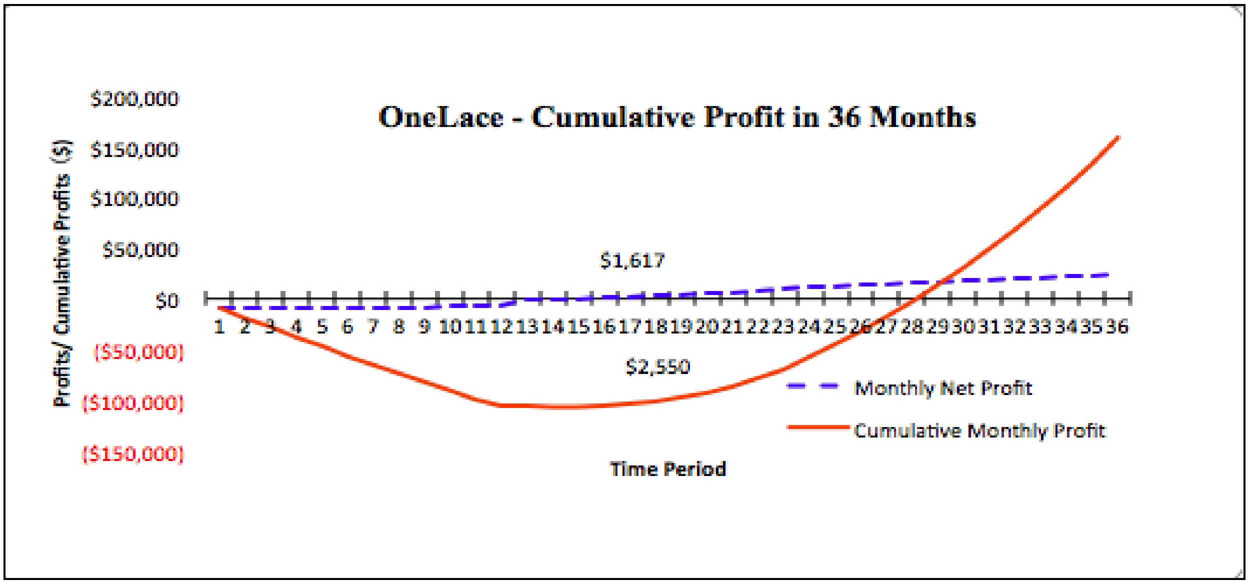
TABLE II: ANNUAL FIXED COST	
Subjects	**Cost**
Rent (factory and warehouse)	$1,000
Leasing of computers, etc.	$0
Heat	$1,200
Electricity	$1,200
Marketing/Advertising	$1,000
Injection Molding (1 @ $25k)	$25,000
Insurance	$1,000
Salesman (1 @ $20K/ Yr.)	$20,000
Executive Salaries (1 @ $25K/ Yr.)	$25,000
Total Fixed Costs	**$75,400**

Package

TABLE III: Market Project in 2017 to 2019			
Starting Date	1/1/17	Ending Date	12/31/19
Years	2017	2018	2019
Monthly Growth Rate	25%	15%	5%
Sales in First Month	20	268	1308
Sales in Last Month	233	1246	2237



Short-term (1-year) Monthly Cash Flow Model



Long-term (3-year) Monthly Cash Flow Model
Breakeven Point in May 2019 (Month 29)