Final Report

ME 450 – Design and Manufacturing III

Winter Semester

Project 16 – Surgical Power Lift

Team 16

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15 April 2008

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Executive Summary

Design Problem
We were contacted by the Neurosurgery and Nursing Departments of the University of Michigan Medical School with regards to a surgical power lift. The lift is to be used by a neurosurgeon in an operating room. The current lift has been used for the past twenty years, and is beginning to slow down and increase in noise level. The current lift also is not very stable, which could cause major problems. The main function of this lift is to provide a stable platform that has an adjustable vertical height. The goal of this project is to design and manufacture a new lift that meets given customer requirements.

Customer Requirements and Engineering Specifications
After meeting the project sponsors, the final design requirements are stability, comfort, noise level, and hand control. Mobility and robustness are also important to the customer. We have come up with the following specifications from the project requirements: a collapsed height of 0.152 m, a raised height of 0.914 m, the lift speed is 0.05 m/s, the dimensions of 0.78 m by 0.533 m, the maximum weight capacity of 227.3 kg and the weight of the lift is 94.5 kg.

Concept Generation and Selection
To generate many of our design concepts, we used literature searches to develop ideas. We then made Pugh charts to decide which concepts would best fit our need.

Final Design
For our final product we decided to use the following concepts: a side by side frame made out of 6061 T6 aluminum alloy for the lean bar, fold down seat, a double scissor lift frame with an electric hydraulic motor, 2 inch stem caster wheels and a compression spring wheel lock mechanism that are attached to a steel base plate. We decided that these parameters would best satisfy the customer requirements and will be ideal for manufacturing the final product.

Fabrication Plan and Cost Analysis
We created a fabrication plan that we followed in order to generate our final lift. We machined the base plate and added the wheel mechanism. Then we added the lean bar frame and the lift to the base plate creating our final model. The total cost for the materials required to build the lift was $4025.92. Seeing as we had a budget of $20,000, our total fell well below that.

Test Results
The validation tests that we conducted on the final lift resulted in a strong, stable model. The results proved this claim because the tests were designed to fit the customer requirements.

Design Critique
The things that we would like to improve on our lift are: the fabrication of the wheel locking mechanism, wiring location, milling as opposed to drilling. The things that we enjoyed about our product are the dimensions, the quietness, the mobility and the stability. These all fit customer requirements adequately.

Introduction

A power lift is needed in order to aid neurosurgeons in the operating room at the University of Michigan Medical Center. The primary function of this lift is to provide a stable platform that has an adjustable height. The current device is wearing out; the motor is getting louder, the lift is moving slower and it is an older model. According to our customers; stability, comfort, noise level and hand control are the biggest concerns in the redesign process. The customers in this project are Ms. Yvonne Bellairs, Dr. Karin Muraszko, and Dr. Scott Miller. The project outcome will be a redesigned product, built specifically to the customer's requirements, with major design modifications. After successfully completing this project, the lift will be very valuable for Dr. Muraszko, as it will allow her to perform operations and instruct her residents more easily and comfortably. The finalized customer requirements can be seen in Table 1.

Table 1: Final Customer Requirements

Stability	Mobility
Comfort	Fluid Resistance
Noise Level	Maintenance
Hand Control	Lift Speed
Robustness	Easily Boarded Lift
Platform Traction	Design Relocations

Engineering Specifications

The project description listed stability and ergonomics (comfort, easily accessed, quiet, hand operated) as the most important requirements for this project. Upon meeting with our customer, she reiterated that stability and comfort were very important. She also listed some other important features that we needed to keep from the current model. The lift needed to have a working seat, a non-slip platform, and weight locking wheels in order to prevent movement during surgery. We translated these requirements into engineering targets by converting the requirements into a Quality Function Deployment (QFD), which can be found in Appendix C. The engineering targets and customer requirements are for the most part unchanged since Design Review 1. We have found a company, Solution Dynamics, Inc. to contract the lift portion of our design and they were able to meet many of our customer requirements and engineering targets for this part of the project.

The engineering targets were tied in to a degree with the customer requirements. We focused on the platform size and weight capacity of the lift. We also looked into the motor's reliability, speed and noise level. The weight of the lift and the lowered and raised height of the lift were other targets we focused on. The customer requirements for these targets are a platform size of 0.787 m (31 in.) by 0.533 m (21 in.) that holds a maximum weight of 227.3 kg (500 lbs.). The company guaranteed the motor to last a lifetime with proper use and maintenance. The weight of the lift is 94.5 kg (208 lbs.) and has a lowered lift height of 0.152 m (6 in.) and a raised height of 0.610 m (24 in.). Solutions Dynamics, Inc. fulfills the engineering targets and customer requirements. The process of determining the engineering targets resulted from just listening to the customer because all the targets are original and are connected loosely to the customer requirements. There are no competitors because this lift was not marketed as commercial product; rather it was built specifically for our customer.

In order to get a better understanding of the project requirements and their importance to the fulfillment of the design revisions, we created a QFD. By creating a QFD, we are able to identify the customer's needs and wants from the customer's perspective, identify the engineering characteristics of the surgical power lift that meet the customer's needs, and set development targets and test methods for the surgical power lift. Ultimately, the QFD helped us transform customer needs into engineering characteristics for the surgical power lift while ranking each requirement characteristic.

When developing the QFD, we used the customer needs given and our engineering judgment to come up with the technical requirements. Each customer need has a certain importance, some more than others. The four requirements that were emphasized the most are stability, comfort, noise level, and hand control. Stability is very important because the user must be secure on the surgical power lift when in surgery. If the lift is moving while it is elevated, it is very unsafe for the user and the patient. Some of the technical requirements that deal with stability are the wheel locks and the weight and height of the lift. Comfort is critical because surgeries can last up to 24 hours and if the user is not comfortable, it could result in injury to or discomfort resulting in possible mistakes. Technical requirements related to comfort are the lean bar support and the seat. Noise level is important because a loud lift could result in discomfort and distractions to the people in the room. Hand control is a key requirement because the user needs to be able to change the elevation of the lift and the movement must be smooth. The hand control must be easily accessible and reliable.

The other requirements are important but we will not show as much emphasis on them as the previous four. These requirements, from most important to least important, include robustness, platform traction, mobility, water sealant ability, maintenance, lift speed, ease of boarding lift, and design relocations. After concept generation some requirements that we felt were not as important became a main concern for us. For example, when looking for a company to build the lift we had no problems finding a stable and noiseless lift but the weight of the lift became an issue. This issue forced us to look more closely at the mobility requirement. Swivel casters are important to allow for ease of moving around and the casters do not have to be replaced often. In order for one person to be able to move the lift, weight must be minimal which was achieved through Solution Dynamics, Inc. Maintenance is inevitable, but to reduce the amount of time it will take, a user friendly lift with easy accessibility to parts and a dependable motor is a must. The company ensured us that the maintenance is easily completed and is done every six months. Lift speed is an important requirement to prevent the user from falling, losing balance, and also to allow for the user to have more control on the lift. The lift speed on the contracted lift is approximately 0.05 m/s. which will provide stability for the user to stay balanced and in control. We have made sure that the company has a low lift height of 0.152 m (6in.) in order for easy access onto the lift. We are currently implementing cord reels and a hollow lean bar frame to make the lift more appealing and for better protection for the wiring. Customized bellows are being included for appearance and an adjustable lean bar and seat for added comfort.

Concept Generation

In order for us to select a certain concept, we used pugh charts which can be seen in Appendix D. A pugh chart is a tool that helps evaluate ideas by setting up a list of characteristics and judging each idea in terms of the individual criteria. This helped us create a more objective selection process.   For each concept, we used a datum to compare the different ideas. For each of the criteria, we decided if the option that we were evaluating was the same (0), better (1), or worse (-1) than the datum. Once the ideas were evaluated, we tallied the results for each option and determined which idea was the best. The five major concepts we evaluated were the motor, seating, wheels, lift frame, and lean bar/seat frame.

Lift Frame

The most important concept we are going to implement is the type of frame. We wanted a frame that can be compact, support a load of up to 227.3 kg, and be stable. The scissor lift is a specialized type of aerial lift, designed to lift larger loads and provide more work space. It is very robust and will require little maintenance, which is a major customer requirement. One disadvantage of the scissor lift is its weight. It will weigh more than 94.5 kg, which is heavier than the previous lift. Although this is an issue, the lift will still be mobile and easy to maneuver.

Motor

The second concept we had to select was the type of motor to use with our lift. We had three different motor options that we were looking into. The three different options consisted of a hydraulic motor, pneumatic motor, and Air Bag Technology. Air Bag Technology was very quiet and ran very smoothly, however, this was very loud. When the lift was lowered, the air had to be released which was very loud. Also, an air hose would need to be attached to the lift which would be very hard to implement into an operating room. The pneumatic motor was very quiet and efficient. One drawback was the cost, seeing how it was around 3 times more expensive than hydraulic. The hydraulic motor was also a legitimate option. Hydraulic motors are very smooth and are affordable. A drawback is that hydraulic motors have hoses that could potentially break and cause oil to leak out. With this being said, hydraulic motors are still very reliable and with the proper maintenance the hose problem can be prevented. The hydraulic motor offers many advantages. It can support an adequate load (227.3 kg for our chosen one), is quiet, relatively maintenance free, easy to use, and weighs less than the pneumatic motor. The designs concepts for the motor can be seen in Appendix A.4.

Lean Bar Frame and Material

Once the type of lift frame and motor were selected, we had the challenge of coming up with a lean bar frame design and determining what materials to use. The easiest option was to use the original concept from the previous lift, which was a fixed lean bar. However, we decided that it would be beneficial to have an adjustable lean bar to meet the needs of a wide range of users. We came up with two ideas for an adjustable lean bar. One design was the side by side concept. The side by side lean bar will consist of three parts; a bar attached to the base, a bar fixed to the platform, and another bar that is adjustable with a chair attached. With the lean bar featuring the platform bar sliding on the bar attached to the base, stability will increase. The second design was the three bar system, shown in Appendix A.1.b. One problem with this design is the height that the lift needs to be raised, and this design would not allow that to happen. We want the lift to go up 24 inches, which could not be met using the three bar system. Because the lean bar will need to be able to withstand loads and stresses over time, it was crucial to select the proper material. Different materials were looked at, including both aluminum alloys and steel. Steel is very strong and is also pretty easy to weld which makes it a very good choice. A drawback with the steel is the fact that it is heavy. We then looked into aluminum alloys, namely 6061 T6 aluminum alloy. This alloy is a medium duty metal so it is strong, while still being lightweight. This is a very easy aluminum to weld, which will be very beneficial. The design concepts for the lean bar frames can be seen in Appendix A.1.

Seat
Another important concept was the type of seat we wanted to implement into our design. The previous lift used a seat that folded up. This approach did not work because when a load was applied, the seat was unable to support the load and would fold back into its original position. To overcome this problem, we looked at two other options: a fold down or stationary seating option. A stationary seat would be very sturdy; however, the user would not be able to move it out of the way when it was not needed. We then looked into the fold down approach. This allows the seat to withstand a large load and can be folded away if the user wants to stand. The design concepts for the seat can be seen in Appendix A.2.

Wheel and Locking Mechanism
Because the lift will weigh more than 94.5 kg (208 pounds), it was critical to find a wheel/braking system that allows the lift to be mobile and maneuverable. It is also important that the lift does not move when the user is on it. One concept that we came up with was a compression lock system with a stem caster. This allows us to build a bracket that is centered on the caster. The bracket is attached to the lift by two fasteners and compression springs. Once a weight is applied to the lift, the springs compress causing the wheels to lock up. A negative with this idea is the fact that the compression springs will wear over time. This issue could be addressed by replacing the springs when they are fatigued. The other options considered were air bearings and manual lock casters. The air bearings are very durable, however, they are not as stable as the other options, and are very costly. The manual lock casters would be very stable and robust; however, they were not a good option because they need to be locked/unlocked manually, which would be very inconvenient for the user. The design concepts for the wheels can be seen in Appendix A.3.

Concept Selection

Lift Frame
We decided to use the scissor lift design. With the majority of the heavy lifting market using the scissor lifts design, it was obvious that it was our best option. Scissor lift frames are very sturdy and strong and will work perfect for the intended use.

Motor
After weighing each option on the pugh chart, it was determined that the pneumatic motor would be the best option. However, the hydraulic motor came in a close second, meaning it would also be a legitimate option. The reason the pneumatic motor outscored the hydraulic motor is the robustness factor. Due to the fact that we are contracting out the lift frame portion, we are forced to use a hydraulic motor. This is because the hydraulic motor is the only option the company offers. The hydraulic lift is also a lot lighter than the pneumatic motor, which is very important.

Lean Bar Frame and Material
After coming up with two ideas for an adjustable lean bar, we decided on the side by side concept rather than the three bar system. The three bar system, shown in Appendix A.1.b, would not have worked because it limited the height the lift could be raised. We want the lift to go up 0.61 (24 in.), which could not be met using the three bar system. It was decided that side by side design would increase stability. We also decided to use 6061 T6 aluminum alloy. This alloy is very easy to weld and is still very strong, and will fit perfect with its intended use.

Seat
The idea we decided on is the fold down approach. This allows the seat to withstand a large load and can be folded away if the user wants to stand. Once we decided on the fold down approach, we needed to figure out a way to implement it into the lift. Originally, we were going to use a spring loaded chair concept but this would not work because the lean bar only sits seven inches higher than the seat and would cause clearance issues when folded up. Another idea was a c-bracket fold down approach, but it was too complicated to implement. To overcome this clearance issue, we decided to use a shower chair concept. It folds down, can withstand a load of up to 113.7 kg (250 pounds), and does not hit the lean bar when folded up.

Wheel and Locking Mechanism
We chose to use a compression+ lock system with a stem caster. This allows us to build a bracket that is centered on the caster. Each caster will have a load rating of 90.7 kg (200 lbs.), which is more than enough to support the lift and a user. The high load rating means a heavier duty system and will allow for the wheels to last for a long time. This was determined to be the best locking mechanism for the lift, seeing how it is easy to use, very reliable, and is easy to maintain.

The "Alpha" Design-Selected Concept Description

Through the many concept generations determined, we have come up with one alpha design. The alpha design can be broken down into four separate concepts: the scissor lift, the lean bar frame, the seat, and the wheel and locking system. Also considered is the positioning of the hand control as well as the possibilities of other accessories.

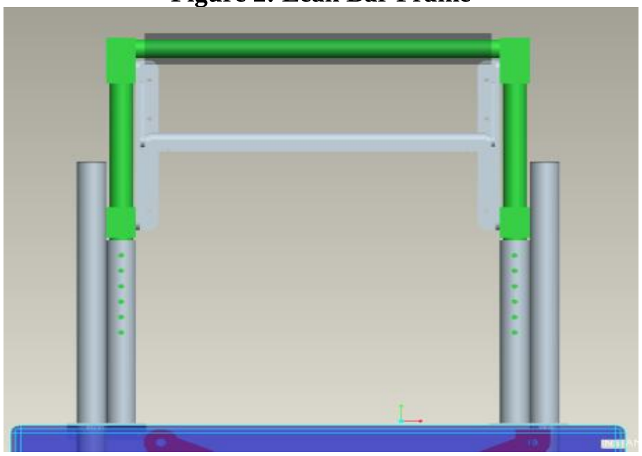
Scissor Lift
After several considerations the scissor lift was decided as the best design. The key attributes of the scissor lift that we have found to be advantageous to our product is that it is sturdy, robust and smoothly rises to the required height. This lift will be contracted out to Solution Dynamics, Inc. as we do not have the time to construct the scissor lift. Included in the contract is a hydraulic cylinder powered by a ½ horsepower motor. Also, the lift contracted can rise to a height of 0.61 m (24 inches) so a lift limit switch has been ordered. A hand control and bellows are also included in the contract. The contracted lift can be seen in Figure 1.

Figure 1: Myti-Lift from Solution Dynamics, Inc.

Lean Bar

The lean bar concept that we have come up with is a two bar with an adjustable feature. As the previous product had a fixed lean bar and seat we have determined that it will be advantageous to have the lean bar and seat be adjustable. To accomplish this, a two bar configuration was needed as shown in Figure 2.

Figure 2: Lean Bar Frame

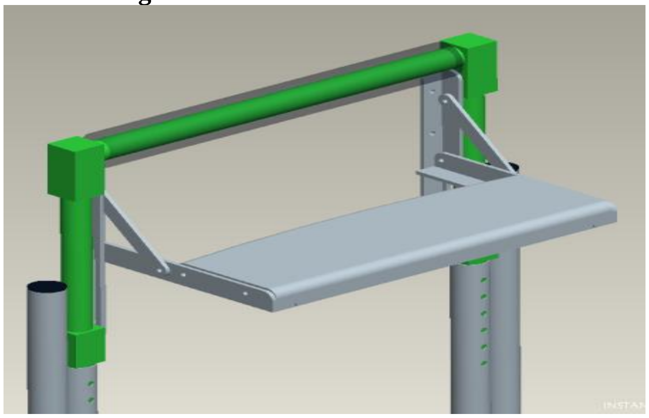


In order to maintain extra stability, two vertical slide bars will be attached to the bottom plate either through welding or brackets. These two side bars will slide within the outer bar of the weld of the lean bar. The inner bar of the weld will be used to connect the lean bar and seat configuration. This will be able to be adjusted 0.152 m (6 inches) in height with the minimum height set for our customer as used in the previous product.

Seat

The design for the seat was researched and found to be a sliding fold down seat configuration. This seat will be contracted out by Samuel Heath. The seat was required to fold down as this will create a more reliable seat for our customer. The seat must slide as it is retracted, in order to avoid coming in contact with the lean bar in its upright position. The seat can be seen in Figure 3.

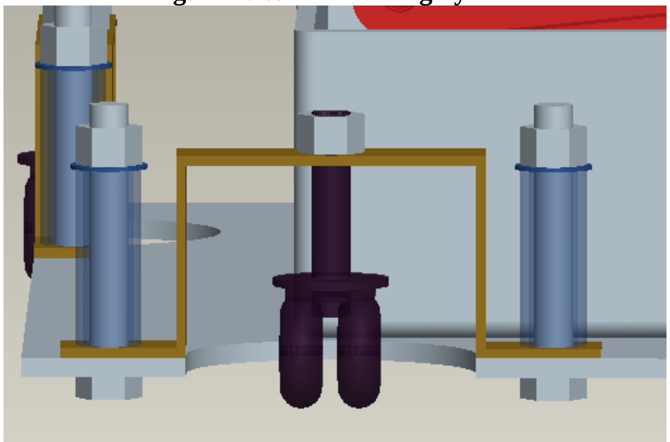
Figure 3: Samuel Heath Shower Seat



Wheel and Locking System

The design for the weight locking wheels incorporates a spring and hat bracket setup. Two compression springs will connect the hat bracket to the bottom plate. Each wheel will then be bolted to a bracket as shown in Figure 4. This will ensure that as a load is placed on the lift, the springs will compress and the base will touch the casters and the lift will be 'locked' into place.

Figure 4: Wheel Locking System



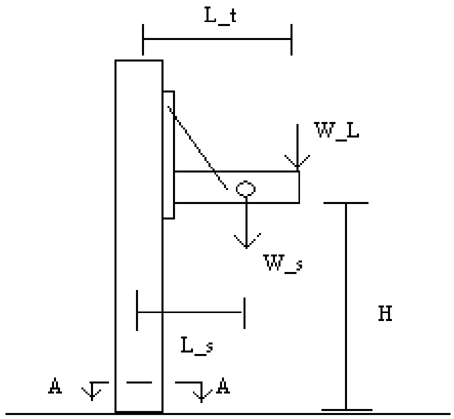
Engineering Design Parameter Analysis

Determination of lean bar tubing thickness using 6061 aluminum alloy

We have previously determined that the material that will be used for the tubing of the lean bar will be 6061 aluminum alloy. One of the benefits of using this alloy is its yield strength. By determining the stress placed on the lean bar created by a person sitting on the chair and comparing this to the yield strength of the aluminum alloy, we can determine the minimum thickness of the tubing that will avoid yielding.

To calculate this minimum thickness, a minimum safety factor of two is used. The moment of a person sitting on the seat is taken at the worst case scenario of having the person applying their weight at the very end of the seat. Also taken into account is the weight of the chair which is applied at its center of mass. The moment diagram, showing the moment force placed on the lean bar is shown in Figure 5. The moment found was 285.9 N-m, which applied 400 MPa of stress on the lean bar when fully extended. This stress will give a minimum tubing thickness of 6.07 x 10^{-6} m which is significantly less then the 3.18 mm (.125 inch) thickness that we will be using in our final product. Using the chosen thickness, we have determined the safety factor of the lean bar to be 202. The calculations for this value can be seen in Appendix H.a. Thus, we can conclude that the lean bar will have a safety factor that is much greater than two, which will be adequate for this project. All calculations and equations used can be viewed in Appendix H.

Figure 5: Moment diagram of Lean Bar



Wheel locking mechanism
In order to have the lift lock into place when weight is applied we are implementing a spring bracket system. These wheels will then need to retract into the lift 0.00635 m (1/4 in.) when an additional load of 50 lbs is applied. This additional load has been determined to be an adequate weight that will be placed on the lift by a person who is stepping onto the lift. This is not the full weight of the person because we do not want the lift to move as a person is stepping onto the lift.

Knowing the total lift weight without a person on it is 270 lbs and that we would like the lift to lock with an additional 50 lbs, we are able to find the compression spring rate (inches/lb) that will fit our application. There will be two springs for each caster giving a total of eight springs. Using the catalog from CenturySpring.com [11], we are able to find a suitable spring. The selected spring has a free length of 0.889 m (3.5 in) and a compression spring rate of 5.25 N/mm (30 lbs/in). All calculations and equations used can be viewed in Appendix H.

For the CES Software, it was found that it gives a very detailed description of materials that would be suitable for the inputted limits. Although the software has many materials that would not be realistic options due to availability, it is very helpful with its extensive database of material and process knowledge. CES not only aided us in the selection of our materials, but also helped in the selection of the best processes for joining and cutting materials if we were to manufacture the lift in the real world. Although Design for Assembly is a very tedious process, it is very helpful when a design is going to be produced in mass quantities. It takes all the parts from the model and eliminates unneeded parts, which will increase the efficiency when manufacturing. The SimaPro Software was more interesting then helpful. It allowed us to do a risk assessment of aluminum and steel, and show the effects that the materials have on the environment. Ultimately, it would be a great aid in determining environmentally friendly materials if the lift were to be manufactured. The DesignSafe Software was useful in helping identify the hazards early. It allowed us to think of the possible hazards based on the options the software gives, and assess the hazard and determine ways to reduce the hazard. Our results can be seen in Appendix K.

Final Design Description

The final design can be seen in Figure 6, page 10. By looking at the alpha design in Appendix G, it can be seen that the two are very similar with a few changes. The biggest change occurs in the lean bar. The alpha design consisted of six 90 degree bends, where the final design consists of only two 90 degree bends. This change was made because it was determined that the extra bends were not necessary and the fabrication process will be much easier. The side by side lean bar frame will still be used. The outside tubes of the lean bar will be used for added stability. A smaller diameter tube will be fixed to the bottom of the lift and will be used as a guide as the height of the lift is adjusted. The user will be able to adjust the seat from 0.46 m (18 in.) up to 0.58 m (23 in.) To manufacture the lean bar we will be using aluminum 6061 T6 tubing with outside diameters of 38 mm (1 ½ in.) and 30 mm (1 3/16 in.), both having a thickness of 3.2 mm (1/8 in.) The aluminum has yield strength of around 30,000 psi, which was found sufficient for our purposes.

To connect the lean bar at the 90 degree bends, two aluminum blocks will be used. The blocks will also be made of aluminum 6061 T6. By using a block rather than bending the tubing, the joints will be much stronger and also easier to fabricate. The blocks will also be used to connect the seat to the lean bar. Having a flat surface rather than a round surface to attach the seat allows for a much more secure base. Because the lean bar is aluminum and the lift is steel, we will be making a plate out of aluminum to weld onto the end of the tubing. This plate will have four holes, one in each corner, to enable the lean bar to be attached to the lift by fasteners. In the end, two aluminum plates will be used to attach the inner lean bar to the lifts platform and two aluminum plates will be used to attach the outer lean bar to the steel base plate of the lift. Each aluminum plate will be 51 x 51 x 3.2 mm (2 x 2 x 1/8 in.)

The actual lift we chose was a scissor lift frame. The scissor lift was chosen because of its robustness, durability and widely used success in the heavy lifting industry today. It has been used in many different industries and continues to be used today, which made it an obvious choice when selecting the type of frame to use. The lift we contracted out is made of steel, and has a lifting capacity of 226.8 kg (500 lbs.). To power the lift, a 0.5 horsepower electric hydraulic motor will be implemented. The lift speed is 0.05 m/s, and will have a controller to allow the user to adjust the height of the lift from approximately seven inches up to 0.61 m (24 in.) at a steady, safe speed. The hydraulic motor also allows for quiet operation, which is a must in the operation room.

Because surgeries may last up to 24 hours, we implemented a fold down seat that allows the user to take a break or even conduct surgery on it. Because of the design of the seat, it fits under the lean bar and will not cause the user discomfort if they want to lean on the lean bar. The seat will be located at a height of 0.48 m (19 in.).

To add stability to the lift, a steel plate will be bolted to the base of the lift. To reduce the weight of the plate, a square will be cut out of the middle. The plate will also be used to mount the casters and braking system. Four, two inch stem casters will be used to transport the lift around the hospital. To mount the casters to the plate, a hat bracket with two compression springs per caster will be used. The compression springs will be used to prevent the lift from moving when an additional load of 22.68 kg (50 lbs.) is applied to the lift. This amount was selected to prevent the springs from compressing when the lift if being transported throughout the hospital. Also, to prevent damage to the floor and lift when a load is applied to the lift, PVC bumpers were attached to the bottom of the plate.

Figure 6: Final Design

Prototype Description

As our product is actual working model and whose components have all been previously tested within industry, no prototype is needed for this given project.

Fabrication Plan

Table 2: Final list of materials

Lean Bar	6061 T6 aluminum alloy tubing OD: 0.038 m (1 ½ in.), t = 0.0032m (1/8 in.) OD: 0.030 m (1 3/16 in.), t = 0.0032m (1/8 in.)
Base Plate	0.53 x 0.79 x 0.006 m (21 x 31 x ¼ in.) steel
90 ° Connecting Joints	0.038 m (1 ½ in.) aluminum square block
Casters	0.051 m (2 in.) Swivel hard Rubber (200 lb.) load rating
Seat	Samuel Heath shower seat
Lift	Solution Dynamics Myti-Lift Table
Wheel Lock Mechanism	20.1kg (45 lb.) load rated compression springs
Lean Bar Brackets	0.0032 (1/8 in.) thick aluminum plate

The first step that we took to create our model was to create the base steel plate. We used a 0.533 x 0.787 m (21 x 31 in.) Carbon Steel, AISI 1060 annealed plate and by using plasma arc cutting, we were able to cut out a 0.406 x 0.610 m (16 x 24 in.) rectangle from the center. This was done to reduce the total weight so as to make the lift more mobile. Next, we cut arcs with diameter of 0.1 m (4 in.) out of each corner of the base plate using the same plasma arc cutting method. The drill press was then used at a speed of 490 fpm to create holes in the base plate for the attachment of the hat brackets, using a 0.013 m (1/2 in.) drill bit. The holes were each located on the outside of each previous created arc. Four 0.013 m (1/2 in.) holes were also drilled 0.029 x 0.11 m (1.13 x 4.32 in.) from the outside of the steel base plate, used to attach the lift to the base plate. We also drilled eight 0.006 m (¼ in.) holes to attach the aluminum slide bars for the lean bar assembly.

The next step was to create the hat brackets. We used the same carbon steel that was used for the base plate. We used the ban saw with a speed of 75 rpm to cut the steel. Three separate dimensions of the steel were needed per hat bracket: 1 piece was 0.095 x 0.025 x 0.003 m (3.75 x 1.0 x 0.13 in.), 2 pieces were 0.06 x 0.025 x 0.003 m (2.375 x 1.0 x 0.13 in.), and 2 pieces were 0.041 x 0.025 x 0.003 m (1.63 x 1.0 x 0.13 in.) The assembly of these pieces can be seen in Appendix F.b. These parts were then welded together using TIG welding, to create the four hat brackets. One hole of diameter 0.013 m (1/2 in.) was drilled into the top center of each hat bracket. Two 0.016 m (5/8 in.) holes were then drilled into the middle of the parallel short pieces. These holes should line up with the holes drilled next to the arc cuts in the steel base plate.

For the lean bar assembly, we first used the ban saw with a speed of 300 rpm to cut the 0.025 m (1 in.) diameter aluminum tube to a length of 0.543 m (21.36 in.). We then cut the two 0.03 m ($1_{3/16}$ in.) diameter aluminum tubes to a length of 0.584 m (23 in.) We then cut two 0.038 m ($1_{1/2}$ in.) diameter aluminum tubes to lengths of both 0.305 m (12 in.) and 0.56 m (22 in.) This can be seen in Appendix F.h.

We next cut two 0.051 m (2 in.) pieces, and two 0.076 m (3 in.) pieces of the aluminum block. The 0.076 (3 in.) pieces are the 90 degree connecting joints, while the 0.051 m (2 in.) pieces are going to be used to connect the seat. A mill was used to produce a 0.0305 m (1.20 in.) diameter hole through the 0.051 m (2 in.) pieces. A 0.0305 m (1.20 in.) hole was milled to a depth of 0.025 m (1 in.) into the two 0.076 m (3 in.) pieces, in the z direction. Then a 0.025 m (1 in.) hole was milled into inner sides of the blocks at a depth of 0.019 m (0.75 in.) We then took the two 0.584 m (23 in.), 0.030 m ($1_{3/16}$ in.) diameter, aluminum tubes and then connected them to the 0.543 m (21.36 in.), 0.025 m (1 in.) diameter; aluminum tube using the two 0.076 m (3 in.) aluminum piece connecting joints, and TIG welded them together. We slid the 0.051 m (2 in.) pieces around the 0.584 m (23 in.) length tubes and welded them at a height of 0.203 m (8 in.) away from the top of the tube. Holes were then drilled in the side of the tubing to fasten the seat into place. We then used 0.0095 m (3/8 in.) bolts and nuts to securely fasten the seat. This process can be seen in Appendix F.c.

We then created two aluminum brackets by bending them through an annealing process. Each bracket had two 0.038 m ($1_{1/2}$ in.) holes milled out. We then used 0.006 m (1/4 in.) nuts and bolts to fasten these to the platform after drilling out the four holes for the bracket. This can be seen in Appendix F.f.

Next we took the two 0.305 m (12 in.) aluminum tubes and used the mill with a 0.0095 m (3/8 in.) drill bit to create 5 holes, with 0.025 m (1 in.) between each of them. This is what makes the seat adjustable. We then had the 0.56 m (22 in.) and 0.305 m (12 in.) tubes welded together, with 0.127 m (5 in.) on the outer tube to extend past the bended bracket. This process can be seen in Appendix F.e.

We then created the 0.0032 (1/8 in.) thick squares which we had welded to the bottom of the 0.56 m (22 in.) tube. Each weldment was then bolted to the base plate with four 0.0064 x 0.025 m (¼ x 1 in.) bolts.

The next step was to remove the lift platform from the lift itself. We were then able to use the mill to create a hole with a diameter of 0.038 m ($1_{1/2}$ in.), located a distance of 0.098 m (3.87 in.) from the sides of the platform to the center of the hole. We took the created lean bar frame and slid it into these holes.

Next we attached the hat brackets using 0.013 m (1/2 in.) bolts with a bushing to hold it secure and placing compression springs over each bolt. We then used a nut and tightened it until the spring reached the calculated height of 0.06 m (2.37 in.). Next the caster was attached to the middle hole of the hat bracket. A lock nut and three washers were placed on the stem to give the proper height, and a nut was then fastened to the top of the stem after it is through the bracket. The hat bracket system is shown in Appendix F.i.

The bellows were then attached to the lift with Velcro. Lean bar padding was also placed on the top bar of the lean bar assembly. Velcro was also placed on the top right connecting joint, and also to the back of the hand control.

The entire assembly process can be seen in Appendix F.i.

Validation Results

The engineering experiments that we chose to test our product consisted of applying a load to a certain part to test the controls of the product. The tests described below were conducted to prove the parameters that we concluded in our calculations.

The first test that we performed was to make sure that the comfort requirements were met. The padded material that wraps around the lean bar for a comfortable rest was leaned on and resulted in a comfortable rest, producing a high comfort level. The seat was tested next; this would consist of sitting in the seat for a selected period of time. The result of this test showed the seat to be a durable and comfortable seat. The final thing tested for comfort was the padded traction platform that we installed on the steel platform. This test was conducted by standing on the pad and observing if it is comfortable for the user. The result of this test showed that the pad was comfortable to stand on.

The second test that we performed proved the calculations made for the selection of our material and the products we contracted out. First, we applied a load at each weld to make sure that it was done correctly and holds a significant stress. This resulted in strong fabrication of the lean bar. Second, we sat in the chair and tested the attachment method for the seat. This would account for the moment that is occurring, and prove that the test proved that there were no stress fractures at the attachment points. This test would also prove the company's claim that the chair can hold up 250lbs.

Next, we tested the braking system by applying a weight onto the lift's platform after the steel base plate with the caster and braking system was added. This test proved the claim that the calculations for the casters can hold our lift's weight. Also, the addition of weight on the lift's platform it proved our braking system to be a functional. Because the compression spring braking system compressed and applied the PVC braking sheet after a 22.7 kg (50 lbs) load rating. This test resulted in our designed braking system working as wanted. We would recommend that more future testing be done for the hat brackets on our wheel locking mechanism because there is doubt as to the fabrication of this mechanism. The doubt is a result of our first failed attempt of the wheel mechanism.

The lift stability test was done by raising and lowering the lift with a person on the platform. This proved the lift's weight capacity, and it's stability at the raised height.

The third test that conducted determined the hand control requirement. We positioned the hand control, used to raise and lower lift, in a reachable area and tested a person on the lift raising and lowering it. The result of this test proved the ease of the hand control.

The next requirement to be concluded was how quiet the motor is. The test was conducted by listening to the lift as it is rising. This test resulted in a low noise level.

Mobility of the lift was determined by the final lift after it is constructed. The requirement was tested by moving it around and determining how hard it is to push up and down a sloped hallway. This test determined the mobility of the lift in the working field for which the lift is going to be in. The lift speed requirement was predetermined by the company that we contracted the lift out to. This speed is 0.05 m/s. The robustness of the product will be determined over time. But the materials and the lift that we chose are guaranteed to last a lifetime.

Since we cannot determine the lifetime of the product we calculated each of these parameters with a safety factor of 2. Each of our current materials and design was much greater than the safety factor of 2. These numbers should be believed because they greatly exceed a general safety factor for a product. Our instructors should believe that our final design is viable because each test performed for each requirement exceeded the expectations needed for us to proceed with fabrication of the product. Our testing parameters consisted of observing and putting a stress or a weight on different parts of the product. This resulted in the design of experiments where we concluded the customer requirements were the most important so we would test in order to make sure that those would be fulfilled before concluding that our product was a success. The tests described and our personal experience will provide us with confirmation that our engineering specifications and requirements are met. Our approach is correct in proving that our final design will be a working, safe product for the function we need to provide the function of the surgical lift. We did the correct calculations with the strongest material to make sure it is the safest design. We also chose the following tests in order to make sure that the lift will be in working correct environment the lift will be used in.

Discussion

After looking back on our design, there are a lot of advantageous traits of our lift, and also some that could be improved. Strength of the model is the dimensions of the lift. We wanted to keep the dimensions very similar to the previous lift, because it was what the surgeon was comfortable with and also a proven size for the operating room. However, we wanted to increase the raised height of the lift, and we were able to add an additional 7 inches to the maximum height.

Another improvement was the stability of the lift. We have dramatically increased the stability over the previous lift which is essential based on the environment in which the lift will be used. We also feel that by making the lean bar adjustable, the lift can be used by multiple surgeons.

The motor that we chose is also a great improvement over the previous model. The hydraulic motor is very quiet, which satisfies one of the top requirements. It also is more modernized and plays a large role in our stability requirement. We also feel that a great strength of our model is how aesthetically pleasing it is. The previous lift was very plain looking, so we wanted to make it better looking, which we feel that we achieved.

One main concern of ours is the design of the hat brackets. We initially planned on contracting the hat brackets out, but the given delivery time was 2 months, so we had to fabricate them on our own. We also wanted to bend the steel to form the brackets, as opposed to welding them. However, we did not have access to a machine with these capabilities, so we resorted to welding them. We initially performed the welding ourselves, and one of the hat brackets broke while we were testing mobility. We then had Bob Coury, an experienced welder, redo our welds and weld both sides of the steel as well, thus making them stronger. The current hat brackets should be strong enough, but there is some doubt as to their lifetime. As a precaution the brackets may require more testing or may need to be checked periodically to make sure no accidents occur in the operating room.

We had initially planned on developing a way to contain the excess wires. However, due to time constraints, we were unable to do this. We were going to drill a hole into the lean bar frame, and place the wire through this hole. Our main concern was the wire getting pinched in the scissor lift. We then wanted to have a recoil mechanism that would reel in the excess wire. Future considerations could be done to incorporate this or a similar option into the design.

One other possible flaw of the design is the casters used. When moving the lift, the casters give quite a bit of resistance, which is not ideal. We believe this is due to the size of the casters. In the future, it is possible that casters better equipped for this could be used.

Recommendations

Our experiences on this project brought up a couple of recommendations for the sponsor. First, the slide bars of the lift frame need to be continuously greased with white lithium grease. This is to keep it operating in a smooth and stable state. Our experience showed that if this is not done the lift begins to struggle its way up the lean bar frame and makes for a slightly shaky ride. Second, when performing maintenance make sure that all electrical cords are properly connected. We ran into an issue where a wire came loose from inside the fuse box and this resulted in the lift not working. It was an easy fix but it could be something that could be the cause of the lift to not respond to the hand control. Next, we would recommend that you check and make sure that the lift's nuts and bolts are properly tightened. This is just to ensure the safety of the surgeon while she is working. The hydraulic fluid must also be checked in order to estimate when a change is needed or if there is leak in the system. The connections to the hydraulic fluid reservoir should also be checked to make sure that everything is tightened and working properly. This maintenance is recommended to be conducted every six months in order for the lift to continue to run properly and safely.

Conclusion

We have developed a final design that will meet the customer requirements using the determined engineering specifications. The following is a final summary of what we did and how we went about it.

Stability, comfort, noise level, and hand control were determined to be the most important requirements. All these requirements have been used in developing our concepts and have been implemented in our alpha design, which was then modified to become our final design.

We developed and followed through with a fabrication plan that produced a working product. This plan gave a detailed description of the process needed if our work is to be replicated. The validation tests that we conducted on the final lift produced results that exceeded customer and sponsor requirements. The final design has been broken down into four subsections: the scissor lift, the seat mechanism, the lean bar frame and the wheel locking mechanism. We created each of these subsections separate in the machine shop and fabricated these with the plan we have laid out above. We then assembled these sections together and created our final model which can be seen in Figure 6, page 10.

Acknowledgements

We would like to thank our sponsors, Yvonne Bellairs, Dr. Karin Muraszko and Scott Miller, for giving us this opportunity to benefit the medical school. We would like to thank Professor Skerlos for coordinating the class in an exceptional way, Professor Dinda for always being there for us, and Professor Mazumder for all the additional help. We would also like to thank Bob Coury and Marv Cressey for helping with the fabrication of our project.

Information Sources

The information we have gathered is limited because the current lift is not patented, so from our first literature search in Design Review #1 we narrowed it down based on the concept designs we have created. The information ranges but is not limited to scissor lifts, metal materials, spring and casters arrangements and shower seat brackets.

We expanded on the previous literature search by focusing on select concept ideas that will provide us with the best outcome for our design. First, we decided to contract out the lift portion of the design to Solution Dynamics, Inc. for their experience in making scissor lifts. We started by gathering information on power scissor lift tables companies. The first company we researched was Herkules Equipment Corporation [1]. They built and customized power lift tables. They only used Air Bag Technology to power their lifts which meant we were restricted to this lifting system. Also, the lift had to be hooked up to an external air compressor in order to raise and lower it. The external compressor and the noise level it produced when lowering turned us away from that lifting company. Next, we looked into Pentalift Equipment Corporation [2]. This company also did customized scissor lift tables and used hydraulics and pneumatics to power the lifting system. We contacted a representative with this company and got a quote for a lift that fit our some of our specifications. The platform size was a little larger then we wanted and the lift's weight made it impossible for it to be mobile. We then researched Solution Dynamics Incorporated [3], who built and customized power scissor lift tables. We contacted a representative with the company and gave them the customer's specifications and the application of the lift. They responded promptly with a quote fitting all of our specifications. The original quote can be seen on in Appendix E. It had the correct load capacity, platform size, raised and lowered height, and weight of the lift. They also had an optional safety skirting and a lift limit switch available. We decided to finalize our lift portion with Solution Dynamics, Inc.

The current lift uses a wheel locking mechanisms, which prevents mobility of the lift as surgery is being performed. For this concept we decided to stick with this idea. We researched compression springs, attaching brackets and casters at Home Depot. We found the correct size caster with the appropriate load rating, and some excellent examples of compression springs that could be used for the locking mechanism. We found casters, 2 inch Swivel Hard Rubber with a load rating of 90.7 kg (200 pounds), on Radford Brothers Industrial Supply website [4]. This would provide a more updated version of the wheel locking mechanism currently on the lift.

A usable seat was a big concern of the customer as well. The information gathered on the seat was to be comfortable, fold down, and adjustable. We found some of these features in the Bass Pro website [5] for padded boat seats. A fold up shower seat from Plumbing Supply [6] was another design possibility we looked into. This was flawed to our design because it was not stable enough for the lean bar frame and also caused problems as to how it would fit under the lean bar. Another source we found was a unique folding shower seat. This seat folds into the brackets it is attached to which allows for the seat to fit under the lean bar. This was an initial problem we faced. The N-1006/A Samuel Heath Folding Shower Seat [7] has the best design, the proper dimensions, and the appropriate load rating to fit our ideas for a useable and stable seat.

Finally, the last thing we researched was the lean bar's frame materials. This left us with different types of Aluminum alloys and Stainless Steel. The first metal we looked into was stainless steel T-304 [8] because of its durability and easiness to weld but was rejected because of its weight. Next, the aluminum 2024-T3 [9] alloy was considered because of its high strength and light weight but was not as easily welded. After researching the aluminum alloy 6061-T6 [10] we found it was light weight, strong, more corrosion resistant, and easier to weld than the 2024-T3 alloy.

The information found came directly from the websites referenced. The sources were found by using www.google.com. The information gap that currently exists is that the current model was a prototype, and therefore creating a lack of direct information to the model. The company, Ohio Med., contracted out to create this model was hired over 20 years ago and is no longer in business. The lack of information will be better known from a thorough examination of the current model. We will have to get our own specifications and translate them into our own design for the new product.

References

[1] Herkules Equipment. Retrieved February 20, 2008, from Herkules Web site: http://www.herkules.us/

[2] Pentalift Equipment Corporation. Retrieved February 20, 2008, from Pentalift Web site: http://www.pentalift.com/

[3] Solution Dynamics, Inc., Industrial Equipment Specialists. Retrieved February 20, 2008, from Solution Dynamics, Inc. Web site: http://www.sodyinc.com/

[4] Radford Brothers Industrial Supply. Retrieved February 20, 2008, from 2 inch Stem Caster Web site: http://secure.data-comm.com/RBIS/StoreFront.bok

[5] Action Outdoor Copolymer Padded Boat Seats. Retrieved February 20, 2008, from Bass Pro Shops Web site: http://www.basspro.com/webapp/wcs/stores/servlet/Product_10151_-1_10001_90997?cm_mmc=nextag-_-200-4-8-_--1-_-38-526-920-04&hvarAID=46KY&mr:referralID=302cc677-dcdb-11dc-a631-000423c27407

[6] Fold up Folding Shower Seat. Retrieved February 20, 2008, from Plumbing Supply Web site: http://www.plumbingsupply.com/foldingshowerseat.html

[7] Samuel Heath Folding Shower Seat. Retrieved February 20, 2008, from Home Annex Web site: http://www.homeannex.com/prodView.asp?idProduct=5723&idF=16622&utm_source=NexTag&utm_medium=CPC&utm_campaign=NexTag&Eng=CA&a64=NexTag&mn9=Samuel%20Heath&keyword=5723-16622

[8] Round Tubing T-304 Stainless Steel. Retrieved February 20, 2008, from Online Metal Store Web site: www.onlinemetals.com

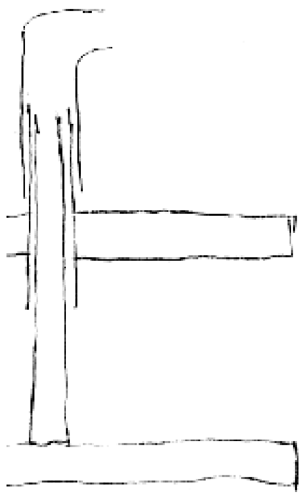
[9] 2024-T3 Aluminum Tube. Retrieved February 20, 2008, from Online Metal Store Web site: www.onlinemetals.com

[10] 6061-T6 Aluminum Tube. Retrieved February 20, 2008, from Online Metal Store Web site: www.onlinemetals.com

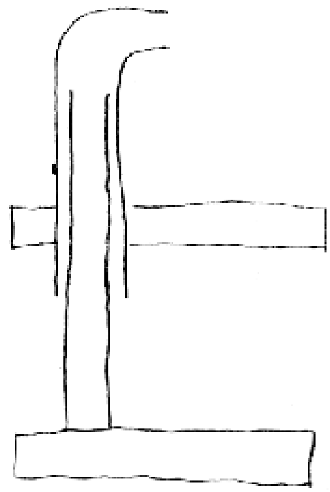
[11] (2004). Century Springs. Retrieved April 15, 2008, from Precision Spring Manufacturer Web site: http://www.centuryspring.com

Appendix A – Concept Generation

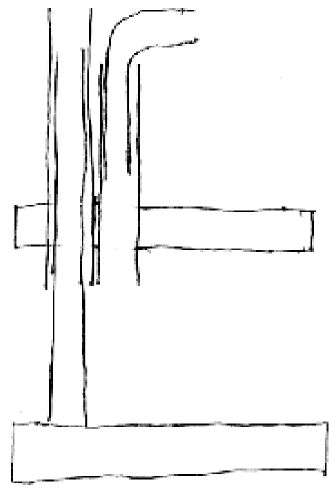
1) Lean Bar



a.) Fixed Lean Bar

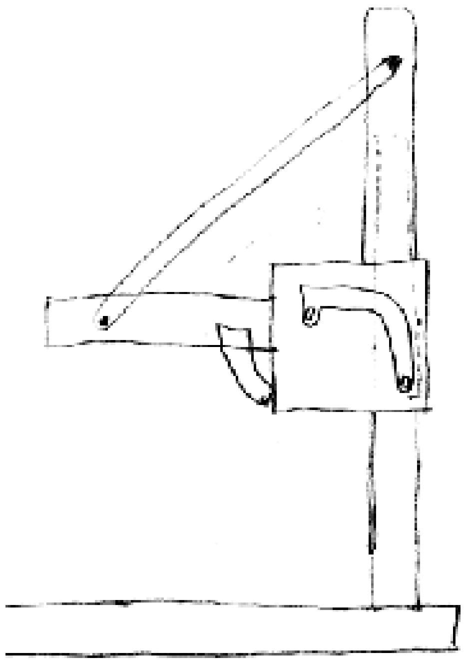


b.) 3 Bar Lean Bar

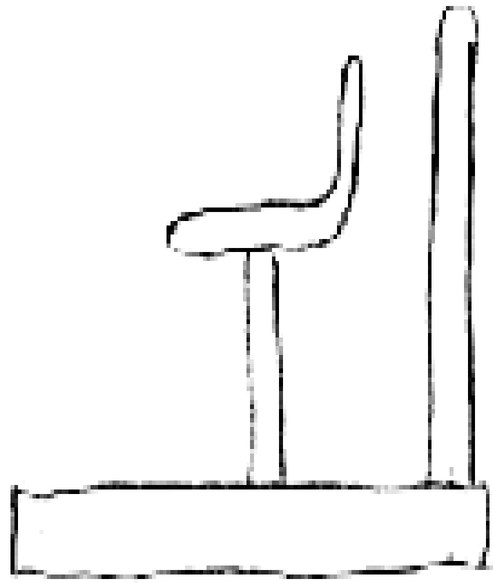


c.) Side by Side Lean Bar

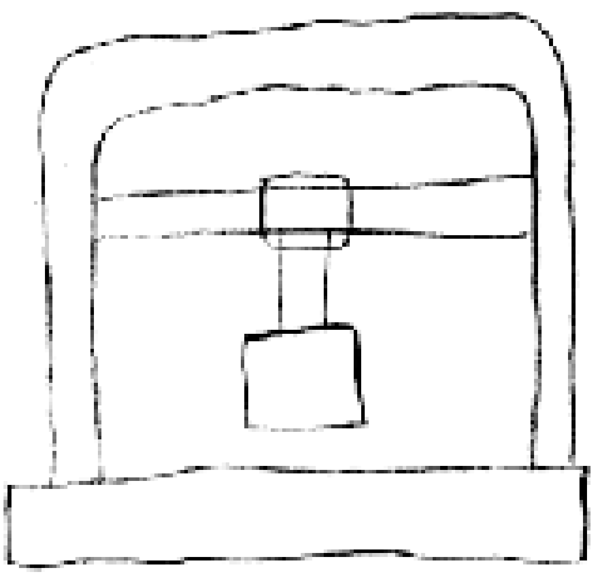
2) Seat



a.) C Bracket Seat



b.) Fixed Seat



c.) Fold Up Seat

d.) Shower Seat

e.) Movie Theatre Seat

3) Wheel Mechanism

a.) Stem Caster

b.) Swivel Caster with Manual Brake

c.) Air Bearing

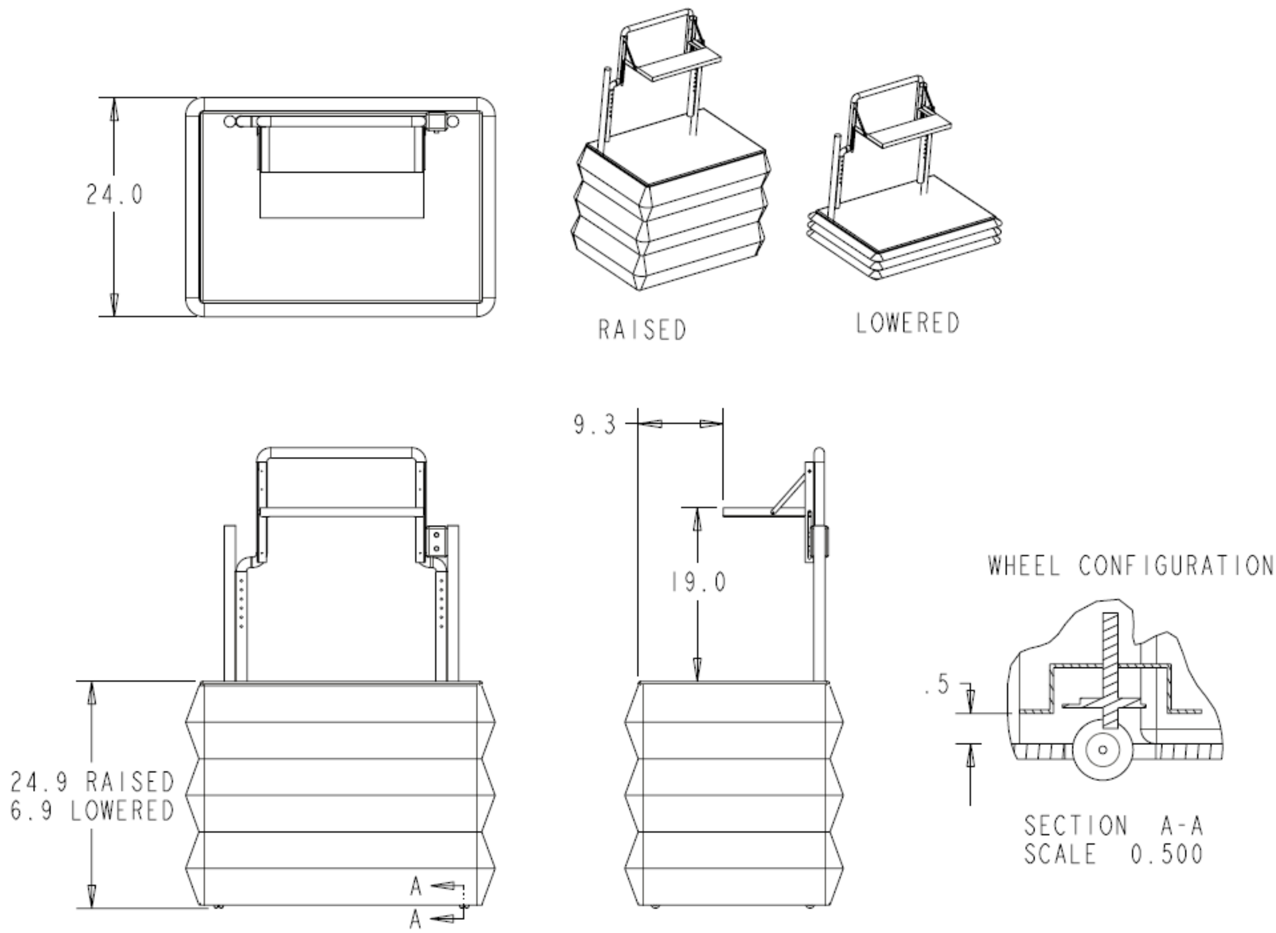
4) Motor

a.) Hydraulic Motor

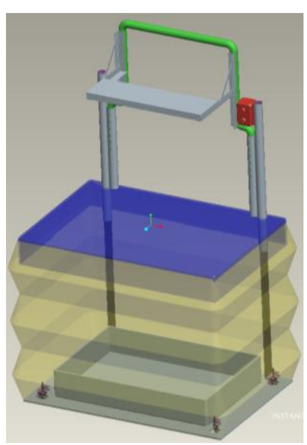
b.) Pneumatic Motor

c.) Air Bag Technology

Appendix B – Alpha Design



a.) "Alpha Design" With Basic Dimensions



b.) "Alpha Design" Rendering

Appendix C – QFD

			Technical Requirements																		
Customer Needs	Customer Weights	Kano Type	Quiet	Fuse Location	Hidden Wiring	Wheel Locks	Cost	Lean Bar	Rollers	Grip for Feet	Motor	Seat	Materials	Manuverability	Accessibility to Parts	Weight	Height of Lift	Dimensions	User Friendly		
Stability	10					3		3	1				1	1		9	3	9			
Comfort	10		9					9				9	3								
Easily Boarded Lift	6									1							9		3		
Noise Level	10		9								9		1								
Design Relocations	5			9	9																
Hand Control	10										3								9		
Platform Traction	9									9											
Water Sealant	7						3						9								
Maintenance	6			3	3						9				9				3		
Mobility	8								9					9		9			1		
Robust	9						9						9								
Lift Speed	6		3								9										
	Raw score		198	63	63	30	102	120	82	87	228	90	194	82	54	162	84	90	134		
	Scaled		0.868	0.276	0.276	0.132	0.447	0.526	0.36	0.382	1	0.395	0.851	0.36	0.237	0.711	0.368	0.395	0.588		
	Relative Weight		11%	3%	3%	2%	5%	6%	4%	5%	12%	5%	10%	4%	3%	9%	5%	5%	7%		
	Rank		2	14	14	17	7	6	12	10	1	8	3	12	16	4	11	8	5		

Appendix D – Pugh Charts

Motor

Selection Criteria	A Pneumatic	B Hydraulic	C Air Bag
Stability	1	1	1
Noise	1	1	-1
Hand Control	1	1	1
Maintenance	1	1	1
Robustness	1	-1	1
Lift Speed	1	1	1
Comfort	0	0	0
Accessible Lift	0	0	0
Mobility	0	0	0
Ease of Use	1	1	-1
Water Sealant	0	0	0
Net Score	7	5	3
Rank	1	2	2
Continue?	Yes	Maybe	No

Seating

Selection Criteria	A Fold Down	B Fold Up	C Stationary
Stability	1	-1	1
Noise	0	0	0
Hand Control	0	0	0
Maintenance	0	0	0
Robustness	1	1	1
Lift Speed	0	0	0
Comfort	1	1	-1
Accessible Lift	0	0	-1
Mobility	0	0	0
Ease of Use	1	0	1
Water Sealant	0	0	0
Net Score	4	1	1
Rank	1	2	3
Continue?	Yes	Maybe	No

Wheels

Selection Criteria	A Air Bearing	B Compression Locks	C Manual Lock
Stability	-1	1	1
Noise	0	0	0
Hand Control	0	0	0
Maintenance	1	-1	-1
Robustness	1	1	1
Lift Speed	0	0	0
Comfort	0	0	0
Accessible Lift	0	0	0
Mobility	1	1	-1
Water Sealant	0	0	0
Ease of Use	-1	1	-1
Cost	-1	1	1
Net Score	0	4	0
Rank	2	1	2
Continue?	No	Yes	No

Skirt (Bellows)

Selection Criteria	A Vinyl	B Steel
Stability	0	0
Noise	1	-1
Hand Control	0	0
Maintenance	1	1
Robustness	1	1
Lift Speed	0	0
Comfort	0	0
Accessible Lift	0	0
Mobility	0	0
Water Sealant	1	1
Ease of Use	0	0
Cost	1	0
Net Score	5	2
Rank	1	2
Continue?	Yes	No

Lean Bar/ Seat Frame

Selection Criteria	A Steel	B Aluminum
Stability	1	1
Noise	0	0
Hand Control	0	0
Maintenance	0	0
Robustness	1	1
Lift Speed	0	0
Comfort	0	0
Accessible Lift	0	0
Mobility	0	0
Weight	-1	1
Water Sealant	0	0
Cost	1	1
Net Score	2	4
Rank	2	1
Continue?	No	Yes

Appendix E – Final Quote

Attn: Chad Britton

April 15, 2008

University of Michigan
912 Baldwin Ave
Ann Arbor MI 48104
Phone: 269-209-0632
Fax:

Quote #08-0213-104J Rev 1

Email: cwbritto@umich.edu

Solution Dynamics is pleased to present the following quotations for your consideration:

Myti-Lift Table

- Model: CLTMYT-05-30W
- Capacity: 500 lbs
- Platform Size: 21” x 31”
- Base Frame: 16” x 24”
- Lowered Height: 6”
- Raised Height: 36”
- Up Speed: 20 seconds
- Motor: 1/2 HP
- Weight: 208 lbs
- 10 ft. power cord
- Smooth Steel Top
- Price: ……………………. $2,350.00 each

Options:

- Safety Skirting: (blue & yellow) …… $210.00
- Lift limit switch (set to 24”) …………$165.00
    - Easily adjusted to different heights

Lead Time: 3-4 Weeks (possibly sooner)

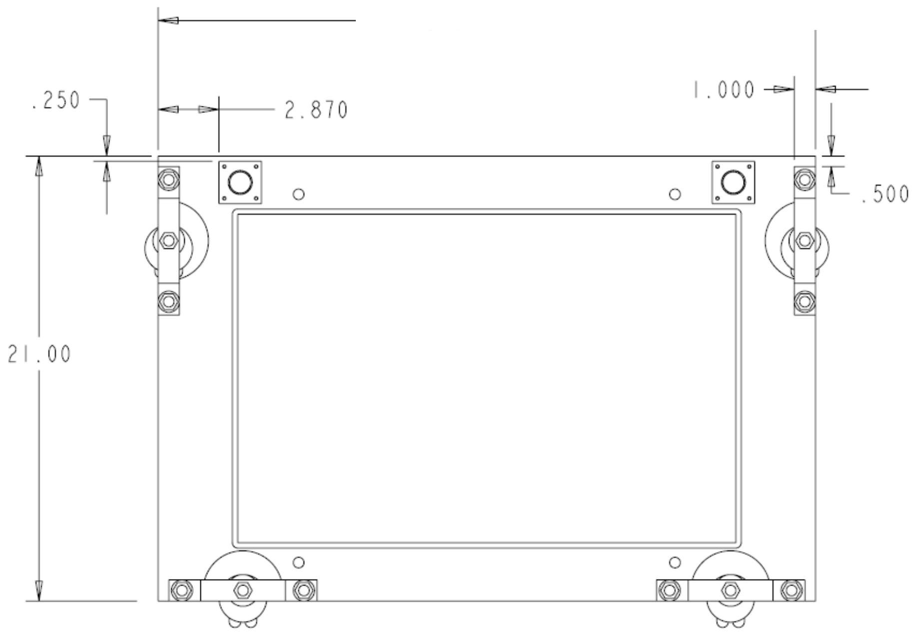
ORDERING:

To order, please call Solution Dynamics at 1-877-860-3620, fax us at 262-860-3630 or email us at sdi@sodyinc.com. We accept the following credit cards.

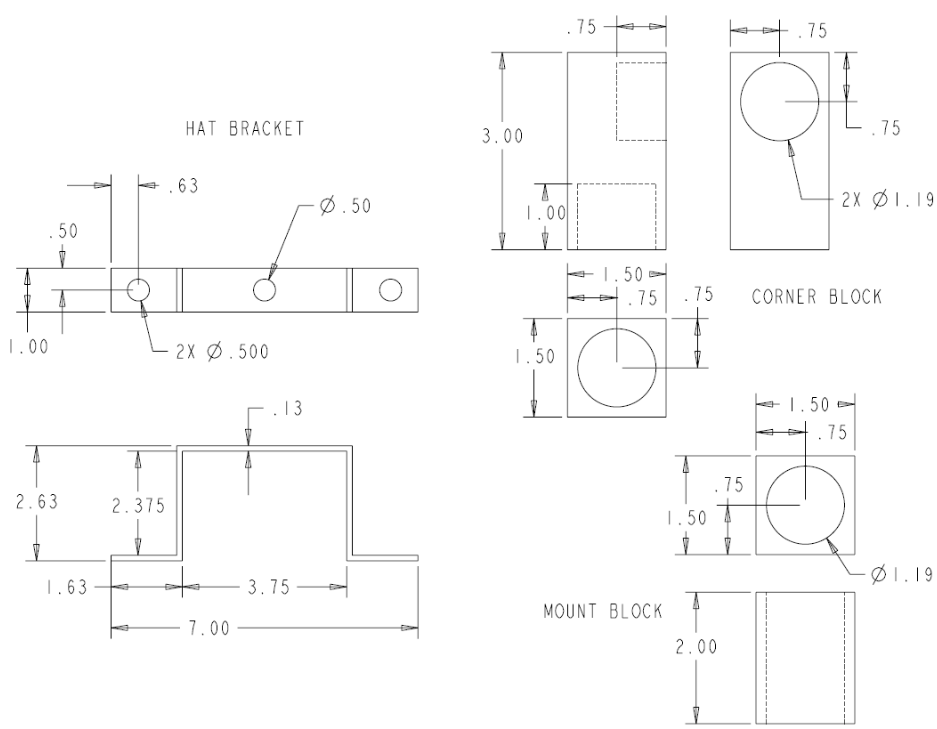
Your Contact’s Name is: Jackie Payne

Appendix F - Final Design Drawings

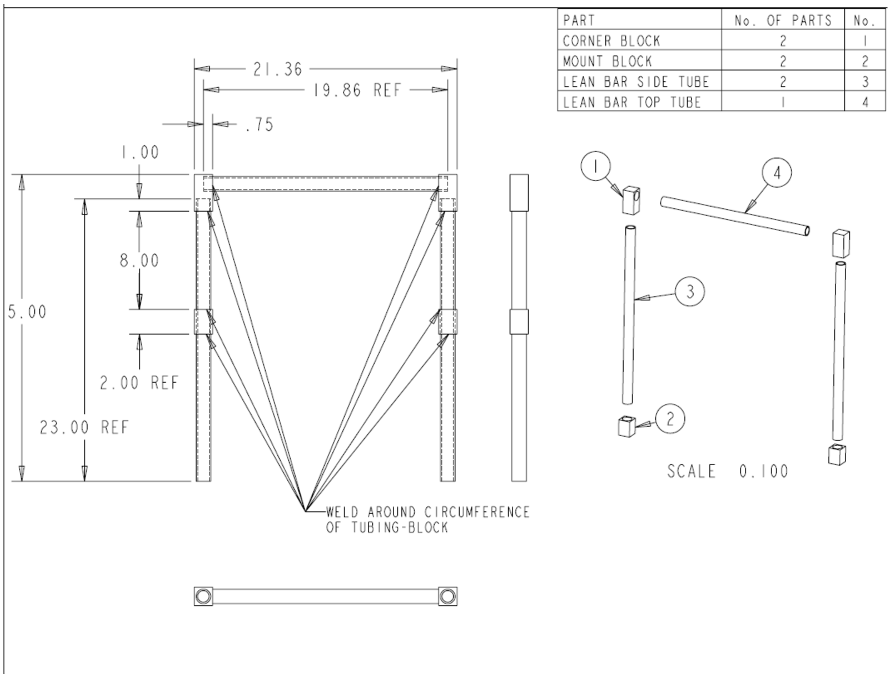
a) Bottom View of Lift



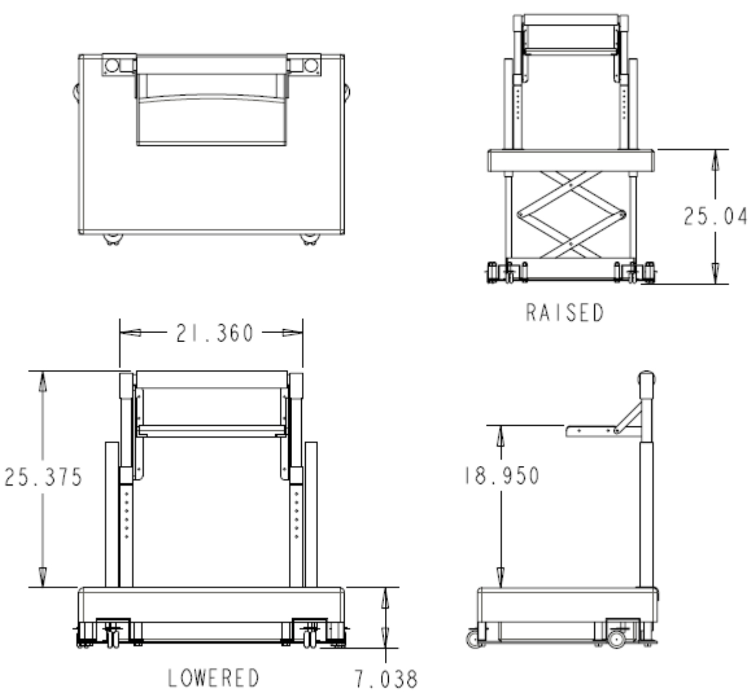
b) Hat Bracket



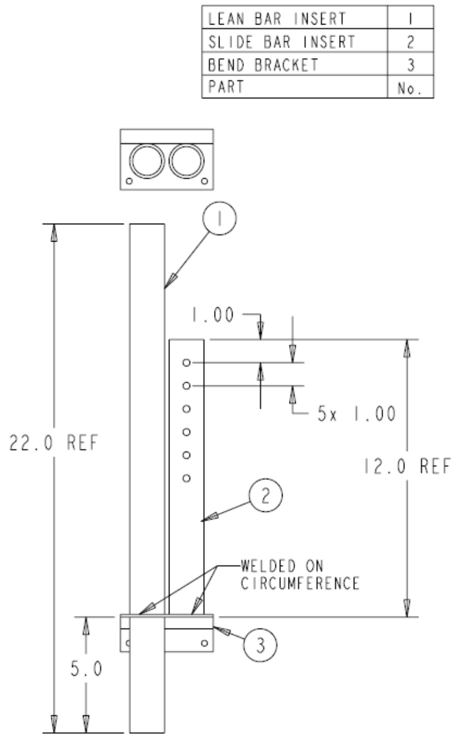
c) Lean Bar Assembly



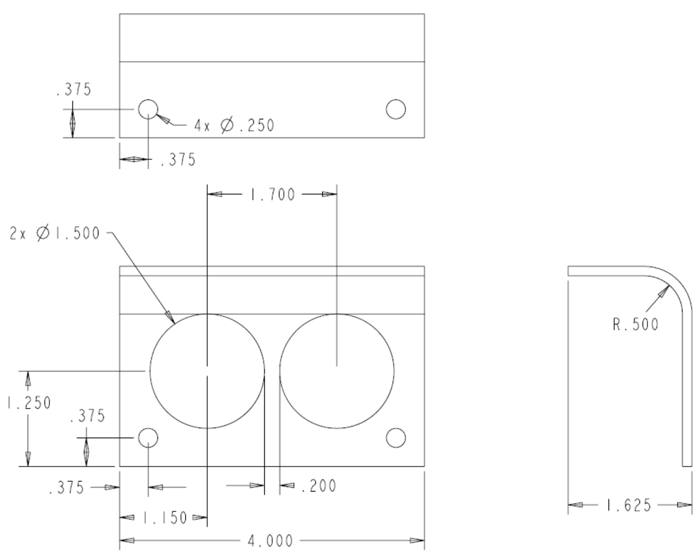
d) Lowered Lift



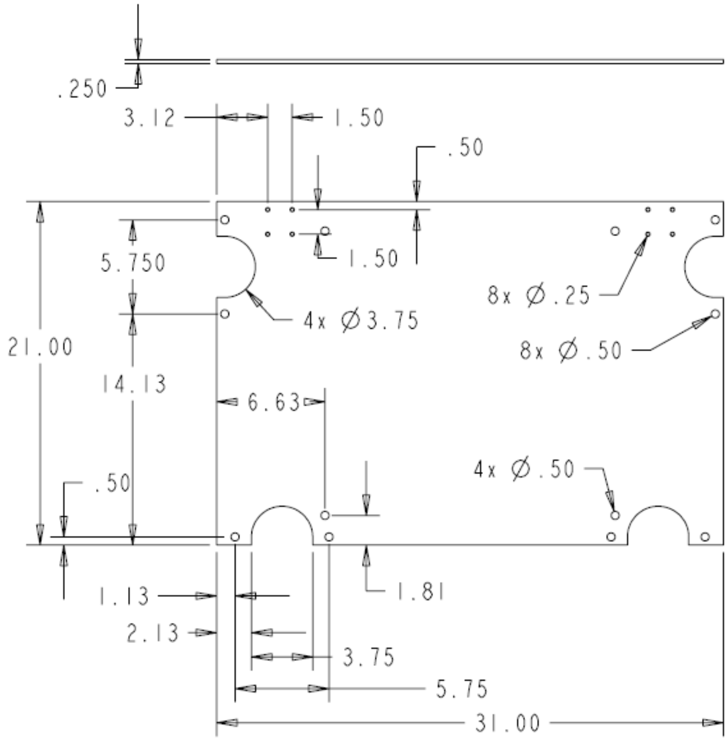
e) Adjustable tube



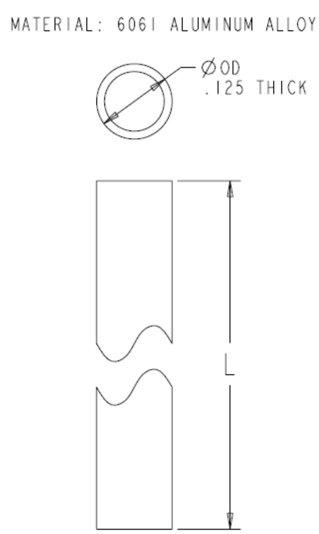
f) Bend bracket



g) Base plate

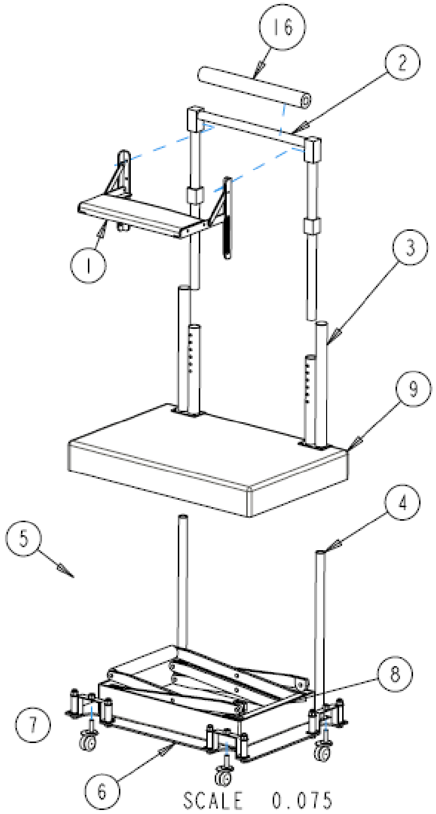


h) Tube lengths

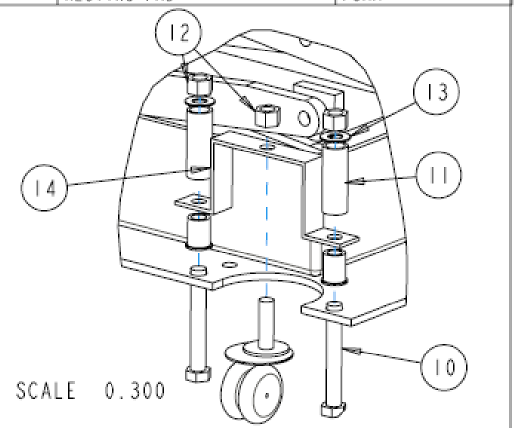


LEAN BAR INSERT	12.00	1.50
SLIDE BAR INSERT	22.00	1.50
SIDE LEAN BAR WELD.	23.00	1.19
TOP LEAN BAR WELD.	19.86	1.19
SLIDE BAR	23.00	1.19
PART	L	OD

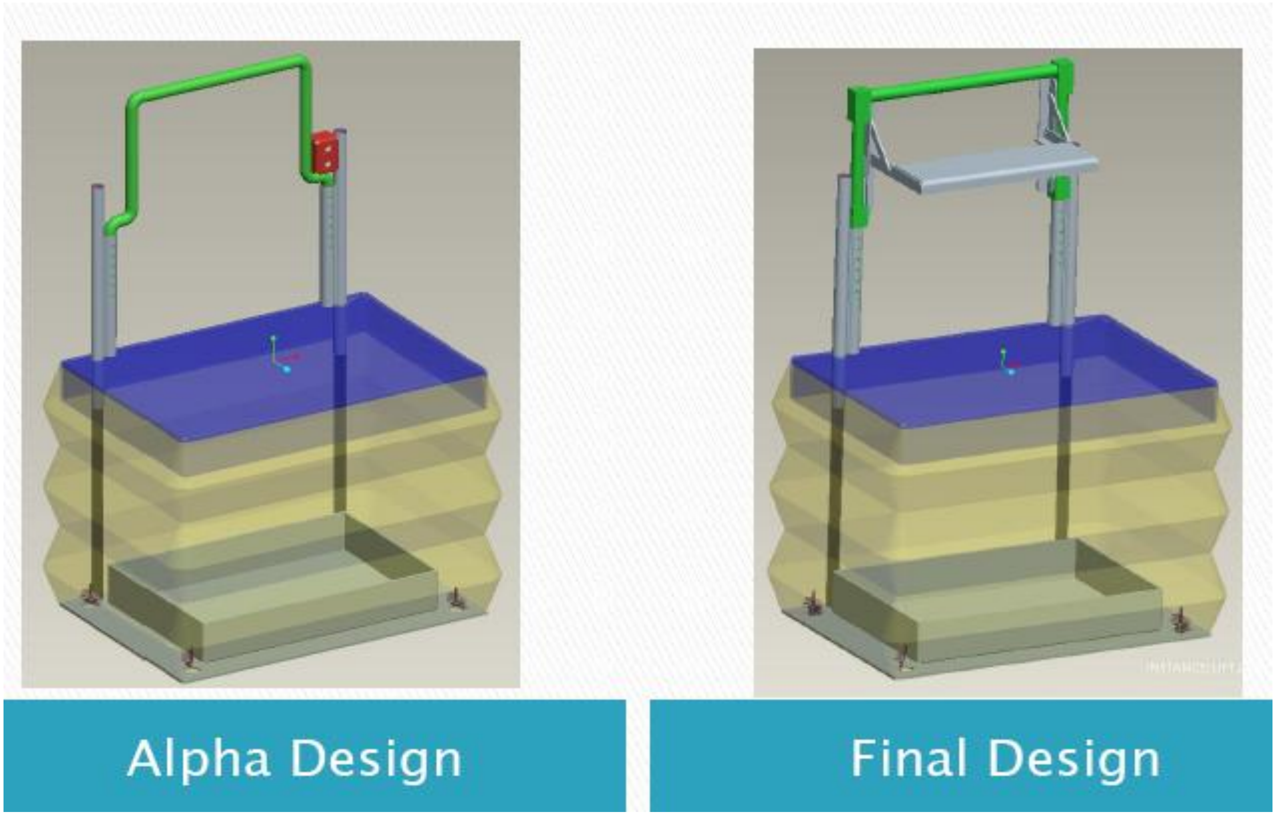
i) Final Assembly



No.	No. of Parts	Name	Material
1	1	SEAT	-
2	1	ADJUSTABLE LEAN BAR	6061 ALUMINUM
3	2	LEANBAR ATTACHMENT	6061 ALUMINUM
4	2	SLIDE BAR	6061 ALUMINUM
5	1	BELLOWS	-
6	1	BASE PLATE	HOT ROLLED STEEL
7	4	CASTER	-
8	1	BOTTOM OF CONTRACTED LIFT	-
9	1	TOP OF CONTRACTED LIFT	-
10	12	HEX BOLT 0.5''-13 X 3.5''	STAINLESS STEEL
11	8	COMPRESSION SPRING	MUSIC WIRE
12	8	HEX BOLT 0.5''-13	STAINLESS STEEL
13	8	WASHER	STAINLESS STEEL
14	4	HAT BRAKET	HOT ROLLED STEEL
15	8	BUSHING 0.5'' ID	BRASS
16	1	RESTING PAD	FOAM



j) Appendix G – Comparison between Alpha and Final Design



Appendix H – Calculations for Parameter Analysis

a) Lean bar tubing thickness

Lean Bar Tubing Thickness

KNOWN		US		SI	
Mechanical Constraints					
Outside Diameter	D_{out}	1.5	in	0.038	m
Outside Radius	R_{out}	0.75	in	0.019	m
Weight from person	W_L	250	lbf	1112.1	N
Distance from tubing	L_t	10	in	0.254	m
Weight from seat	W_s	6	lbf	26.7	N
Distance from tubing	L_s	5	in	0.127	m
Height of Seat	H	25	in	0.635	m
Material Properties					
Density of material	ρ	0.098	lbm/in^3	2712.6	kg/m^3
Yeild Strength of the Material	σ	29010	psi	2.00E+08	Pa

CALCULATE MINIMUM TUBING THICKNESS					
Safety Factor	S	2			
Yeild strength with safety factor	σ_s	58020	psi	4.00E+08	Pa
Moment	M	2530	lbf-in	285.85	N-m
Moment of Inertia	I	1.09	lbm/in^2	4.54E-07	kg/m^2
Inside radius (maximum)	R_{in}	7.50E-01	in	1.90E-02	m
Thickness (minimum)	t	2.39E-04	in	6.07E-06	m

$$\sigma = \frac{MH}{I} \quad \text{(Eq. 1)} \qquad M = W_L L_t + W_s L_s \quad \text{(Eq. 2)}$$

$$I = \frac{1}{2}\pi\rho H\left(R_{out}^4 - R_{in}^4\right) \quad \text{(Eq. 3)}$$

In order to determine the safety factor we first used Eq. 3 to determine the moment of inertia. We then used Eq. 2 to determine the moment. Using these values and plugging them into Eq. 1, we were able to determine the stress placed on the lean bar. Then by dividing this stress from the yield strength, we were able to determine the safety factor to be 202. The values used in these calculations can be seen in the table above.

b) Wheel locking mechanism- springs

KNOWN		US		SI	
Weight of Lift w/o Person	W_L	290	lbs	1289.984	N
Weight add to lock	W_{tl}	50	lbs	222.411	N
Displacement to lock	X	0.25	in	0.00635	m
Number of springs	N	8			

ANALYSIS					
Spring rate	R	25	lb/in	4378.169	N/m
Min. allowable disp.	D	1.7	in	0.04318	m
Length of disp. w/ lift	L	1.45	in	0.03683	m

$$R = \frac{W_{tl}}{X} \qquad \text{(Eq. 4)}$$

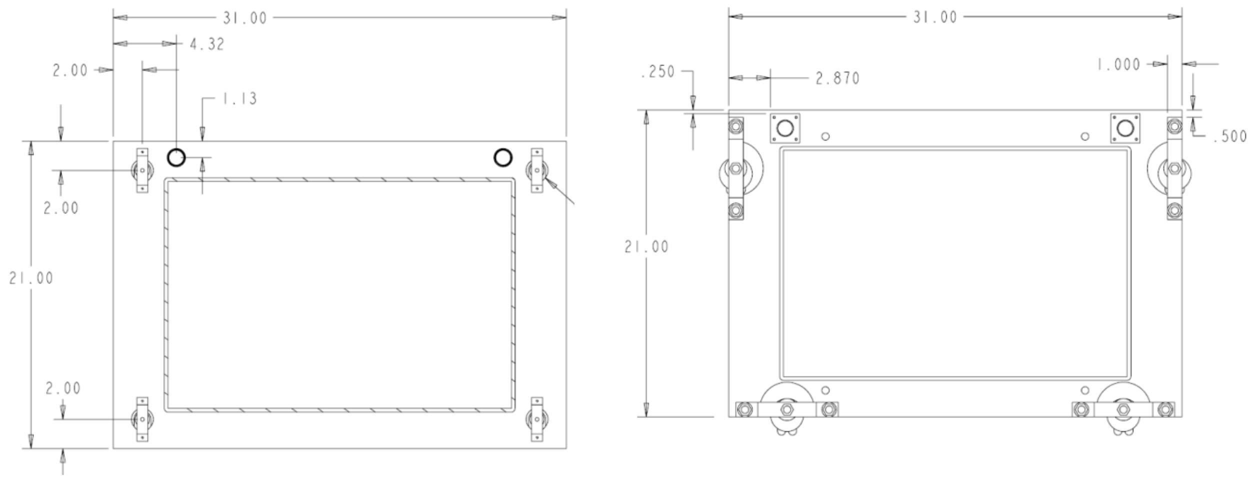
Appendix I: Bill of Materials

Part #	Part Name	Qty	Material	Size	Total Cost	Function
				(inches)		
CLTMYT-05-30W	Solution Dynamics Myti-Lift Tab	1	Steel	21 x 31	2725	Lift
1G293	Caster 2 In Swivel	4	Rubber	2	57.72	Wheels for model
N-1006	Samuel Heath folding shower sea	1	aluminum/wood	11 x 18.5	330.13	Seat for model
26306012	Aluminum tubing	1	aluminum	OD: 1, t-1/8, L-72	26.19	Lean bar
AAA00600	Carbon Sht	1	steel		29.9	
26307512	Aluminum tubing	2	aluminum	OD: 1-1/4, t-1/8, L-72	73.8	Lean bar
29900030	shearing	1	shear	shear	5	shear
26309514	Aluminum tubing	2	6061 T6 aluminum	OD: 1.5 , t-1/8, L-72	134.4	Lean bar
20712000	Aluminum plate	1	6061 T6 aluminum	4 x 4 x 0.19	26	Strength
7000170	Steel Base Plate	1	Steel	21 x 31 x 0.25	29.9	Base plate
21425300	Aluminum Block	1	6061 T6 aluminum	L- 1ft., 1.5 sq. ft	20.66	90 deg joints
32221	plug ground 3 wire 15A	1	-	-	7.99	outlet
12949	glue contact cmnt QT DAC	1	-	-	6.99	glue
17110	spry kryton true blue 12 oz	1	-	-	3.49	paint
11880	sprypaint clear 12 oz	1	-	-	4.99	paint
10718	lube graphite .21 oz	1	-	-	1.49	lube
1089465	spry kryton sunyellow 12 oz	1	-	-	3.49	paint
84823	grease wht lith 10.25 oz	1	-	-	5.99	grease
45370	pipe insulation 1" gray	1	-	-	1.99	Lean bar
12993	paintbrush chip2 "wht brsl	3	-	-	5.97	for glue
056	fasteners	12	stainless steel	-	1.8	fasten
056	fasteners	20	stainless steel	-	6.6	fasten
51262	cup cstr 2" sq wal c04	1	-	-	2.99	
6102685	tread stair safety 4x17"	1	-	-	6.49	
51262	cup cstr 2" sq wal c04	1	-	-	2.99	
58636	tape crpt T/0 1.41x42'	1	-	-	6.49	tape plastic on base
	washer	20	stainless steel	.5-	3.4	fasten
	nuts	6	stainless steel	.5-13	1.38	fasten
	nuts	2	stainless steel	.5-13	0.5	fasten
	bolts	8	stainless steel	1/2-13 3.5L	8.8	fasten
92198A726	hex head cap screw	2	stainless steel	1/2", L-3-1/2	23.38	
98480A018	locking pin	2	stainless steel	D-3/8, L-1-3/4	11.04	lean bar height
2962T2	bearing	9	bronze	D-1/2, L-7/8	176.04	hat brackets
94075K57	conductive plug	1	n/a	1.25	8.87	outlet
84775K134	rigid PVC foam sheet	1	PVC	24 x 24 x .394	35.07	keep lift in place
95005K371	hook and loop	1	polyester	2" x 5"	16.14	velcro for hand control
98480A016	locking pin	4	stainless steel	3/8"D, 1-3/8	21.64	lean bar height
8884T25	bumpers	2	rubber	1"D, 1"H	21.6	base
6893T35	switchboard mat	1	rubber	3 feet	39.12	base
46875K43	corner surface guard	4	rubber	1-1/16 H, 1"D, 3" x 3"	20.8	corners
72306	compression springs	8	steel	3.5 L, 1W, .850D	109.69	springs
Total					**4026**	

Appendix J: Description of Engineering Changes since Design Review 3

Figure 1: Base Plate

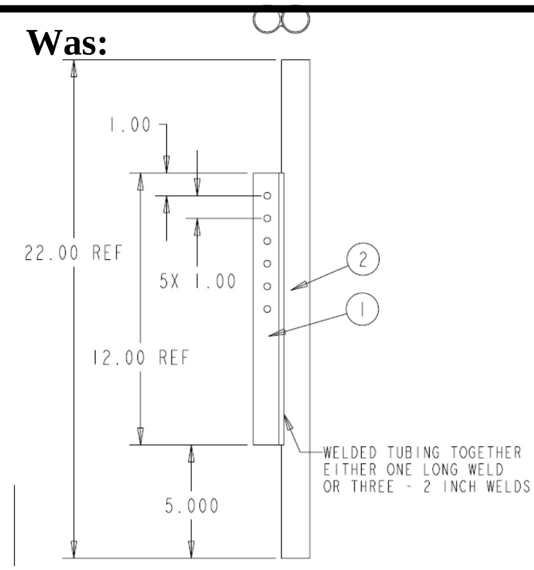
Was: **Is:**



Changed hole positioning to fit the size of the casters and slide bars.

Figure 2: Adjustable Tube for Lean Bar Assembly

Was:



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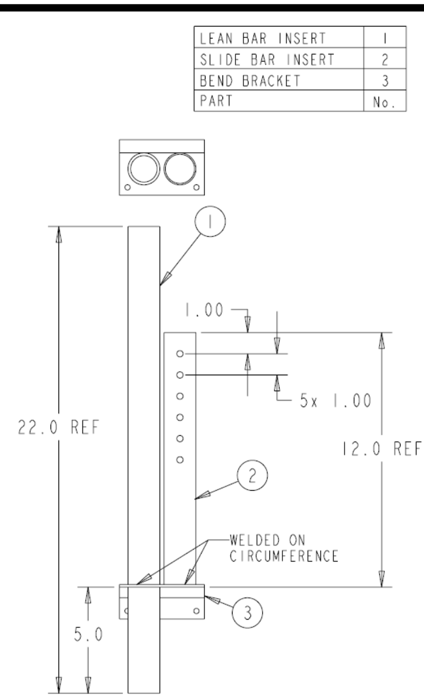
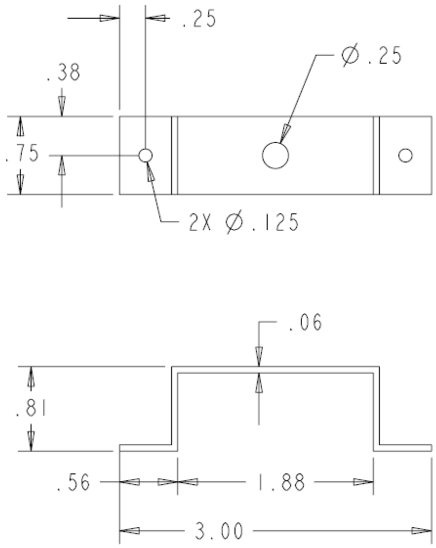


Changed welding to implement bent bracket.

Figure 3: Hat Brackets

Was:



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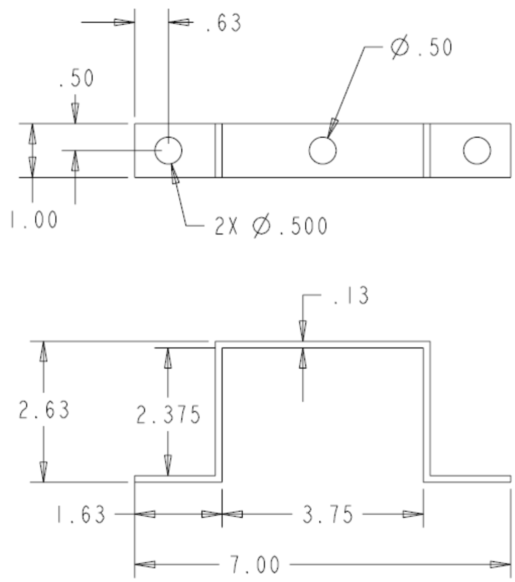
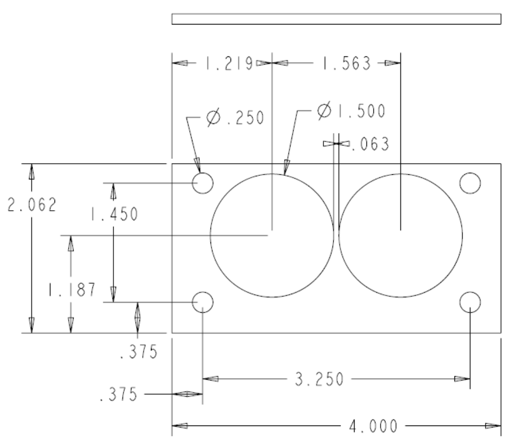


Changed to fit the size of the casters.

Figure 4: Bend Bracket

Was:



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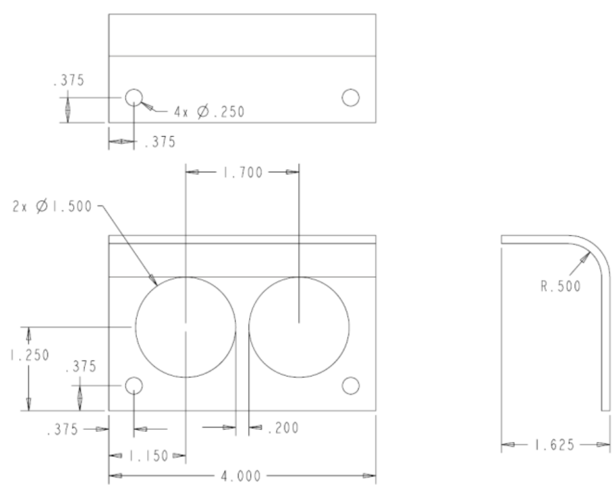


Bend was used to increase stability and strength. Also, a 0.2'' clearance between tube holes to allow a bolt to pass in between.

Appendix K: Design Analysis Assignment from Lecture

1) Material Selection Assignment

Material Selection for Lean Bar

Function	Sitting, stability, sliding
Objective	Minimize mass and cost
Constraints	(a) Cost C_m<$100/kg
	(b) Density (2600-3000 kg/m^3)
	(c) Material that can be welded
	(d) Yield Strength>250 MPa
	(e) Availability

Top 5 Materials Choices

1. **Wrought Aluminum Alloy, 6061, T6**
2. Cast Aluminum Alloy, 354, T6
3. Wrought Aluminum Alloy, 2014, T6
4. Wrought Aluminum Alloy, 2024, T3
5. Wrought Aluminum Alloy, 7020, T6

Reasons for Final Choice

1. Least expensive of the five
2. Uses are for heavy duty structures, pipe, furniture
3. Easily available
4. Easiest to weld of five

Material Selection for Steel Base Plate

Function	Stability, mobility
Objective	Minimize mass and create a stable base
Constraints	(a) Cost C_m<$100/kg
	(b) Density (7000-8000 kg/m^3)
	(c) Material that can be welded
	(d) Availability
	(e) Must be able to fabricate easily

Top 5 Materials Choices

1. **Carbon Steel, AISI 1060 (annealed)**
2. Carbon Steel, AISI 1015
3. Carbon Steel, AISI 1030
4. Cast Austenitic Stainless Steel, ASTM CE-30
5. Low-Alloy Steel, AISI 4130

Reasons for Final Choice

1. Made of same material as lift
2. Easily available
3. Least expensive of the five
4. Easily machined

2) Design for Assembly

Table 1: Original Design

Part ID	Num. times carried out	Two digit manual handling code	Manual handling time per part	Two digit manual insertion code	Manual insertion time per part	opertaion time (sec)	operation cost (cents)	figures for estimation of minimum parts	Name
1	1	00	1.13	06	5.5	6.63	2.65	1	Seat
2	4	10	1.5	00	1.5	12.00	4.80	0	Seat bolts
3	4	10	1.5	38	6	30.00	12.00	0	Seat nuts
4	1	00	1.13	00	1.5	2.63	1.05	1	Adjustable lean bar
5	2	00	1.13	96	12	26.26	10.50	0	Corner block
6	2	10	1.5	96	12	27.00	10.80	0	Mount block
7	2	20	1.8	00	1.5	6.60	2.64	0	Lean bar side tube
8	1	20	1.8	00	1.5	3.30	1.32	0	Lean bar top tube
9	2	00	1.13	00	1.5	5.26	2.10	1	Locking pin
10	2	00	1.13	00	1.5	5.26	2.10	1	Lean bar attachment
11	2	20	1.8	00	1.5	6.60	2.64	1	Lean bar insert
12	2	00	1.13	00	1.5	5.26	2.10	1	Slide bar insert
13	2	00	1.13	96	12	26.26	10.50	0	Bend bracket
14	4	10	1.13	00	1.5	10.52	4.21	0	Bracket bolts
15	4	10	1.5	38	6	30.00	12.00	0	Bracket nuts
16	2	00	1.13	00	1.5	5.26	2.10	1	Slide bar weld
17	2	20	1.8	00	1.5	6.60	2.64	0	Slide bar plate
18	2	20	1.8	00	1.5	6.60	2.64	1	Slide bar
19	8	10	1.5	00	1.5	24.00	9.60	0	Slide bar bolts
20	8	23	2.36	00	1.5	30.88	12.35	0	Slide bar washers
21	8	10	1.5	38	6	60.00	24.00	0	Slide bar nuts
22	1	94	3	00	1.5	4.50	1.80	0	Base plate
23	1	94	3	00	1.5	4.50	1.80	1	Scissor lift (contracted)
24	4	25	2.36	00	1.5	15.44	6.18	0	Lift bolts
25	4	10	1.5	38	6	30.00	12.00	0	Lift nuts
26	4	00	1.13	00	1.5	10.52	4.21	1	Hat bracket
27	8	00	1.13	96	12	105.04	42.02	0	Hat bracket side
28	4	00	1.13	96	12	52.52	21.01	0	Hat bracket top
29	8	00	1.13	96	12	105.04	42.02	0	Hat bracket bottom
30	8	00	1.13	00	1.5	21.04	8.42	1	Hat bracket bolt
31	8	00	1.13	00	1.5	21.04	8.42	1	Spring
32	8	00	1.13	00	1.5	21.04	8.42	1	Bushing
33	8	23	2.36	00	1.5	30.88	12.35	0	Hat bracket washer
34	8	10	1.5	39	8	76.00	30.40	0	Hat bracket lock nut
35	4	10	1.5	00	1.5	12.00	4.80	1	Caster
36	8	10	1.5	38	6	60.00	24.00	1	Caster nut
37	1	20	1.8	00	1.5	3.30	1.32	1	Resting pad
38	1	00	1.13	00	1.5	2.63	1.05	1	Bellows
						912.41	364.96	17	Design Efficiency **5.59%**
						TM	CM	NM	

Table 2: Re-Design

Part ID	Num. times carried out	Two digit manual handling code	Manual handling time per part	Two digit manual insertion code	Manual insertion time per part	opertaion time (sec)	operation cost (cents)	figures for estimation of minimum parts	Name	Notes
1	1	00	1.13	06	5.5	6.63	2.65	1	Seat	
2	4	10	1.5	35	7	34.00	13.60	1	Seat snap	[1]
3										
4	1	00	1.13	00	1.5	2.63	1.05	1	New adjustable lean bar	[2]
5										
6										
7										
8										
9	2	00	1.13	00	1.5	5.26	2.10	1	Locking pin	
10	2	00	1.13	00	1.5	5.26	2.10	1	Lean bar attachment	
11	2	20	1.8	00	1.5	6.60	2.64	1	Lean bar insert	
12	2	00	1.13	00	1.5	5.26	2.10	1	Slide bar insert	
13	2	00	1.13	96	12	26.26	10.50	1	Bracket snap using casting	[3]
14										
15										
16	2	00	1.13	00	1.5	5.26	2.10	1	Slide bar weld	
17	2	20	1.8	00	1.5	6.60	2.64	1	Slide bar plate	
18	2	20	1.8	00	1.5	6.60	2.64	1	Slide bar	
19	8	10	1.5	35	7	68.00	27.20	1	Slide bar snap	[4]
20										
21										
22										
23	1	94	3	00	1.5	4.50	1.80	1	Scissor lift (contracted wider base)	[5]
24										
25										
26	4	00	1.13	35	7	32.52	13.01	1	Hat bracket with bend and snaps	[6]
27										
28										
29										
30	8	00	1.13	00	1.5	21.04	8.42	1	Hat bracket bolt	
31	8	00	1.13	00	1.5	21.04	8.42	1	Spring	
32	8	00	1.13	00	1.5	21.04	8.42	1	Bushing	
33	8	23	2.36	00	1.5	30.88	12.35	1	Weld nut	[7]
34										
35	4	10	1.5	00	1.5	12.00	4.80	1	Caster	
36	8	10	1.5	38	6	60.00	24.00	1	Caster nut	
37	1	20	1.8	00	1.5	3.30	1.32	1	Resting pad	
38	1	00	1.13	00	1.5	2.63	1.05	1	Bellows	
						387.31	154.92	22	Design Efficiency	**17.04%**
						TM	CM	NM		

Notes for Re-Design

[1] Implement a snap system for the bolt and nut of the seat assembly.
[2] Instead of using welded square blocks, use tubing with a rectangle profile and drill holes where needed.
[3] Combine the bolts, nuts and bracket to make a bracket that will snap into place once inserted.
[4] Implement a snap system for the bolt and nut of the slide bar assembly.
[5] Contract out a wider base for the scissor lift.
[6] Instead of welding each piece of the hat bracket, bend material to proper shape.
[7] Instead of using a lock nut, use a weld nut that implements both the attributes of the washer and nut.

3) Design for Environmental Sustainability

We started with 2 materials previously selected using CES, and then we determined what mass of these materials would be needed in the final design. We then used SimaPro to look up the closest materials. From this we were able to determine the mass of air emissions, water emissions, use of raw materials, and waste. The values can be seen in Table 3 and also in Figure 5.

Table 3: Total mass of aluminum and steel based on material effects

	Mass (kg)	
	Aluminum	Steel
Raw Materials	1577.145	24.480
Air Emissions	81.236	8.932
Waste	19.285	0.092
Water Emissions	1.167	0.007

By looking at Figures 1-4, you can see that the aluminum has a greater impact on the environment. This is true for all four of the EcoIndicator 99 damage classifications. The three categories in which steel is the closest to aluminum are resp. organics, ecotoxicity, and acidification.

Of the damage meta-categories, resources are most likely to be important based on the EI99 point values. The reason for this is that for the aluminum, this value goes much higher than both human health and ecosystem quality. The value for resources is 0.107, while the second highest value is 0.006 for human health. This can be seen in Figure 2.

As can be seen from Figure 4, the aluminum has a higher EI99 point value than steel. The aluminum has a point value of 2.5, while the steel has a value of 0.2. When the life cycle of the whole product is considered, the aluminum will have a greater impact than the steel. This is not very good but is unavoidable, considering what the total weight of the lift would have been if steel was used. The aluminum was also available, which factored greatly into our decision.

Figure 1: Percentage of effects of two materials on environemt

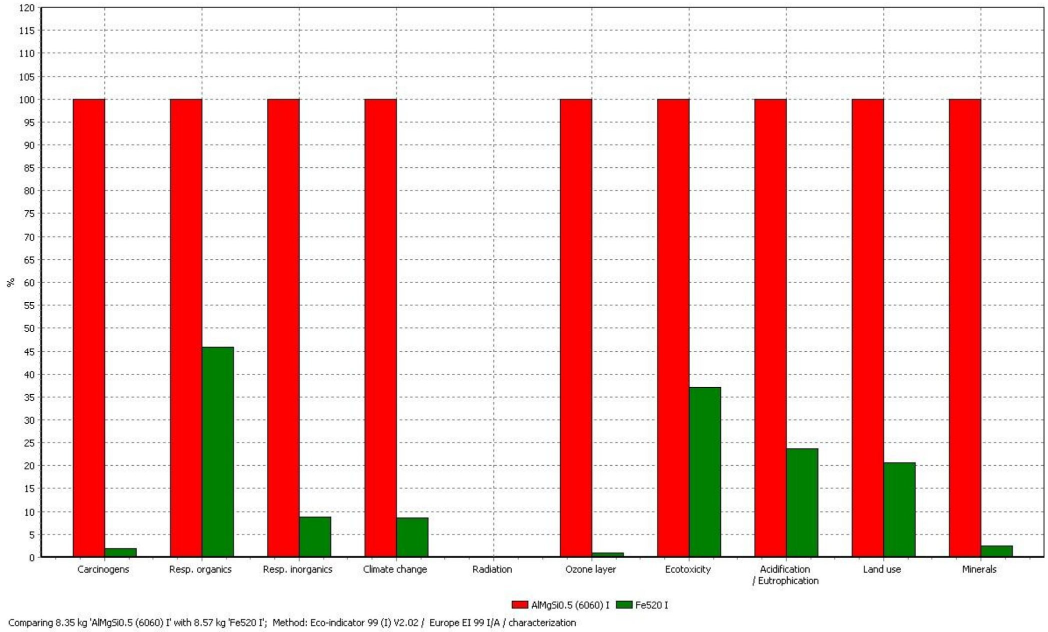


Figure 2: Perecntage of effects of materials on meta-catergories

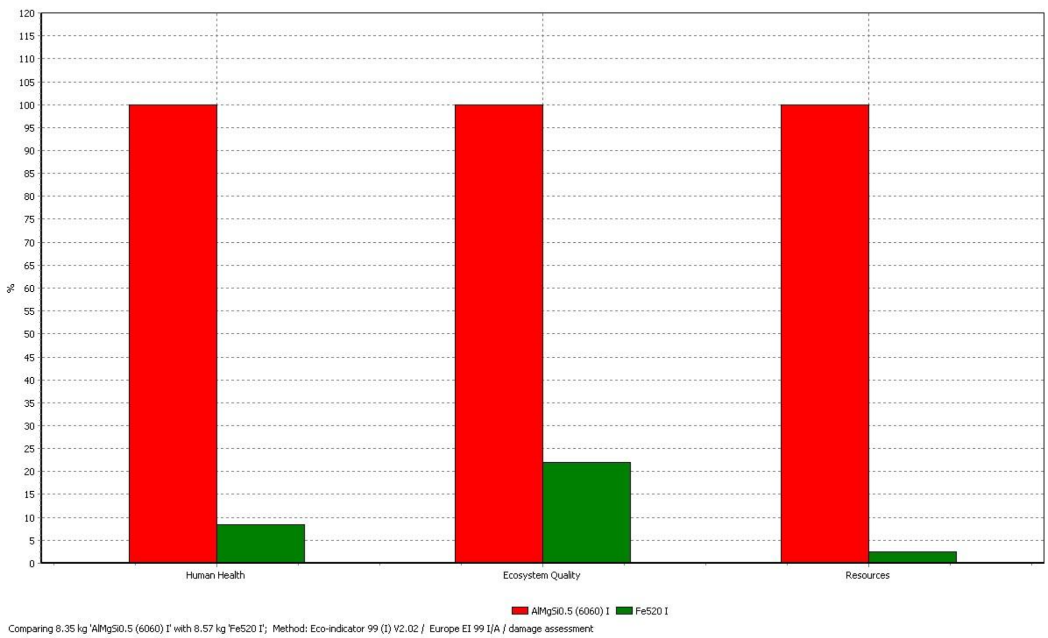


Figure 3: Effects of materials on meta-catergories

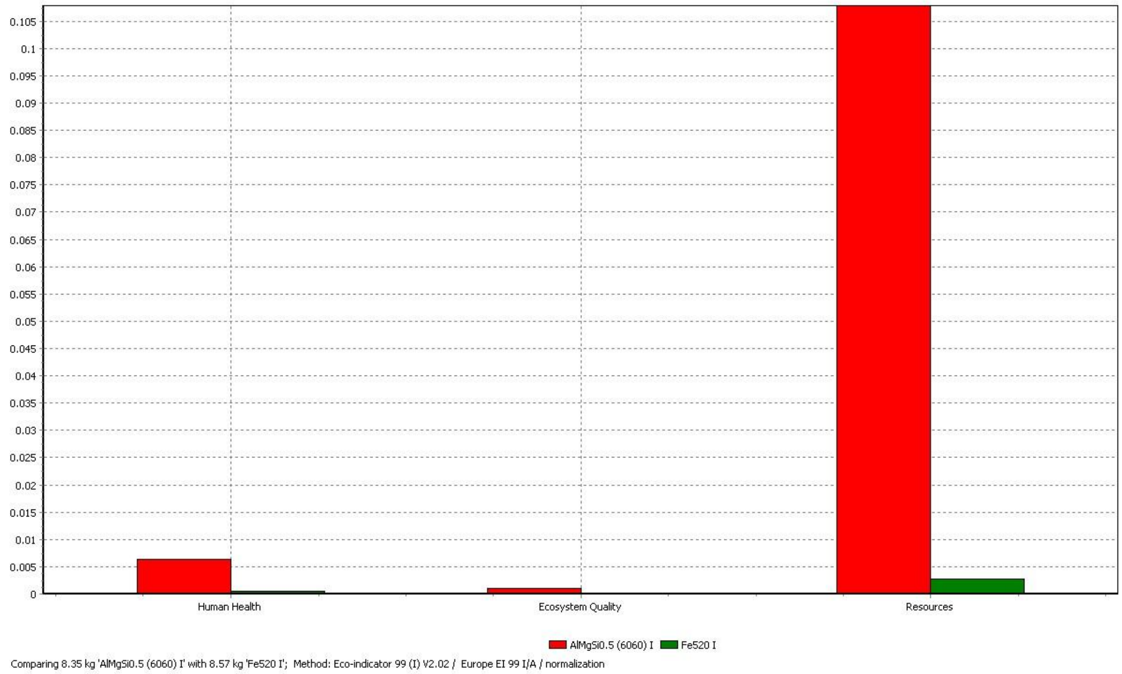


Figure 4: Contribution of meta-catergories to materials

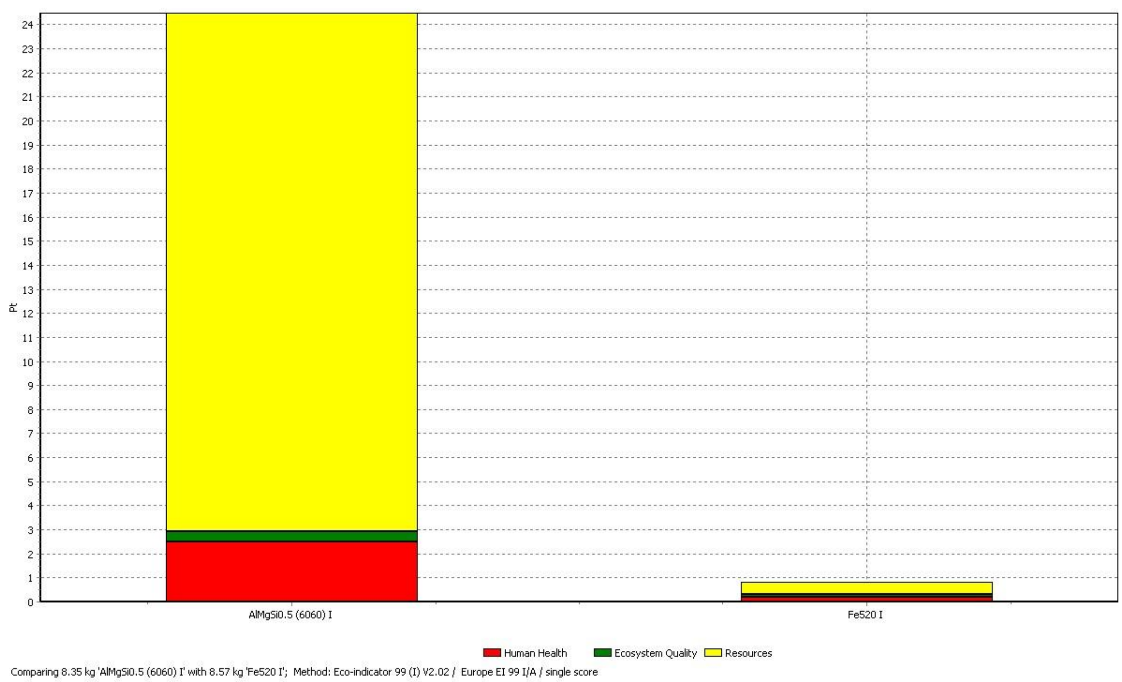
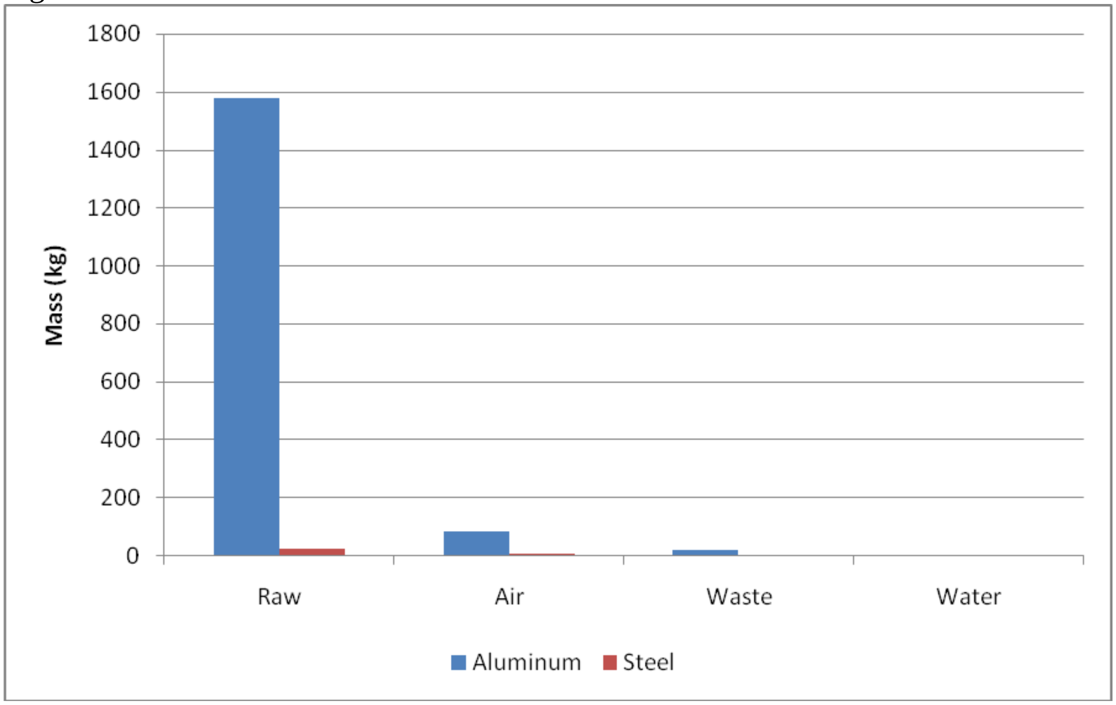


Figure 5: Mass of effects on environment of materials



4) Design for Safety

The major risks for our design include the wheel locking mechanism, the hydraulic motor and the seat. The risk with the wheel locking mechanism is that it could fail, which would make the lift not mobile, and unstable. These provide risks for the surgeon and the patient. For example, if the mechanism were to fail it would drop slightly which could cause the surgeon to lose balance and possibly fall. This would also cause a risk to the patient because if the surgeon isn't stable then the patient isn't safe.

Another risk we assessed is the hydraulic motor leaking or a hose breaking and thus creating a non-sterile environment in the operating room. This problem would put the surgeon at risk because with the loss of oil pressure, the lift can suddenly lower. Also, the patient would be at risk because of the instability of the surgeon.

The third risk we found is the seat failing. This could produce a problem because the weight limit on the seat is 250 lbs. so if that is exceeded then the seat would fail. This puts the surgeon at risk for falling while using the seat and this could cause a risk to the patient if the surgeon is using the seat while operating.

Table 1: DesignSafe Anaylsis

Surgical Power Lift 4/14/2008

designsafe Report

Application:	Surgical Power Lift	Analyst Name(s):	Tony Frankini
Description:	A lift that is used to all a surgeon to operate at different heights.	Company:	
Product Identifier:		Facility Location:	
Assessment Type:	Preliminary		
Limits:			
Sources:			

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	mechanical : machine instability The lift is at its least stable point when the lift is changing heights	Serious Frequent Unlikely	High	Have user hold on to the lean bar when adjusting the height	Serious Frequent Negligible	Moderate	
All Users All Tasks	electrical / electronic : energized equipment / live parts If a wire is not insulated, the user could get shocked	Minimal Remote Unlikely	Low	Periodically check the lifts wiring to ensure wires are not showing	Minimal Remote Unlikely	Low	
All Users All Tasks	slips / trips / falls : slip A liquid could get on the grip pad and the user could slip and fall off the lift	Slight Frequent Unlikely	Moderate	Ensure the grip pad is not worn out and cleaned after every use	Slight Frequent Unlikely	Moderate	
All Users All Tasks	slips / trips / falls : trip The lean bar and/or wiring may get in the way and cause the user to trip and fall off the lift	Slight Frequent Unlikely	Moderate	Ensure the wire is not in the way of the users feet	Slight Frequent Unlikely	Moderate	
All Users All Tasks	slips / trips / falls : instability If the user moves a lot while on the lift, the stabilty will decrease and increase the users chances of falling	Serious Frequent Possible	High	Have the user wear a safety harness to prevent falling from the lift	Serious Frequent Negligible	Moderate	
All Users All Tasks	ergonomics / human factors : deviations from safe work practices The user may lean or do something unsafe on the lift and increase chance of injury	Slight Remote Possible	Moderate	Ensure user is following proper safety protocal	Slight Remote Unlikely	Low	

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	noise / vibration : personnel fatigue Surgeries can last a long time causing the user to become fatigued	Slight Remote Possible	Moderate	Have user use seat periodically to take a break	Slight Remote Unlikely	Low	
All Users All Tasks	material handling : excessive weight The lifts load capacity could be exceeded causing an abnormal stress on the lift	Minimal Occasional Negligible	Low	Apply warning labels that have weight capacities	Minimal Occasional Negligible	Low	
All Users All Tasks	environmental / industrial hygiene : contamination If not properly cleaned and sterilized, the lift could become contaminated.	Serious Frequent Probable	High	Have cleaning protocol that is followed after every use	Serious Frequent Unlikely	High	

The difference between risk assessment and Failure Mode and Effects Analysis (FMEA) is that risk assessment is based on setting acceptable level of harm and giving low relevance to lack of scientific evidence which decisions are based. The FMEA is used to spot risks and used to initiate efforts to control or minimize risks with cause and effects relationships. FMEA documents a failure, its mode and its effect.

The difference between acceptable risk and zero risk is that acceptable risk describes an event whose probability of the risk happening is small but the benefit is great. This makes the individuals or group take on the event weighing more the benefit over the risk. Zero risk is complete elimination of a risk. The distinction does show up in our project. We weighed more to the acceptable risk part which showed true in our final product. We calculated all the safety factors and came to the conclusion that we were in a zero risk category. But after fabrication we realized that there is some acceptable risk with the seat, the motor, the wheel locking mechanism and the wiring of the lift. Our sponsor has weighed this into account when contracting it out to us and put the lift into an acceptable risk category.

5) Manufacturing Process Selection

Seeing how our model is made specifically for one customer we would have to build this design when ordered. Because this is a specific model for one purpose there is not a wide range of possible users. Due to this fact, if our model were to go into full production we estimate the production volume to be between 10 and 50 units. However, because our concept can be used in other situations such as elderly assistance, the production volume could increase with design modifications. With these expanded uses of the model the production volume could increase to as much as 500 units.

Justified choices for manufacturing process:

Lean Bar: Determined thought CES that TIG welding was the most appropriate approach for joining the lean bar frame. TIG welding produced very high quality welds on metals such as aluminum.

Steel Plate: Determined through CES that plasma arc cutting (PAC) would be the best process for cutting through the steel plate. PAC will produce accurate cuts in our chosen material.

Reasons for choosing manufacturing process:

Lean Bar: Cost of TIG welding is expensive but the heat treatment for the welding process produces a heavy duty, clean, and precise weld. TIG welding works well with thin sheets of metal and does not require heat treating the metal before welding. It can be used manually but is easily automated, which would be beneficial for manufacturing the lean bar in production.

Steel Plate: PAC can be used for numerous metal thicknesses. The metal does not need to be heat treated in order for PAC to be used. PAC is manual and can also be automated, which would be used in the production of our base plate. The PAC process is most frequently used for cutting carbon steels, which is the material used for the base plate.