Adjustable Height Changing Table

Final Report

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Abstract
This report summarizes the design process for an adjustable height changing table. The table is needed for two parents raising a growing boy with Cerebral Palsy, Epilepsy, and Cortical Blindness. He is getting too large to be lifted onto his current table and a table that can raise and lower him is needed. Three possible designs are presented, along with a design matrix that summarizes the merits and pitfalls of each design. Finally, the future work for this project is addressed along with the final design.

1.0. Introduction

1.1 Problem

Marc Patterson is a seven year-old boy living in Oregon, WI. Unfortunately, Marc suffers from Cerebral Palsy, Epilepsy, and Cortical Blindness causing him to rely on his parents for many daily activities. He needs to be changed a few times daily and his parents do this by manually lifting him to his current changing table. As a growing boy he is becoming too large and heavy to lift many times a day. The goal for this project is to design and build a changing table that will safely and efficiently raise and lower Marc so his parents do not have to. This design must aesthetically blend into the home environment.

1.2 Background Information

Cerebral Palsy (CP) is a serious disorder that affects almost 800,000 children and adults in the United States today (omit)[1]. Cerebral Palsy is a broad term used to describe a group of neurological disorders that affects basic brain and nervous system functions. Cerebral Palsy can impair, with varying severity, the individuals' movement, hearing, thinking/learning, vision, and other cognitive development. These symptoms can range from completely overbearing to minor inconveniences [2].

Cerebral Palsy (CP) is caused by injuries to or problems in the brain. Some causes that are possible, but are not limited to, include bleeding in the brain, head trauma, brain infection, and infections in the mother during development. Typically, these problems manifest within the first two years of an infants life or fetal development in the womb [2]. Additionally, premature babies are at a higher risk of acquiring Cerebral Palsy. In some cases the cause of CP goes unknown.

There are five main types of Cerebral Palsy. The portion of the brain that was harmed and the symptoms that are present classifies these types. The five types are spastic, ataxic, tremor, rigidity, and athetoid [3]. Spastic CP is the most common of the five, which results in tense contraction of the muscles. Additionally, the most severe type is athetoid, which results in constant, uncontrolled motion of the head, limbs, and eyes. An individual with CP can either have one or a combination of these types [3]. There are many other symptoms that are related to CP that do not involve a movement. Some of these symptoms include joint problems, unsteady gait, and digestive problems such as difficulty suckling, vomiting, or difficulty swallowing. Additionally, Cerebral Palsy can affect the individual's speech, breathing, and cause an increase in drooling [2].

Unfortunately, there are no known cures for Cerebral Palsy. Treatment and physical therapy are the typical routes that are taken. Treatment is usually taken with the team approach, with the interaction and correspondence of doctors, dentists, physical therapists, social workers, nurses, and other specialists that depend on the symptoms present [2].

As for our client, Marc developed his Cerebral Palsy, Epilepsy, and Cortical Blindness due to complications during labor. Unfortunately, Marc suffered a prenatal stroke causing widespread damage to his brain during birth. Marc's Cerebral Palsy resembles athetoid CP and he has trouble sitting still and controlling his movements. Marc is seeing daily progress in his treatment both at home and in school.

1.3 Motivation

The motivation for this product is to help ease the financial burden on the Patterson family. Current changing tables on the market today range from $2000-$4000. Because the Patterson family is already paying a lot of money to help Marc get better, they can't afford an expensive changing table. We would also like to make the table aesthetically pleasing. All of the changing tables on the market are manufactured for clinical settings, so they look like they belong in a hospital. We intend to design a table made out of wood that could be placed in a bedroom and make Marc feel more at home. It is estimated that over 500,000 children and adults have Cerebral Palsy in America [2]. So, if we can help the Patterson family then we may be able to help other families as well.

2.0 Design Specifications

The current changing table used by the Patterson family has one major flaw: it is too tall. This aspect of the table makes it difficult for a person to lift Marc up onto the table. Because Marc is only seven years old, he is only going to get bigger, which means, it is only going to get harder to lift him. For the new changing table design, it must be able to support Marc's weight when it is fully raised in the air. In order to support his weight, we are going to use a hydraulic lift that is capable of lifting 300kg. The new table design must also be sturdy. Because Marc has Epilepsy, Cortical Blindness, and Cerebral Palsy, he is unable to control his body from shaking. The table will need to be able to withstand vigorous movements and kicks exerted by Marc. In order to make the table sturdy, it will be placed next to a wall so it can't move in that direction. The table will also be on a track roller guide block system which will also improve the sturdiness of the table. For safety reasons, there will be a permeable membrane on the track system so fingers can't get pinched or caught in the tracks. DELETE! There will also be a curtain to hide the lift mechanism when the table is raised up off of the ground. This will eliminate injuries and also add aesthetics to the table. Since the table is being placed in a bedroom, aesthetics are very important. In order to match the rest of the bedroom, the table will be furnished out of wood, which will be finished with a clear, polyurethane coat. Next, the new table design must be user friendly. When Marc is lying down on top of the table, there must be enough room for him to stretch his body without falling off the edge of the table. There must also be room on top of the table for changing supplies such as diapers and baby wipes. Because there may be human-waste or other unhygienic substances on the table, the new table design must be easy to clean. The clear, glossy finish applied to the wood will not allow anything to settle into the wood. Thus, cleaning the table will be very easy. When Marc is on the table, it must also be easy for a person to lift him up. A hydraulic foot pump will be the mechanism used to lift the table up. That way, all a person has to do is lie Marc down on the table. Then, push up and down on the foot pump until the table is at the desired height. The foot pump will ease the burden of lifting Marc up onto a high surface several times a day. With all of our design features, the table will cost about $400, which is our current budget.

3.0 Design Alternatives

The group has developed with three design alternatives as solutions to its problem statement and client needs. Two of the designs use a lift system and vary on the storage area. The third uses a linear actuator system. These three alternatives are described below.

3.1 "Whole" Table

Our first design, known as the "whole" table (see FIG 1), utilizes a scissor lift to raise and lower Marc. This design has a storage unit built around and over the lift. The storage unit would be constructed like a computer desk. The scissors lift would be placed and secured to the desk in the area cutout for the operator's feet. Designing the desk around the lift in this way would shield most of the lift from the user when the lift is in motion, preventing pinch injuries to an operator's hand. When the lift is fully lowered, the desk would rest on the ground naturally. At this height, Marc would be able to lift himself onto the tabletop. The lift would then raise Marc and the storage desk together. This, however, results in some problems. The load capacity of the lift would have to be very high to raise this much weight with an appropriate safety factor. This would raise the cost to construct the lift. The weight might make the whole system top heavy, making the table susceptible to tipping.

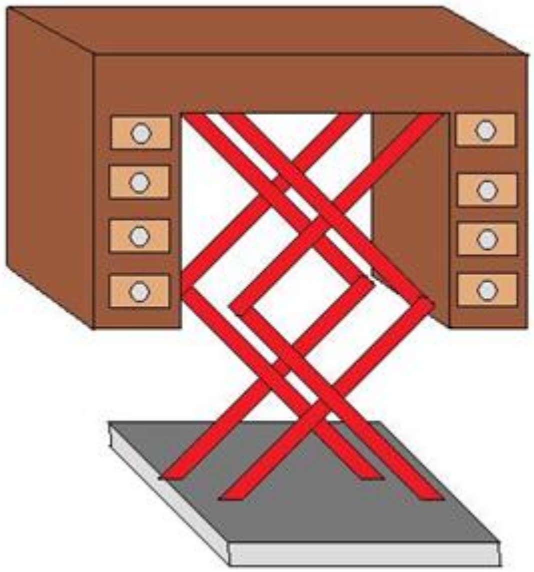

FIG 1: This is a representation of the "whole" table design.

3.2 "L" Shape

The "L" shape design (see FIG 2) would have storage space in the shape of an "L," located around and under a scissor lift system. This design would maximize storage capacity. The bottom of the "L" would be at a height where Marc could easily climb on under his own power. The lift would only need to raise Marc. This would permit a lower lift load capacity, with a high safety factor. In between the lift platform and the storage unit side, this design would incorporate a track and roller system. This would stabilize the lift while in motion or at its maximum height. It would permit movement by the person while not affecting the lift or causing a safety concern. The lift would be fully exposed in this design, however. An apron would need to be made that would extend with the lift to cover it while in use.

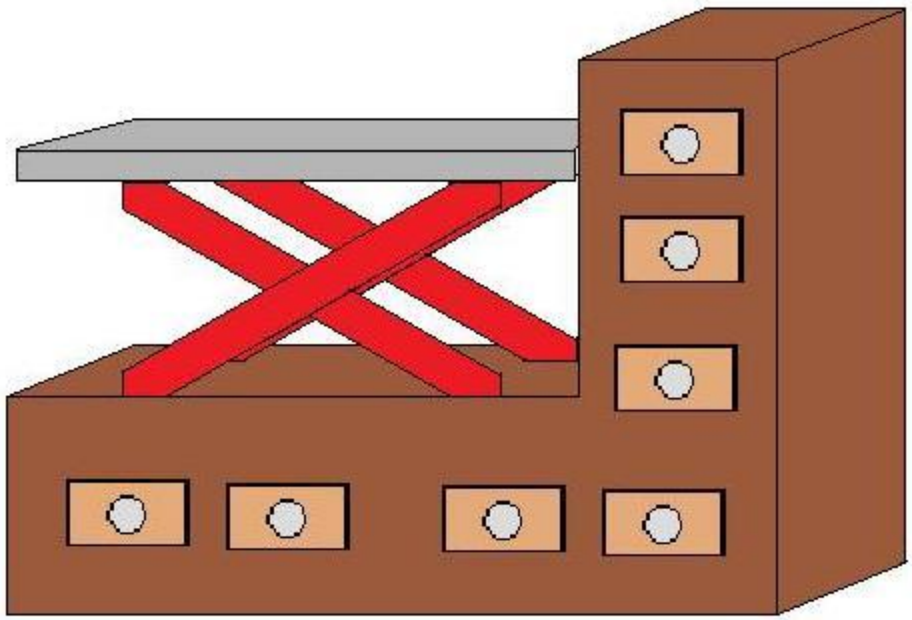

FIG 2: This is a representation of the "L" shape design.

3.3 "Legs" Design

The final design alternative would function like a normal coffee table (see FIG 3). Each table leg would have a linear actuator system located at its base. This would extend the legs, raising the table. With this design, however, there is no available storage space. The cost to install four separate linear actuator systems, one in each leg, would significantly raise the cost of the table, far in excess of the budget. It would also pose a safety problem, in that if one leg fails to rise, or collapses, the whole table could tip.

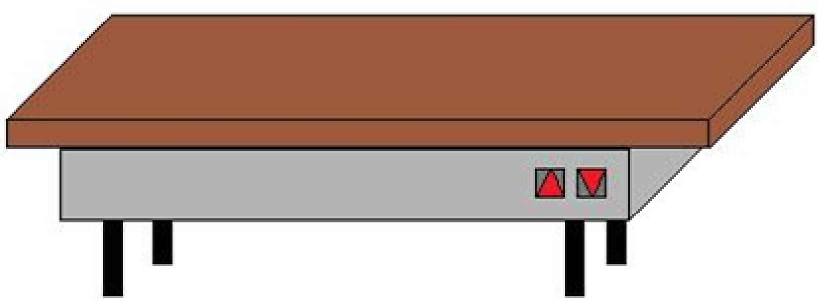

FIG 3: This is a representation of the "legs" design.

4.0 Design Matrices

For the design matrices, we asked our clients to rate the aspects of our design in terms of importance. These categories were as follows: aesthetics, cleaning, cost, ease of use, maintenance, safety, and storage space. Our clients chose safety to be the most important part of the designs. They want to feel at peace when they are using the lift table, and not worry about anyone getting injured by it. The next two most important categories were cost and aesthetics. One stipulation of this project is that it needs to be more affordable than the current products on the market. The design also needs to look like it belongs in a home setting rather than a hospital or nursing home.

Maintenance, ease of use, and storage space were the next most important categories. We want our design to require very little upkeep to maintain the functionality of the design. As this changing table will be used in a home rather than a hospital, we want it to not require any complicated or strenuous steps when using it. The current changing table that our clients use has many drawers used for storage, which is something they want to have in the new changing table. The extra storage space included in the design also improves the aesthetics of the design.

The final category and least important was cleaning. The design needs to be able to be cleaned easily but it is not as vital to the design as the functionality of it. Currently our clients use a sanitary pad which they are able to clean with wet wipes. Our group then weighted each category in the design matrices according to how our clients rated them in terms of importance (see FIG 4).

Category (Pts)	"L" Shape	"Whole" Table	"Legs" Design
Safety (30)	20	10	25
Cost (20)	15	15	5
Aesthetics (20)	15	15	15
Maintenance (15)	10	6	9
Ease of Use (15)	15	15	15
Storage Space (15)	15	10	5
Cleaning (5)	3	3	5
Total (120)	93	74	79

FIG 4: Design matrices for the alternating height changing table designs

5.0 Final Design

The design that was chosen for development is the “L” Shape design. The “L” Shape design scored the highest in the design matrices with a total score of 93 out of 120 because of its low cost, safety, and large amount of storage space compared with the other design alternatives. The “Whole” Table design was dismissed from consideration as the final design because of its weak score of 74 which resulted from its low score in the safety category. The “Legs” design was also dismissed because it scored a 79(see FIG 4). It did have the highest safety score, but it also had the lowest cost score because of the need required to purchase the four linear actuators required to extend the legs of the design.

Our group felt the “L” Shape design was indeed the best design of the three. The cost of the design is under budget, it is aesthetically pleasing, it has storage space, and of course it is a very safe design. We feel extremely confident in moving forward with this design.

FIG 5: Image of the final prototype.

6.0 Device Testing

We tested the adjustable height changing table at two tempos: rigorous and slow. This was done to calculate the maximum capabilities of the lift. For the rigorous tempo testing, a group member quickly pumped the foot pedal to raise the lift until the table was fully raised. A full stroke was performed each time to ensure that the minimum number of strokes required to raise the lift to its maximum height was found. Next, the release pedal was pushed all the way down so the table would be lowered at its maximum speed. This process was repeated 5 times and each time the table had a 68kg dynamic load on it. The average time it took to raise the table at the fast pace was 9.1 sec and required, on average, 22.6 pumps. It took an average of 3.0 sec for the table to be fully lowered.

For the slow pace, a group member calmly pumped the foot pedal until the table was fully raised. Then, the release pedal was gently pushed down so the table would be lowered slowly. Again, this process was repeated 5 times and each time the table had a 68kg dynamic load on it. The average time it took for the table to be fully raised was 20 sec and required an average of 21.6 pumps. It took 5.4 sec for the table to be completely lowered at a slow pace. To see if the table could withstand lateral and translational forces, we had a 68kg group member simulate shaking movements similar to movements which Marc would make. Although no quantitative data was recorded, it was noted that the base of the table did not leave the ground and the table was successfully able to withstand the forces. For additional testing, we had a 45kg woman, similar to the weight of Marc's mother, raise and lower the table. No data was recorded but she was able to raise and lower the table easily.

(A) Rigorous Tempo			
Trial #	Time up (sec)	Pumps	Time Down (sec)
1	9.5	22	4.0
2	9.9	24	2.7
3	8.7	23	2.7
4	8.7	23	2.7
5	8.5	21	2.7
Average	9.1	22.6	3.0

(B) Slow Tempo			
Trial #	Time up (sec)	Pumps	Time Down (sec)
1	22.0	21	4.6
2	17.4	21	4.5
3	21.2	22	5.1
4	20.0	22	6.5
5	19.1	22	6.1
Average	20.0	21.6	5.4

FIG 6: Data collected from design testing. Table (A) displays data from the Rigorous tempo testing. Table (B) displays data from the Slow Tempo testing.

7.0 Market

Specific data relating to the number of people who might need the assistance of a changing table does not exist. This makes it difficult to many people with disorders that, depending on the severity of the symptoms, could use a changing table. The product could be used in a nursing home setting for geriatrics. Cognitive disabilities, Spina bifida, or even some severe cases of Down syndrome are all examples of disabilities that the changing table could benefit [4]. Although built for the home environment, our changing table can also be used in a school or in a nursing home setting.

8.0 Budget/Cost Analysis

Our client gave us a budget of $400. We slightly exceeded that budget, spending just over $427 on materials. When calculating the manufacturing cost, we added in parts we received for free, as well as $515 for labor. This brought our total to a little over $963. After comparing our device to other similar products in the market, we assigned a reasonable profit margin of about $540. We believe our product could sell on the open market for about $1500.

If the product were to be manufactured in bulk, whether in the 10's, 100's, or 1000's, optimization of parts would decrease manufacturing costs. Obviously, buying wood in bulk would also result in a cost savings. For the lift, we did have to disassemble and not use parts. A lift mechanism tailored to our need, would save money and therefore we could buy it less. As part of fine tuning production, we would like to develop a less bulky lift that weighs less and a smaller sized piston. This would also result in decreased manufacturing costs, allowing us to be more competitive in the market place. As time went on, we would find more efficient ways to fabricate the lift, which would reduce our labor costs.

9.0 Future Work

A very specific lift table is needed to fit the design specifications. A lift table from Northern Tool + Equipment was chosen for the current protoype. It fits most of the design specifications in that it is able lift 2935.83 N (660 lbs), its lowered height is .295 m (11.625 in), its raised height is .749 m (29.5 in), and it only costs $169.99. One minor problem with the lift is that it does weigh 533.79 N (120 lbs), but, overall, it is a very good option [5]. Other options for the lift will be considered as time goes on. A lift better tailored to the specific needs of the table is desired. It should be less bulky, have a lighter weight, and have a smaller piston size to make each pump more efficient.

There are many additional features that could be added to the lift table to improve its functionality. Marc tends to move around quite a bit and as the lift is moving up or down, so the sturdiness of the table is an issue. A track roller guide block system will be implemented in the future to improve the sturdiness of the table. For safety reasons, there will be a permeable membrane on the track system so fingers can't get pinched or caught in the tracks. This feature could prove vital to the safety of the design, and for protecting the patient from harm. The legality of restraining straps is something that needs to be researched. There are laws in place to protect children against child abuse, and this design must follow any laws that relate to it. We will also need to test the strap to make sure it is in accordance with its own safety laws.

Some testing remains to be done. A quantitative number on the amount of force that would be able to tip the table will be tested for, as well as the amount of weight it takes to collapse the lift. By the end of the semester, we will be able to deliver our product to the clients, and it will help make their lives less strenuous. Once the semester has ended, our group may come to the decision that our design is marketable and we may try to move forward in either producing more of our design or selling our design to a company. There are many people in the United States with cerebral palsy, and many people would be interested in an affordable adjustable height changing table.

A school coordinator from a California School District has shown interest in purchasing two lift tables for the schools she is in charge of. She had learned of the project from the design project website. At that point during the design process, only a brief description was included on the website, yet the school coordinator was genuinely serious about purchasing two models. At this time, she has not been notified as to the cost of the project with the cost of labor and profit included. If she still shows interest in purchasing two of the models, we will assemble and ship two design tables to her. Before that though, the patent feasibility of the design must be researched.

This design is novel in that it is the only product that is designed to be specifically for the home environment. There are changing tables that alternate its height, but they are for the hospital or clinical environment. There are also changing tables for a home environment, but they are unable to alternate its height. So in that regard, this design is unique. There is a market out there as noted before with the California School District school coordinator that contacted our group and by the research we did on the number of people that could possibly benefit from an alternating height changing table.

10.0 References

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11.0 Appendix

11.1 PDS

Product Design Specification

Problem Statement

Marc Patterson is a seven year old boy living in Oregon, Wisconsin. He was born with Cerebral Palsy, Cortical Blindness, and Epilepsy. He is making good progress at home and school, but he still is dependent on his parents for virtually everything. Marc needs to be changed a few times a day and he has grown large enough that it is getting very difficult to lift him onto his changing table. The goal is to design a changing table which can alternate its height so that it is easier to place Marc on the changing table.

Client Requirements:

· Must cost no more than $400

· Must be able to be easily adjustable its height through a hydraulic lift to make lifting Marc easier

· Must be powered manually (foot pump) or with electricity

· Must be able to support a 50 lb boy

Design Requirements:

1. **Physical and Operational Characteristics**

a*. Performance Requirements*
The changing table must be able to alternate its height from 12 in. to 36 in. from the floor while also supporting a 50 lb boy.

b. *Safety*
It must alternate its height at a safe and manageable rate. This is to ensure that Marc feels safe while on the changing table.

c. *Accuracy and Reliability*
Our design is expected to be close to 100 percent reliable, which includes raising and lowering the table safely every time. The device is designed to be highly accurate and deliver desired heights with a +/- 6-inch range.

d. *Life in Service / Shelf Life*
The device is designed for cyclic use. The client expects to use the table for changing 5-10 times a day. A single use will consist of a 2-step cycle, going up and then lowering back down. The device must also be cleaned daily and sanitized after every use. The client requests a shelf life of 2-3 years, but the expected shelf life for the device is up to 10 years. The limiting factors

for shelf life on the device is the mechanical design used for raising and lowering the table and Marc's growth rate (height and weight).

e. *Operating Environment*:

Our device would be used in bedrooms, or other household rooms. This does not mean that our device should only work in these places. It should be capable of performing on any horizontal surface.

f. *Ergonomics*:

The device must be extremely user friendly. Anyone who is at least 1.5 meters tall should be able to operate the device with ease.

g. *Size*:

The changing table must be 60 in long x 20 in wide so Marc can comfortably lie down. The height of the changing table will range from 12-36 in from the floor.

h. *Weight*:

The weight of the changing table will be light enough so that two people can move it by hand. In order to accommodate this request, the changing table will weigh between 100-150lbs.

i. *Materials*:

The materials used, mainly wood, must be aesthetically pleasing considering the changing table will be placed in a bedroom. The materials must also be durable in terms of mechanical wear and tear because the changing table will need to stay intact for many years.

j. *Aesthetics, Appearance, and Finish*:

The wood used to make the changing table will have a clear, glossy finish to match other objects in the room.

2. Production Characteristics

a. *Quantity*: 1 deliverable.

b. *Target Product Cost*: Less than $300 -$400

3. Miscellaneous

a. *Standards and Specifications*: N/A

b. *Customer/Patient related concerns*: N/A

c. *Competition*: There are other specialty changing tables on the market that range in price from $2,000 up to $5,000.

11.2 Budget

Item (receipt)	Purpose	Unit Price	Used	Subtotal Price ($)	Total Price with WI sales tax ($)
Lift	Lifting	199.99	1	199.99	210.99
Unfoak Base Cabinet	Cabinet	58.71	1	58.71	61.94
Artesian Small Round Bun	Legs	2.48	4	9.92	10.47
2X6X92 5/8 Stud	Base	3.5	2	7	7.39
1X2X10 Red Oak Board	Finished Edges	9.47	4	37.88	39.96
3/4" 18mm Oak Plywood	Table Top	43.97	1	43.97	46.39
5.2 mm 4X8 Oak	Skirt	24.95	1	24.95	26.32
Satin Polyurethane	Finishing	10.47	2	20.94	22.09
4 FT Lashing	Strap	2	1	2	2.11
Total				405.36	427.65

11.3 Budget with Labor Costs

Actual/Estimated Cost					
Item (receipt)	**Purpose**	**Unit Price**	**Used**	**Total Price ($)**	**Total Price with WI sales tax ($)**
Lift	Lifting	199	1	199	209.95
Unfoak Base Cabinet	Cabinet	58.71	1	58.71	61.94
Artesian Small Round Bun	Legs	2.48	4	9.92	10.47
2X6X92 5/8 Stud	Base	3.5	2	7	7.39
1X2X10 Red Oak Board	Finished Edges	9.47	3	28.41	29.97
3/4" 18mm Oak Plywood	Table Top	43.97	0.75	32.9775	34.79
5.2 mm 4X8 Oak	Skirt	24.95	1	24.95	26.32
Satin Polyurethane	Finishing	10.47	2	20.94	22.09
4 FT Lashing	Strap	2	1	2	2.11
Bolts, Nuts, Washers	Base	0.5	13	7.5	7.91
Screws	Everything	N/A	UNK	5	5.28
Sandpaper	Finshing	0.5	~5	2.5	2.64
Floridian	Fabric	9.59	1.25	11.9875	12.65
Nu Foam 18"	Cushion	11.19	1.25	13.9875	14.76
Labor	Construction	25	20	500	500
Labor	Sewing	15	1	15	15
Total				924.8825	963.25

11.4 Project Timeline

	January	February				March				April					May
	28	4	11	18	25	4	11	18	25	1	8	15	22	29	6
Product Development															
Background Research															
Develop design alternatives															
Select final design															
Order parts															
Construction															
Testing															
Presentations															
Mid-semester						3/4									
Final														4/29	
Deliverables															
Progress Reports															
Mid-semester Report							3/9								
Final Report															5/4
Meetings															
Advisor															
Client															
Website															