SWIMMING POOL AND HOT TUB LIFT

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Abstract
The pool and hot tub lifts built with allow Ron Hiller, a man living with multiple sclerosis to independently enter and exit his pool and/or hot tub. The lifts consist of modified and/or combined Bruno lifts that have been tested for durability and lifting success. The lifts are small enough to be installed on top of Mr. Hiller’s decks and will not be too much of an obstruction on each deck. The lifts will have the ability to rotate, move over the pool and back, and to lower and raise Mr. Hiller with the use of a remote. The seat is a large mesh seat that will not be tarnished by the pool and will secure to the lift allowing stability for Mr. Hiller’s body and head. A ramp will also be built to allow Ron access to his pool deck to relax and spend time with friends and family.

There are many pool lifts available on the market today, however many are in the $2,000 range. Also most pool lifts are built for use of an in-ground pool. Many hot tub lifts are built for use in an indoor hot tub. These lifts we built are unique for Ron Hiller and will be able to lift his large stature into and out of his aboveground pool and outdoor hot tub. These lifts will return to Ron the enjoyment he once had when he was not confined to a wheelchair and could use his pool and hot tub freely.

1 Introduction
1.1 Background
1.1.1 Multiple Sclerosis
Multiple sclerosis (MS) is an inflammatory disease in which the myelin sheaths surrounding the spinal cord and brain are damaged, affecting the ability of nerves to communicate. This non curable disease leaves muscle coordination and strength severely diminished, taking away motor skills often taken for granted. MS is an unforgiving disease that can effect motor skills, vision, sense of feeling, coordination, bodily functions, and cognition. Often, people suffering from MS may be confined to a wheelchair or walker because of its negative effects on the central nervous system, balance and motor skills. MS can vary in severity from patient to patient and from day to day for a given patient. The cause and cure of MS are unknown to physicians. Currently, doctors believe a number of factors can contribute to the causes of multiple sclerosis including the environment, genetics, possible viruses, and even hormones.

Though the cause is unknown, statistics have shown a link between environment and multiple sclerosis trends. For example, the prevalence of MS increases in temperate climates of areas further away from the equator. There also appear to be demographic patterns. For instance, in the United States, it is far more likely to see MS in Caucasians than in any other racial group.

Genetics may also play a role based on the correlation of first, second, and third degree relatives of someone with MS being at an increased risk of getting MS as well. Researchers believe that multiple genes may affect the likelihood of getting MS, but further research is necessary to identify or isolate the genes responsible.

1.1.2 The Client
Ronald Hiller is a 56 year old man who lives with Multiple Sclerosis. Originally from the Bronx, New York, he resides in Ashford, CT, with his wife and dog. He and his wife have a son, and grandchildren, including a newborn baby boy. Ron is an out-going and friendly man who does his best to take the cards life has dealt him and maintain a positive attitude and spirit of
generosity. Ron worked as a fire-fighter for many years before his MS advanced. Since his multiple sclerosis has taken away his ability to continue being a fire fighter, Ron has focused his time in volunteering for the “Hole in the Wall Gang,” a camp for children with chronic illnesses and disabilities, founded by Paul Newman in 1988. All of the camp’s services are provided free of charge to the families of the children who attend the camp.

Mr. Hiller was diagnosed with MS when he was 16 years old. Until recently, the disease has not altered Mr. Hiller’s way of living sufficiently. Within the past ten years, however, Ron’s MS has advanced significantly, leaving him without the strength and motor ability to walk. Ron is confined to a motorized wheelchair to navigate around his home and yard. He often suffers from pain and weakness in his legs. Mr. Hiller currently retains most of his upper body strength and control. Despite this unfortunate condition, Mr. Hiller’s determination and attitude have left him grateful for the blessings in life and allow him to serve as an inspiration to others. One improvement in his life he has asked us to help with, is his ability to use his pool and hot tub.

1.2 Purpose

Mr. Hiller would like to be able to enjoy swimming in his pool and relaxing his tired body in his hot tub once again. Swimming in a cool pool during the summer allows the cooling of core body temperature, something that is extremely important for regaining strength. Due to the hot and humid summer days causing exhaustion on top of his MS, it makes it difficult for Mr. Hiller to enjoy his pool.

Being in a hot tub, recommended by his neurologist, is greatly beneficial to the circulation and health for individuals suffering from multiple sclerosis, as well an activity Mr. Hiller would enjoy. The hot tub will create an environment that stimulates exercise, increases blood circulation and heart rate, reduces blood pressure and essentially relaxes muscles, helping to relieve pain.

Since currently, there are only stairs to his pool and his hot tub is grounded on the side of his deck, in order to get in and out with his condition and decrease any pain in doing so, he requires a lift which would do the hard work for him. The lifts are motorized and securely anchored, creating a safe way into and out of the water. With the assistance of the lift, Mr. Hiller will no longer be held back by his lack of strength in his lower extremities for the enjoyment of his pool and hot tub. The lifts will allow him to be carried and submerged into the water without having to walk or stand. Once he is finished swimming, this same device will raise him from the water, returning him back to the wheelchair. In order to provide a layout where Mr. Hiller would be able to get in and out of his hot tub using the lift, the hot tub lift will be placed on the deck attached to the back door of his house. A ramp will be built to his pool deck, and another lift will be attached to the pool deck.

1.3 Previous Work
1.3.1 Products

There are several companies which produce this device needed for Mr. Hiller. ABLEdata is a company which carries several lifts for both the pool and hot tub. Most lifts are specific for people with disabilities related to mobility or spinal cord issues. The option of portable versus powered arises when dealing the construction or setup of lifts. Several are portable and even come with rechargeable batteries and remote controls. They even offer a lift which is operated via water power from the hose outside of the home. However, there are a few important qualities seen across all of the lifts which make for a better product. For one, it is key that the entire
device be made of a material compatible for the job it is to do. A stainless steel with a UV resistant powder coat finish would be a great choice due to its high corrosion resistance. A lift with 360 degrees rotation and arm rests which can flip is a great aspect. An adjustable molded seat, back, and leg rest along with a water resistant seat belt and a 300 pound capacity is standard for many of the lifts. It is also possible to build a lift which is collapsible into a storage position, providing the proper measurements upon expansion.

Most lift designs require the assistance of another person to control, however there are a few designs that allow manual use of the person being lifted.

1.3.2 Patent Search Results

Patents are a set of exclusive rules made for the inventor of a product to be consumed by the public. After searching for patents out for devices similar to the one we will construct many models were found including patent number 5,465,433 was released in November 14, 1995 by David Nolan of Kentucky for a seat lift suitable to be submerged in water shown in fig. 1.1. This compact and lightweight lift includes a seat on a frame extending off of the edge of the cement pool top and down into the pool. The seat lift includes a cylinder, frame, seat and a block which wraps around the cylinder, moving with the frame as support.

Figure 1.1. Patent Number 5,465,433. A device which follows the above patent shows a lift designed for an inground pool lift.

1.4 Map of rest of report

There are several components to the project which will be mentioned in this report. The first part of importance that will be discussed is the optimal design. This design is broken down into the objective, subunits and analysis. There are several conditions from outside elements which needed to be taken into consideration for a project such as the lifts. Engineering standards
is of great importance as well as realistic constraints including areas such as economy, environment, manufacture, ethics, health, safety, social and politics. With regards to safety, it entails a large range of aspects, considering any error could cause injury, error, or even potentially death. For the report, safety will be addressed from different angles inclusive of biological and chemical hazards, radiation, thermal and a couple of others relevant to our design. Building this project, it was necessary to discuss the impact of engineering solutions on global, economical and other levels, all which would affect the endeavors of future engineers. With this said, throughout the production of the lifts, the group as a whole has and will continue to learn a great deal about the materials and technological parts of engineering, stated in the report as life-long learning. Of course, with every project comes costs and great financial planning to obtain the product desired within a reasonable and affordable price range. For the building, a budget is kept and updated which is also included in the report. A timeline is also a part of the report because diligence and timely fashion are crucial to the success of the design project planning and constructing. With a team of five, each member is held responsible for certain tasks and a section of the report is dedicated to these individual contributions. To wrap up the report, a conclusion will be included as well as references, acknowledgements and an appendix included at the very end.

2 Project Design
2.1 Optimal Design

We have discussed a number of different designs that could possibly be used for the lifts necessary for Mr. Hiller. We chose our optimal design based on first and foremost Mr. Hiller’s safety. Other factors that led us to finalize our design to the resulting product include: money available in our budget, ease of use, time availability, weight distribution, and strength.

2.1.1 Objective of Optimal Design

This project will safely and successfully allow Mr. Hiller to enter and exit both his pool and hot tub by creating and implementing lifts that can lift a human and lower him electrically with the use of a remote. Mr. Hiller has also requested that a ramp be built to enable him to use his pool deck for relaxation and socialization. Our specific design used previously owned Bruno lifts that were modified and combined to create a safe, small lift to avoid creating a hazard around the pool and hot tub. The lifts have a winch connected to a 12 volt battery to power the lowering mechanism. Through waterproofing the circuitry should be read for the outdoor conditions these lifts will face. The original Bruno lift is depicted in fig. 2.1.1.
The lifts were initially designed as scooter or wheelchair lifts to assist loading into and out of a car, so they will need to be greatly modified to allow Mr. Hiller to be lifted. Since there was an addition to the shaft length the preloaded capacity of the lifts changed and we had to test both of the lifts with adequate weight. A back-up design was prepared as well, which would have been carried out if the Bruno lifts were proven inadequate for the pool lift.

Analysis has been done to account for the torques, stresses and strains that the lift and its supports will be impacted with. The analysis shows that the Bruno lifts will effectively be able to carry Mr. Hiller into and out of the pool.

This section will describe each part that is involved in both the optimal lift design as well as each part integrated into the back-up design. It will also describe the ramp that is to be built leading to Mr. Hiller’s pool deck.

2.1.2 Alternative Design 1

Our first alternative design lift actually acted as our optimal design before meeting with Dr. Enderle about the realistic capability of building the lift. It would be made of carbon steel and then sprayed with a stainless steel coating to make it resistant to weather corrosion. It would stand around 10 feet tall and be placed as close as possible to the pool/hot tub while also being adjacent to their respective porches. It would be installed on top of a large concrete base for stability, and extend upward 8 feet until it reaches a nylon bearing that will allow the remaining 2 feet of steel shaft to rotate. This would allow the boom to swing over the water. There would be a locking mechanism for the rotating shaft so that it could lock in place while Ron gets into and off of the lift. An electric winch system and a series of pulleys extending up the cylindrical shaft and over the boom will be responsible for raising and lowering Mr. Hiller in the vertical direction. The mesh chair that will hang off of the end of the boom will be detachable. This would allow Ron to place it on the seat of his wheelchair and sit on top of it when he gets ready to go outside. Once at the pool, the chair could be attached to the boom and Ron would not have to try to navigate into the chair. After swimming, it will be easy to get into from the water, and then he can be raised and placed back into his wheelchair. The design is shown in its entirety in fig. 2.1. The mesh chair is not depicted, but will hang down from the end of the boom.
2.1.3 Alternative Design 3

Our second alternative design would be made from the same materials and components as alternate lift 1, only rearranged. The base of the rotation would be on the bottom of the lift, and hence that is where the bearing would be located. This would cause the entire lift to rotate around its axis. A locking mechanism would be used to prevent the lift from swinging uncontrollably. The lift would lock in the ‘loading zone’, where the client would get into the chair, and then unlock and slowly swing to the ‘swimming zone’, where the lift would lock again so that the client may safely dismount after being lowered into the water.

The lift design would have a shorter main shaft, and then a boom that extends at an angle as shown in fig 2.2 below. There would be a pulley system that would run the entire length of the boom and shaft, connecting the chair to an electric winch. The cables that run through these pulleys would be composed of fiber for an optimal combination of a high strength and low weight material. The concrete base measuring 36in x 36in x 42in deep that serves to anchor the entire lift would have an approximate mass of 4567.5 lbs, assuming a density of 145 lbs/ft³. The chair of the lift would be a mesh hammock style seat which would prevent retention of water.
The angled mechanical design would result in the use of less tubing than a more traditional T-shaped design. This alteration would provide a more cost efficient lift, allowing us to save money. This angled design would allow use of shorter shafts which would make transportation slightly easier. Incorporated with the pulley system would be a safety locking mechanism, a precaution for possible winch malfunction. For example, if our client was lifted in the air and the winch failed, this safety feature would recognize the rapid cable acceleration and would lock the cable. This would prevent the chair from dropping any further, and therefore save the client from impact with the ground.

Lastly, this alternative design can be applied to either the pool or the hot tub. The location of the pool lift would be on the ground located next to the pool deck and the pool, while the location of the hot tub lift would be on the ground next to a sliding door of the client’s house and the hot tub.

2.1.4 Alternative Design 3

Alternative design 3, for the pool was a variation on alternative design 1 and the optimal design. This design would be to change the location of the lift so that it is up on top of the deck as opposed to next to it, which is similar to our optimal design. The idea would be that it would minimize the amount of cement we would need underground which would reduce costs for not only the cement, but also for the hole that would need to be dug. Rather than a 36”X36”X42” hole filled with cement, only about an 8” diameter by 42” deep hole would be necessary to support a 4” thick pole that would act as the support for the deck and the lift.

The rest of the support would be placed up on the deck. This would consist of a 3’X3’ metal plate drilled onto the deck or held to the deck using J-hooks. The plate would have a hole allowing the pole that is in the ground to go through and extend a few inches above the deck. On top of this plate, the lift would be mated over the pole. The lift would consist of multiple parts. First would be a 3 foot tall, hollow pipe, with legs extending out of the sides and attached at the
corners of the metal plate. The hollow pipe would fit over the pole that is in the ground. On top of this hollow pipe would be a nylon bearing that allows for rotation. On top of this rotating bearing would be the rest of the lift, which consists of an addition 2 feet of height, with a 5 foot boom so it can extend out over the pool. Attached to this boom would be a handle for rotation to make turning the lift easier. An electric wench would be attached to the two foot pole and would run a steel cable up over the boom through three pulley systems. The line would have a carabineer attached to the end so that a mesh seat can be used by Mr. Hiller. He can slide it over himself while still seated in his wheelchair and use an additional carabineer attached to the seat to hook himself onto the lift. This design can be seen in fig 2.4 below.

![Figure 2.1.4 Alternative Design 3](image)

This design would be advantageous because it would cut the amount of cement and digging necessary. It would also allow a better distribution of the weight bearing on it by allowing some weight to be put on the base on top of the deck while still giving the deck support from the ground. Drawbacks to this design are that in order to dig under the deck and install the pole, a contractor would need to be hired to not only take away part of the deck to be able to have room to dig, but also to rebuild the part of the deck that was torn away because the hole is so large, compared to the smaller, easier to dig holes which will be used for the pylon supports. This would increase our budget by hundreds of dollars, which is the primary reason it is not the optimal design.

2.1.5 Alternative Design 4

In order to lift Ronald Hiller from his wheelchair into his pool and hot tub we intend to use a lift that has a moving part that can go down to his seat and up into the pool. The moving mechanisms we have looked at are either hydraulic lifts or a winch lift system. This design would utilize a hydraulic lift. The lift would be attached to a metal plate which is attached to a cement block in the ground. The shaft of the lift would be approximately 6 feet tall. Attached
by a hinge to the top of this lift would be the boom of the lift which would range from at an angle of approximately 135 degrees to 90 degrees. Welded to both the boom and shaft would be a support beam creating a triangle including the hinge. This would provide the support necessary for this design. The hydraulic pump would be attached to the boom of the lift. This would give it a straight line of action to the pulley at the end of the boom. The rope and seat would be attached to the end of the boom. The lift would be able to move vertically four feet moving the chair down to Ron’s wheelchair and still have enough lift to clear him over the edge of the pool. This set up would allow Ron to be lifted out of his chair to a height of at least 6 feet which is more than enough to clear the edge of the pool and then finally placed down into the pool.

The second and more important change for this design would be the change in where the rotational axis is located. In the first design it is located at the top of the shaft between the shaft and the boom. In this design since the angle between the shaft and boom would be welded the location for rotation must change. The rotational axis here would be at the base of the lift. The shaft is hollow which would allow a smaller diameter rod to be placed inside of the shaft. This rod would be welded to the plate attached to the cement. The shaft would slide over this rod and be allowed to rotate around it freely. Using either a nylon bearing or a ball bearing support, there should be no trouble rotating the lift. By attaching the joint between the shaft and boom with a hinge, there are only three pieces of metal required above the rotational axis, much less than in the original design. At the base of the shaft there would need to be a solid piece of metal or a thick cylinder to support the torsional strain that is caused by Ron’s weight on the end of the boom. The weld between the shaft and base would need to be strong and the bearing would need to be able to support the weight of the lift and Ron. A depiction of this lift has been shown in fig. 2.1.5.

Figure 2.1.5 Alternative Design 4

2.2 Subunits
The lifts can be broken down into multiple units including vertical movement by winch and actuator as well as rotational movement.
2.2.1 Bruno Lift
2.2.1.1 Pylons for Support

In both cases with the hot tub and pool, these lifts will be located on decking. In order to avoid the decking from being ripped up from the torsion created by the lift the legs will be secured to wood pylons below the deck that we will be installing. In order to do this we require a pylon digger as well as Sonotube molds which allow cement to be cured in a perfect cylinder. These pylons will help support the weight and torsion that will be created by this lift. Using simple bolts the lifts can be attached down into these pylons. The Sonotube molds come in varying diameters; we will be using the 8 inch diameter tubes with a depth of 3 ft. which requires .039 cubic yards of cement. This requires only 2 80 lbs. of concrete per hole. Since there will be 6 holes this means we will only need 12 bags. The support posts will be 4x4 which are easy to find in any length. In order to accomplish this task we hired a contractor, Jim from Evergreen decks to create these supports for us. In doing so we can cut the 4x4 to the perfect length so it will be touching the bottom of the deck when we put the top of the deck back on.

Looking at fig 2.3 in the next section it can be seen how the bolts go through the end of the lift into the decking. These places are where we will be lining up our pylons for support.

2.2.1.2 Lift Base
The NEAT market carries multiple versions of the BRUNO lift which have varying components and add-ons. Each of these lifts however has the same base as seen in Figure 2.3 above. The open cylinder seen can fit different shaft lengths which are important for our project as we need to extend the height of the lifts. The base legs are sufficient support for the lift as these lifts have predetermined weight capacities. In order to secure the lifts down they will be bolted through the deck into wooden beams below for extra support. The only addition to this base will be a bracket at the joint in order to allow us to bolt the lift down in three places, the end of each support beam and the middle. Since we will be extending the length of the shaft we will also be lowering the determined weight load for that specifically rated lift. We used parts from the two disassembled lifts in order to create leg extensions for the lifts where necessary. The corner shape of the base will give us space to place the lift on the deck as well as create a loading area for our client. With on leg of the lift touching the pool edge, the other will be pointed out into the deck. Ron can pull his wheelchair up into the space between the base below the lift itself and turn himself towards the pool so that the tip of his wheelchair is touching the edge of the pool. From there it is only a matter of 45 degrees of rotation for the lift. This will mean that the load on the lift will always be distributed between the two legs of the lift, the strongest area of the base.

2.2.3 Rotation at the Base
Above the base there are many ways in which the Bruno can be assembled. In both the hot tub and pool scenarios we need rotation. There are two different methods for rotation using these lifts, the first being at the base of the lift, the second being at the top of the shaft. In our case we will be using base rotation devices for both lifts because these are the parts accessible to us. The rotation is dependent on a drive chain attached to the motor. The motor is a 12v motor that will be run using a car battery. As seen in fig. 2.2.4 above, the drive chain goes around the universal base attached to teeth which are part of the shaft. We will be extending the shaft either in the middle or the top so these teeth as well as the way they fit should not be effected. The rotational motor is housed in plastic casing as seen below:

The lifts at the NEAT market include these housings, but as seen in the picture above, there is plenty of space for the weather to take its toll on the lift. We will be using rubber and epoxy to weatherproof the lift. Coating the lift properly will be discussed in a later section.

The entire lift is powered by a 12V battery, in this case we will be using a car battery. The rotational motor has one wire coming out of it for power, and two going out to the circuit.
board for control from the remote. The circuitry for many of these used lifts is exposed. Once we obtain the parts we will have to determine which motors work, and which circuit boards and motor combinations we can use. There are at least three lifts at the NEAT market that have the rotational motors for these lifts. All of these lifts have a weight capacity over 350 lb. which is more than enough for our purposes, and this lets us know that the motor can handle these weights.

2.2.1.4 The Shaft

The shafts for the Bruno lifts vary between each different type from square to circular to hexagonal. Depending on which motors and circuit boards we can get working together, we will determine which shaft fits that need. The average height of these Bruno lifts is 3.5 feet. Our client Ron, sitting in his wheelchair is around 4 feet 8 inches high. We needed to increase the shaft of the lifts to get the boom of the lift up to Ron’s face so that the winch and seat can be at Ron’s wheelchair seat height. The shafts were increased using a collar weld. In order to accomplish this the shafts and pieces from the disassembled lifts were prepared for welding. After talking to Pete and Serge in the machine shop to create a strong weld for each shaft we decided to use a collar weld. With this method the two adjoining shafts are welded together with a collar piece of metal over or inside of the shaft. Essentially the collar welded to the two shaft ends increases the surface area of weld and holds the joint in place from bending. The process required a lot of grinding and cutting to get the pieces prepped for welding, and after the welding the welds were ground flat.

![Figure 2.2.6: The Shaft’s Location within the lift.](image)
This will ensure that the load is not distributed to the weld spot which would make it much easier for a failure to occur. Since we added the extension to the shaft in the middle, we were able to keep the bottom and top the same which allowed us to change the base or head of each lift.

### 2.2.1.5 The Boom

There are two main different types of Bruno lift booms available to us, the ones that use an actuator and the ones that use a winch for vertical motion. We chose to use the winch as it allows the booms reach to be the longest in comparison to the actuator which effectively shortens the length of the boom as it changes the angle at which it is attached to the shaft. A picture of the boom attachment can be seen below:
Just like the rest of the Bruno, the boom attachments are universal. Among the different Bruno lifts we picked up from the NEAT market we assessed the lengths and structures to determine which lifts we wanted to use. The two main booms we will be working with can be seen in the pictures below:

2.2.1.6 The Winch

In order to move our client vertically from his seat into the air, and then down into the water and vice versa, we are using a winch system. The Bruno lifts at the NEAT market had winches like these pre-loaded for the weight capacity we need (they are all loaded for at least 350 lb.) As seen in fig. 2.2.9 attached to the boom as well as a close up in fig. 2.2.10, the winch motor is located on the boom right next to where the cable comes out of the boom. It turned out through testing that 3 of the motors supposedly rated for 400 lbs could not handle 250 pounds and had to be replaced.
The winch like the rotational motor is powered by 12V. The controls for the winch run through the circuit board on the Bruno lift. In order to control the winch there is a simple up and down button on the remote control. The winch speed is only 10 feet per minute which is more than slow enough and safe enough for our client’s needs. In order to protect the winch we will be creating a housing coated in spray on protection.

2.2.1.7 The Remote and Circuitry

A key component of our design and of the Bruno lifts is the motorization of all the motions. In order to rotate and move the client vertically, motors are used. In the case of vertical movement a winch is used, and in the case of rotation a drive chain and motor are used. This is all powered by a 12V battery, but the controls for these systems are run through a circuit board. There is no direct contact between the power source and the motors. The lifts at the NEAT market had these components but for many of them the circuitry was exposed and the condition of the remote was not well known. For each motor there is a connection to the circuit board which is connected to the remote and thus controls the power flow to the motorized components. The biggest task for us when we got the lifts was to understand the circuit flow as well making sure the remote to motor connections work. Testing of each component only took a couple of minutes, but the troubleshooting of non working components as well as taking out each component we want required a better understanding of the circuitry and connection between the remote and motors.

![Figure 2.2.11: Bruno Lift Controller and Rough Circuitry connection Schematic]

Just as is the case with the rest of the lift, the circuitry needs to be weather proofed. In order to do this, we are covering the circuits with acrylic to prevent connections and we also are put hosing around the circuits.

2.2.1.8 Seat

The seat for the lift is an important factor contributing to durability, ease of use, and comfortability of the pool and hot tub lifts. The chair used will be an AliMed Full Body Seat Sling, model number 78251, shown below. AliMed, Inc is a medical supply company based in Dedham, Ma.

Because Ron Hiller is not a particularly small man, a size large seat will be used. Its dimensions are 47- ⅜” wide by 58- ¼” long. The seat has a weight capacity of 450 pounds, which will more than account for the weight of Ron Hiller, which is 250 pounds. The 450 pound weight capacity will also allow for the extra weight that will be added to the seat and Mr. Hiller when both are soaked with water from the pool, which can add a significant amount of weight.
The Full Body Sling Seat is lightweight and mesh, which will make the lift more water compatible because of its quick drying ability. By not holding water for a long period of time, the seat will be more durable and have a longer product life. The seat also features a head rest that will be more comfortable for Mr. Hiller and will give better stability as the lift is in motion. This stability will be a good safety feature for the lift by eliminating the possibility of whiplash while the lift is raised, lowered, or rotated.

The seat has four chains on each corner that are used to connect the seat to the lift. Because the seat will be detachable, Mr. Hiller will be able to slide the seat under himself while still seated in the wheelchair and then connect the seat to the lift. This will also allow only one seat to be needed for both lifts. This will cut the budget for the seat in half as opposed to a permanently attached chair or rigid seat that is featured in many other pool lifts. The two chains on the left will be connected using one carabiner while the two chains on the right will be connected using a second carabiner.

The cost of the mesh seat is $94.50 with a shipping and handling charge of $13.49. This gives a total budget for the seat of $107.99.

2.2.1.9 Connecting the seat to the Lifts

The carabiners mentioned above will be Black Diamond Quicksilver2 Screwgate Carabiners, shown in fig 2.2.13 below. The carabiners were purchased from Mansfield supply.
Figure 2.2.13. Black Diamond Quicksilver2 Screwgate Carabiner

The carabiner has a weight of 56 grams, or 0.12 lbs., so the weight for each carabiner is essentially negligible on the lift. When the screw gate is closed, the carabiner has a strength of 25 kN, or 5620 lbs. Thus, the carabiners will be strong enough to lift a 250 pound man. The gate has an open clearance of 17 mm. The screwgate is a safety feature that allows the carabiner to lock into the chains on the seat without the chance that the chains would become unhooked while the lift is in operation.

Both carabiners can then be hooked onto the cable of the winch for lifting, rotating, and lowering. They can then be easily released once in the pool or wheelchair. The screwgate is user friendly because it is easy to twist, but dependable to not become open during use. Even if by some small chance the carabiner does open, it has an open gate strength of 8 kN, or 1798 lbs, so accidental opening would not cause failure of the seat or lift.

This carabiner was chosen because it has a locking screwgate, user reviews all recommended the use, and they are inexpensive. Each carabiner costs $7.95, and two carabiners will be required. Shipping costs $5.99. The total cost will be $21.89. Cost of shipping can be eliminated if the carabiners are ordered to a specific store location and picked up. That would give a total cost of $15.90.

2.2.2. Ramp Design
In order to get onto the deck of his above ground pool, Mr. Hiller needs a ramp wide enough for his wheelchair. Currently, as can be seen in fig 2.14 above, there are a set of stairs to get to the deck, which are no longer useful for Mr. Hiller, but can still be of use to his family, so we don’t plan on tearing down the stairs. Instead, the ramp will be placed just to the right of the stairs, and a landing will be created so that Mr. Hiller will be easily able to navigate the ramp and deck in his wheelchair. We have acquired quotes from different contracts but due to budget and Ron’s wants for his deck we currently have not worked out a good ramp for him. We still have 2800 dollars in the budget and are trying to work out a way to get Ron his ramp.

2.2.3 Backup Design Plan
In case the Bruno lifts fail to meet the stability and lifting standards for this project, the lift design from fig 2.15 will be used for both the hot tub and the pool. The lift is a light duty free standing jib crane made from A36 steel and is designed to lift a capacity of 750 lbs (340.19 kg) and the total weight of the crane is 733 lbs (332.6 kg). The thin cylindrical base of the crane is anchored by j-hooks into a concrete base. Four triangular base supports stabilize the base/shaft junction. The cylindrical shaft of the crane is covered at the top by a rotating shaft which will cover the roller bearings, located at the top of the shaft, which, along with the rotating shaft, will allow the crane to rotate if necessary. Finally, the beam that will extend over the pool is an I-beam. In fig. 2.2.15, the I-beam has a 10 foot span. This is false. Our design has a 6 foot span I-beam. However, since the company does not have any 2D or 3D representation of the model, we used their 10 foot I-beam span to represent our backup design. It is only the I-beam span that is the difference between our design and fig. 2.2.15, everything else is the same. However Attached to the I beam are four angles, one pair placed, on both sides of the beam, 18.16 inches from the side of the I-beam connected to the shaft, the other pair 84 inches, on both sides of the beam, from the same side of the I-beam. These angles are used to limit the movement of the geared trolley placed between the two placed angles. Attached to the trolley is a winch that will hook
onto a carabineer that will link the cable from the winch to a sling where the client will sit on to be lifted in and out of the pool. Finally, the crane will be coated with UV, water, and rust protection spray.

2.2.3.1 Concrete Base

![Figure 2.2.16: Solidworks Diagram for concrete base for lift](image)

The concrete base for the lift has base dimensions of 48inchesx48inches (121.92cmx121.92cm). The depth of the base must be 42 inches deep in order to meet the State of Connecticut’s mandated law stating that any support pylon must go at least 42 inches into the ground in order to avoid damages from permafrost. In order to make this concrete base, a contractor must be hired or a backhoe must be rented to dig a hole 42 inches deep. A volume of 2.07 cubic yards (1.58 cubic meters) of dirt must be removed and the same volume of concrete must be poured in. In order to obtain this volume of concrete, 94, 80lbs bags of concrete must be purchased and mixed. Once the concrete has been poured, the top of base must be leveled off as much as possible and while the concrete is still wet, four j-hooks will be placed across from one another as shown in fig. 2.2.15, distance between one j-hook to the j-hook across the base must be 21 inches (53.3 centimeters), also shown in fig. 2.2.15. The j-hooks placed in the concrete must fit the 15/16 inch (2.38 centimeter) diameter holes on the lift’s base plate.

The cost of making these concrete bases will be expensive. In order to ensure a level concrete base and the tools necessary to lift 2.07 cubic yards of dirt, a contractor must be hired due to our group’s lack of experience. The cost of a contractor to dig these holes and fill them with cement may cost around $2500. Included in this quote is the price of 94 80lbs bags of concrete which comes to $940 if each bag cost, on average, of $5 per bag.
2.2.3.2 Base Plate

A 2D depiction of the base is shown in fig. 2.2.15. The base is a cylinder with a diameter of 24 inches (60.96 centimeters) and a height of 0.5 inches (1.27 centimeters). The base is also made out of ASTM A36 Steel. Therefore the base would weigh about 55.5lbs (25.2kg) and have a density of 0.28 lbs/in$^3$ (7750kg/m$^3$). Four holes are drilled into the base. The holes are drilled across from each other as seen in fig 2.17. The distance between one hole and the one across from it is 21 inches (53.34 centimeters). The diameters of the holes are 15/16 inches (2.38 centimeters). The holes will allow the j-hooks that are imbedded in the concrete to go through the base plate. The holes are also the places where the shaft supports, which are welded onto the shaft, are attached to the base plate, as seen in fig. 2.2.15. A 3D depiction of what we think the base would look like, since the actual dimensions were not clearly stated in fig. 2.2.15, is shown below in fig. 2.2.17.

![Figure 2.2.17: SolidWorks depiction of the metal base plate, the blue ring shows where the shaft will be placed](image)

2.2.3.3 Shaft supports

The four solid shaft supports, made of ASTM A36 steel, are placed and welded perpendicular to each other around the shaft. The shaft supports are triangular in shape. The height of each support is 24.7 inches (62.84 centimeters), the length of the base of the support is 3.375 inches (8.573 centimeters), and the thickness of each support is about 0.5 inches (1.27 centimeters). The volume of each support shaft comes to around 20.84in$^3$ (34.2cm$^3$). With the density of A36 steel of 0.28 lbs/in$^3$ (7750kg/m$^3$), the mass of each shaft support comes to about 5.84 lbs (2.75 kg). At the bottom of each shaft support is a square plate, dimensions unknown,
with a 15/16 diameter hole. These holes are placed through the j-hooks bolts after the base plate has been placed through the bolts. Only once the shaft is set, can the nuts be screwed onto the j-hook bolts. Since the square plates attached to the base of each shaft support have unknown dimensions, a 3D representation of the shaft supports cannot be done and assuming these dimensions may lead to misrepresentation.

2.2.3.4 Stationary Shaft
The hollow stationary shaft, shown as part 3 in fig. 2.2.15, of the crane is also made out of ASTM A36 steel. It is 120 inches (304.8 cm) and has an outside diameter of 8.625 inches (21.9 centimeters). The inside diameter is unknown based on fig. 2.2.15. Therefore the volume and mass of the shaft cannot be determined. However, the density of the object is known to be 0.28 lbs/in\(^3\) (7750 kg/m\(^3\)). One end of the shaft has four welded shaft supports and stated before. The other end of the shaft contains a roller bearing system that will allow the lift to rotate. The top part is also covered by the rotating shaft. About 42.1 inches (106.9 centimeters) from the top of the stationary shaft, a rectangular base, dimensions unknown, protrudes from the shaft with two thoroughly drilled holes lying on the same axis. This protruded base will help set the rotating shaft cover in place. Due to the unknown value of the inner diameter of the shaft and the unknown dimensions of the protruded base from fig. 2.2.15, a 3D AutoCAD representation of the object cannot be done.

2.2.3.5 Rotating Shaft Cover
The solid rotating shaft cover covers the gaps created by the overlap of the stationary shaft and the rotating shaft as seen in fig. 2.2.15. The dimensions of this cover is unknown, however it is made out of ASTM A36 steel. Therefore, it has a density of 0.28 lbs/in\(^3\) (7750 kg/m\(^3\)). Also a hole with a diameter of 8.625 inches (21.9 centimeters) must be bored through in order for the cover to fit around the stationary shaft. Again, due to unknown dimensions, a 3D AutoCAD drawing cannot be made.

2.2.3.6 Rotating Shaft
The hollow rotating shaft is placed over the top of the stationary shaft, as shown in fig.2.2.15. The rotating shaft has a height of about 42.1 inches (106.9 centimeters) and an external diameter of about 10.8 inches (27.4 centimeters). The internal diameter is not depicted in fig. 2.2.15, therefore it is unknown. Due to the unknown internal diameter, the mass and volume of the rotating shaft is unknown. However, since the rotation shaft is made of ASTM A36 steel, it has a density of 0.28 lbs/in\(^3\) (7750 kg/m\(^3\)). The rotating shaft is set in place by 5/8 inch x 1.75 inch (1.59 centimeter x 4.45 centimeter) bolts from the top of the rotating shaft that will connect the rotating shaft and the I-beam. Therefore at the top of the rotating shaft, are two metal ASTM A36 steel wedges welded onto the rotating shaft, the bigger wedge facing the short side of the I-beam while the shorter wedge faces the longer side. The dimensions of the wedges are unknown but two holes, both 5/8 inches (1.59 centimeters) in diameter, are placed on the same horizontal axis are drilled through the rectangular base of each wedge. Due to the unknown dimensions of the welded wedges and the unknown value of the inner diameter of the rotational shaft, a 3D AutoCAD representation of the rotating shaft cannot be made.

2.2.3.7 Roller Bearings
The roller bearings depicted in fig. 2.2.18 are placed at the junction of the I-beam and the stationary shaft in order to allow manual rotation of the lift. The bearings that come with the crane have an inner diameter measurement that can range from 1 inches to 47.25 inches (2.64 centimeters to 120 centimeters) and an outer diameter range of 1.2 inches to 96.85 inches (3.04 centimeters to 246.0 centimeters). The height of the roller bearings and the material of the roller bearings are unknown. Therefore the mass, density, and volume of the roller bearings cannot be calculated. In this project, these bearings will be limited to a maximum of 90 degree rotation in order to prevent the client to swing dangerously around and to keep him over the pool/hot tub and/or deck at all times.

2.2.3.8 I-beam and angles

The I-beam is placed on top of the shaft where 12.6 inches (31.75 centimeters) is measured on the side with the larger wedge and 72 inches (182.98 centimeters) is measured on the side with the smaller wedge as seen in fig. 2.2.15. The I-beam is 6 inches (15.24 centimeters) tall, 84.5 inches (214.63 centimeters) long, and 6 inches (15.24 centimeters) in width. The center of the I-beam is called the web and it is located 3 inches in from both sides of the I-beam when viewed from a frontal view of the I-beam. The thickness of the I-beam, all around, is assumed to be 0.5 inches. With this safe assumption, the volume of the I-beam is measure out to be 718.25 in$^3$ (1177.93 m$^3$). Since the I-beam is also made out of ASTM A36 steel, the density of the I-beam is 0.28 lbs/in$^3$ (7750 kg/m$^3$). The mass of the I-beam comes out to be 165.2 lbs. The angles placed on the I-beam, as stated before, have the dimensions of 7 inches by 2.6 inches by 0.25 inches (17.78 cm x 6.35 cm x 0.635 cm). The angles are bent so that 3 inches are bolted into the I-beam with 5/8 inch x 1.75 inch (1.59 centimeter x 4.45 centimeter) bolts. The remaining 4 inches will protrude out of the I beam. The angles are set so that the 3 inch sides of the angles are facing away from each other and the protruding 4 inch sides are facing towards each other, as depicted in fig. 2.15. These angles will limit the movement of the trolley. The 2D and 3D representation of the I-beam and angles can be seen in fig. 2.2.15.
2.2.3.9 Trolley

The geared trolley, depicted in fig. 2.2.19, uses gears to move across the I-beam. This allows the client to move over the pool/hot tub in order to be lowered down into the pool or raised up out of the pool/hot tub. A looped chain hangs down from the trolley and acts as the driving mechanism to move the trolley across the I-beam. The gears that are connected to the I-beam should be 5 inches (13.75 centimeters) or lower in order to attach to the I-beam. The materials that make up this trolley and the dimensions of the trolley are unknown. However, the trolley is said to hold up 1000 lbs (453.6 kg). The geared trolley is placed between the two angles where the movement of the trolley will be limited to a distance of 65.84 inches (167.23 centimeters). This trolley in fig. 2.2.19 will be modified in order to secure a winch on the trolley.

2.2.3.10 Winch and cable
The winch used in this design is an 880 lbs (362.10 kg) electric overhead hoist lift. It will be welded onto the trolley, which will be already placed on the I-beam between the two angles. As depicted in fig. 2.2.20, the winch is controlled by a remote, which will power the winch up when the client wants to get out of the pool or down when the clients wants to get into the pool. A waterproof coating will be placed on the remote to avoid any water from entering the remote and short-circuiting it. A 5 foot (1.52 meter) cable connects the remote to the winch. The winch is made out of housing material, the motor and gears are made up of cast iron and aluminum respectively. Since our design requires a single line lift, this winch will be able to lift 440 lbs. (199.6 kg) at a rate of 33 feet/min (0.168 m/s), which meets our requirements for our design. The winch is powered at 110/120 volts which the outdoor outlets are capable of supplying that amount of voltage. The cable wrapped around the winch is made out of high carbon steel. This cable will also be coated with waterproof and rustproof chemicals to sustain longevity. The cable has a length of 38 feet (11.58 meters) and a diameter of 1/8 inches (0.3175 centimeters). At the end of the cable is a heavy duty hook. Attached to this hook is a Black Diamond Rocklock Screwgate Carabineer. The carabineer connects the hook to seat where the client will be sitting on. The carabineer is 0.187 pounds (85 grams) and is capable to holding forces up to 5395.4 pounds (24 KN).

2.3 Analysis

It is important to be able to analyze the forces acting on the lift in order to determine the reacting forces that act along the shaft and base. The weight of the chair and our client, Mr. Hiller, applied across the boom of length D causes a torque, otherwise known as a moment, at the top of the shaft with length L. The equation to find the torque applied on the shaft is:

\[ \text{Torque} = F \times D \times \sin \theta \]
F represents the weight acting on the end of the boom, D is the length of the boom, and θ is the angle between the force being applied (F) and the boom (D). For this lift design, the weight was estimated to be 300 lbs, which converts into 136.4 kg. This means that there will be approximately 300 lb-f, or 1,334.5 Newtons of force being applied downward at the end of the boom. The angle between the direction of the force and the boom is 90 degrees. The length of the boom, D, is adjustable, but will be approximately 3 feet, or 0.9144 meters. Therefore, torque can be calculated by the following:

\[
Torque = 300 \text{ lbf} \times 3 \text{ feet} \times \sin 90^\circ = 900 \text{ lbf \cdot ft} = 1220.3 \text{ N \cdot m}
\]

Figure 2.21 below depicts the lifting system and defines locations for the variables mentioned above. The weight of the boom was ignored because it is insignificant compared to the weight of the client and chair at the end of the boom.

![Diagram of Optimal Lift Design](image)

**Figure 2.2.21: Diagram of Optimal Lift Design**

Torsion occurs when a torque is applied to the shaft, which results in shear stresses and an angle of twist on the shaft. To find these values, it is necessary to first find the polar second moment of area, J. This can be found by:

\[
J = \frac{\pi \times (D - d)^4}{32} \quad (2)
\]
D and d are the outer and inner diameters of the shaft respectively. Exact measurements weren’t given, so the estimated values for D and d are 0.1 meters and 0.7 meters respectively. Given these values, the polar second moment of area was found to be:

\[ J = \frac{\pi \times (0.1 - 0.07)^4}{32} = 7.952 \times 10^{-8} \text{ m}^4 \]

From this, the shear stress and angle of twist on the shaft can be calculated with the following equations:

\[ \tau_{\text{max}} = \frac{T \times R}{J} \quad (3) \]

\[ \theta \text{ (angle of twist)} = \frac{T \times L}{G \times J} \quad (4) \]

T is defined as the torque that was previously solved for, R is the radius of the shaft, L is the length of the shaft, and G is the shear modulus or modulus of rigidity. The length of the shaft was approximated at 0.9144 meters, or 3 feet, and the radius of the shaft as 0.05 meters. G, the shear modulus, is a constant, and can be assumed to be 80 GPa for carbon steel.

Using the values, the shearing stress and angle of twist using equations 3 and 4 were found to be:

\[ \tau_{\text{max}} = \frac{1220.3 \text{ Nm} \times 0.05\text{m}}{7.952 \times 10^{-8}} = 767 \text{ MPa} \]

\[ \theta \text{ (angle of twist)} = \frac{1220.3 \text{ Nm} \times 0.9144\text{m}}{80 \times 10^9 \text{ Pa} \times 7.952 \times 10^{-8} \text{ m}^4} = 0.175 \text{ radians} = 10.05^\circ \]

If the assumed values are correct, these calculations show that it is pertinent that the design be well analyzed because the shaft will be placed under severe stress and try to twist to relieve this stress.

The value for the angle of twist will change if the shaft is lengthened during the design process since its equation depends on variable L. The length of the shaft could be extended up to 5 feet, or 1.524 meters. If this were the case, the angle of twist would be calculated as follows based off of equation 4:

\[ \theta \text{ (angle of twist)} = \frac{1220.3 \text{ Nm} \times 1.524\text{m}}{80 \times 10^9 \text{ Pa} \times 7.952 \times 10^{-8} \text{ m}^4} = 0.2923 \text{ radians} = 16.75^\circ \]

This increased angle of twist as a result of lengthening the shaft will be something that needs to be carefully analyzed and additional supports may need to be added to decrease the twisting angle of the shaft.

The calculation of the compression in the base plate legs can be determined in a similar fashion. Since the moment is known at the top of the shaft, the moment will be equal and opposite at the bottom of the shaft. The base length, depicted as B in fig. 2.2.20, is approximated
to be about 1 ft, or 0.3048 meters. Therefore, to find the compressive force at the end of the base lengths, the torque equation (equation 1) is just rearranged to:

\[
\text{Force} = \frac{\text{Torque}}{\text{Distance}} = \frac{1220.3 \, Nm}{0.3048 \, m} = 4003.6 \, N
\]  

(5)

Therefore the compressive force is 4003.6 N. However, this will be alleviated by the pylons and support underneath the porch, so this large compressive force shouldn’t pose as a significant problem.

In conclusion, this analysis has shown that it important to be careful when we install and test the device, because significant high stresses and forces are acting on the lift design. However, these Bruno lifts were designed to be able to carry this much weight, so only the redesigned and increased shaft length should pose a potential problem which will need to be carefully tested for safety purposes.

3 Realistic Constraints

3.1 Engineering Standards

For the construction of the lifts, all of the standards for building and safety such as patents and state regulations had to be taken into consideration. When digging for cement placement for pylons or in case of the back-up lift, the composition of the land beneath and angles of the terrain must all be incorporated. When considering ramp construction, state regulations for measurements must be followed or the ramp will be deemed a violation, preventing it from use. More specifically, for engineering purposes, all of the designs and any sketches had to be documented. Several values were obtained from calculations, lengths, weight angles and materials which were all recorded for future reference and verifications. The Bruno lifts give a weight capacity of 400 pounds so for the pool lift, it is important that any sort of piece we add to the lift to extend the height or length must not cause the total weight including Mr. Hiller and water to exceed 400 pounds. This has been considered and to account for the possibility of exceeding the weight capacity, the back-up design has been included.

3.2 Economic

Initially, the back-up design was considered as an optimal design, however, the cost to build two would have far surpassed the budget we had. This constraint caused us to take a step back and reconsider the design. The cost of one new Bruno scooter lift is upwards of $1000. This doubled, plus the price of shipping, a ramp, and all other parts to alter the lifts would heavily outweigh our budget. This turned us towards the NEAT marketplace, where six used Bruno lifts were found at only $50 each. This will allow us to purchase all six, and use the parts to create two working lifts. The cheap cost of the lifts will also leave money to purchase the materials for a lift of the back-up design if it so needed. Because lift failure is completely possible with the use of used lifts, it is important economically to save as much money as possible to leave the option for a back-up lift.

The cost of hiring a contractor to build a ramp can cost around $2,500, so originally we thought we would have to eliminate the ramp altogether or find someone to donate materials or labor. Luckily we were able to get the budget required, just as of now Ron has turned down one contractor we had ready to build the ramp due to a disagreement over the ramp materials and location.
3.3 Environmental

Because the lifts will be permanent structures outdoors, it is important that we consider the climate and its effects on the lifts. New England winters can be harsh, so it is important that the structures of the lifts are not compromised by snow, ice, or rain. The Bruno lifts are designed for outdoor use so they have been manufactured with weather in mind. However, as a precaution, we have included weatherproof and UV-proof coating for our designs.

The environment has also put limits on when and where we may build our lifts. Because the weather will not permit us to build on-site until the spring, so we must do the bulk of our reconstruction and testing in more of a lab setting, which is difficult because it will not incorporate the porches upon which the lifts will be installed. Also, if the back-up plan must be initiated, the cement base cannot be laid until the permafrost melts in the spring. For the most part, the weather affects the installation of the lifts.

Another environmental factor that affects the design and implementation of these lifts is that the lifts will be built on top of the porches in Mr. Hiller’s yard. The decks should be able to hold the lifts and the added weight on their own, however, to account for these restrictions, cement and pylons will be built under the deck to support the weight of the lifts and Mr. Hiller.

3.4 Sustainability

In building the lifts, we have incorporated materials which can hold up through various weather conditions, water damage, weight and so on. Since these lifts are for a pool and hot tub, they will be exposed to a great deal of water containing chlorine. Chlorine is a strong chemical which can easily break down the durability and quality of materials if the wrong one is applied. Keeping this in mind, we have decided to use a mesh seat which will hold up and allow the water to pass through with ease. The choice of lifts meant for the outdoors along with a weather resistant coating creates a durable and resistant device which will hold up while outside. The real stability of the lifts will come from the pylons underneath the porches which will be placed inside the ground. These pylons and their cement supports are where the actual lifts will be anchored which will create a great strength for the weight the lift will have to sustain.

3.5 Manufacturability

Time and resources, or capabilities are the major manufacturing issues for the lifts. In order to complete certain parts, assistance will be needed. The timing factor is important because the process of building lifts which can hold up under the conditions we desire takes time and attention. The material and money we have to work with is a determinant in the way we must go about building the lift. Ideally, we would use all of the best materials used, but due to limitation of funding we must choose wisely to incorporate durability, safety, and price. Often times, the same job and a functionally safe device is possible without spending a ton of money which is what we are trying to accomplish. We want to use pylons which require cement supports which will need to be laid down prior to building the rest of the lift so that needs to be planned out and set in place in a timely fashion. Welding of the materials may also need to occur at on the device so we must have the ability to weld or the access to a safe welding area. This welding needs to occur in the machine shop which creates restraints on time and place of the construction. This is also something that needs to be completed in timely and orderly manner.

3.6 Health and Safety
A device that does not create health or safety hazards for Ronald Hiller is crucial and steps of prevention must be integrated into the design of the lifts. One concern is ensuring the equipment remains sterile at all times, even when exposed to the harsh outside air. The metal will likely be resistant and hold up through any change in weather and moisture, so that is not a major issue. The seat however, will be exposed to water and moist conditions which can leave room for microbial growth. The chlorine in the pool and hot tub acts as a disinfectant, killing off bacteria when the seat is exposed to it. However, health conditions when the seat is not in the water must be considered. The device must be able to handle the stress and strains which it will be placed under. Since our client is a relatively heavy man, the seat and lift need to be able to hold him securely and without risk. This will require testing to take place to ensure stability and strength. We will use materials and such that will last through these conditions, but actual thorough testing cannot occur until the construction is completed. The seat must be attached in a manner which does not run the risk of falling off or breaking, causing injuries. The lift itself must be secure because running the risk of failure is a factor we want to minimize. Also, we must make sure the lift does not swing uncontrollably and at dangerous angles so no falling of the client or damages to the device will occur.

4 Safety Issues
Several safety issues play a role in the construction and entire operation of the lifts.

4.1 Electrical
Failure of the winch is a definite electrical concern. If the winch fails, we need to make sure that our client will not be dropped uncontrollably, which could cause extreme injuries or even death. Another addition would be a safety stop to ensure that the winch, if failure occurs, would eventually stop going up. It is of utmost important that the housing of the remote is completely waterproof so as to not destroy the circuitry because it is will be in contact with a pool and will remain outdoors throughout the year.

4.2 Mechanical
The mechanical properties of the optimal designs must be able to withstand the weight of Mr. Hiller and any water added to the seat when lifting in and out of the pool. The analysis on both the boom and the lift itself needs to be done correctly to accurately project how well each lift will be able to succeed in lifting Mr. Hiller in and out of the pool. The alternate pool lift design has mechanical safety issues with rotation as well because it bears a great deal of weight on the bearing. The rotating part and the trolley must be able to lock in place and account for the shifting weight along the boom.

4.3 Biological Hazards
Water diffusion into the components of the lift could potentially create algae buildup, which would eventually need to be tended to. A simple algaecide from a pool store could be used to remove this possible growth. The wood used in pylons and in the ramp can accumulate the growth of bacteria or fungus, so it important to use a chemically treated wood to keep it to a minimum.

4.4 Decontaminations
Because the lifts have been previously owned, it is important to clean them before using them as prototypes or reconstruction for the final lifts. The coating should not need to be decontaminated. The seat however, will need to be safe of germs and bacteria. During cold weather when the seat is not in the water, bacterial growth is not as likely to happen because of the weather. However, in the hot and moist conditions of the summer, decontamination must be considered. With the chlorine in the water, each time the seat is submerged it will be disinfected. However, regular cleaning is essential and will prevent any growth when not in use. Using a mesh seat should allow the seat to be able to be washed in a washing machine with ease. The wood used in the ramp and as pylons should be chemically treated so that they will last a long time.

4.5 Chemical hazards
The chlorine in the water of the pool and the hot tub, although a great disinfectant, could also potentially cause corrosion of the parts of the lifts. The material of the seat and the steel coating of the lift itself cannot guarantee that no damage will occur. However, using the materials we have chosen will increase resistance and create a longer lasting device.

4.6 Radiation
The pool and hot tub outside will be under great heat exposure from the sun. The UV radiations could be of concern because it could potentially degrade any welding done. Since UV radiation does not affect anything other than surfaces, internal damage will not be of concern.

5. Impact of Engineering Solutions
These two lifts will greatly impact the life of Ronald Hiller and the people he enjoys spending time with. Mr. Hiller’s Multiple Sclerosis has advanced enough to confine him to a wheelchair, rendering him as what society deems “disabled.” The positive attitude Ron has has given him confidence in most aspects of his life despite his inability to walk. One area of his life that he has had to change in the years he has been in a wheelchair has been the use of his pool and hot tub. As he used to spend his summers with his wife entertaining friends in his pool and hot tub, in recent years he has been able to only use his hot tub with the help of a friend physically lifting him in and out of it, but as Mr. Hiller and his friends age, this task is an unrealistic option. Mr. Hiller has become completely unable to use his pool because he cannot get up on his deck that has stairs rather than a ramp. The lift will allow him not only to be lifted in and out of the pool, but also building two lifts, one for the pool and one for the hot tub, will give Mr. Hiller happiness and ability to do more of the things he enjoyed before his MS advanced so much.

These lift designs could also affect the market for pool and hot tub lifts. Currently, most pool lifts are sold to health clubs and/or public pools, but these lifts have been designed to be incorporated at a home, which could create a whole new market for lift devices if a cheaper way to manufacture and sell pool lifts could be found.

Now, on the market, most pool lifts are designed for in-ground pools. This lift will be one of few options for an above ground pool lift. Also, most pool lifts have the functionality of two locking positions where the lift can be set in the position for loading and the position in the pool.
Also, these lifts are originally used to lift scooters into and out of cars, but with a few alterations, they will be modified to be able to lift a person. This shows the versatility of lifts making only a few changes.

The hot tub lift design would impact the market also because many hot tub lifts are manufactured for indoor hot tubs. These are able to use walls and ceilings as supports for the lift. This lift will be outdoors and will rely mainly on the support of the cement base.

Many lifts on the market are also designed for lighter people or children, whereas these lifts will be lifting an overweight, middle-aged man. This means that designs already on the market would need to be altered to consider the additional weight that will be applied to it.

Environmentally, the lifts will provide a structure that needs not to be removed for the winter months. The lifts will be permanent structures that would only be taken down by removing the whole apparatus from the cement in the ground. This is an improvement on similar models that are typically used for indoor pools. While there are many lifts that are used outdoors, few can deal with the weather of the harsh New England winter.

Many pool and hot tub lifts are designed as mass produced lifts that can be used for many different people, but these lifts are designed specifically for Mr. Hiller. This could open doors economically by more companies designing unique lifts built to fit a person in particular.

### 6. Life-Long Learning

The knowledge acquired through the design of this project have included a smorgasbord of valuable lessons stretching across a broad variety of subjects. First, the client, Ron Hiller, has opened our minds to become more involved with multiple sclerosis and its effects on people. Mr. Hiller has been rendered unable to do some of the things he loves and it has given us a real life example of this incurable disease as opposed to just hearing about the symptoms and its effects. We have now seen many of the ways that MS forces people to adjust their everyday behaviors as simple as driving a car, entering and exiting a home, or mowing the lawn. Mr. Hiller has also shown us that just because something affects your life negatively, it does not mean it has to end your life completely. Mr. Hiller is still just as involved as he was before he became confined to a wheelchair, as he still volunteers for “The Hole in the Wall Gang,” a summer camp that serves children dealing with cancer and other various illnesses. Mr. Hiller has such a positive attitude about life that he even has told us he does not consider himself to be disabled. This has taught us that it is trivial to worry and complain about small things such as tests when people who have had to deal with huge issues can still look at life in an optimistic manner.

This project has opened our eyes to the realities of what goes into manufacturing a large mechanical device. Every step of the design process is vital and requires careful planning and research. The lift we have designed has gone through several alterations before production has even begun. So many factors contribute to the final design. Measurements, materials, environmental properties, availability of resources and workspaces all must be considered and must work in compliance with each other to create a successful final product. This project also has demonstrated that engineering is not always necessarily about designing a brand new product, but can involve the incorporation of existing devices as well as the modification of pre-existing devices to improve their use.

Working together on this project has taught us the importance of teamwork. Teamwork and communication are the most important aspects that will lead to the success of designing,
ordering parts, building, and implementing of these lifts. The teamwork necessary for this design has expressed to us how important each department or level of manufacturing is to the success of a company and its products. We have found through this project that it is vital to be able to put aside differences to achieve a common goal as we have seen that we are all very different people from different backgrounds but we can get along and work together to help Ron Hiller regain the use of his pool and hot tub.

From the mathematical analysis of this design, we have learned that in the real world, we will not have an answer we have to achieve where we will be told if we are right or wrong, but rather we must look at the problem and try to find a solution on our own, without knowing the correct answers. While analyzing the statics of our lifts, we realized that if we are not correct in the mathematical parts, we will not know because unlike in a class where if you do a problem wrong, you will be corrected and told the correct answer, there are no solution manuals to check our analysis.

Our computational skills have improved with this project. The designing of these lifts has required us to obtain knowledge in SolidWorks and other CAD programs. Without this project, most of us would probably not have taken the time to learn how to use SolidWorks, which as it turns out after going through the tutorials and using it to “build” our lifts, is extremely helpful when compared to hand-drawing schematic pictures of the lifts. Another program we were introduced to is Dreamweaver which has allowed us to become familiar with creating and uploading to websites.

Finally, this design process has demonstrated to us the importance of money. Design has weighed heavily on the availability of money, which has shown us the importance of budgeting as well as eliminating components that are not entirely necessary. It is now clear to us that money is in fact a very limiting factor in industry and every aspect of life. It is key that you do not try to live a lifestyle that is more expensive than what you can afford. Budgeting is a vital skill to have to live a successful life without overspending.

7 Budget and Timeline
7.1 Budget

The updated budget of what has been spent up to this point is everything we need except for the ramp which we still have 2800 dollars.

<table>
<thead>
<tr>
<th>Item</th>
<th>Vendor</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruno Lifts</td>
<td>NEAT</td>
<td>4</td>
<td>200</td>
</tr>
<tr>
<td>Batteries</td>
<td>Sears</td>
<td>2</td>
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<tr>
<td>Mesh Seat</td>
<td>MedEx Supply</td>
<td>1</td>
<td>72.03</td>
</tr>
<tr>
<td>Caribeneers Steel Rings Spraypaint</td>
<td>Mansfield Supply</td>
<td>Misc.</td>
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<td>Electrical Tape Spade Bits</td>
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<td>Heavyweight Polypropylene 1&quot; strap</td>
<td>Strapworks</td>
<td>1</td>
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</tr>
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</table>

Beg. Budget 4700
The remaining budget is intended to be used for a ramp for Ron in order to get up to his deck.

Table 7.1  Budget Overview

7.2 Timeline

Below is a timeline, showing what was planned on getting done, all of which was accomplished.
8 Team Member Contributions

8.1 Katelyn Burkhart

Our team has been working on designing and building two lift devices that will transport our client, Mr. Ronald Hiller, from his porch into his hot tub, and also from the ground into his above ground pool. Mr. Hiller is unable to get into both his hot tub and his pool because of his Multiple Sclerosis, which has confined him to a wheelchair. Even though he can’t use his legs, Mr. Hiller has complete control of his upper body, and therefore will be able to use his hands with the lift device we create for him. We have all contributed to writing the design reports thus far.

Personally, I have been in charge of programming our design into Solidworks, and updating as necessary. This has required some training on my part, since I have never used Solidworks before. I am familiar with CAD software, so the transition was slightly easier to make than it would have been with no experience. The Solidworks design took a significant about of time to construct, and this design is no longer our optimal design. Martin has been reworking our optimal design in CAD this time. Our previous Solidworks design is depicted in fig. 8.1 below.
In addition to Solidworks, I have also written the introduction for our Project Statement, the Executive Summary, part of the Introduction, and Objective for our Proposal. We all came up with alternative designs, and it was my responsibility to write a report about one of them with Isis, one of my teammates. In the Optimal Design Report, I wrote the introduction, parts of the Subunits section, and the Analysis section. The analysis section took a bit of time to calculate. Eileen and I visited with Dr. Hennessey to discuss the best way to calculate the stresses in our lift, and she told us about trusses and provided us with more information about how to draw the free body diagram of our lift.

I was with the team when we visited Mr. Hiller in September and took preliminary measurements of his backyard. I was also present for the team budget meeting with Dr. Enderle in October. I was responsible for calling Ron and setting up meetings for our team to go out and visit him, as well as the meeting with the contractor and some of our team to go out and visit him in October. In November, the team and I met with Ron’s son, Michael Hiller, who is a subcontractor, and he agreed to design the ramp and as long as we were able to pay for the material cost and help with manual labor.

Next week after finals, our team plans to drive to NEAT marketplace to purchase the used Bruno lifts for our new design. That way we can work on remodeling and redesigning after we know exactly what we have to work with.

In conclusion, we have effectively acted as a team, and the work has been split up amongst ourselves on all assignments thus far. We plan to continue to split assignments up equally in the future as well.

Our team has been working on designing and building two lift devices that will transport our client, Mr. Ronald Hiller, from his porch into his hot tub, and also from the ground into his above ground pool. Mr. Hiller is unable to get into both his hot tub and his pool because of his Multiple Sclerosis, which has confined him to a wheelchair. Even though he can’t use his legs, Mr. Hiller has complete control of his upper body, and therefore will be able to use his hands with the lift device we create for him. We have all contributed to writing the design reports thus far.
Personally, I have been in charge of helping to dismantle and reassemble the four Bruno lifts into the two final lifts. I removed the shaft from Lift 4, which we will not be using, and cut it down so that we could weld it to the shaft of Lift 2 and increase its height by 2 feet. After the cutting is complete, we sanded the ends down and found a cylindrical piece of metal that will slide over the pieces we will be welding together for additional weld strength. This same procedure was repeated with Lift 1, where the additional shaft length was taken from Lift 3.

I waterproofed the electrical components by brushing the acrylic conformal coating onto all of the circuits on the lifts. This coating should protect the PCB against moisture and corrosion. A hard plastic shell was used around the outside since we would like to prevent water from even getting into the circuit in the first place. The circuits were a little tricky to remove, as the screws were tiny and it was important that small plastic washers be in place underneath the board so that the metal connections of the circuit would touch the metal base.

Also, during senior design, the top motor on Lift #2 broke, so it had to be replaced, which was trickier than we thought. The holes of the second winch weren’t aligned correctly, so they had to be cut wider. Also, reattaching the boom to the lift was tricky because the wires weren’t long enough, and need to be spliced and lengthened by about a foot.

One of the last things the team and I did was remove the small metal blocks on the gears of the lifts which prevented them from rotating 360 degrees. These blocks were welded on, so to get them off, the team and I clamped the gear in a vice, and then used a metal saw to slowly cut through the block. Once it was cut off as well as could be managed with a saw, we grinded the rest of the base of the block down until it was level with the gear using the hand held grinder.

I also will be helping to install the lifts at their destination at our client Ron’s house. We will be bolting the lifts through the deck into pylons underneath the deck supported by cement sonotubes.

8.2 Martin Collier
At the start of the semester along with the team I brainstormed different ideas for how we could get Ron in and out of his pool and hot tub. The decision came down to a winch or hydraulic system. Looking at previous designs of the two systems lead me to side with winch which later became our focus. The team and myself made an appointment and met with Serge and Peter to discuss possible lift builds for our project. At the time we decided to go with a stationary base with a rotating boom.

The entire team made our first trip out to Ron’s house in Ashford. We figured out all of the requirements for our project including locations for our lift as well as method for installation which included placing cement in the ground first and allowing the lift to be installed later at any time. I took on the responsibility of contacting a contractor to get a deck and ramp built for Ron’s hot tub and pool respectively as well as the cement bases needed for our lifts. I contacted Jim a contractor who built a ramp for Ron in the past. Eileen Isis and I met with Jim at Ron’s house and we discussed what we needed. I gave him my email address and 3 weeks later he returned to me an estimate for what we needed. We included this estimate in our original budget and realized fast that it was too much. We brainstormed on how to cut this cost out and came to the realization that Ron does not necessarily need a ramp to get on the deck, we can use the lift to
get him up there as well as into the pool. After cutting this cost from our budget we focused on the lift itself.

In our original lift design there were many metal components as well as other random pieces such as winches, nylon bearings, pulleys, hooks, and more. I took over the budget at this point. Looking at the entire sub units we needed I made an excel sheet. In one column I put the piece, in the second the price per unit, in the third the total cost (because we have two lifts), and finally a hyperlink to the exact page where these items can be purchased. In two cases I had to submit a quote request for parts, one being the nylon bearings and the other a metal base plate. The companies responded to me via email. The budget was changed over time as we changed our design. In preparing assignments for the class everyone chipped in equally, the largest amount of work contributed was during the optimal design report in which I described half of the components to our lift and the purpose for why we chose them.

Our team went out and met with Ron again to make sure we were all on the same page. We let him know about our new idea which did not require a ramp/deck. I asked him if he would be opposed to moving the hot tub next to the pool in order to only need one lift but he did not want to do this because he would like to use his hot tub in the winter. We made an appointment to meet with Dr. Ederle to discuss our design and our budget. Dr. Enderle suggested we look at the trampoline lift project from two years ago since they had a very similar need. I called Ron at this point just to reconfirm that he knew we would not be building a deck and the lift would take him from the ground and that we would probably not be moving the hot tub because with a lift it does not matter that he can’t climb in and out of his hot tub onto the deck by himself.

After the meeting with Dr. Enderle I looked into alternate parts we could use to create the lift using the jib crane. The main change is using a prebuilt jib crane instead of assembling our own as well as using a trolley for lateral movement rather than rotation on a bearing. The change in design called for a budget revamp. I again did the budget in the same manner looking for the part, price, and exact ordering location.

We decided to visit the NEAT market to see if there were used seats or motors we could buy. Once there we noticed that the Bruno scooter lifts would fit our lifting needs very well. We did research after visit and decided we would buy the used lifts and parts at the market and assemble our two lifts. For the final report I researched the breakdown of each lift and how we are going to go about assembling two working lifts that fit Ron’s needs. I am still in charge of keeping track of our budget.

At the start of the second semester the team and myself went to the NEAT Marketplace and purchased our four used lifts. Through extensive testing of every component of the lift and circuitries we determined what motors, circuits, and lift bases worked best for our needs. We selected to use two of the lifts and disassemble the other two lifts to use as parts. The various components needed were two motors, one for vertical movement and one for rotational. Throughout the semester I learned the inner workings of the motors and had to take two of them apart to fix their lead connections. In doing so we found the strongest motors for vertical movement. I attached two motors originally that we thought should work, after testing they failed however under the weight. By the end of the semester I switched out the two original motors three times and ended with our current configuration. In switching the motors I had to also change the drive chains, one of which broke during testing.

I learned to mig weld in order to increase the length of both of our shafts as well as the length for one of the four base legs. In order to accomplish this I took the shafts and pieces from
the disassembled lifts had to grind them and prepare them for welding. After talking to Pete and Serge in the machine shop I figured a way to create a strong weld for each shaft. The method is called a collar weld where the two adjoining shafts are welded together with a collar piece of metal over or inside of the shaft. Essentially the collar welded to the two shaft ends increases the surface area of weld and holds the joint in place from bending. The process required a lot of grinding and cutting to get the pieces prepped for welding, and after the welding I had to grind the welds flat.

After completing the physical modifications to the lifts, I started testing again with weights on our mesh seat we ordered. Problems occurred with remotes, circuitry, and the motors. Luckily we had extra remotes and since they are relatively universal this was an easy fix. The circuitry required waterproofing since it was so exposed. In order to do this Katelyn used an acrylic coating to completely cover the circuit so even if water got in there would be no connections made. The motors proved to be a big problem at the end of the semester, two of the smaller motors gave out during testing and I had to replace them with stronger motors. In order to replace the motors the entire boom had to be taken off and taken apart to get access to the drive chain and its axis of rotation.

For installation on site, I planned out the support system using three pylons per lift. After getting in contact with a contractor I went through the business office and Jen to get a purchase order necessary for getting the work done. The pylons will have holes drilled into them so we can bolt the lift bases down through the deck. I created a plan for the pylon spacing and I also got the bolts, spade drills, and other components ready so when we can install the lifts everything should go smoothly. I also had to drill into the lift bases to make the wholes ½ inch for a larger bolt support system.

8.3 Isis Curtis

The beginning of the senior design semester started with the assignment of projects and groups. My group assignment was initially the CoolPac, with members Jaspreet and Kerri. We meet up right after class to start planning and organizing when we would meet and get the project going. Upon arrival to my meeting on the seventeenth of September at 1:30pm, I received an email from a different group telling me that I was suppose to take a trip with them to finish our client in Ashford, CT. I was so confused by the entire thing and came to found out through emails I had not seen, that I was switched off of the CoolPac project and into a project providing two lifts for a man with multiple sclerosis, specifically for his pool and hot tub. I quickly got started making several phone calls, trying to get in contact with my new group. Finally, after a long search, I got in contact with my team members and went along to Ronald Hillers home. My new team, number 15, included Katelyn, Eileen, Martin and Victor. I quickly got a good idea of what the project would entail and how much worth it would have to our client once he started talking about his life and struggle with multiple sclerosis.

After the first meeting, to ensure we were all on the same page and formatting our work together to complete projects efficiently, we decided to meet weekly. These meetings typically occurred on Fridays and or Tuesdays and are crucial to the progress of the project. For each due assignment, we were each assigned different sections to complete. There were other meetings I needed to attend to gather a greater idea of the approach. One included a meeting with a contractor to obtain a better idea of how we would build a ramp for the pool area and a platform for the relocated hot tub. It was very informative and allowed an idea of pricing on how much these components would cost. Another meeting I attended was to meet with Serge and Peter from
the machine shop to speak with people who know best which materials were best for the tasks they would be used for. I quickly learned which metals and lengths and weights would be most applicable to our lifts. For the statement and specifications, I completed the introduction, overview and the realistic constraints. For the proposal, I also completed the introduction which included searching for patents similar to our lifts for the pool and hot tub. Trying to find patents compatible with the specific lifts we were trying to construct was quite a challenging task. There are so many patents out there, it is a challenge to sift through and find the one most applicable. I took part in our required PowerPoint presentation as well, giving the class a great understanding of our client, Ronald Hiller, and his need for the project completion. Alternative designs were required for the lifts, with each containing at least one change to the original design. I worked on the second of three alternative designs which focused on changing the location of the lift to on top of the deck as opposed to next to it. As for the optimal design, I completed the introduction, realistic constraints and safety issues. We decided it was crucial to meet with Dr. Enderle on October 26th to further discuss our budget issues and our plan of attack for the improvement of the lifts. For the completion of 100 tasks, I typed up several of our tasks, including dates and which team members were responsible for those tasks.

Prior to the due date of the final report, I met with my group to discuss aspects to simplify the completed report. As a group, we recently took a trip to NEAT marketplace to meet with Don and pick out pieces which would be beneficial to our project design. He helped us obtain prices, availability and a better idea of what to look for. We plan on purchasing six lifts within the next week and I will be responsible for helping with some of the transport of the lifts for the parts we plant to order in the near future. My work on the project will continue throughout January break and onto next semester.

From the start of the semester I have been the main contact between the group and Ron, dealing with informing him as well as getting his input. I went out to Ron’s house for nearly every meeting and noted his wants and needs. I also drove to pick up the lifts and supplies which included the NEAT marketplace and Mansfield supply. I also drove when we had to go to the Depot Campus to get our lifts back that were mistakenly taken from the lab. When it came to waterproofing I was in charge of protecting the batteries. I bought battery boxes and filled their openings with caulk. I took stayed in contact with various contractors during the bidding process and dealt with the paperwork with Martin when we had to meet with Jen for the final contractor decision. I took care of writing the introduction for Owner’s manual as well as NSF report.

8.4 Eileen Molloy

The team project for my group is to build two lifts for Ronald Hiller of Ashford for his pool and his hot tub. We have all met multiple times a week to discuss design and to work on the reports. We typically meet every week on Friday afternoon to make sure we are all doing our part, along with other meetings throughout the week when necessary. During meetings we discuss our design and how we might alter it. On days reports are due, we meet to compile each of our parts together and edit them to make sure they are well integrated. I have gone to Ronald Hiller’s home a number of times. The first time I visited Ron’s home, it was for our initial meeting with him and to measure the pool area and see the layout of the land. Upon our initial trip to Ron’s house, I spoke with Ron about what he hoped to get from our project and recorded his height, weight, and wheelchair type. Another time, Martin, Isis and I went to meet with a
contractor to find quotes for how much building a ramp and laying cement for our lifts would cost. In our most recent visit to Ron’s house, we discussed with him our current designs and made clear to him what we would and would not be capable to do. We took a second set of measurements of the land of where we intend to put the lifts and I recorded the information. I researched the specifications of his wheelchair, which we initially thought would be necessary when we planned on building a ramp for his pool deck.

Design-wise, I have taken part in every step of initial brainstorming, as well as narrowing down our optimal design. Katelyn and I met with Dr. Hennessey to get help with analysis of our design. During this meeting we spoke about truss analysis. I also met with Dr. Enderle along with the rest of the team to discuss our design. Upon Dr. Enderle’s suggestion, we have once again changed our design to better comply with safety and strength of the lifts. During both meetings, I sketched drawings of our design for Dr. Enderle and Dr. Hennessey to allow better visualization of what we were thinking.

For the project statement, Katelyn and I collaborated for the introduction, and everyone offered up questions. For the project specifications, I wrote the “Other Data” for the pool and hot tub. In the project proposal, I wrote the objective and methods for the project description. For the Proposal Presentation, I presented part of the methods for the pool, and the methods for the hot tub. I also contributed to making slides in Powerpoint for the presentation. I wrote the report for alternative design 2, while also taking part in the discussion of what our other alternative design reports would be about. Finally, for the optimal design, I reasearched the type of seat and carabiners we would use for our designs and found sites to buy them online. I also wrote the Impact of Engineering and Life-Long Learning sections. I also met with Isis to help her with the Realistic Constraints.

We all visited the NEAT marketplace and talked to Don, who helped us with information on their prices and the available lifts they have. Within the next week, we hope to go back to NEAT to purchase the lifts and I will be responsible for transporting at least three of those lifts back to school to our work station. We also hope to order any smaller parts that we need for our lifts, which I will be responsible, along with Isis, of filling out order forms.

We all met to decide what would be in our next presentation. I recorded a preliminary list of tasks that we should add in our task list which my team members then used towards filling in tasks in Microsoft Project. We split up the final report to write parts and then met to collaborate and edit each part.

This semester, I had many tasks to perform to get our lifts towards completion. I purchased and transported the lifts from NEAT marketplace to the lab. I used the machine shop to cut and alter pieces we needed to extend the heights of our lifts. I determined the best way to lengthen the short leg that needed to be extended. I was put in charge of designing and implementing how to waterproof the wiring, which I did using self-adhesive electrical tape to protect wires from disconnecting and from environmental elements. I drove out to Ron’s house multiple times to update him on our progress or to meet with contractors. I changed motors that needed replacing by disassembling the lift and removing the broken motors and reattaching another. I filled out multiple purchase requisition forms and went to Mansfield supply and Sears for supplies. I helped my teammates complete their tasks throughout the semester. They also helped me a lot with my obligations. Our senior design project was truly a collaborative effort between the five of us, and I had a great team to work with over the past year.
8.5 Victor Nguyen

During the first week after the teams were announced, I met up with Honorio and Michael to discuss about our tasks. I also emailed the advisor from the company to introduce myself and the team and to request to meet with him at this company. However, due to a mix up with the teams, I was reassigned to Team 15. Shortly after the reassignment, Katelyn contacted me to join with her and the rest of the team to meet with our client, Ron Hiller, on that Friday, 09/17/2010. I met with the rest of team and we drove to Ron Hiller’s house in Ashford, CT. Once we arrived, I first introduced myself and Ron gave us a tour of his property, especially the hot tub and pool. After inspecting the pool and hot tub, I recorded measurements of the dimensions of the hot tub, pool. I also recorded the height and width of the staircase to the pool deck because Ron asked us if we could also build a ramp to his pool in place of the stairs. I also recorded the height of the sliding door from the ground where Ron proposed our team to move the hot tub. Finally, I recorded Ron’s height, weight, wheelchair model, and voltage of the outdoor electrical sockets. I also took pictures of the pool and hot tub at different angles. I posted these pictures on Facebook where only my team could see and use them as reference.

On my first team meeting, using the measurements I recorded, I calculated the dimensions of the ramp that needed to be built and the dimensions of the hole needed to be dug in order for the top of the hot tub nearly the same height as the bottom of the sliding door. Also in this team meeting, due to my previous experience with Dreamweaver, I was made the team’s web designer. On Thursday, 10/7/2010, I came into the Senior Design lab to refresh my memory with Dreamweaver and setup the homepage website and Team Members link. The next day, I uploaded links to the Project Statement, Proposal, and Specifications.

The following week, I covered the introduction and conclusion of our project proposal presentation. I also uploaded our team’s alternative designs on the website. After our team meeting that Friday 09/17/2010, I was assigned to write up several parts of our final design of the optimal design paper. The parts of the final design I was assigned were the handle arc, boom, boom support, and arc support bar, and the pulley system. For each part, minus the pulley system, I used SolidWorks to measure the dimensions of each part and show how each part connects with other parts of the design. For the pulley system, I found a pulley that would withstand the forces I expect would be applied to the pulley system. I also assisted Katelyn in the overall mathematical calculations of the different forces and momentum applied to the final design. Once the optimal design paper was finally put together, I uploaded it to the website.

Finally, after meeting with Dr. Enderle on 10/26/2010, I first looked up the lift design from a Senior Design project two years ago and took note of the parts the project used, the design of the lift, and their calculations of the forces around their design. I then discussed it with the rest of the team and came up with a final new design of our lifts for Ron Hiller. However, this new design was more expensive than our original design. Also, Dr. Enderle did not like the straightforwardness of our design so we were left to think up another design that will be more creative and elaborate.

The solution came when my team and I visited the NEAT market in Hartford on 11/16/2010. At the market, we came across many Bruno© scooter lifts. However, these lifts had loose wires and missing parts. So we decided to purchase 6 of these lifts to use put together the two lifts we need for the hot tub and pool. We brought this idea to Dr. Enderle and he liked our design.
In the coming weeks, I will be continuing updating the website. I will also assist in help carrying the lifts from NEAT market back to UConn. Finally, I will help assist in the construction of the two lifts based on our new design my team and I have developed.

For the second semester of senior design, I visited NEAT marketplace to browse for any items we could use for our project design. After a few minutes of searching, my team and I came across a couple of Bruno© scooter lifts. We then decided to go back in a few weeks with payment to take four Bruno© lifts back to our senior design lab. However a few weeks afterwards, somebody had mistakenly taken our lifts so I had to go to depot campus to retrieve the lifts back. I went back to Ron’s place twice and measured the dimensions of the areas we have selected to place the two lifts. After the measurements, I helped weld and grind down the shaft extensions. I also assisted in fixing the kink on Lift 1 to make a flat base. I also designed, made, and reattached all the waterproofing equipment for Lifts 1 and 2. I also assisted in changing the mesh rope for both lifts. I was also the test dummy for feasibility testing of Lifts 1 and 2. I picked out the carabineers and rings for the attachment of the seat. I also assisted in the fixing and replacement of all four motors on both our lifts. I also helped discover what made our chain break in our last test with Lift 1. I also helped in searching for a marine deep cycle battery and helped deliver the batteries to the design shop. I helped find cardboard to trace out the bases of the lifts in order to help Jim mark where we want the sonnotubes to be placed. Finally, I met with Jim, our contractor, and assisted and oversee Jim marking the places for the sonnotubes.

9 Conclusion
As a team of engineers, our final goal is to create lifts for Ronald Hiller that will enhance his life, even while dealing with a disease as challenging as multiple sclerosis. There have been several challenges which have arisen during the project but the team has been able to work through them, having a great understanding of what these lifts will do for our client. There are many constraints and safety issues to take into consideration when designing and remodeling this lift as indicated in the report. For example, the analysis has shown that it important to be careful when we install and test the device, because significant high stresses and forces are acting on the lift design. However, these Bruno lifts were designed to be able to carry this much weight, and our testing at 280 lbs., 30 lbs. more than needed has proven successful.

We were successful in getting our Bruno lifts to work by the deadline for the alternative plan. We did not need to use our alternative plan and thus saved a lot of money which can be used for the ramp.

As mentioned previously, it is critical that the lifts are weather-resilient. They will be outside during the winter months and will have to endure the intense weather conditions of the New England region. Along the same idea, the lifts must be very water proof since not only will they be exposed to wind and rain when not in use, as well as exposed to highly chlorinated water when submerged into the pool or hot tub. It is also necessary to make sure the chlorine will not eat away at the coating.

We created our lifts and modified them to be unique to our client Ron. We have tested the weight and figured out how to waterproof the lift. We determined how to install the lifts, and make it a user friendly and long lasting product. Ron should be able to enjoy these lifts for years to come, with only needing to switch the battery if necessary.
10 References


11 Acknowledgements

We would like to acknowledge several people for supporting our project and helping us with the design process. First and foremost we would like to thank Mr. and Mrs. Ron Hiller for allowing us to visit his home and help improve his life. We would like to thank our sponsor, Dr. John Enderle. We appreciate the guidance we have received from Emily Jacobs and Marek Wartenberg. Many others have provided help to us throughout our design and redesign processes. We would like to acknowledge Dr. Theresa Hennessy, as well as Serge and Peter from the machine shop, for their assistance in design and analysis of our lifts. We would also like to thank Michael Hiller, who will be volunteering his time and labor to collaborate on building a ramp with us. Finally, we would like to thank Don, from NEAT marketplace, for helping find the necessary lifts we will be modifying.

12 Appendix

12.1 Updated Specifications
12.2 Price Quotes and Purchase Requisition

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