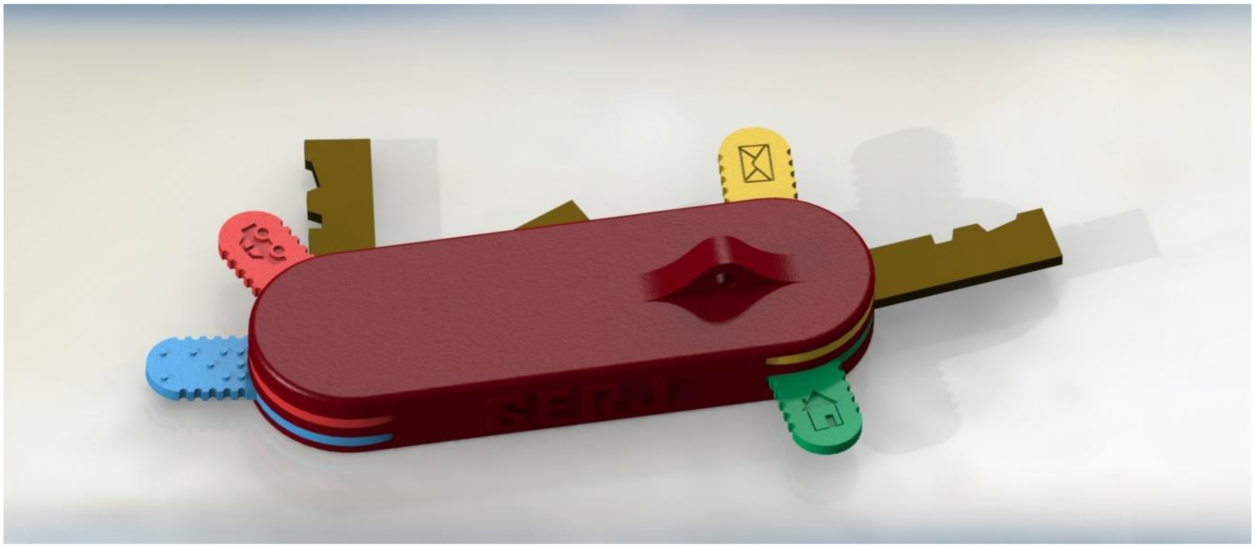
MAE 2250: ODP FINAL REPORT



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OPEN DESIGN PROJECT

PROJECT OVERVIEW

Our team was given the task of using 3D printing and CNC machining technology to design and develop a unique product that has not existed previously on the market and could be sold at a retail price of $99 or less. The allotted budget for design and prototyping was $99. The planning and designing techniques taught in MAE 2250 allowed our group to successfully design and develop a finished product on time. First, we set up a brainstorming session and narrowed our ideas down to three strong contenders. Second, we narrowed down our three choices to one and immediately began developing CAD models and well as developing a timetable for the remainder of the project. After developing a preliminary design, this design was then 3D printed for the first prototype and tested against several loading and moment conditions to find flaws in the design. Finally, a finished product was created, presented, and ready to sell.

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SECTION 1: TEAM OVERVIEW

TEAM MEMBERS AND CONTACT INFO

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TEAM MEMBER RESPONSIBILITIES

Report Responsibilities

The chart below represents the primary responsibilities and co-responsibilities of each member for the design report.

		Segun	Emma	Joseph	Rayne
	Overview and Summary				
Section 1	Team members & Contact info				
	Responsibilities				
	Weekly Updates				
	Gantt Chart				
Section 2	Brainstorming ideas				
	Final 3 Designs				
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Section 3	CAD and Initial Design				
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	Surveys				
	AHP				
	Morph Chart				
	Benchmarking				
	Machining				

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	Final Design				
	Calculations				
	Project Reflection				
Section 5	User Manual and Marketing				
Section 6	Sources				
	Meeting Minutes				
	Presentation Slides				

Project Responsibilities

Rayne - I went MIA for the PDR, and was not responsible for any of it. I hope that I made up for that in the CDR and FDR, where I was responsible for the survey, benchmarking, gantt chart, critical path, CDR presentation, testing, patents, the commercial, the website, and the final design review presentation.

Emma - Having already had experience with CAD modeling and finite element analysis, I contributed most by creating the models for our prototype and final product in SolidWorks. I conducted hand calculations as well as computer simulations in ANSYS to confirm that our model would be able to stand up to the cycles of loads applied in everyday use. I also conducted some prototype testing and analysis, gathering data that was used to improve the next prototype and final product.

Joe - Early on I came up with the ideas for the collapsible mug the phone cradle. Once we settled on the Swish Key, I used the technical writing skills that I have developed on my project team to author the user manual and safety guide. I also created both generations of our morph chart and wrote up or reflection and survey results.

Segun - I played a large administrative role in planning meetings for the team as well as establishing templates for the presentations and report. In addition, I was responsible for taking down notes for each meeting as well as developing the decision and hierarchy matrices to decide what important aspects we needed to focus on for the product. I was also partially responsible for the early designs of the final three choices for our product.

WEEKLY UPDATES

Week 1 – Brainstorming: We thought of several ideas for products, each solving a different problem.

Week 2 – Narrowing down: Each of the ideas from our brainstorming session was subjected to greater scrutiny. We considered the demand for each product, and products that would be difficult, or even impossible, to efficiently manufacture were immediately thrown out the window.

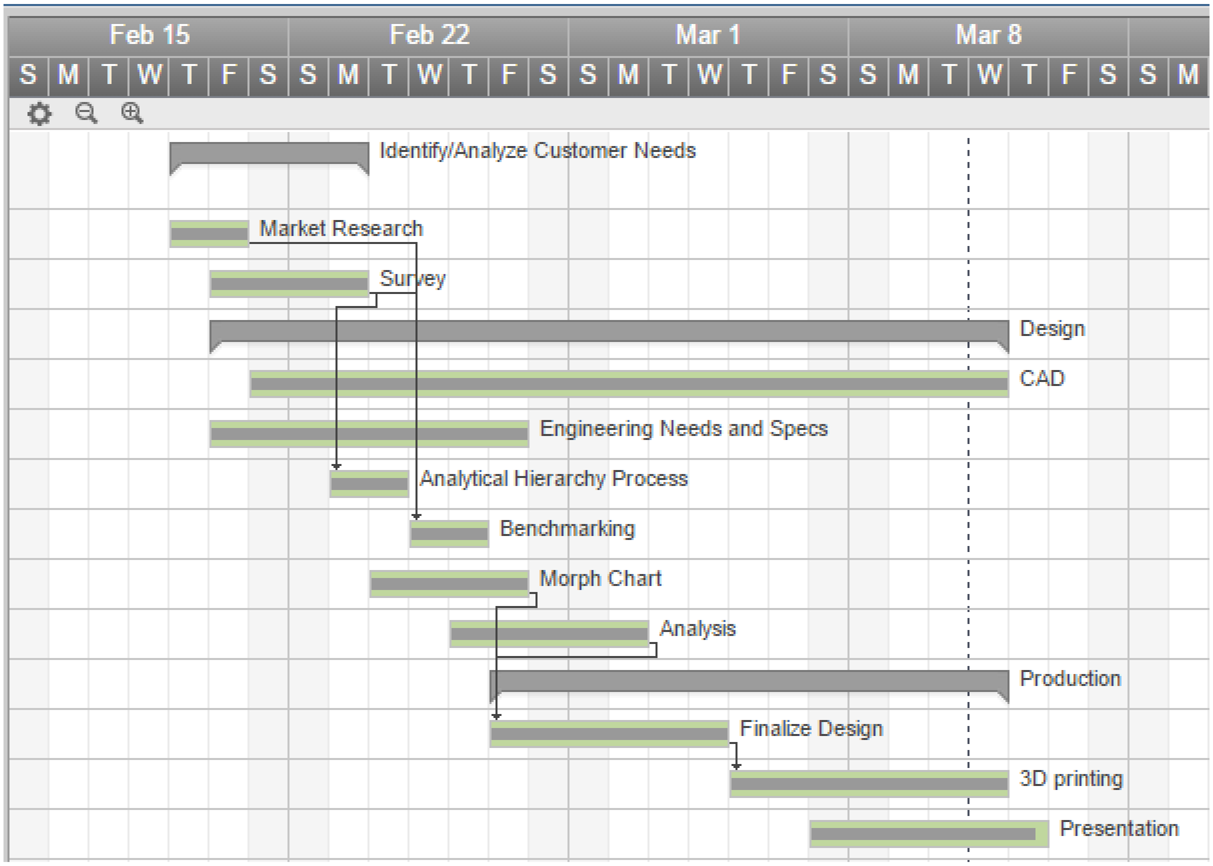
Week 3 – Refining our chosen idea: We refined our idea, an object which can hold and organize keys, into a pocket-knife-like product out of which keys can rotate. We then created the first CAD model of our product from various sketches.

Week 4 – First iteration: We printed our first prototype, and were pleased to find that it performed well under extreme loading conditions. However, some design flaws, such as not being able to fit the tabs inside the body, needed to be corrected.

Week 5 – Final testing: We printed and tested a second prototype which is able to fit the tabs. This prototype, which was printed with a different printer, had a lower IZOD impact strength than our first prototype, and broke when thrown against a wall. We thus learned that our product's material would have to be as strong as our first prototype's material in order to function correctly.

PRELIMINARY GANTT CHART

Task Name	Start Date	End Date	Duration	Predecessors
Identify/Analyze Customer Needs	**02/19/15**	**02/23/15**	**3**	
Market Research	02/19/15	02/20/15	2	
Survey	02/20/15	02/23/15	2	
Design	**02/20/15**	**03/11/15**	**14**	
CAD	02/21/15	03/11/15	14	
Engineering Needs and Specs	02/20/15	02/27/15	6	
Analytical Hierarchy Process	02/23/15	02/24/15	2	3FS -1 day
Benchmarking	02/25/15	02/26/15	2	2FS +2 days, :
Morph Chart	02/24/15	02/27/15	4	
Analysis	02/26/15	03/02/15	3	
Production	**02/27/15**	**03/11/15**	**9**	
Finalize Design	02/27/15	03/04/15	4	10FS -2 days,
3D printing	03/05/15	03/11/15	5	12
Presentation	03/07/15	03/12/15	5	



This is our Gantt chart and critical path, we naturally followed this schedule very closely except we finished with 3D printing and CAD 3 days ahead of schedule.

SECTION 2: CONCEPTUAL DESIGN & PRODUCT SELECTION

INITIAL BRAINSTORMING IDEAS

Our first meeting was spent brainstorming ideas in order to select a product to design. The ideas ranged anywhere from simple to complex in form, machinability, and utility in order place no restraints on creativity, increasing the chances of selecting a viable and useful product to design. In the end, our list had to be whittled down to three ideas for the design project. Items were eliminated for various reasons, including cost, ability to fabricate, complexity, market size, relevance to the assignment, and repetitiveness to past/current designs. Below are all of our preliminary ideas with a brief description, as well as whether or not they made it to the Final Three:

- **Snowbike tires:** The snowbike tires would function in the same manner as snow tires for cars, except placed on bikes to improve traction on icy and snow covered roads and trails
    - **Rejected:** This idea proved too complex and too expensive to fabricate. The design would have to have a specific groove pattern on the tires as well as be made from an amount of specialized rubber unavailable to and too expensive for the group.
- **Compact Snowshoe/ski:** This product was meant make it easier to trudge through the snow. The product would consist of two attachments: a snowshoe and a ski attachment for travelling uphill or downhill.
    - **Rejected:** This idea proved too complex to fabricate. Not only would the group have to design attachments for various shoe sizes, but also accommodate for shoes of various types and brands.
- **Collapsible Bottle:** This product was imagined to act as a water bottle when in use and able collapse into a thin disk when not in use to increase portability.
    - **Accepted:** There is a good market size for those who use water bottles and, although fabricating a bottle to collapse and stretch into place seemed a bit complex, it was more feasible than some of the other rejected ideas.
- **Phone Cradle:** A phone cradle is a product that can clip onto a table or desk and act as a “cradle” for your phone, allowing it to charge or play music while you work, sleep, or exercise.
    - **Accepted**: This idea was thought to appeal to a large market, as this works for almost anyone with a cellphone, smartphone, or music device that could be charged or play music. It seemed easy and relatively cheap to manufacture and served a purposeful function.
- **3D Printed bracelets:** These serve no real mechanical function. They were simply conceptualized for aesthetic purposes.
    - **Rejected**: This product serves no real purpose and the team decided to divert focus elsewhere
- **Compact & Safe box opener:** This product would be an improvement to current boxcutters by being more compact and with added safety features to prevent self-injury.
    - **Rejected:** There was really no real improvement to be made to current box cutters and most already have added safety features, such as retractable blades.

- **Cuff Protector:** This product would attach to the bottom cuffs of jeans and other pants to protect them from being damaged by ground salt
    - **Rejected:** This product would need to accommodate a large variety of jeans sizes and fabrics. In addition, such a cuff protector would most likely cause discomfort for the user as the protector would constantly batter the shins of the user. In addition, such complaints of ground salt ruining pants beyond repair was found to be minimal
- **Integrated Earmuffs:** This product was designed to function as a set of earmuffs to protect ears from the cold and to function as speakers with earbuds integrated into the earmuffs.
    - **Rejected**: Such a product was thought to be unoriginal and unmotivating for the consumer to buy. Several oversized headphones already exist and would provide ample comfort in the cold. In addition, the user could simply put in some earbuds over a skull cap or regular earmuffs without trouble..
- **Front Protective Cover for Phone:** This device was thought to function as a protective screen/cover for a phone to protect the screen in case it were to hit a sharp corner or fall to the ground. It would be built into a phone case and retract when the phone is in use.
    - **Rejected:** This device already exists for many smartphones. There really is no significant way to improve this.
- **Key Box:** This device was conceptualized to function as a Swiss Army Knife for keys, replacing the unorganized and cluttered form of the key ring.
    - **Accepted:** This product provided the possibility to create something unique. In addition, it was deemed to be easy to either machine or 3D print compared to some of the other items on this list.
- **Headphone Case:** This product was conceptualized to serve as a way to store earbuds in a convenient manner. The case would attach to the back of the music device and retract the headphones on a circular spindle inside the case when not in use.
    - **Rejected:** This idea would not have been too complicated to make, but this was a product that has been attempted many times in the past for this project. The team wished to create a product that was more original.
- **Stable bed tray:** This tray was conceptualized to perform in a stable manner, regardless of the slope or instability of the surface. This was primarily thought to be for those who are bedridden and need their food delivered to them.
    - **Rejected:** This tray was deemed too complex to create. Although the tray component would be easily machinable, the legs of the tray proved a serious challenge. They would need to automatically and immediately adjust their height to keep the tray orthogonal to the field of gravity. It was deemed highly probable that the use of gyroscopes would need to be employed for this to work.
- **Ring flashlight:** This product was conceptualized to integrate two existing items: a ring and a flashlight. There would be a small, but powerful LED light attached to the ring. The purpose of this product was to eliminate the need of carrying a large flashlight around as well as improving the mobility of carrying around a light-producing device.
    - **Rejected:** The ring itself would not be difficult to machine or 3D print. The main issue came from integrating electrical components onto the ring. Since the team was not very experienced with constructing circuits or LED lights, it was decided that this would not be the best product to pursue

- **Textbook clip/weight:** This device was conceptualized to keep pages from flying all over the place when trying to study or work on assignment. It would work by attaching a weighted clip to the pages for them to stay in place.
    - **Rejected:** There was no real incentive from the team to create this. In addition, this idea was unoriginal as many other groups were considering this same idea at the time.

FINAL THREE DESIGNS WITH PROS AND CONS

The Key Box, Collapsible Bottle, and Phone Cradle were thought to be viable products. We immediately created sketches and rough designs from the customer needs and desires to further visualize our products. With this, the team was also able to find some constraints and limitations with each product as well as some methods in which the product could function successfully around those constraints. Finally, the team was able to develop a list of positive and negative aspects about each product.

The Key Box

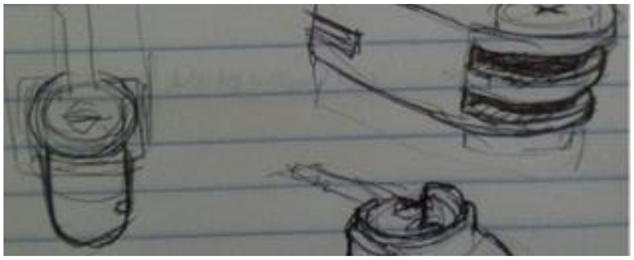


Figure 2.1

Customer Needs: A quick and efficient way to select a key instead of fumbling around with a key ring

Constraints and Limitations: The Key Box needed to be able to fit in one's pocket comfortably. This automatically put a limit on how many key could viably fit into the Key Box. In addition, too many keys (i.e. too much depth) would destabilize the product. In addition, the keys needed to be easy to insert and remove. Also, there was the consideration that not all keys would fit well or at all into the Key Box (skeleton keys or automatic car keys). The Key Box would have to be designed around these constraints and limitations.

Releasing the Key: The basic design for the Key Box was modeled after a Swiss Army Knife. The body would be longer than the length of two keys with a depth to hold two or three keys per side. The primary issue then came with the actual release mechanism. There were several ideas as to how the key in the Key Box would be released:

1. **Strip Deformation:** One method, modeled after the release mechanism for a switch blade, involved the deformation of a metal or polymer strip in order to "unlock" the key. Basically, the user would push a thin strip to the side to allow the key to rotate freely.
2. **Spring Load:** Another method involved the use of springs. A linear spring would be attached to the wall of the key box and when a button was pressed, it would act as a

trigger to release that key. A similar idea was presented, but with a torsional spring. The key could be put back into place simply by rotating it back into its rest position.

3. **Friction and Tabs:** This method proved to be the least complicated. The key would be stored in a rest position simply by the force of friction between two walls of the Key Box. When the key is needed, a tab positioned orthogonal to the key could be turned, rotating the key along with it.

Key Insertion: The consideration of "screwing" keys into the box was automatically thrown out for the convenience of the customer. Our ultimate idea was to place the keys on "tabs." These tabs would consist of a circular body to place the key in as well as a tab on the outside of the disk orthogonal to the key to provide a way to deliver a moment to turn the key. Once the key is in the tab, the tab itself would be placed into the Key Box and be held between two grooves by friction.

The Collapsible Bottle


Figure 2.2

Customer Needs: A way to store liquid, but not have the bottle be a burden when it is empty.
Constraints and Limitations: The bottle, or a bladder in the bottle, *must* be waterproof (otherwise it would not come close to serving it function). In addition,
Waterproof Bladder: Because of the nature of the bottle, the team thought it would be wise to place a waterproof, polymer bladder inside of the bottle that would deform easily, but be resistant to multiple compressive and tensile loadings.
Method of Collapse:

1. One idea to keep the bottle extended was to create a series of cylindrical cones that could be rotated to lock in place. This idea, however, partially violated one of the constraints of being compact. In addition, this idea ran a serious risk of damaging the waterproof bladder due to shear stress.
2. Another method the team came up with is one in which the bottle was made up of an "accordion bladder," being able to collapse into a thin disk when not in use and function as a stiff bottle when filled with liquid

<u>The Phone Cradle</u>

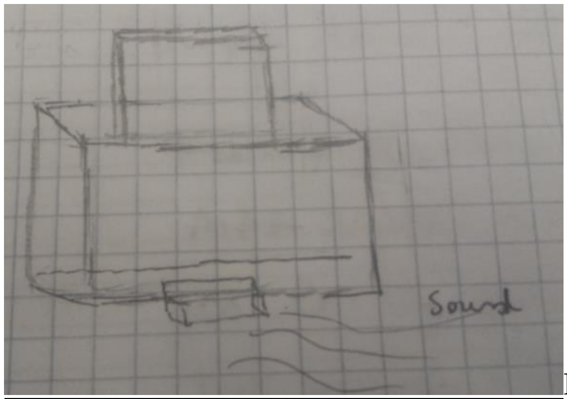


Figure 2.3

<u>Customer Needs</u>: A mobile cradle in which a phone can be placed to charge and/or play music.
<u>Constraints and Limitations</u>: The phone cradle must be able to stay attached to a wall or desk and be easily removed for mobility. In addition, it must accommodate a variety of phone shapes and sizes
<u>Attachment:</u> The team came to a general consensus that the support from the phone cradle should come from clamps instead of screws to increase mobility and ease of use for the consumer. A secondary idea arose that involve the use of an adhesive.
<u>Phone Storage</u>: There were two ways in which the the team thought to store the phone:

1. **Grooves:** The phone would be placed into a "sink" inside of the cradle in order to stay in place. This proved problematics, however, as this would only be able to accommodate a set variety of sizes of phones and music devices, violating one of our constraints
2. **Springs:** This proved to be the best idea out of the two. Basically, there would be a set two linear springs attached to each of the wall orthogonal to the thin side of the phone, and a cushion on each set of springs to attach them in parallel. In this way, virtually any phone of any size can be accommodated to the Phone Cradle

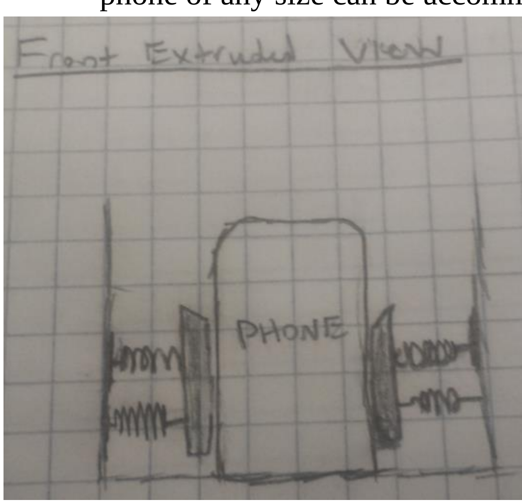


Figure 2.4: The Spring constraint idea for the Phone Cradle

<u>Pros and Cons of Each Product</u>

Product	**Pros**	**Cons**
Key Box	● Mobility - Highly mobile and able to fit in the pocket of a consumer ● Organization - The Key Box allows for the user to do away with the clutter of a key ring. It is easier for a consumer to choose and select a key ● Ease of use - The Key Box already has each key selected. All that it needed from the user if for him or her to select a tab, rotate it, and access the key, rather than fumble through the clutter of a key ring	● Variation of Inserts - Must be able to fit a variety of keys ● Complexity of Design - This is the most complex of the three designs, involving multiple rotating and interdependent parts. If this is the final choice, then it will need to be designed to near perfection for it to work properly. ● Limited Market - Those who carry a large number of keys (10 or more) would not be able to use this product and have it fit easily into a pocket. in addition, height becomes another issue
Collapsible Bottle	● Mobility - When in its collapsed form, the bottle is highly mobile, much to the comfort of the consumer ● Inexpensive - The material to make this bottle was estimated to cost anywhere from \$5.00 - \$10.00, so they could be produced cheaply ● Large Market - There are many people who use water bottles, especially those in	● Shear Forces - If the locking mechanism is triggered by rotation, then this provides the risk of the waterproof bladder or lining failing due to shear stress ● Production - There was no clear way to machine, laser cut, or 3D print this product with collapsible properties, which provided a serious issue. ● Competition - There

	college, in the gym, or at work.	are already products very similar to this idea out there that appear to work well.
Phone Cradle	● Removes Clutter - This product can create space for one's desk by placing not only the phone inside, but also pens, pencils, etc. ● Inexpensive Alternative - The acoustic design allows musics to reverberate into the room. Instead of paying a large amount for an expensive electronic docking device, the phone cradle could act as an inexpensive alternative ● Large Market - This product would appeal to many who have a cellular or musical device as a way to charge it or play music from it	● Mobility - Unlike the Key Box and Collapsible Bottle, this product is not very mobile. it can't fit in your pocket and if were placed into a bookbag, it would take up a fair amount of volume ● Variety of Phones - This product not only needs to take into consideration a variety of phones, but a variety of music devices that alval ry widely in shape, size, and button placement.

PUGH DECISION MATRIX AND SELECTION

In order to formally select our product, the team took some basic criteria, as well as the pros and cons, into consideration. Each product was pitted among each other by being assigned specific values in the matrix. -1 denotes a harmful criterion. 0 denotes a neutral criterion. 1 denotes a positive criterion. The product with the highest score would be the one the team selects

Criteria	Bottle	Keybox	Phone Cradle

Mass	1	1	0
Fabrication	-1	1	1
Mobility	1	1	-1
Price	1	1	1
Production Time	-1	1	1
Laser Cut	-1	0	1
3D Print	-1	1	1
Market Size	1	0	1
Competition	-1	1	1
Durability	-1	1	1
Reliability	0	1	0
Ease of Use	1	1	0
SUMS	**-1**	**10**	**7**

- **Product Selection - The Swish Key:** Based on the Pugh Decision Matrix, the team ultimately decided to select the Key Box, renamed the Swish Key. Ultimately, the bottle was deemed to difficult to machine in the shop or to produce with a 3D printer. Although it would appeal to a large market, the issue of the durability of the bladder as well as its fabrication led to the bottle's elimination from the project. The Phone Cradle was a close second. Although both products were deemed to be reasonably machinable and were within the realm of possibility of 3D printing, the keybox ultimately won in mobility, reliability, and mass, which is why we decided to go with it instead of the phone cradle.

PROJECT PLANNING

We started planning by envisioning the design. We all bounced ideas off each other until we had a simple set of goals for the project (taking the survey and our competitors largely into account). Our list of goals is elucidated below.

The product will...

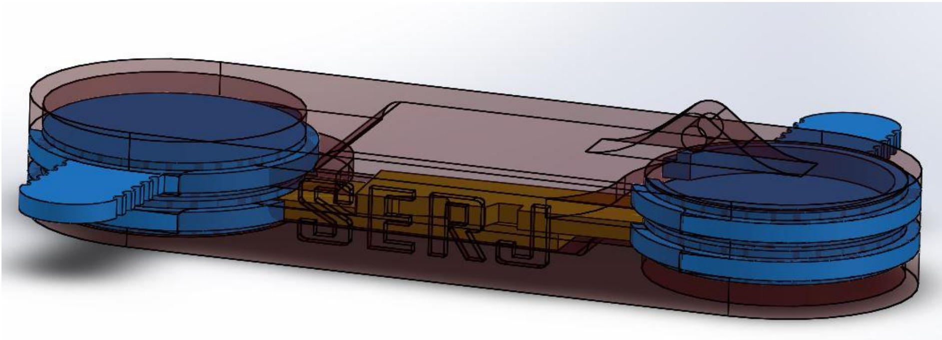
1. Organize keys visually
2. Store a variety of keys
3. Be simpler than our competitors
4. Withstand around three years of use

We then planned our meeting times, which were every monday (variable time) and saturday (as needed), we also agreed to do most of the work individually because thats how most of us liked to work.

From there all the planning came naturally and we were able to keep ahead of our preliminary gantt chart throughout the process.

SECTION 3: DETAILED DESIGN & ANALYSIS

INITIAL CAD AND PROTOTYPE DESIGNS



The initial CAD model was used to print the first prototype. Unfortunately, the back of the body was made too big in the model, which prevented the tabs from fitting inside.

In the first prototype, we discovered this defect in the model. We also found that the worst loading conditions (being dropped, sat on, and over-opened) would not be an issue. However, the tabs left too much wiggle room

for the keys.

In the second, and final, prototype, the issues with the body were fixed. Here, you can see that all four tabs fit into the slots. Also, the key ring hole on the top was enlarged to allow attachment to larger key rings.

ENGINEERING NEEDS AND CONSIDERATIONS

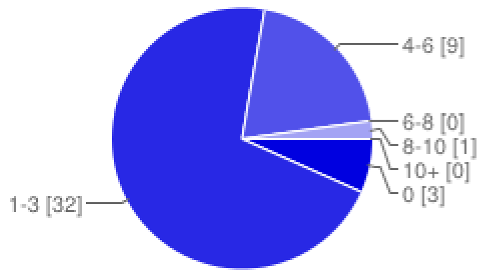
Through our survey, it was found that most people use their keys about four times per day. Since we want our product to last for three years or more, it must withstand

4 cycles/day*365 day/year*3 years = 4380 cycles. In order to achieve this, our product would have to stand up to the loading caused through regular use with a Safety factor of 4 or greater.

Along with the regular loading, our product would have to be able to survive other common, although unintentional, loading conditions. These loading conditions are: being dropped on the floor, being sat on while in someone's back pocket, and being over-opened, that is, having the tabs pushed up against the body of the box even though the tab is already in the fully-open position.

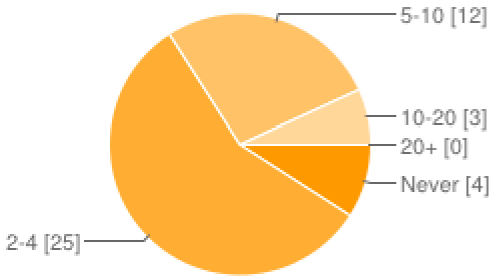
SURVEYS AND FEEDBACK

How many keys do you use regularly?



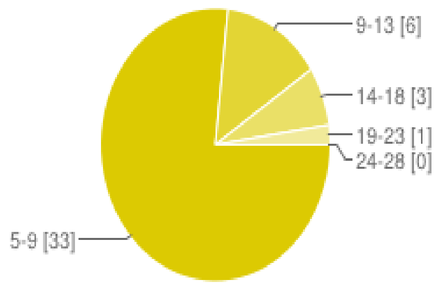
0	**3**	7%
1-3	**32**	71%
4-6	**9**	20%
6-8	**0**	0%
8-10	**1**	2%
10+	**0**	0%

Roughly, how many times a day do you use a key?



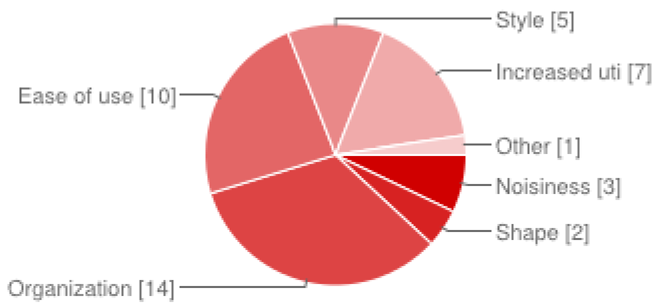
Never	**4**	9%
2-4	**25**	56%
5-10	**12**	27%
10-20	**3**	7%
20+	**0**	0%

How much money would you spend to replace your key ring if the replacement improved on your choice aspect?



5-9	**33**	73%
9-13	**6**	13%
14-18	**3**	7%
19-23	**1**	2%
24-28	**0**	0%

What aspect of key rings would you want changed?



Noisiness	**3**	7%
Shape	**2**	4%
Organization abilities	**14**	31%
Ease of use	**10**	22%
Style	**5**	11%
Increased utility	**7**	16%
Other	**1**	2%

These surveys were highly informative. The most important outcome of the surveys was to confirm a demand for the Swish Key. This is seen in the data of surveys one and two. Many people use keys often enough to warrant a product such as this, and survey three shows a willingness to pay to improve on the existing key ring. As seen in survey four, organization is the most desired improvement to the key ring, and it is also the focus of the Swish Key. Survey four also confirmed a need for utility and ease of use, which had a profound effect on the design process.

ANALYTICAL HIERARCHY PROCESS

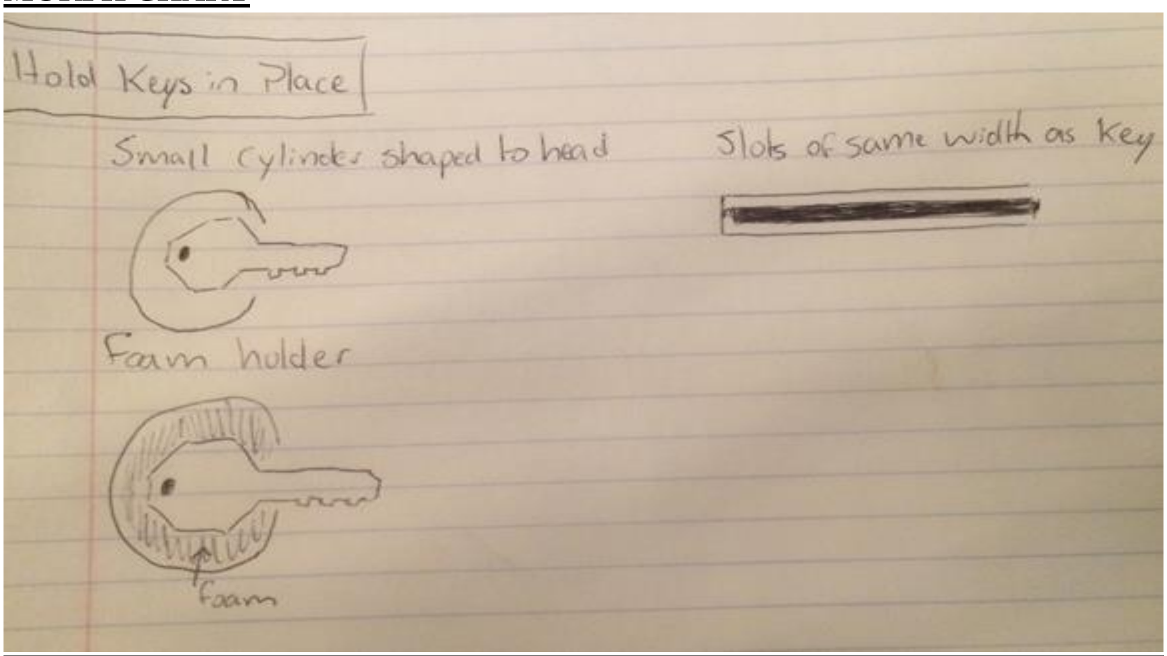
In order to ensure that the right aspect received the appropriate amount of development focus, an Analytical Hierarchy Chart was constructed. The values assigned to each index represented the the importance of the row element in relation to the column element. For example, in row 4 of column 1, the relation is how important reliability is compared to material cost:

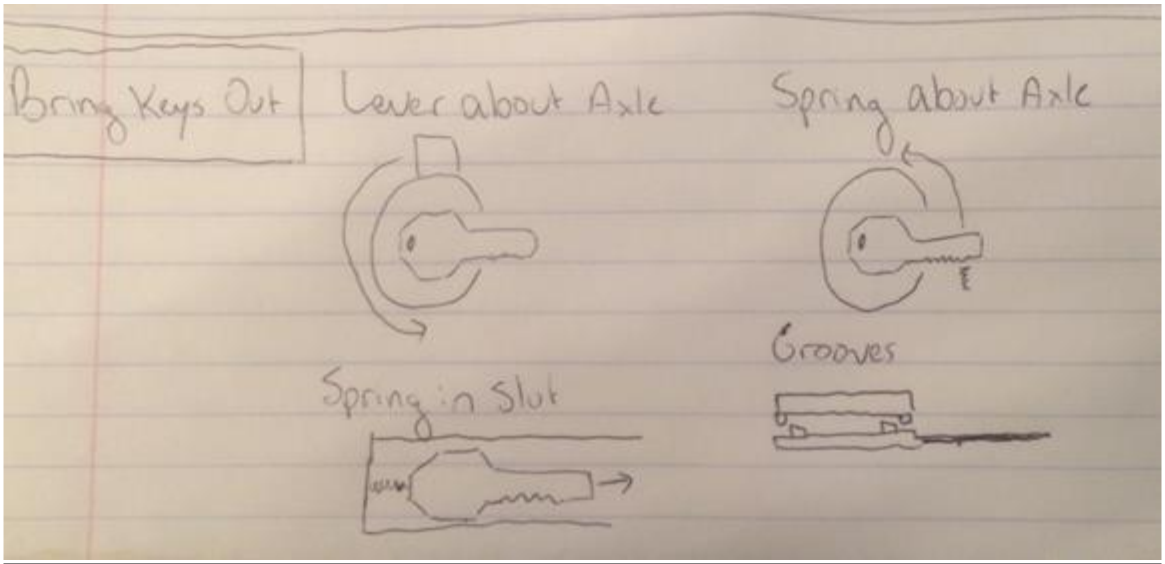
- 1 represents equal importance.
- 3 represents slightly more importance over the other
- 5 represents ample importance over the other
- 7 represents high importance over the other
- 9 represents the utmost importance over the other

	material cost	Mobility	production time	reliability	Row Sums
material cost	1.0000	0.1429	0.2000	0.1429	1.4829
Mobility	7.0000	1.0000	4.0000	5.0000	17
production time	5.0000	1.4000	1.0000	7.0000	14.4000
reliability	7.0000	0.2000	0.1429	1.0000	8.3429
Column Sums	20.0000	2.7429	5.3429	13.1429	

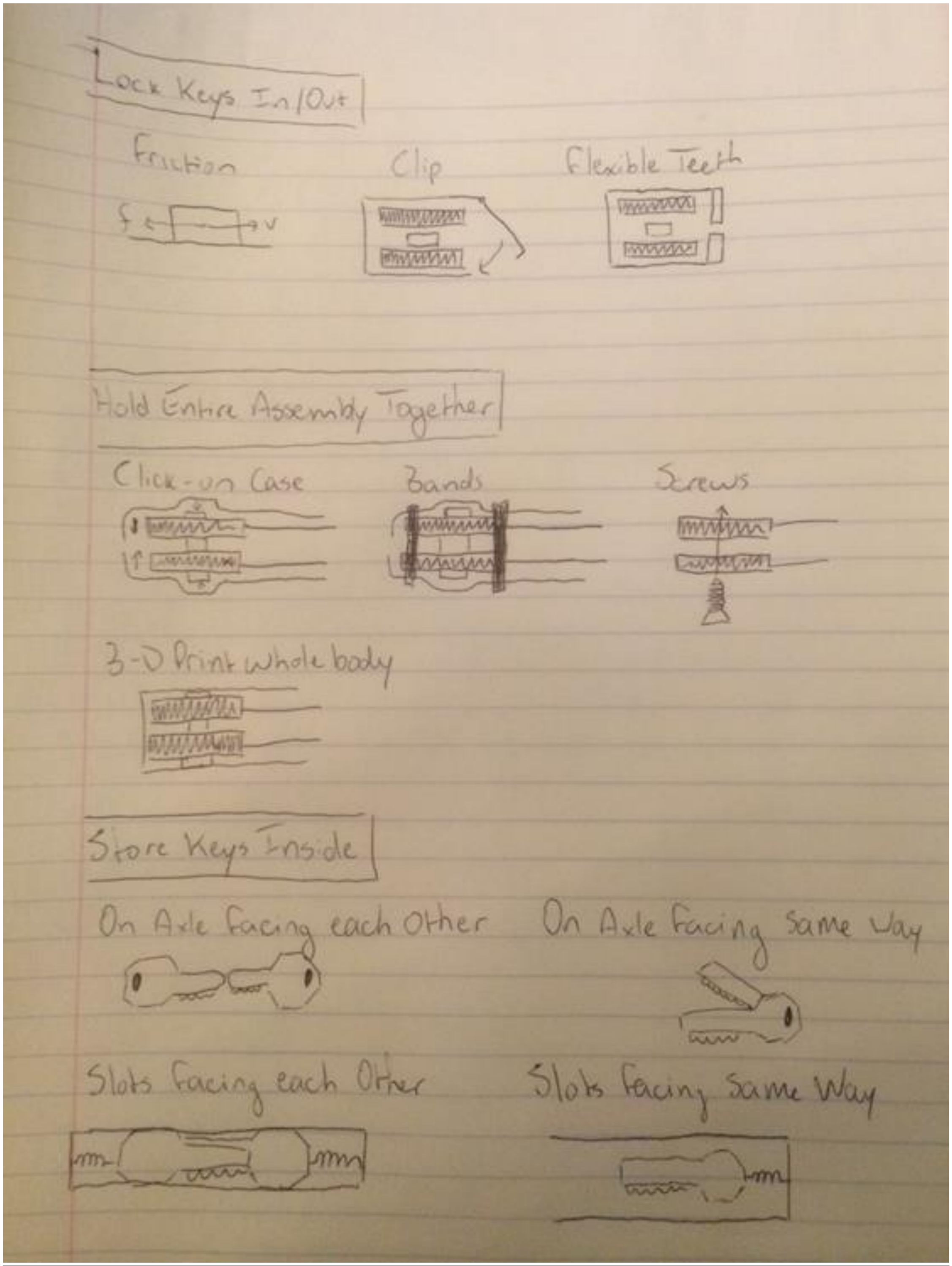
From the matrix, it was found that the least important of the criteria was material cost. Although this would have an impact on the viability of the Swish Key, it was something that was determined to be of secondary concern. In addition, mobility proved to be the most important aspect of the Swish Key.

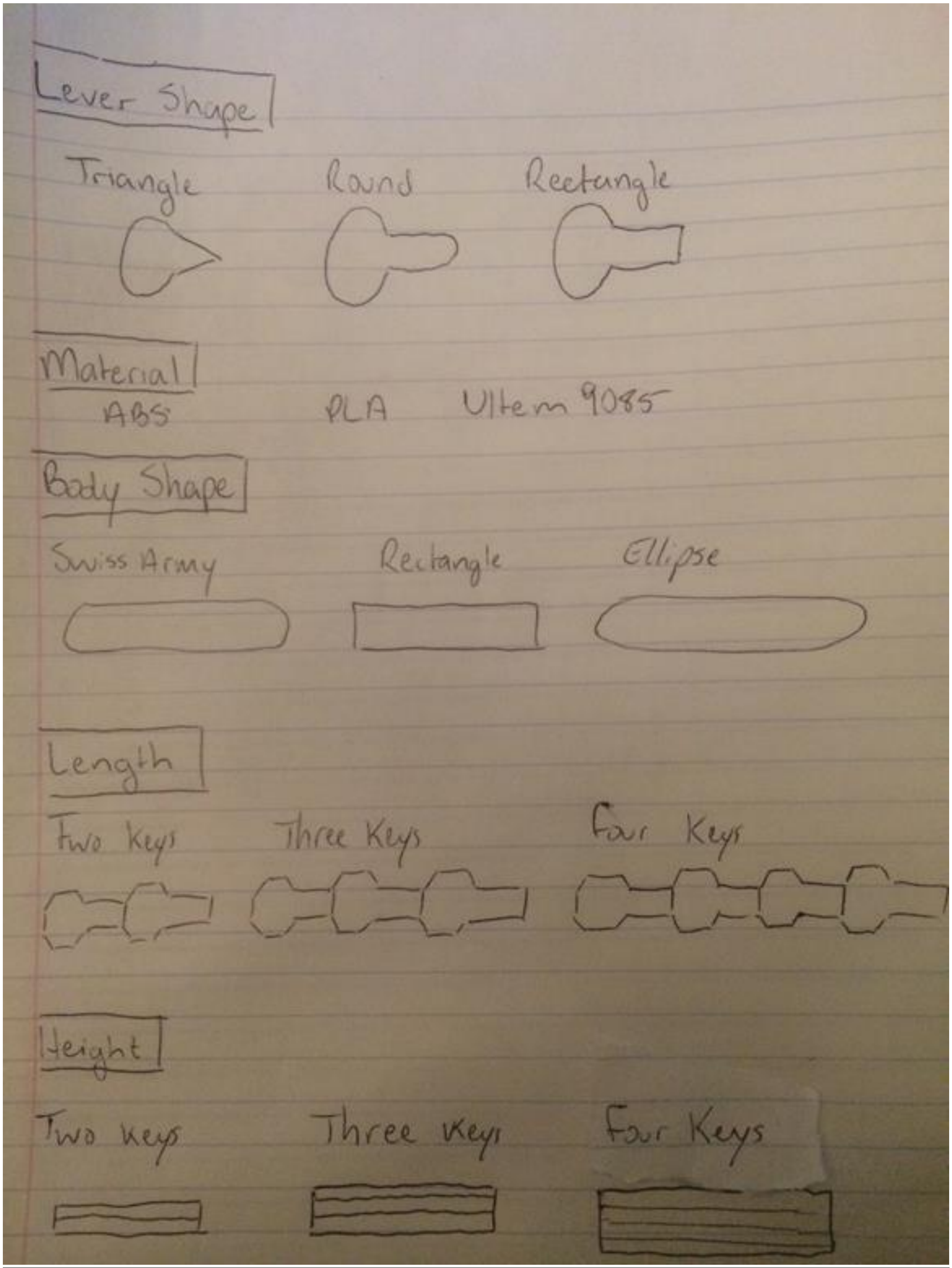
MORPH CHART





Bring Keys Out
Lever about Axle
Spring about Axle
Grooves
Spring in Slot


Lock Keys In/Out
Friction
Clip
Flexible Teeth
Hold Entire Assembly Together
Click-on Case
Bands
Screws
3-D Print whole body
Store Keys Inside
On Axle facing each Other
On Axle Facing Same Way
Slots Facing each Other
Slots Facing Same Way

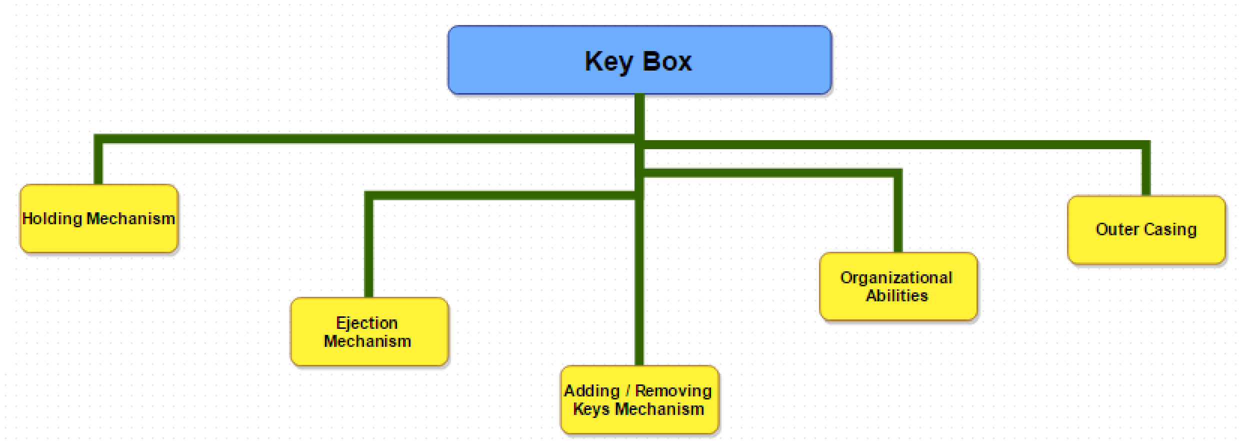

Lever Shape
Triangle
Round
Rectangle
Material
ABS
PLA
Ultem 9085
Body Shape
Swiss Army
Rectangle
Ellipse
Length
Two Keys
Three Keys
Four Keys
Height
Two keys
Three keys
Four Keys

BENCHMARKING, PRICING, AND COMPETITORS

	Our Product	Fan Key	Key Smart
Weight	30.23 g	8.50 g	22.6 g
Dimensions	4.4 x 1.4 x 0.6 inches	3.5 x 1.2 x 0.6 inches	5.5 x 4.3 x 0.3 inches
# of Keys	Currently, 4	30+	Options ranging from 2-22
Cost	40$	30$	20-32$
Material	ABS	Aluminum	Aluminum and Steel
Production	3D printer	CNC	CNC
Other considerations	More secure	Prone to falling apart	Prone to falling apart
	Superior organization	on par with key ring	on par with key ring
	More customizable	generic	Can add a flash drive
	Simple Assembly	Complex assembly	Complex assembly

This table describes the main differences between our product and the main competitors on the market. As you can see, quantitatively, our competitors appear superior, but this is misleading for a bevy of reasons. If we were actually developing this product for mass production, we would be able to offer more competitive prices by buying our own 3D printers. Furthermore, our product is vastly superior qualitatively; we have eliminated many of the issues that people complained about on Amazon. Issues like the product falling apart (because the same mechanism for ejecting keys for use loosens the screws that keep the keys in place) or being complicated to assemble we have eliminated with our sleek and simple 3D printed design. We have implemented the organizational abilities that are clearly required to elevate this concept above that of the simple key ring and we have added the marketability of a 3D printed design. Overall, our product is superior simply because it actually makes improvements on the key ring rather than adding complexity without significant benefits.

FUNCTIONAL DECOMPOSITION AND PATENTS



This is a functional decomposition of a product intended to store keys and eject them for use.

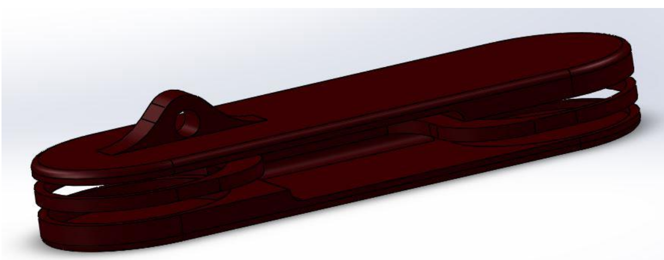
There are numerous patents describing a very similar product to ours invented around the 1950's. Patents US 2863312 A, US 2295123 A, US 2300979 A, and US 2695511 A, all named "Key Holder" describe several, very similar products that hold keys. They all employ an axle that goes through the hole of the key, and use a variety of designs for the outer casing. They all use complicated mechanical parts to add and remove keys, as well as eject them. All but one patent completely disregards organizational abilities, and the one which does mention it uses a different system.

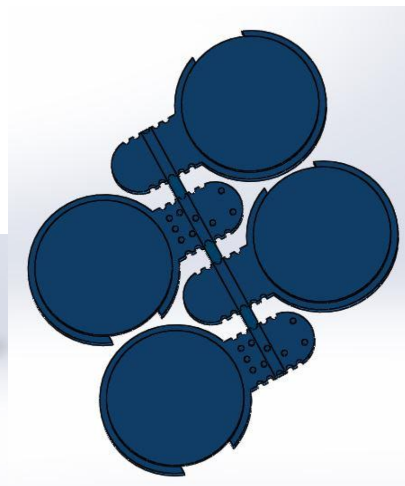
Starting in the 1980's there was a new wave of key holding inventions Patents WO 1991003185 A1, US 4646913 A, US 5199560 A all improve upon the designs of their past but all require that the keys be cut or made only to have teeth. Patents US 4653299 A and US 8146736 B2 both use a sliding mechanism to eject the keys.

There are a few remaining patents, US 5215190 A, WO 1996039888 A1, CN 100493407 C, WO 1999033370 A1 but they all are designed to be machined out of metal and assembled using mechanical parts, or use assorted mechanisms to eject the keys. None of the patents are designed with 3D printing in mind. Our design is vastly different than anything that has been patented because it only has two unique parts, it's simplicity, allowed by 3D printing, is truly revolutionary.

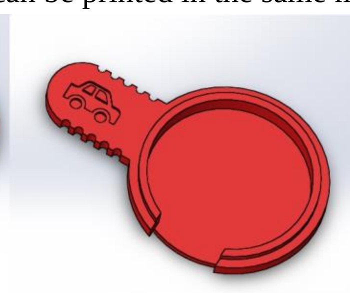
MACHINING AND ASSEMBLY PLAN

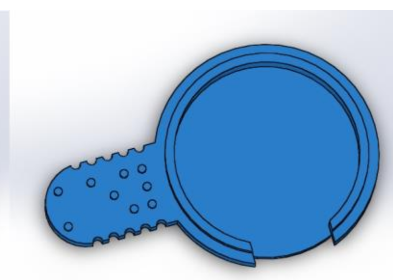
Our product consists of 5 parts, all of which are 3d-printed. These 5 parts are printed in two sets: one set includes the body, the other set includes all four of the tabs, as shown below.





Other, customized versions of the tabs can be printed in the same manner.





SECTION 4: PROTOTYPING AND FINAL DESIGN

PROTOTYPE I

We printed our first prototype, and were pleased to find that it was sufficiently strong and impact resistant for our needs. However, not all types of keys fit, and the ones that did still had room to wiggle. Also, design flaws prevented our first prototype from fitting together correctly: the spine of our prototype body is too big, preventing the tabs from fitting inside, as seen below.

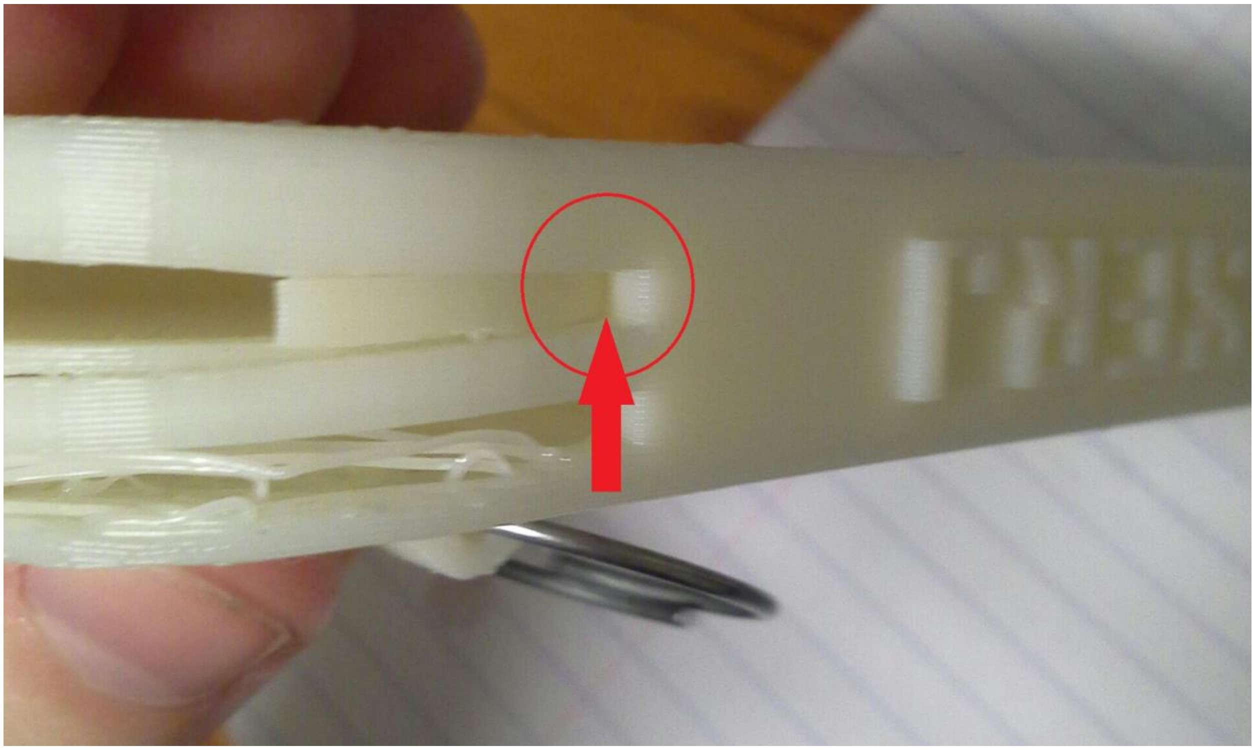


Figure 4.1: Prototype 1 image: Here, the red arrow points to where the tab runs up against the edge of the spine, and is unable to fit inside.

We did stress testing on the skeleton of this prototype once we knew it couldn’t work. It was loaded as shown below with no keys or the key holders in their slots.

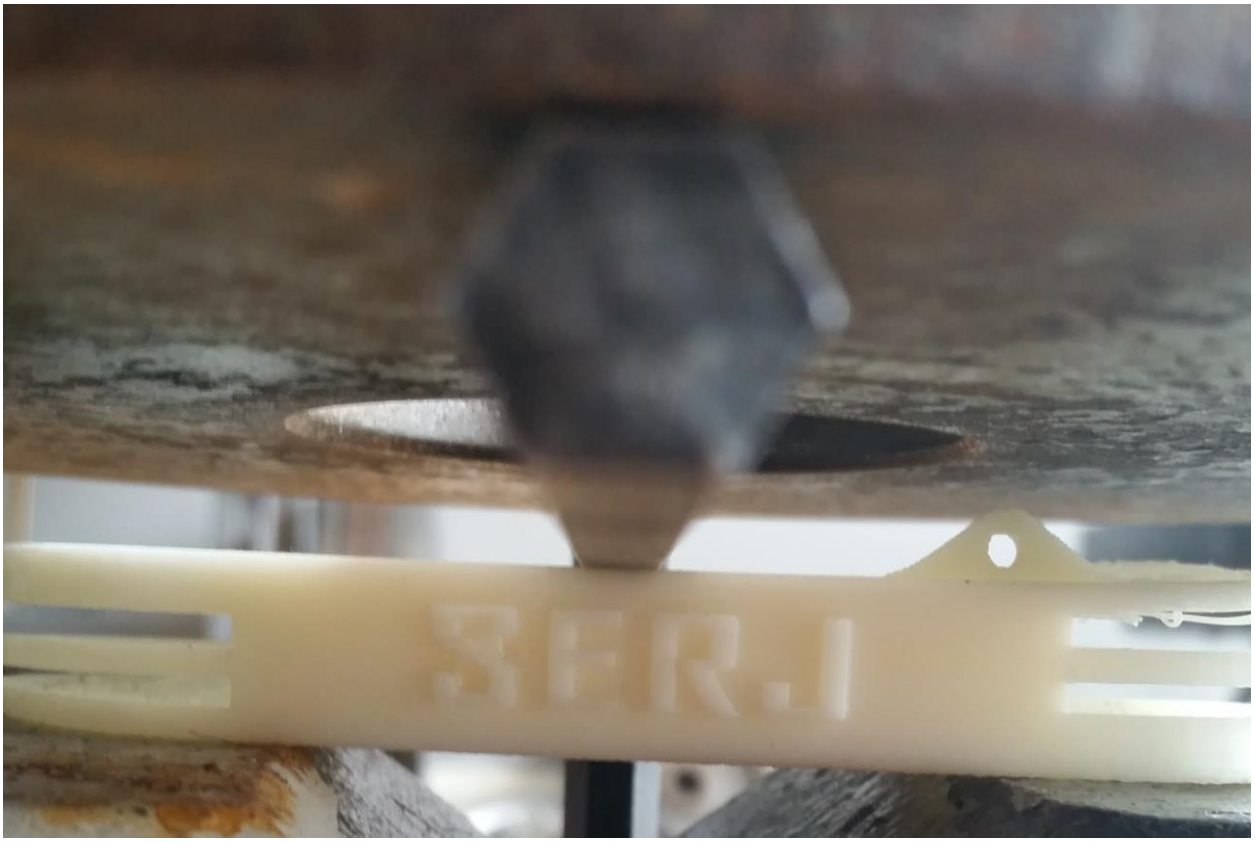
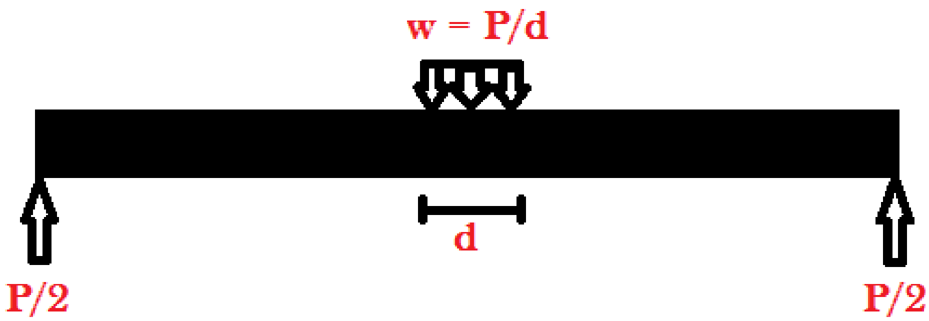
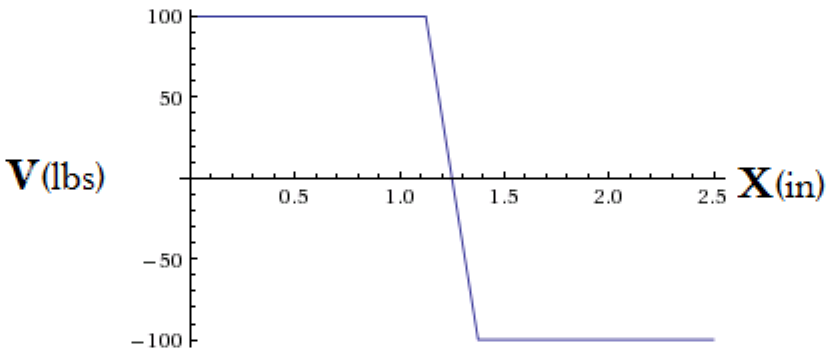
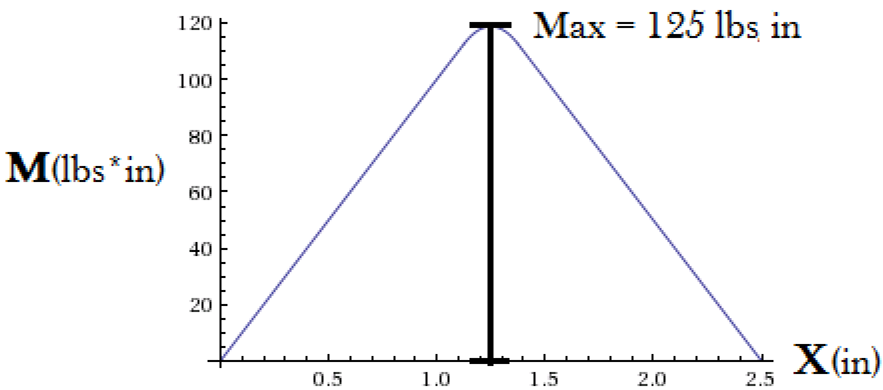


Figure 4.2: 3-point bending to test stresses and moments
This loading can be idealized as the image shows below.



Where the prototype started cracking and breaking when *P* reached 200 lbs, and *d* had a value of .25 in. The shear and moment diagrams are below, Graph is courtesy of WolframAlpha.





The maximum moment experienced under this loading is higher than we would ever expect the product to experience in it's lifetime of normal usage. Furthermore, the product is much stronger when it has the key holders and keys inside of it. Both of these factors almost entirely eliminate the possibility of breaking the body of the product by sitting on it or through any other normal loading conditions.

PROTOTYPE II

We printed and tested a second prototype which is able to fit the tabs. This prototype, however, was printed with a different printer, which creates a material with only one fourth of the first prototype's IZOD impact strength. This second prototype thus snapped when thrown against a wall, as seen below, unlike the first prototype. However, the tabs, which were used from our first prototype, were unscathed. From this, we learned that the material for our product must have around 100J/m impact strength in order to meet our preferred performance standards.

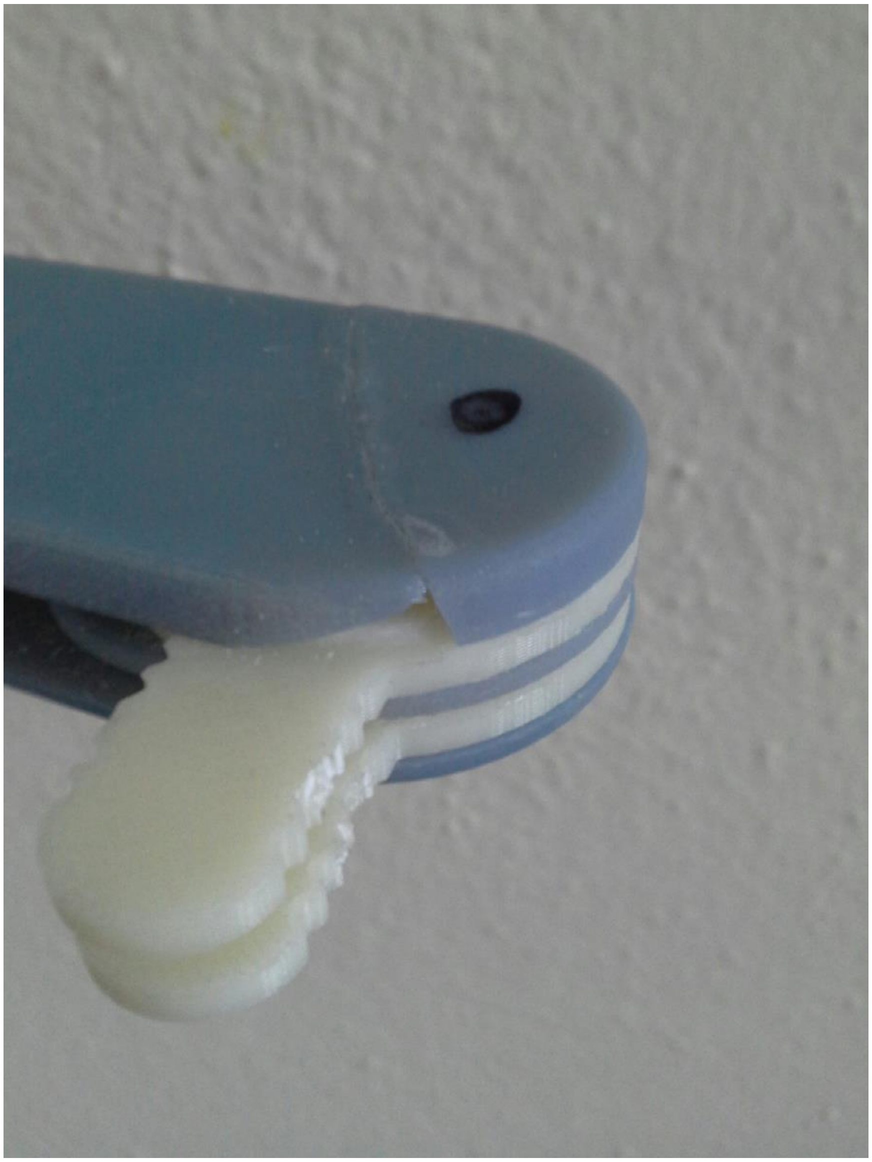


Figure 4.3: Prototype 2 image: Here you can see where a piece of the gray material with lower impact resistance broke off, since glued back together, from being thrown at the wall.

FINAL PRODUCT

Our final product fits inside a 110mm x 21.7mm x 52.5mm bounding box, with a true volume of 30.06cm^3. It's mass is 30.66g, making it both small and lightweight. A hole in one side allows a keyring to be attached, to keep our product together with other amenities which one would have kept on a keychain, such as key fobs or a bottle opener.

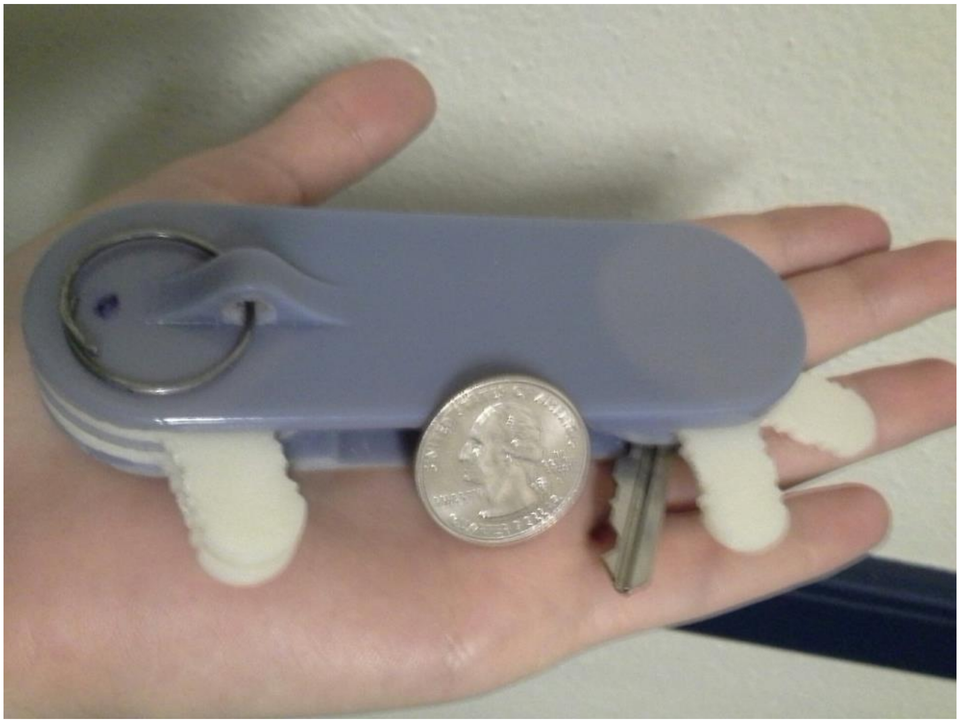


Figure 4.4: The final Swish Key

ENGINEERING ANALYSIS AND CALCULATIONS

Finite Element Analysis:

Being used to turn a key in a lock is the repetitive, daily loading condition that our product would have to endure. By keeping the surfaces which would contact a tab fixed, and applying a moment to the outer surfaces, the loading conditions of turning a key in a lock were replicated in ANSYS simulation software. This test assumes that there is only one tab and key in the box, meaning the other shelves would experience more stress since they have no support from other tabs being present. This created the worst case scenario. A moment of 0.56Nm, the average moment needed to turn a key in a lock, was applied. The Safety Factor in figure 3 is calculated for selectively laser sintered (SLS) nylon, the material Shapeways refers to as “Strong & Flexible Plastic.” Our lowest safety factor is at an acceptable 4.8865, and our highest total deformation is at a barely noticeable 0.65708mm, as seen in figure 2.

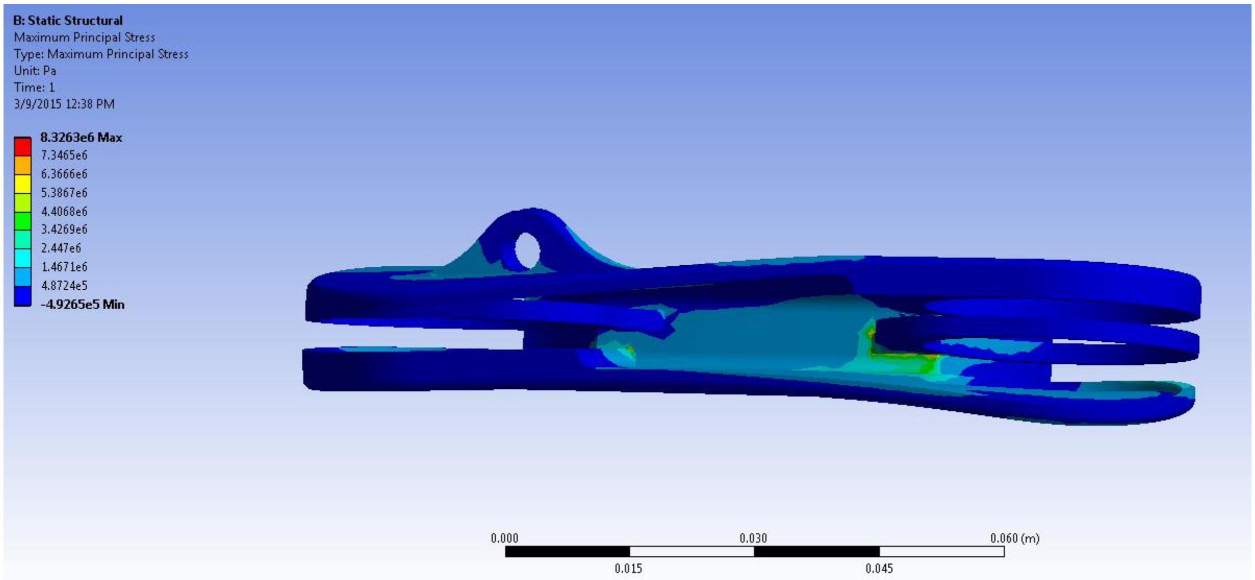


Figure 4.5. shows the maximum principal stress on our model using finite element analysis in ANSYS. The maximum principal stress, 8.3263MPa, is barely seen in red.

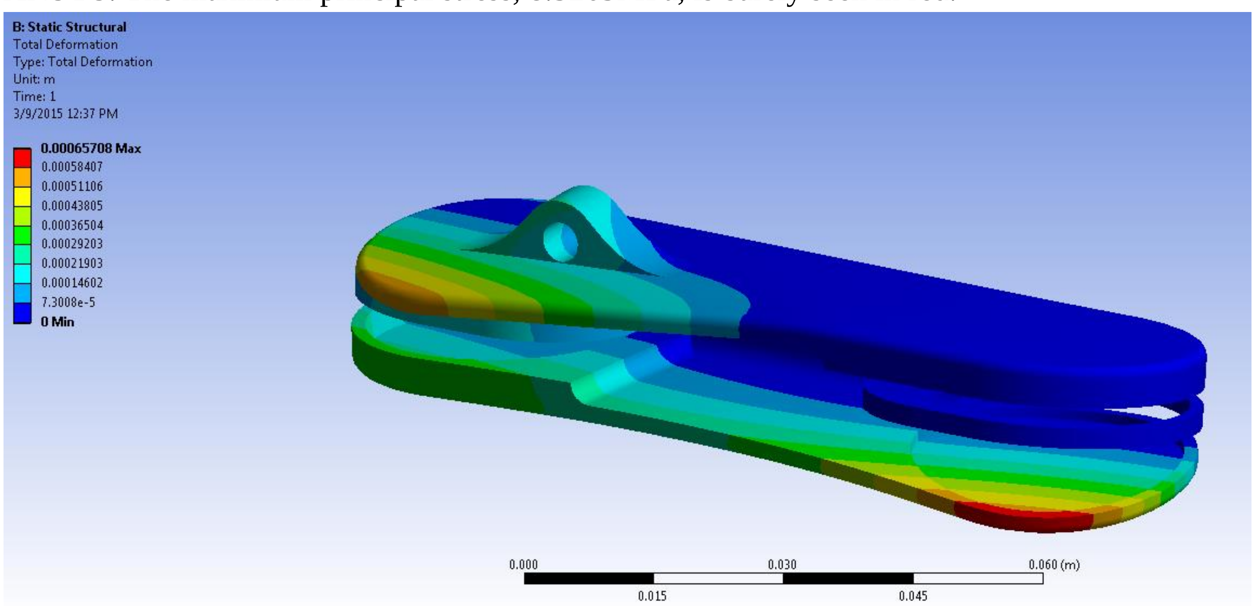


Figure 4.6. shows the total deformation on our model. The maximum, 0.65708mm, is shown in red. The actual deformation is multiplied 9x in the visual, for dramatic effect – this is true for all three of the ANSYS-generated images.

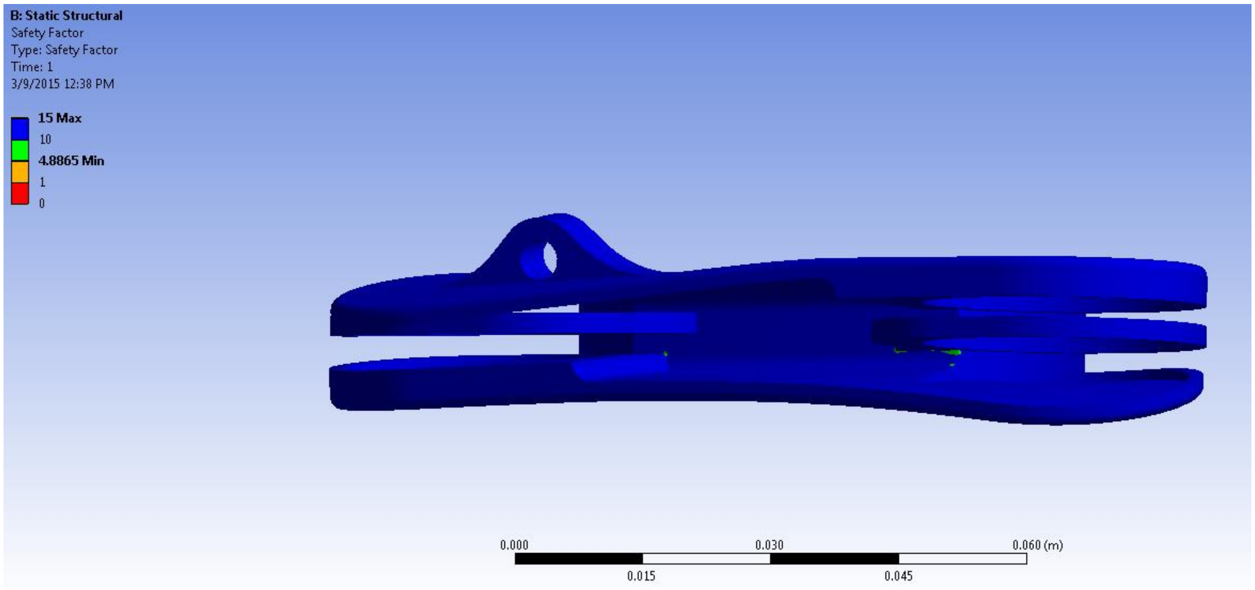


Figure 4.7 shows the Safety Factor of our model under the given loading conditions, and for SLS nylon as the material. Small patches of green show our lowest safety factor to be 4.8865, with most of the model at a SF of 15 or greater.

Extreme loading conditions:

We concluded the most extreme loading conditions for our product to occur when it is dropped, when it is sat on (for example, while being in someone's back pocket), and being opened too much (i.e. continuing to push on one of the tabs even after it is in the fully opened position). Our prototypes stood up to all of these loads multiple times with ease in testing. This shows that our product will be able to perform correctly as long as it is made of 3d printed ABS (the prototype material), or a material with equivalent IZOD impact strength, Young's modulus, and tensile yield strength.

Material choice:

The important properties of our prototype material, as previously stated, are IZOD impact strength (IZOD), Young's modulus (E), and tensile yield strength (σ_y). For our prototype material, IZOD = 100J/m, E = 2.32GPa, σ_y = 37MPa. For our ANSYS calculations material, SLS nylon, IZOD = 440J/m, E = 1.7GPa, σ_y = 46MPa. While SLS nylon has a slightly lower Young's modulus and tensile yield strength, it is slightly lighter (with a density of 0.95g/cc compared to ABS at 1.04g/cc) and much more impact resistant. Both materials would be good candidates to be used in our product, the choice depends mostly on which is more cost efficient to produce.

PROJECT REFLECTION

If we were to continue this project, perhaps the next iteration of our prototype would include a hinge that would allow putting in and taking out keys to be easier. Lining the inside of the body with another material to reduce friction between the tabs could be investigated. Through further testing, we might find areas of excess material which we could remove to reduce weight and size. A more effective means of holding the keys may also be needed. It is currently slightly more difficult to use the Swish Key than it is to use a key ring to open a lock.

SECTION 5: USER MANUAL & MARKETING MATERIALS

Adding Keys to the Swish Key

1) Gently remove the key holders from the main body. This can be done by slightly bending the grooves holding the holder in place back and pulling out the piece.
2) Push the memory foam away from the central pin on the holder and place the hole of your key over the pin. Release the foam.
3) Add the holder back to the body by again bending the grooves apart and placing the holder inside. Be sure to place the key facing the center of the assembly

Using the Swish Key

1) To reveal a key to be used, simply rotate the lever perpendicular to the desired key until the needed key is out.
2) Use the key as you would any other
3) Return the key to the body by rotating the lever until the key is fully inside the body

Safety Precautions

1) Keep away from children and pets. Small, removable components are a choking hazard.

2) Material NOT food safe, keep out of contact with substances to be ingested.

Video: https://www.youtube.com/watch?v=G6w2BlqqY1k&feature=youtu.be

Website: **https://sites.google.com/a/cornell.edu/serj-international/home**

SECTION 6: APPENDIX

SOURCES

For testing:
http://www.aboutcivil.org/simply-supported-UDL-beam-formulas-bending-moment-equations.html

Patents:
https://www.google.com/patents/US2863312?dq=key&hl=en&sa=X&ei=iKL_VO7GLIe7ggTjgoGwDQ&ved=0CCoQ6AEwAjgo

https://www.google.com/patents/US2300979

https://www.google.com/patents/US2300979

https://www.google.com/patents/US2863312

https://www.google.com/patents/US2695511

Benchmarking:
http://www.amazon.com/Fan-key-Compact-Organizer-Holder-Solution/dp/B00LRI2AVG/ref=sr_1_1?ie=UTF8&qid=1426203980&sr=8-1&keywords=fan+key

http://www.amazon.com/KeySmart-Compact-Key-Holder-Red/dp/B00JXQQXQM/ref=sr_1_1?ie=UTF8&qid=1426204012&sr=8-1&keywords=smart+key

Material properties data:
https://courses2.cit.cornell.edu/mae2250/Emerson/3D_Printing.htm

https://www.solidconcepts.com/content/pdfs/material-specifications/sls-nylon-12-pa.pdf

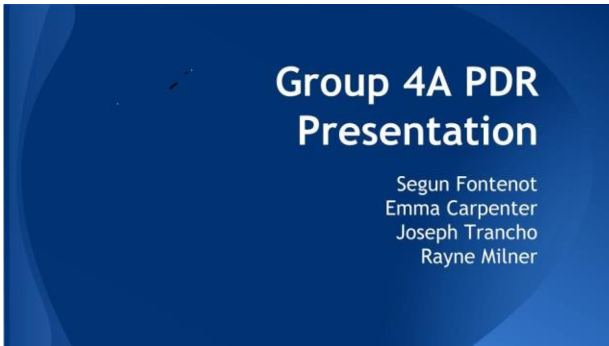
MEETING MINUTES

Meeting Date	Start TIme	End TIme	Attendees	Short Description
2/12	2:45 pm	3:30 pm	All members	Brainstorming

2/16	1:00 pm	2:00 pm	Segun, Joe, Emma	Choosing the three final ideas
2/21	12:00 noon	1:00 pm	All members	Finalizing the Key Box Choice
2/23	5:00 pm	6:30 pm	All members	Survey, Charts, and CAD Design
2/26	1:00pm	2:00pm	All members	Finalizing CDR
2/28	12:00PM	1:30PM	Segun, Joe, Rayne	Discussing Prototype
3/6	3:00 pm	3:30 pm	All Members	Assigning roles for the final design report and filming
3/9	6:45 pm	8:15 pm	Segun, Rayne, Emma	Filming for commercial and working on final report
3/11	6:00 pm	12:30p m	All Members	Work done on the Final Report, website, FDR, and commercial
3/12	1:00 pm	2:00 pm	All Members	Final elements placed on the FDR

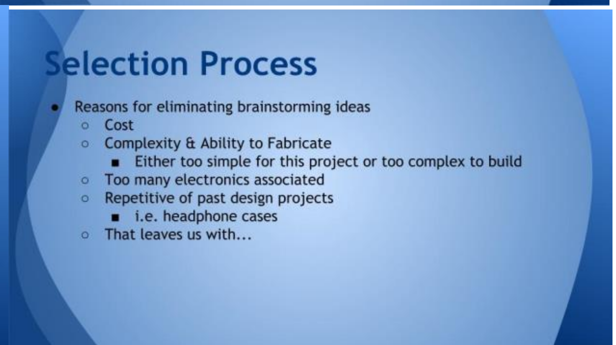
ALL PRESENTATION SLIDES

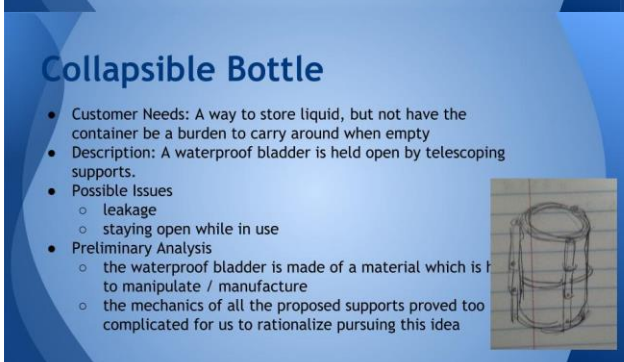
PDR Slides

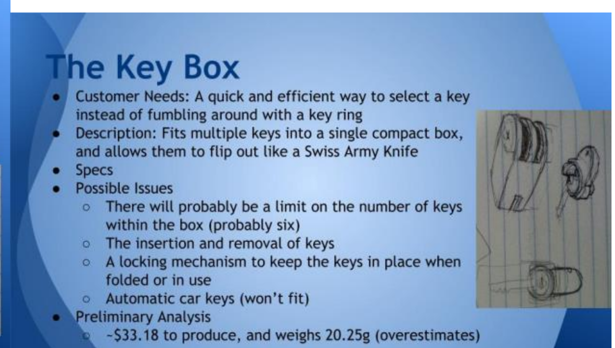

Group 4A PDR Presentation
Segun Fontenot
Emma Carpenter
Joseph Trancho
Rayne Milner

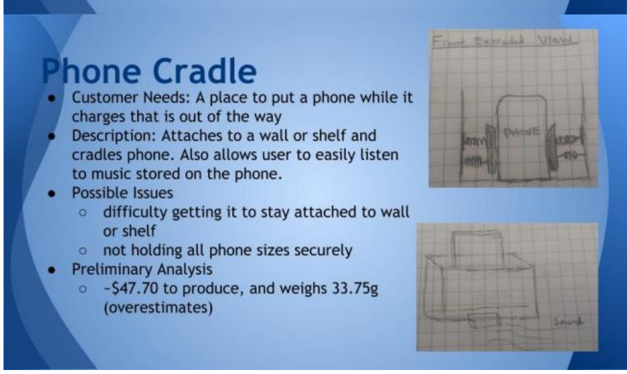

Brainstorming Process
We started off the process looking to create products that fit a broad criteria
Usable in everyday life
Fixes or alleviates a minor/moderate annoyance
Provides an useful function
Has some sort of mechanical property to it
Fits a customer need


Some of Our Preliminary Ideas
Snowbike tires/accessories
Compact snowshoe/ski
Collapsible mug/bottle
3D printed bracelets
Earbuds in Ear Muffs
Front protective cover for phone
Stable bed tray
Ring Flashlight (think Green Lantern)
Key Box
replaces the key ring
Textbook Clip/Weight
Headphone Case
Phone Cradle
Cuff protector (from ground salt)
Phone Zoom Lensing


Selection Process
Reasons for eliminating brainstorming ideas
Cost
Complexity & Ability to Fabricate
Either too simple for this project or too complex to build
Too many electronics associated
Repetitive of past design projects
i.e. headphone cases
That leaves us with...


Collapsible Bottle
Customer Needs: A way to store liquid, but not have the container be a burden to carry around when empty
Description: A waterproof bladder is held open by telescoping supports.
Possible Issues
leakage
staying open while in use
Preliminary Analysis
the waterproof bladder is made of a material which is h
to manipulate / manufacture
the mechanics of all the proposed supports proved too complicated for us to rationalize pursuing this idea


The Key Box
Customer Needs: A quick and efficient way to select a key instead of fumbling around with a key ring
Description: Fits multiple keys into a single compact box, and allows them to flip out like a Swiss Army Knife
Specs
Possible Issues
There will probably be a limit on the number of keys within the box (probably six)
The insertion and removal of keys
A locking mechanism to keep the keys in place when folded or in use
Automatic car keys (won't fit)
Preliminary Analysis
~$33.18 to produce, and weighs 20.25g (overestimates)


Phone Cradle
Customer Needs: A place to put a phone while it charges that is out of the way
Description: Attaches to a wall or shelf and cradles phone. Also allows user to easily listen to music stored on the phone.
Possible Issues
difficulty getting it to stay attached to wall or shelf
not holding all phone sizes securely
Preliminary Analysis
~$47.70 to produce, and weighs 33.75g (overestimates)
Front Extended View
PHONE

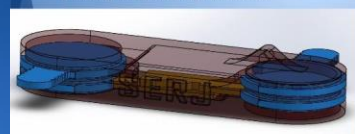
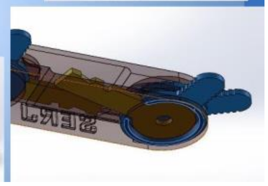
CDR Slides

CDR

4A:
Emma Carpenter
Joseph Trancho
Rayne Milner
Segun Fontenot

Design

- The head of each key sits in a shallow well attached to a tab
- The main body can deform slightly, allowing each 'well' to to be slid inside, and snap into a hollow pocket
- Once assembled, the tabs stick out, allowing each key to be rotated

Pugh Decision Matrix

Criteria	Bottle	Keybox	Phone Cradle
Mass	1	1	0
Fabrication	-1	1	1
Mobility	1	1	-1
Price	1	1	1
Production TIme	-1	1	1
Laser Cut	-1	0	1
3D Print	-1	1	1

Analytical Hierarchy Chart

	Bottle	Key Box	Phone Cradle
Total	-1	6	5

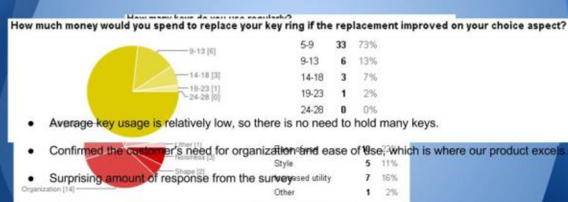
- **Bottle:** Ultimately, the bottle was deemed to difficult to machine or produce with a 3D printer. In addition, the issue of the durability of the bladder as well as its fabrication led to the bottle's elimination from the ODP.
- **Phone Cradle:** This was a close second. Although both products were deemed to be reasonably machinable, the keybox ultimately won in mobility, which is why we decided to go with it instead of the phone cradle. It also wasn't a very unique or interesting idea in our minds

Analytical Hierarchy Chart

	material cost	Mobility	production time	reliability
material cost	1.0000	0.1429	0.2000	0.1429
Mobility	7.0000	1.0000	4.0000	5.0000
production time	5.0000	1.4000	1.0000	7.0000
reliability	7.0000	0.2000	0.1429	1.0000

Most important factors: Mobility, and Reliability

Survey



- Average key usage is relatively low, so there is no need to hold many keys.
- Confirmed the customer's need for organization and ease of use, which is where our product excels.
- Surprising amount of response from the survey

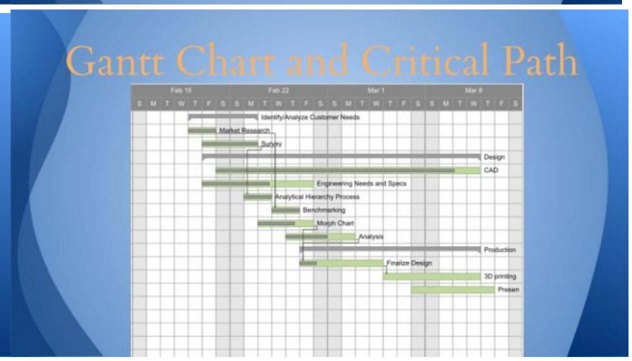
Morph Chart

Functions	Methods	Methods2	Methods3	Methods4
Hold Keys in Place	Small Cylinder shaped to head	Slots of same width as key	Foam holder (flexible)	
Bring Keys Out	Lever about axle	Spring loaded about axle	Spring loaded straight out	
Lock keys in in/out position	Friction	Clip	Flexible teeth	
Hold entire assembly together	Click on outer casing	Bands	Screws	
Store Keys inside	On axle facing each other	On axle facing same way	In slots facing each other	In slots facing same way
Lever Shape	Triangle	Rounded	Rectangle	
Material	ABS	PLA	Ultem 9085	
Body Shape	Swiss army knife	rectangle	cylinder	Ergonomic
Length	One key	two keys	three keys	
Height	2 keys	3 keys	4 keys	

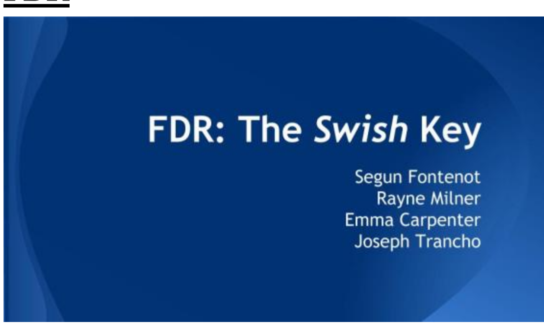
Analysis

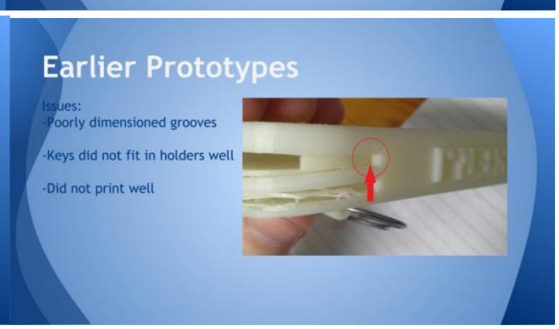
- **Weight:** The prototype is expected to weigh 30.23 grams and will be made from 3D printed ABS
- **Cost:** ~$8.50
- **Load Cycles:** According to the survey, most people use their keys 2-4 times a day. If we want our key box to last 3 years of use, it will need to withstand 4cycles/day*365days/year*3years = 4380 cycles.
- **Stresses and Moments:**
  - Consistent heavy loading condition: turning key in the lock - the exact forces depend on the particular lock.
  - our prototype should withstand 25.55kN of force
- **Patents:** Some similar designs were patented, but our product has unique features not covered in the patents

	Our Product	Fan Key	Key Smart
Weight	30.23 g	8.50 g	22.6 g
Dimensions	4.4 x 1.4 x 0.6 inches	3.5 x 1.2 x 0.6 inches	5.5 x 4.3 x 0.3 inches
# of Keys	Currently, 4	30+	Options ranging from 2-22
Cost	~8.50$ for production	30$ retail	20-32$ retail
Material	ABS	Aluminum	Aluminum and Steel
Production	3D printer	CNC	CNC
Other considerations	More secure	Prone to falling apart	Prone to falling apart
	Superior organization	on par with key ring	on par with key ring
	More customizable	generic	Can add a flash drive



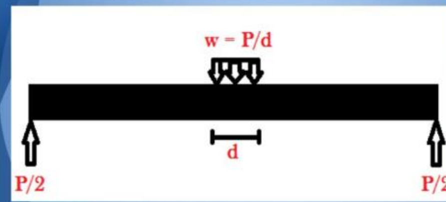
FDR



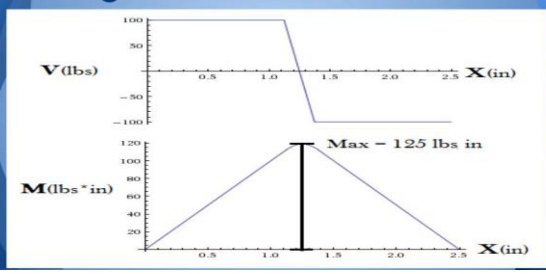


Testing

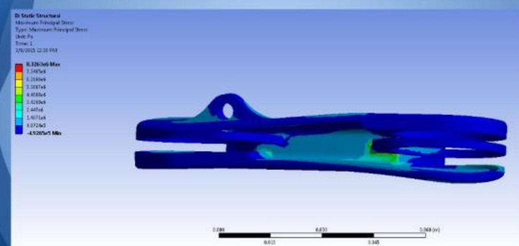
Testing Setup FBD



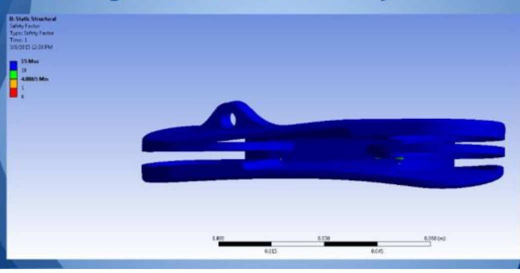
Testing: Shear and Moment



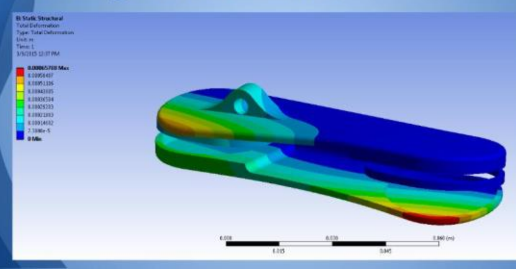
Testing: Maximum Stress



Testing: Factor of Safety



Testing: Deformation



Marketing

Website

Video

Dimensions

- 30.66g
- 110mm x 21.7 mm x 52.5mm TOTAL
- 110mm x 14.3 mm x 35mm BODY

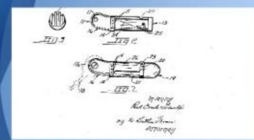
Our Competitors

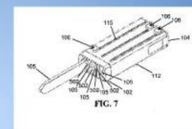
	Our Product	Fan Key	Key Smart
Weight	30.23 g	8.50 g	22.6 g
Dimensions	4.4 x 1.4 x 0.6 inches	3.5 x 1.2 x 0.6 inches	5.5 x 4.3 x 0.3 inches
# of Keys	Currently, 4	30+	Options ranging from 2-22
Cost	30.81$ for production	30$ retail	20-32$ retail
Material	ABS	Aluminum	Aluminum and Steel
Production	3D printer	CNC	CNC
Other considerations	More secure	Prone to falling apart	Prone to falling apart
	Superior organization	on par with key ring	on par with key ring
	More customizable	generic	Can add a flash drive

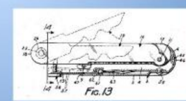
Fan Key

Key Smart

Patents







Price

$30.81 using Shapeways "Strong & Flexible Plastic" (SLS nylon).
If we were our own comapny, we would use an independent 3D printer, lowering the production cost to $16.96

Image courtesy of Shapeways https://static1.sw-cdn.net/rrstatic/img/materials/wsf-colors.jpg

Looking to the Future

1) Sleeker design
2) Hold more keys
3) Cut material