Monitor lift for Adjustment of Computer Display
&
Oil Paint Cap Removal Aid

Team4
Patrick Keating
Thuy Pham
Daniel Zachs
Katie Zilm

Client:

Brooke Hallowell, Ph.D., CCC-SLP, F-ASHA
Associate Dean, Research and Sponsored Programs
Director, School of Hearing, Speech and Language Sciences
College of Health and Human Services
Grover Center
Ohio University
Athens, OH 45701
Hallowel@ohio.edu

Spring 2007 April 20th, 2007
Table of Contents

FINAL DESIGN ..............................................................................................................
Abstract.........................................................................................................................
1 Introduction ................................................................................................................
  1.1 Background (client and disability).................................................................
  1.2 Purpose of the project .................................................................................
  1.3 Previous Work Done by Others ...............................................................
    1.3.1 Products ............................................................................................
    1.3.2 Patent Search Results........................................................................
  1.4 Map for the rest of the report ....................................................................
2 Project Design ............................................................................................................
  2.1 Design Alternatives ......................................................................................
    2.1.1 Design 1 ..........................................................................................
    2.1.2 Design 2 ..........................................................................................
    2.1.3 Design 3 ..........................................................................................
  2.2 Optimal Design ..............................................................................................
    2.2.1 Objective ..........................................................................................
    2.2.2 Subunits ............................................................................................
      MonitorLift...................................................................................................
        1.2.1 An Overview
        1.2.2 The Monitor Platform
        1.2.3 Sliding PVC Guide-Tube System
        1.2.4 Spring Raising System
        1.2.5 Spring System Continued
        1.2.6 Sub Unit Breakdown of FBD
        1.2.7 Entire Monitor Lift Force Body Diagram
        1.2.8 The Dash-Pots
        1.2.9 The Base Platform
        1.2.10 Testing of the whole system
      Oil Paint Cap Remover....................................................................................
        2.2.1 An Overview
        2.2.2 The Base Unit
        2.2.3 Rubber Feet for Stabilization
        2.2.4 The electronic circuit
        2.2.5 The motor
        2.2.6 The Cap-Head
        2.2.7 The Clamp
        2.2.8 Testing of the whole system
3 Realistic Constraints ..............................................................................................
4 Safety Issues ...........................................................................................................
5 Impact of Engineering Solutions............................................................................
ABSTRACT

Monitor Lift

A monitor lift was recently requested from the Ohio State University Neurolinguistics Laboratory. Current research involving the use of a monitor to display visual stimulus is being conducted in this lab. The laboratory deals with patients who have brain disorders that result in their inability to communicate effectively through visual, verbal or physical means. The current way to determine if a person comprehends a certain stimulus presented to them is to measure the response of their eyes, this eye reaction allows for communication between practitioner and patient. The current practice for measuring the patient’s reaction is through the use of a monitor/ eye tracking system. The current problem is that the monitor is stationary requiring the patients to be maneuvered to the device opposed to the device to the patient. Many of these patients have a hard time moving and following orders and thus one can see the need for an accommodating monitor lift.

Our monitor lift design implements simple mechanical devices that effectively and simply raise the monitor lift. Our design is unique because it incorporates springs and dashpots to assist and maintain the moving and positioning of the monitor lift. Through various testing and calculations a unique equilibrium will be obtained with this device allowing for simple raising and lowering of the system. The system relies on simple natural physical laws achieved by simple mechanical parts allowing for safe and effective operation as well as good cost management and maintenance. Our device will effectively address the problems faced currently and will promote a safe and functional environment within the Neurolinguistics Laboratory.

Paint Cap Remover

A device has been requested through the National Science Foundation which will effectively remove the cap to an oil based paint tube. This device must require minimal physical exertion in its operation and must effectively remove the cap. Our client currently suffers from the debilitating disease known as Multiple Sclerosis or MS. This disease affects the nervous system and as a result has many symptoms that effect ones ability to correctly function. The symptoms most affecting our client’s ability to remove the cap cover are weakness and loss of dexterity. Due to the symptoms afflicting our patient we have designed a device that will allow for a safe and effective means of removing the paint cap requiring little or no strength or dexterity.

The device to be created involves a small motor which will rotate a machined cutout section, which is the negative shape of the paint cap. The motor will spin at a slow rate allowing for the tube to be placed in between two uprights, and thus allowing for the removal of the cap in a safe and effective manner.
1 INTRODUCTION

1.1 Background

**Monitor Lift**
Often times neurological disorders result in impaired auditory and visual sensory. The extent of one's inability to hear or see resulting from their neurological disorder is unknown due to the fact that they are limited in their ability to express the extent of their disabilities. For patients with neurological disorders it is hard to communicate through traditional means such as verbally, or with some physical indication. The neurological disorders that these patients suffer from spans to all areas of their body, effecting mental comprehension, physical mobility, speech and other means of providing communication pathways with practitioners and caretakers. The level of comprehension that these patients possess is often times unknown because of their inability to respond after receiving some sort of visual stimuli from say a computer monitor. Specifically in the case of neurolinguistic patients their inability to communicate verbally proves to be a great barrier when measuring auditory and visual comprehension.

**Paint Cap Remover**
Multiple Sclerosis is a chronic inflammatory disease that affects the central nervous system of the body. The central nervous system spans the entirety of one's body, affecting every aspect of the body's ability to function. The nervous system provides muscles ability to function as well as how they are to function. Dexterity and the fundamentals of motion and strength all find their core from the nervous system. MS results in the deterioration of an essential part of our nervous system basic component, the neuron. The neurons inability to function properly due to a deteriorating outer sheath results in many symptoms. In our particular case the individual who requires the device does so because of his loss of function of one hand and the overall strength decrease in both hands. On a side note the disease has left him with no lower body function. The individual’s loss of strength and dexterity from the disease demonstrates the need for an assistance device that will allow him to perform a task that up to this point cannot be done because of the disease he suffers from.
1.2 Purpose Of The Project

Monitor Lift
Currently in the Neurolinguistics Laboratory at Ohio University, studies are being done to measure the comprehension of neurological patients in response to auditory and visual stimuli. The purpose of the monitor lift project is to provide a means to deliver the auditory and visual stimuli to the patient as well as provide a platform for any medical devices used in tracking the response of the patient. The Monitor used currently remains stationary on a desk, resulting in limited mobility of the unit. The inability of the monitor to move results in hardships on the patient due to the fact that the patient has to accommodate the position of the device opposed to the other way around. The lift would allow the patient to remain in a comfortable position while the movement requirements of the device for an effective means of studying the patient would rely solely on the device itself and not the patient. The lift would deliver the stimulus at the correct plane of sight of the patient as well as allow for the implementation of an eye tracking mechanism to record the patients eye responses to stimulus. The eye movement of the patient is one of the only means of communication between the tester and the patient with regards to their comprehension of various stimulus, thus it is of the utmost importance to move the eye movement tracker to the patient since the patient cannot align to the correct positioning of the eye sensor.

Paint Cap Remover
The purpose for the paint cap removal aid is to replace the ability of ones hands through the use of a battery operated, motor implemented device. The lack of strength and dexterity that the individual has must be mimicked by such device without destroying the tube of paint. The device must remove the cap of a standard 1.25oz paint tube, accounting for the variation in shape of the tube due to the loss of paint over the course of time. Currently the lack of a device leaves the individual with the inability to paint resulting in catastrophic implications concerning his independence and livelihood.

1.3 Previous Works Done by Others

Monitor Lift
A previous University of Connecticut team in connection with Ohio University neurolinguistics laboratory attempted the same monitor lift. The 1999 project resulted in a monitor lift that was bulky and distracting to the patients. Their unit consisted of a frame and a control unit. A steel frame in connection with a linear actuator lift was
used. The implementation of a scissor like motion was used in conjunction with a track connected to the raised platform. The initiation of the linear actuator results in the vertical motion of the platform through the horizontal movement of the legs along the base track. A basic two button control is used to raise and lower the lift to a desired height.

**Paint Cap Remover**

An attempt on the Oil Paint Cap Removal Aid has not been recorded. No results were found in connection with the NSF, or any other institution. The highly specific nature of the project has led to an inability to find any attempts at such a project.

### 1.3.1 Products

**Monitor Lift**

ABLEDATA currently has an “At Ease Monitor Riser” Model # (VR200 & VR100). These monitor lifts are designed to raise and lower monitors to eye level in order to reduce neck and back strain when using a computer. The device does not rely on electrical motor use or hydraulics and is operated by manually lifting the device to desired height.

The Able Ergonomics Corporation discontinued a simple monitor stand in the year 2000. This stand had the ability to raise and lower the monitor manually to a desired height. The device did not have a user control and was not manufactured with the use of a motor or hydraulic piston.

Ergo Store Online offers a manual monitor lift with no storage capabilities. The MTR-250 Monitor Arm is a monitor lift that accommodates only a computer monitor and requires the physical lifting and lowering of the device.

**Paint Cap Remover**

Only similar product on market to Oil Paint Cap removal is a product such as Black and Decker's Spacemaker can opener. Employs the use of an electric motor and spins the can underneath a blade resulting in the opening of a mental can. Such a device could not be used to open a Paint Cap but similar workings are employed in the implementation of this device.
1.3.2 Patent Search Results

Monitor Lift

A search of the website http://patft.uspto.gov for “monitor lift” yielded 31 results, three of which were directly related to the monitor lift at hand.

Patent #7,059,539 a lift that employs the use of a telescoping tube, used to lift a firefighting monitor. Inventor Steingass; Robert W. (Valparaiso, IN), McMillan; Stewart G. (Valparaiso, IN), Shepard; Larry (Kentland, IN) in conjunction with Task Force Tips Inc. (Valparaiso, IN) December 23, 2003

Patent #6,997,422 a patent that broadly encompasses methods and apparatus capable of force balancing through the use of springs between two individual components. Inventor Sweere; Harry C. (Minneapolis, MN), Ergun; Mustafa A. (White Bear Lake, MN), Lindblad; Shaun C. (Lino Lakes, MN), Overn; H. Karl (Vadnais Heights, MN) in conjunction with Ergotron, Inc. (St. Paul, MN) August 20, 2003.

Advanced Multimedia Product Corporation
Described as a stowable device that relies on the combined functioning of a gas piston spring as well as a natural coil spring. The device is released via a push button mechanism.

Patent #5,437,235 A Computer Work Station: July 31, 1995
No affiliated corporation
Described as a fixed table form computer work station with a recessed compartment for a computer. Relies on the balancing of springs in order to raise the monitor out of the recess. No detail given with regards to the nature of the mechanism.

Patent # 6,352,226 a device that is used to remove a monitor from a stowed position through the implementation of a flexible track typically including a rotary drive. Flexible track can be of chain, belt or cable. Device traverses monitor between upper and lower dimensions. Inventors Gordon; Seth A. (Eugene, OR) in conjunction with Rosen Products, LLC (Eugene, OR) May 2, 2000.

Patent #6,189,849 Lift System: February 20, 2001
Ergotron, Inc.
A device that accommodates only a flat panel screen and works on a sliding low profile bar. Minimal detail with regards to the internal units of the mechanism.
A lift system that requires the function of multiple linkage arms. Works on a height and tilt gas spring to maneuver the lift up and down.

**Paint Cap Remover**
Patent #4,414,866 Cap Remover: November 15, 1983
Cap remover enables the use of a hook device to get under the cap lip and through a prying motion opens the cap. The device works on springs and a system of pivot arm bars.

Patent #6,158,305 Cap Remover: December 12, 2000
Blackhawk Molding Co., Inc.
A cap remover that relies on manual prying off of a flip cap. The device is mounted and has a design that accommodates the flip cap being removed. A spring allows for the adjustment of the device to accommodate similar caps who only differ in size. The architecture of the design allows for easier removal of the cap because of its ability to increase ones leverage, all while holding the bottle neck and cap in place.

Patent #3,178,813 Electric Can Opener: April 20, 1965
One of the original designs of the modern day can opener. Was designed to make a permanent cut on the top of a metal can around the brim allowing for the removal of the top. The can was placed into the unit and the cutting device was lowered. A small motor rotates the can round under a cutting wheel and the metal is penetrated.

- many other designs but all function very similar to 1965 can opener

### 1.4 MAP FOR THE REST OF THE REPORT

The rest of our report will focus on the designing that has gone on over the past semester. Both projects have gone through numerous processes to reach their final optimal designs. In the following sections the three alternative designs will be described in great detail as well as the resultant optimal designs that incorporated the best technology from the many test phase designs. The report will go through the designs highlighting the strong points and the weak points with each. The reasons for their strengths and their weaknesses will be presented and explained so as to gain an understanding of where the optimal design came from. As the report continues these weaknesses will gradually fade away due to revamping of the designs and gaining a
better understanding of the nature of the project. The optimal design will incorporate aspects of the alternative designs and in some cases rely heavily on technology that was stripped from the previous designs.

The physical design of the project is not all that will be commented on with regards to this final report. The nature of the budget and the breakdown of parts pricing will also be explained in the following sections. The physics behind the working parts of our designs will also be described. The requirements and strict guidelines will be given as well as how we were able to accommodate them within our projects.

The last few sections of the paper will focus on broader topics concerning safety issues, realistic constraints, engineering issues, as well as life long learning. The reason we say that they are broader is that they apply to all the projects being tackled this semester. Though the topics of these last few sections lend themselves to broad descriptions we will talk of how they apply directly to our project so as to convey an idea of where our project fits in the engineering world.

2  PROJECT DESIGN

2.1 Design Alternatives

2.1.1 Design 1

2.1.1.1 Objective

Monitor Lift

The first alternative design is completely different from the originally proposed design for the monitor lift. It will still perform the same functions and lift the monitor at least 12 inches off of the desk. The original design used a hydraulic lift. The hydraulic lift system has many components (motors, switches, pumps, valves, etc.), and therefore many possible places for defect. Hydraulic systems are also notorious for being messy and there is a possibility that it would be too loud for a clinical/laboratory setting. The new design does not involve any hydraulics or electronics. There are far fewer ways for it to fail. It will not make any noise, and it will be easy for the user to lift the monitor to the height they desire manually. Many new safety components have been included in the first alternative design.
The first alternative design for the monitor lift is a manual lift with the following major components: a base, two arm bars connected by a circular pivot joint, a spring mechanism and a safety clamp (see Figure 1a above). Safety measures incorporated into the new design are counterweights, hinges, safety straps to secure the monitor and raised edges on the monitor platform.

**Oil Paint Cap Remover**

For the first alternative design for the paint cap remover, changes were made to try to improve the effectiveness of the removal system as well as fix problems with the original design. Our new design is shown in its entirety in Figure 1b below. Alterations were made to how the cap-remover head is brought down onto the cap. The hinged arm is replaced with a spring guided platform. This helps to significantly reduce the amount of strength needed to lower the cap remover and will make it easier for someone with minimal grip to operate the device. The clamp design was also taken into consideration. It was noted that a tight clamp squeezing the paint tube might compress the paint and force it out of the bottle unnecessarily. To prevent this from happening we’ve designed a non-compressive clamp which will not expel any paint from the tube.

**Figure 1a- Monitor lift in active upright position and in stationary storage/zeroed position.**

**Figure 1b: Front View of Entire Paint Cap Removal Device**
2.1.1.2 Subunits

Monitor Lift

2.1.1a Monitor Platform
The subunit monitor platform is a steel frame. The safety concern of the monitor falling on the patient was taken into consideration and elevated edges and the strap attachment accessory were added in this design. The circular cut out at the base and back of the platform allows for bundling of the wires in a clean and neat fashion allowing for the wires to be “behind the scenes” and not be distracting while taking an active role in the operation of the operation of the machine. The drop down steel frame box which will contain the housing for the eye tracking device will be welded to the bottom of the platform ensuring that it travels in sync with the monitor itself. The safety straps will be able to accommodate a variety of straps and attachment clamps. A circular hole will be drilled in the accessory so as to accommodate hooks/tie downs. The hinge will maintain the level nature of the monitor as the entire unit moves up and down. The hinge will mimic a simple door frame hinge and can be modified to fit the platform. Figure 1c shows an aerial and side view of the platform described above.

Figure 1c- Monitor platform (side view/ top view) with attachment mechanism and safety constraints taken into consideration.

2.1.1b Arm Bar/ Working Interior
The simple yet effective design of a spring in equilibrium attached to a joint and two arm is our first alternative method to the monitor lift system. The main component of this new system is the middle section of the lift stand that attaches to the monitor platform and the base platform at opposite ends. The new design relies more heavily on the physical mechanical operation by the person administering the test, but simplifies and alleviates the problem of the hydraulic, more automated lift. The spring joint couple will be calibrated to a desired equilibrium resulting in an easier operation and less physically demanding operation. The two arm bars will be attached to a
circular pivot joint in a V like fashion. Attachment blocks will be welded to the bars as a point of attachment for the springs. Figure 1d shows the middle working components of the lift.

![Figure 1d- Middle workings of lift consisting of two steel bars circular pivot joint, spring, and block attachments.](image)

### 2.1.1.23 Circular Pivot Joint/ Arm Bar Connection

The circular joint at the middle of the machine connects the working movable parts to the base and the top shelf which houses the monitor and the eye tracking device. The motion of the two arms, and ultimately the whole monitor, relies on the smooth nature and secure attachment of the arm bars. The circular joint mimics the nature of wheels on a sliding chair. The middle component will be the moving part sliding in between the two outside stationary parts. An inner bearing will allow for this movement. Within this joint will be stop mechanisms to only allow the arm bars to extent to a maximum of 45 degrees (12 in high) and a minimum of 0 degrees. The top bar will attach to the inner sliding piece while the bottom bar is permanently affixed to the outside parts that are stationary. This allows for the movement of the top arm bar. The simple inner workings of the joint will allow for easy maintenance and will replace the complicated hydraulic lift in the previous design. A metal bearing interior will be housed in a high density polymer casing. The inside of the pivot joint will be able to accommodate the wirings from the monitor which will run down through the hollow arms. The hidden wires will leave a clean look to the machine without sacrificing functionality. The backing of the joint will accommodate the friction from the spring throughout various cycling in the laboratory. Figure 1e below shows the circular joint schematic.

![Circular Pivot Joint](image)

**Figure 1e- Side and front view of the pivot joint negating the points of attachment**
2.1.1c Integration of Arm Bar and Pivot Joint
The mechanical nature of the arm bar requires a solid attachment to the point of motion, the circular pivot joint. The means of attachment will be a machined triangular piece of steel that will be welded and secured to the arm bar. The triangular piece will then be inserted and attached to the inner bearing. The triangular tip will allow for precise integrating of the arm into the circular joint. The triangular nature will also allow for a wider range of movement when approaching the lower limits of the monitor lifts height. The triangle shape will allow for the close proximity of the upper arm bar with the lower arm bar as the angle shown approaches 0 degrees. The tip of the piece will be inserted through the movable piece within the joint and will not be attached to the stationary outside pieces which will be welded to the bottom arm bar. Figure 1f shows the basic schematic diagram of the point of attachment.

![Arm Bar Connection to Pivot](image)

Figure 1f- upper arm bar attachment to circular pivot joint.

2.1.1d Arm Bar Integration of Spring Mechanism
The bars on the system will be hollow and will either be preformed during manufacturing or will be constructed from four individual length steel bars welded together. The small attachment welded to the end of the bar will incorporate a stainless steel loop which will be screwed into the bar with a washer and nut and possibly a backing plate for support. This loop will allow for the quick release of springs and provide a means for continually changing and replacing springs as they wear over time. The springs themselves will be chosen with Hooke’s law taken into consideration. The analysis of this equation proves that a variety of springs will do since we have two variables to play with in regards to the type of spring. Hooke’s law is $F = -kx$ [1] in which $K$ is the spring constant, $F$ is the restoring force of the spring, and $x$ is the distance the spring will travel. Knowing that the monitor is 80lbs (36.29kg) exerting a force of 355.642N. With the angle of the applied force ranging from 0-45 degrees it is evident that the spring must have a restoring force of between 0 and $\cos(45)^*355.642$ or 251.48 N. The length of the bars must be 8.5 inches minimum in order to have a hypotenuse distance of 12 inches vertically. The weight
of the components must be taken into account as well when considering the restoring force of the spring. Figure 2.6 shows the arm component with the spring attachment and spring.

Figure 1g- Top arm bar with spring attachment. Lower arm bar will mirror this image. Circular pivot joint was left out to highlight the identified subunits.

2.1.1e Base Subunit
The base subunit was an area of concern with regards to the safety of the machine. The moment becomes greater around the circular pivot joint as the arms are lowered. This constant changing of moments requires a steady anchored base. The problem arises in regards to having a heavy base to support the weight shifts, while still maintaining a light frame that could occasionally be transported. The solution to this problem comes in the form of removable weights being placed in designated and designed weight boxes that are attached to the base. These boxes are positioned so as to counterbalance the outward hanging monitor. A safety clamp was also installed on the front and back of the base so as to anchor the device to the table it is on. The high strength steel will be welded into a square frame. The clamps will be welded on as well as the weight boxes which will accommodate a variety of weight devices (sand bags, heavy metal, fluid bags, etc.) Figure 1h shows the aerial view and a side view of the base.

Figure 1h- Top and side view of the base subunit, detached from other subunits for clarity.
Oil Paint Cap Remover

2.1.1f Descending Platform
The descending platform, like the hinged top of the original design, houses all of the electrical components and the cap head. To reduce the amount of force needed to operate the device, the hinged arm of the previous design has been removed. The hinged arm would have to support the whole weight of the components used to remove the cap, including the motor and head. Although the hinged arm would be easy to lower onto the paint tube, the sheer weight of the unit would make it difficult for someone with limited strength to lift it up again. The first alternative design solves this by replacing the hinged arm with a descending platform. The platform uses the weight of the motor and electrical components to its advantage. Four springs are attached to the corners of the platform and are tethered from above to overhang support bars. A total of 8 support bars (4 horizontal support bars and 4 vertical support bars) make a box-like cage around the entire device and provide a structural scaffold for the descending platform. The platform itself, which can be made out of aluminum, is 10” by 10” can be either ¼ or ½ an inch thick.

![Figure 1i: Descending Platform](image)

The user then applies a very small amount of force on the depression handle that is attached to the platform. The 4 corner-springs which rest at equilibrium are easily stretched when the handle is pulled downward. This allows the platform to be lowered toward the tube of paint which has been placed into the clamp. The spinning cap head approaches the cap of the paint tube. Our cap-head design is shown below in Figure 1j and is the same as in the original design.

![Figure 1j: Paint Cap Remover Head](image)
2.1.1g The Clamp

To prevent the tube from spinning along with the head, the tube must be restricted from spinning. Our original design used a tight clamp to secure the paint tube from spinning. One major drawback that we were asked to consider was that a tight clamp might put too much pressure on the paint tube. This could result in the tube expelling paint superfluously. Not only would this be a waste of paint but it would be very messy and would require unnecessary cleaning of all parts involved in the device. Our design is unique because it will secure the paint tube without expelling the paint. The key to our design is that it takes advantage of the ovular shape of the paint tube. If you look at the tube from a birds-eye angle you can see that its width is larger than its depth, resulting in an oval shaped tube. This can be seen in the figures below. Figure 1l shows a top view of a full paint tube after it has been placed into the box-shaped clamp. The clamp fits around the outside of tube without applying any pressure to the tube. These simple metal clamps are cheap and come in many sizes at local hardware stores or online stores.

Figure 1k. Front view of the clamp

Figure 1l: Paint tube in different sizes.

Figure B shows what happens once the cap head remover comes into direct contact with the cap of the paint tube. When the cap head locks into place over the cap of the tube, both the tube and the cap begin to rotate counterclockwise. However, since the tube is wider than it is deep, it is prevented by the clamp from rotating fully. The clamp stands firm and holds the tube with minimal pressure, and this allows for the cap to be twisted counterclockwise. After several rotations the cap will be removed. At this point there is no pressure on the tube because nothing is twisting it. The final result leaves the paint tube sitting loosely in the square clamp with its cap
removed. The tube can be easily picked up out of the device after the device is switched off and the user is ready to use the paint.

Figures C and D show the concept: that although the depth of the tube will decrease as the paint gets used up, the width will remain nearly the same and the clamp will still be functional.

The unique feature of this simple metal clamp is that it will work properly and efficiently for the paint tube no matter how much paint is remaining in it. Because of the distinctive sealing of the tube at the base of the bottle the width of the tube will not be variable. Therefore since the clamp is rectangular shaped it will prevent the tube from rotating no matter how full it is. Even if the tube is almost completely empty, it will still have relatively the same width as when it is brand new.

2.1.1h The Springs
The final component of this alternative design is the spring. As can be seen from figure 1 and 2, there are 4 springs on each of the corners of the descending platform. The spring system is the biggest change from the original design, and it makes use of the weight of the descending platform to help operate our device. Instead of trying to manipulate a heavy bending arm, the user is able to exert very little effort to move the platform.

Using Hooke’s Law for the springs involved in our design, it is possible to mathematically determine the type of spring needed for our system. As the user applies more force to the system, the springs can further depress and lower the platform to the paint tube. The user can easily depress the platform several inches with only a couple of lbs of additional force. Most importantly, the system requires very little grip strength and can be operated with one hand.

2.1.2 Design 2

2.1.2.1 Objective
Monitor Lift

The second alternative design for the monitor lift relies again on the nature and function of springs. However, how the spring is used is completely changed offering a more stable and mechanically achievable function. The first alternative design relied too much on the constant weight of the monitor and relied too heavily on the precise measurements and weight calculations of the pivoting arm bar. The second alternative combines safe, sturdy nature of the hydraulic design structure and the easy mechanical, less technical, operational functioning of the spring design. We were warned of the messiness and unreliable nature of hydraulics thus stuck with the spring as the focal point of the lifts functionality. The V arm of the second design and
the complicated pivot joint that would have to be manufactured was replaced with a more stable and geometrically sound (box) frame. Figure 2a seen below shows the second alternative design for the monitor lift. The platforms and safety devices (clamps, straps, raised edges on the platform) from the first alternative design have remained the same but the moving parts and guide bars are new.

Figure 2a - the complete monitor lift in the maximum and minimum height position. Attachment to fixture (table) in the laboratory is diagramed in this drawing and laboratory table is not to be included in the project.

Oil Paint Cap Remover
For the second alternate design for the paint cap remover, we have further modified our device which should directly affect the reliability and longevity of the system. Our new design is shown in its entirety in Figure 2b, below. A big concern was that the descending platform would be able to swing around freely. The springs were originally not restricted in any motion. To fix this we have implemented sliding PVC guide-tubes and relocated the depression handle from the side to the top of the descending platform.

Figure 2b- Front View of Entire Paint Cap Removal Device
2.1.2.2 Subunits

Monitor Lift
2.1.2a The Monitor Platform

The top platform will be constructed the same as in the first alternative design except that it will be made of aluminum instead of steel. The high-strength aluminum will still provide enough strength to support the monitor but it will be lighter than if made of steel. In addition to the safety devices previously mentioned in the first alternative design, circular holes will be placed on the platform in all four corners allowing for safety guide bars to be implemented throughout the whole functioning of the lift. The safety bars ability to pass through the plate allow for the movement of the monitor as well as providing shear horizontal plane stability. Figure 2c shows the platform.

![Figure 2c](image)

Figure 2c- An aerial and side view of the complete schematic of the top platform that will house the monitor throughout its operation.

2.1.2b Attachment of Top Unit to Functional Middle Unit

The attachment of the monitor lift platform to the functional middle lift unit is important in that it must hold the two pieces together and accommodate the forces and weight that the monitor will impart on it. The hinge in the first alternative design has been changed since its ability to hold the monitor in the correct position is questionable. Instead, a piece of high strength aluminum will be welded to the underside of the top platform. This piece will be of the same geometric shape as the point of attachment of the middle lift top piece (circle). The welded intermediate piece will be of slightly larger size than that of the top of the middle lift piece so as to assure that it can be welded to the lift part or in the case of an adhesive being used allow for greater surface area and thus a stronger connection between the two subunits. Figure 2d shows the attachment piece as well as highlighted parts of attachment. The shaded in areas represent the points of contact where the two pieces will join.
2.1.2c Middle Functional Unit of Lift

Design of this lift focuses on the use of a single heavy duty spring that is encased within three hollow cylinders that adapt within each other. The middle unit consists of three hollow cylinders in which the bottom cylinder remains attached to the lower unit and will house the collapsed other two cylinders when in the lowered phase. The circumference of the cylinders gradually goes down as one looks at the ascending units. These cylinders allow for easy movement in the vertical direction while supplying constant horizontal support from any shearing stresses that may be applied. Another key feature of this design is that the spring will be housed within the hollow cylinders, as a result will have limited, if any, flexural movement. The motion of the spring will be limited to the vertical direction and any flexural tendencies of the spring will be negated by the inner structure of the cylinders. A requirement of the top two cylinders is that their combined height is no less than 12 inches, due to the fact that all the motion of the lift depends on the maximum limits of the motion of the two top pieces. Another thing to consider is that the units, especially the lower unit, are able to accommodate each other so as to allow for complete movement of the machine. The nature of the movement resembles the physics of an adjustable computer chair with some major modifications. Figure 2e shows the middle functioning piece in its maximum and minimum positions.

Figure 2d- View of attachment. Aerial and side views are shown to get an idea of how attachment will occur.
2.1.2d Internal Workings of Middle Subunit
The internal workings of the middle subunit are simple in design and rely on the functionality of a single spring. The spring is anchored to the very base of the bottom subunit within the structure. The spring is then guided by the design of the middle unit up to the top of the peak cylinder. The two points of attachment within the middle subunit are the points of force on the mechanism and are the main reason for the lifting force of the machine. This chamber created by the three interlocking cylinders is air tight with the ability to release and take in air as desired through an air valve.

The upward force of the spring within the mechanism will counter the weight of the upper unit. The force of the spring will be just below the equilibrium force to hold the monitor. With the air valve open the monitor will force the spring down slowly due to the constraints the spring is designed to be within. If the spring is just under the equilibrium force of the monitor as the air valve is open the pressure is released and the sole thing keeping up the upper unit is the spring which supplies a force just under that to hold the monitor (slow decent). To then raise the monitor the air valve is opened and the lift is physically raised up creating a larger volume in the middle unit resulting in the influx of air. Because the spring is almost in equilibrium with the monitors down force, the effort to raise the lift is minimal. Once the desired height of the monitor is achieved the air valve is then closed so as to create an air tight chamber within the middle unit. Since the air cannot escape the middle unit the lift is suspended and held at the desired height. The air pressure within the unit is capable of compensating for the slight downward force the spring cannot handle.

2.1.2d Base Subunit
The base subunit is similar to that of the hydraulic lift we designed earlier. The shape mimics that of the top subunit and is of the same dimensions to provide the smallest footprint possible. The base of the middle lift mechanism will be welded to the solid bottom of the stand. The base will have the ability to clamp down to the table that it sits on to provide a safer operation of the monitor. The guide bars are mounted at their designated spots on the base unit. The simple nature of the base allows for easy placement on the desired table and provides a solid foundation for operation of the machine. Figure 2f shows a side and aerial view of the base subunit.
2.1.2e The Descending Platform
The descending platform is similar to its form in the first alternative design except that guide bars have been attached at each corner and the depression handle is located on the top of the platform rather than the side. To reduce cost and overall bulkiness we have also reduced the size of the entire device. The platform itself, which can be made out of aluminum, is 6” by 6” can be either ¼ or ½ an inch thick.

2.1.2f Sliding PVC Guide-Tube System
A new innovation we have added to the system is a sliding PVC guide-tube system. A problem with our alternate design 1 was that the springs allowed for full free motion. It would be too easy for the user to miss the tube entirely. To prevent this free range of motion we have implemented a guide system for the descending platform. Attached at the four corners of the platform are brackets. These brackets clamp onto a
set of four small PVC pipe sections. The PVC pipes are large enough to fit over the vertical support bars, but are only a short section of pipe, approximately 2 inches long. Essentially this forms a cylinder inside of a hollow cylinder. They will be able to slide up and down on the bars with minimal friction. The main function of these guide-tubes is that they will eliminate all movement in the XY plane. This means that the only movement of the descending platform will be up and down in the Z axis. This easy innovation fixes the problem of the paint cap remover trying to align with the cap of the paint tube. Now it will come down directly on top of the cap, removing it easily and with precision.

Figure 2h- The Sliding PVC Guide-Tube System

Figure 2h shows how the guide tube system will work. The PVC pipe (shown in grey) can slide over the guide bar both up and down with little friction.

2.1.2g The Clamp
The clamp is the same design as in the first alternative design.

2.1.2h The DC Motor
To open the cap of the paint tube, the motor must have a low amount of rotations per minute. Most small DC motors spin at a high rate. Since we’re lowering a spinning head onto a stationary tube, we don’t want it to be spinning too fast. King Right Motor Co. Ltd provides a small 12 volt motor with a relatively low RPM (ONLY 54 rpm).

2.1.2i The Springs
The spring system is the same as in the first alternative design except that the springs’ degrees of freedom in motion have been limited by the new guide bars.
2.1.3 Design 3

2.1.3.1 Objective
Monitor Lift
In the third alternative design of the monitor lift, we will use a linear pneumatic slide and the four guide bars with spring support into the device. This design is completely different from the past designs. Through comments from our professors, advisor, and peers, our initial design was not the best idea due to the complexity and messiness of the hydraulic system. The first alternative design relied too much on the constant weight of the monitor and relied too heavily on the precise measurements and weight calculations of the pivoting arm bar. The second design focuses on the use of spring and compact air cylinders. These previous designs rely heavily on the use of spring to lift the heavy 80 pounds monitor upward. The disadvantage of these designs is the life span of the spring. The nature task of this monitor lift device is frequently used and repetitive, therefore, in the third alternative design, we use the sliding system of the pneumatic actuator which is idealistic for our lifting application. We will replace the telescope cylinders with the linear pneumatic slide which is non-rotating and vertically travel up to 12 inches. The system has ports, cushion controls, and port controls that can be specified in any combination and in several locations on the cylinder head and cap for easy accessibility. The pneumatic slide that does the lifting has an extra long life with a wide range of control and switch accessories. The anodized aluminum alloy shafts that sliding up and down smoothly and precisely with the ability of reducing the corrosion and wear out by the use of extra long self-lubricating bronze bushings. Also, the anodized aluminum alloy toll plate with combinational tapped and counter bored holes and a precisely machined mounting surface make the tooling attachment simple. Figure 3a below represents an overview of the monitor lift with all of its main components. The same safety devices that were used in the previous alternative designs are used in this one as well.
Oil Paint Cap Remover

For our third alternate design for the paint cap remover, we have further modified our device which should directly affect the reliability and longevity of the system. Our new design is shown in its entirety in Figure 3b, below. Alterations were made to reduce the size of the device and to make it simpler. It was suggested that a device be created where the user puts the cap in a device and holds it while it is removed. This does not work since our client does not possess the grip or strength in his hand to do so. This design was created keeping in mind that the client basically has only very limited use of only one hand. A big concern with the previous designs was having the cap head on a descending platform. The concern was that the cap head might miss the cap and the device would be unreliable. The size and complexity of the device was also questioned. To fix these problems the descending platform has been eliminated from the design. Instead of the paint tube being placed in the clamp and the cap head being brought to the tube the tube’s cap is placed in the cap head and the clamp is then placed over the tube. This ensures that the cap head will not ever miss the cap and it also greatly reduces the size of the device. The clamp will be the same design except it will be a clear plastic instead of metal allowing the user to view the tube while the device is in use.

2.1.3.2 Subunits

Monitor Lift

2.1.3a The Monitor Platform

The monitor platform for the third alternative design is the same as in the second alternative design except there are no holes for guide bars. Instead of guide bars, 4 springy legs are attached to the bottom of the platform with steel plates, one in each corner.
2.1.3b The Springy Supporting Legs

The nature of the design relies on some simple forces involved in the raising and lowering of the lift. There are no angular forces that are of significance thus the forces that have to be in balance are in the vertical longitudinal direction. Some simple weights have to be taken into consideration when calculating the downward force in Newton’s (weight of the monitor and the platform). Total downward force = 376.78 N.

Since this force is large and requires a very secure supporting system, we implement the use of springs inside the four supporting steel legs. The top part of the spring will be welded to the steel plate which is screwed to the monitor platform. The bottom part of the spring will be welded to the bottom of the bottom surface of the body. The shape of the springs being used is open-coil helical. The middle member of the sliding frame will be placed inside coil springs. The purpose of this is that the spring will resist the applied compression or downward forces, and it will store the energy in a push mode, so that when the monitor is being raised, it will provide raise smoothly. Figure 3c shows the position when the spring is fully extend, this position is the monitor is fully raised by the pneumatic lift. At this position, no force is being applied to the spring since it is fully extended. Figure 3c also shows the full retraction of the spring when the monitor is lowered at maximum level. The two pins (D) and the slots (C) between the middle of the two side members (B1 and B3) will restrain the spring from extending further. Another safety consideration for this configuration is that the total lengths of the supporting legs in both fully extension and retraction have to be the same with the lengths of the pneumatic slide in both fully extend and retract forms. If they are not exactly the same, it will cause the unbalance of the monitor and disaster will occur.

![Diagram of the supporting legs and spring system](image)

Figure 3c – Left: Maximum extension; Right: Maximum retraction
2.1.3c The Linear Pneumatic Slide

A pneumatic actuator converts energy (in the form of compressed air, typically) into motion. We have found a specific pneumatic slide from the supplier named Parker Inc. which provides us the specifications desired. The HBT15 is fitted for our application because it is a thrust slide and performs a medium duty linear motion of which it is lifting vertically 80-lb object. Figure 3d shows the picture of the HBT15.

There will be a switch which drives the cylinder in both directions, upward and downward. The control switch is easy to use and is portable.

The specifications of the HBT15 pneumatic slide meet our design’s specifications. The descending load is \(80\text{lbs} + 4.76\text{lbs} = 84.76\text{lbs}\), which is less than the force outputs on both extend and retract at 80psi. The maximum suggested stroke is 24in in which is exceeded the required extended stroke which is 12in. Since the slide itself is 8.57in, the maximum required stroke length for this device is 3.43 inches. This is an advantage of the design because the device does not need to move upward in a great length, it also enhances safety issue. The disadvantage of this device is that since the pneumatic slide is 8.57 in tall, the monitor cannot be lowered close to the laboratory table. Future implementation will be applying another pneumatic system that is compact in size and includes all the required specifications.

2.1.3d Mounting of the pneumatic slide

For safety purpose, there are twelve dowel pin holes to be mounted to the bottom platform of the lift. The tool plate is made of anodized aluminum to prevent corrosion and is great in durability. Mounting can be done by applying screws with variation of sizes that fit the pin holes. In addition to the pin hole, we can place the clamp around the tool plate to stabilize the pneumatic slide.
2.1.3e The Base Platform
The base platform is the same as the previous design and uses the same safety clamps as in the previous designs to anchor it to the laboratory table.

Oil Paint Cap Remover

2.1.3f The Base Unit
The base houses everything essential to the actual removal of the paint cap, including: the DC motor, the motor circuit with batteries and switch, the motor gear, the cap-head gear, and the cap-remover head. The basic idea of the base is as follows. The user places the cap of the paint tube in the cap head on the base. There is a rectangular groove around the cap head. The clamp is placed over the tube and fits snugly into the groove. The rectangular groove is the same dimensions as the end of the clamp and is 0.5 inches deep, which is deep enough that the clamp will stay in place as the paint tube rotates inside of it. Once the clamp is in place, the user can turn the device on.

This device has been designed to be portable. It is smaller than all of the previous designs, being only 5”x5” and about 3” tall. It is not very heavy and does not have any cords. This raises concerns that it may move around or not be stable during operation. To eliminate this concern rubber feet have been implemented on the bottom of the device. The rubber feet will provide traction to the base unit which translates into it being more stable.

Figure 3f: Base Unit- Top, Inside and Bottom Views
2.1.3g Rubber Feet for Stabilization
The paint cap remover has been designed to be unobtrusive and light. To keep it from moving around while in operation, each corner of the base unit sits upon a rubber foot. Each foot is cylindrical with slightly rounded edges. This provides the paint cap remover with some added traction.

2.1.3h The Cap-Head
The cap head was originally on a descending platform and was put on the tube’s cap by the device. To make sure that the cap head does not miss the cap, the cap head is now located in the base unit and the paint tube’s cap is placed into the cap head by the user. The shape of our cap-head design has not changed from the first design.

2.1.3i The Clamp
The clamp is the same rectangular, loose-fitting design that has been used since the first alternative design. In the previous designs the clamp was to be made of metal. Since the clamp is being placed over the tube and covering it entirely in this design it will instead be made of a strong, clear plastic. Polystyrene would be suitable since it has high clarity and is very durable. This will allow the user to be sure the tube is positioned correctly at all times, and see when the cap has been loosened and know that they should stop the motor.

2.1.3k The DC Motor
The DC motor and all other electrical components are the same as in the previous design.
2.2 Optimal Design

Monitor Lift

2.2.1 Objective

Our optimal design for the monitor lift takes into consideration all of the different ideas we have developed in our previous designs and highlights the strong parts while eliminating the weaker ones. Ultimately, this design simplifies the complexities of the other designs while increasing the reliability and safety of those designs. The use of hydraulics was eliminated because of their loud sound and messiness. While pneumatics lifts are much cleaner than hydraulics, they still brought a level of complexity and unreliability, and are in general still too noisy for our project. Probably the best of our alternative designs was the bending arm with which relied on springs. This design was very quiet and powered solely by the stored energy in the springs. Unfortunately there were two major downfalls to the springed-arm system. The first main problem was that we had no definite way to keep the monitor level. When the arm bent downward the monitor would lean forward and run the risk of falling completely off of the supporting platform. This risk was unacceptable. The second problem was that there was no failsafe system to protect the users and patient if the spring should fail. Because the lift has to go up and down repeatedly, the springs perform a significant amount of repetitive work. We need a system that allows for a safe way to manage the unlikely event of a spring failure.

Our optimal design uses a combination of three main principles to make our device reliable, safe and fit the parameters of the lab which it will be used. It uses sliding PVC guide tubes to keep the platform stable. It also uses an arrangement of springs and dash-pots to enable the user to have full manual control over the lift. This new system will be very quiet and reliable. It will also have multiple fail-safes, preventing any catastrophic failure of the entire system. The design will be portable, and not confined to one specific desk or laboratory room. The full device is shown below and each component will be described in much further detail.
Chart 1. Monitor Lift
2.2.2 Subunit

Figure 1.1 - An overview of the monitor lift.
1.2.2 The Monitor Platform

During the design of the monitor, the center of gravity was taken into consideration and the environment of the monitor was studied. The engineers who designed the monitor did so in a way that it could be free standing and balanced when placed on a flat surface. Knowing that the monitor can free stand on a flat table the idea was to mimic this table like surface in the machining and designing of the top platform. The top platform will be constructed of high strength aluminum in which elevated borders (B1b) will surround the solid floor panel of the base, also made of aluminum. Aluminum is lightweight metal with a dull silvery appearance [1]. These features are very appropriate for our application since the platform will be placed on the top of the laboratory table. The color of aluminum will not distract the patient due to its dullness of shade. Other equitable properties of aluminum are its non-toxic, non-magnetic, and non-sparking features. Magnetism might affect the electric interference in the laboratory, so it is important to avoid it. The most important characteristic of aluminum is its tensile strength of about 49 megapascals in a pure state and 400 MPa as an alloy [1]. This characteristic will prevent it from mechanical failure or failure during operation. Aluminum is about one-third as dense as steel or copper, make it easy for machined and cast [1]. It has excellent corrosion resistance and durability because of the protective oxide layer [1]. Because of these excellent and adequate properties, we decide to choose aluminum as our main product.

The safety of the patient is of great concern to us in the designing of the lift and thus certain measures were taken to ensure their safety at the advice of others. The raised side bars (B) are a safety measure to help keep the monitor from sliding and moving during operation. The monitor platform (A) will be tailored to the dimensions specified in the project thus further increasing the safety of the device. Tie down accessories will be placed on either side of the platform allowing for a multitude of straps to be implemented in tying down the monitor, again further anchoring the monitor to the solid frame design. Previous designs of such a lift had a problem with unsightly wires. This was taken into consideration in that a hole (C) will be machined in the back of the top platform so as to allow the discrete exiting of the wired down the backside of the lift in a bundled fashion. Figure 1.2a and 1.2b illustrate the locations of the side bars and the hole as well as their dimensions.
1.2.3 Sliding PVC Guide-Tube System

A new innovation we have added to the system is a sliding PVC guide-tube system. A significant problem with previous designs is keeping the monitor level. The sliding
PVC pipes will fix this problem and provide stability for the entire system. The PVC pipes will be fitted into the corners of the descending platform. The platform will have 4 circles bored in the edges for the PVC tubes. The PVC pipes are large enough to fit over the vertical support bars, but are only a short section of pipe, approximately 2 inches long. Essentially this forms a cylinder inside of a hollow cylinder. They will be able to slide up and down on the bars with minimal friction. The main function of these guide-tubes is that they will eliminate all movement in the XY plane. This means that the only movement of the descending platform will be up and down in the Z axis.

**Figure 1.3 – The Sliding PVC Guide-Tube System**

Figure 1.3 shows how the guide tube system will work. The PVC pipe (shown in grey) can slide over the guide bar both up and down with little friction.
1.2.4 The Entire Lowering System

A crucial part of building the device which can be raised and lowered 12 inches is the U-shape of the lowering platform. This is due to the nature of how dashpots and springs perform. When a 12 inch stroke of a dashpot is extended, the entire dashpot will be just over 24 inches. But when the stroke is at its lowest position, the dashpot will still be over 12 inches long to house the entire stroke. Therefore the dashpots cannot be placed underneath the bottom plate because the system would be at 12 inches in its lowest configuration.

We ran into a similar problem for the springs. When we first designed the sliding PVC spring system, we didn’t think about one of the biggest considerations of springs: Solid Length. When a spring is fully compressed, it doesn’t compress to a 0 height (or even close). Compressive springs have a condensed length or “Solid Length” which is sometimes half of the total length of the spring. Therefore if we used a 2 foot spring, the compression would leave a foot of unusable length.

How do we deal with this problem if our goal is to lower the platform to the level of the desk? We came up with the unique idea to make the platform U shaped. Figure 1.4a below shows how the U-shape will compensate for the 12 inches of dead length:

![Figure 1.4a: The Side View of the U-Shaped Platform](image)
As you can see from figure 1.4a, the bottom plate hangs much lower (12 inches lower) than the top plates. Because of the U-shape of the aluminum platform, when the dashpots and springs become condensed, the monitor will be 12 inches below that level, which will allow it to be flush with the table.

Figure 1.4b shows the same U-Shaped system from a top view. Both the PVC guide-tubes and the Dashpots are found on the two top plates. The guide rod will extend up and through the PVC guide-tubes, which are attached to the top platform and will slide up and down over the rods as the platform is raised and lowered.
All plates will be formed from the 7075T6 CALIFORNIA .25 X 59 X 96 22707 aluminum sheets that we are purchasing from Aaluminum.com. They will be welded together and reinforced with L-shaped corner brackets. They will each be formed from one very large sheet of aluminum that is strong and durable.

1.2.5 The Details of the L-Bar System

Aluminum L Bar

L-Angle Aluminum Base Bars

Enlarged Side Cross Section

Figure 1.1- Side View of Aluminum angle bar that will surround top platform perimeter.

The structural support of our monitor lift is as crucial to the functioning of the device. In order for the mechanisms that were put into place to work one must work off a solid aligned frame that will withstand the stresses and constant cycling of use throughout the life of the product. The safety of our machine was one of the most important factors that went into the design. The prominence of safety can be seen in such features as the L shaped Aluminum that will surround the perimeter of the top platform. It could have been a lot cheaper, more easily fabricated and lighter had we
not decided to add the upright aluminum siding, but the chance of the monitor falling off of the platform would increase dramatically.

This design consists of four L shaped aluminum pieces that could be machined by one of the individuals in our group or could be purchased preformed. The decision as to how the part will be obtained will be decided as fabrication begins and will depend on the advice of those around us as well as the time constraints we are limited too. It might come about that machining this part ourselves could result in a weaker subunit and therefore provide an unsafe tabletop for our monitor. If that is the case we will outsource this fabrication to a company and obtain the part from them.

**L-Angle Aluminum Base Bars**

![Side View of L-Angle Aluminum Base Bars](image)

*Figure 1.2- Side view of the angle bar from the outside.*

Another angle of this angle bar provides a better understanding of what is happening with regards to the fabrication of this subunit. This is just one of four corner pieces that would be adjoined to the others creating a square encasement for the computer monitor lift. The angle depicted is at 90 degrees and the planks that the monitor would sit on are not visible from this angle, as they are shielded by the outer wall of the Aluminum. This raised wall design allows for the secure placement of the monitor. On two of the four sides of this raised outer wall will be placed another aluminum plate that will make that side look Z shaped which allows for the U shaped nature of our optimal design. This lower encasement is just part of the total upper unit and is more for safety than for the functioning of the lift.
The top figure shows the cross section of the piece of L bar that will be used. The way in which this will be constructed was talked about above and depends on a couple factors. If we are to construct it we will most likely construct the upright and the horizontal piece out of quarter inch aluminum and through some sort of adhesion or spot welding we will attach the pieces. The attachment should not be a problem due to the fact that there is a high surface area of contact between the two pieces. The way this is designed requires that the bottoms piece of this L be wider so as to allow for the upright placement of the other piece. By not connecting them at the joint we are making the connection stronger and the machine safer.

With regards to the figure above one can see that on the left is just the subunit alone without the monitor in place, and the one on the right shows the lower partial portion of the monitor and how it will be accommodated within the surrounding metal structure. The figure below shows a wider view of the cross section and shows the entirety of the lower half and how it will be situated within the subunit.
Figure 1.3- Depicts the entire subunit of the bars and how they will accommodate the monitor.

This figure depicts the nature of the side bars and how they will accommodate the large monitor. The top half of the monitor is neglected because the top half serves no purpose in demonstrating the nature of the L subunit containment bars. This is a cross section which means that this L shaped secure of the monitor will encompass the front and the back of the monitor. One should also note the snug fit of the monitor in this unit and how the dimensions of the base L bars will be tailored to the monitor device they will contain. This secure fit of the monitor stops the monitor’s motion along the Z and X direction of a 3-D Cartesian plane.

Safety is of the utmost importance and is taken into consideration with the anchoring and stability provided by these L bars. Since the L bars are made of a high strength metal they will be able to withstand the natural forces inflicted upon them throughout various cycles of use. The height of the L uprights will be determined later as cost and analysis progress, though the height of the monitor and the center of gravity will be taken into consideration so as to prevent any tipping of the monitor during a range of forces applied to the machine.

Another important factor with these uprights is that they will be able to accommodate an attachment for the taller upright U bars that will directly impact where
the dashpots and springs attach. Other figures will describe their attachment to this unit above. Another feature of this type of housing for the base of the monitor is that it allows for the attachment of a multitude of tie down brackets in which heavy duty straps can be lashed on to permanent safety brackets welded onto the vertical side of the L bar.

**L Bar and Upright U Bar Integrated**

Point of Attachment of U Bar to The L Bar Base Unit

**Figure 1.4 - Shows side and cross sectional view of how uprights are attached to previously described L Bar base unit.**

The figure above shows the attachment of the subunits of the bottom of the frame to the functional unit of the uprights that make up the u shaped bar seen in the complete schematic. The side view shows the flat face of the Aluminum L Bar that runs along the perimeter and is vertical in position. The lower monitor supporting piece can be seen as the smaller bar on the picture in the left and the horizontal bar on the bottom in the picture to the right. The grey uprights will be made of the same aluminum material that the stand and rest of the device is made out of. This will reduce the risk of bimetallic corrosion and will allow us to conserve metals keeping the budget of the device down as well as prevent the loss of scrap/potentially wasted metal material.

It is important to see that the uprights are also flat metal material that will be flush with the upright of the base unit (which houses the monitor). An adhesive substance could be applied to both surfaces and allowed to set for a period of time. The flat nature of both surfaces also lend themselves to be treated before bonding creating a more secure, safe and structurally sound connection between the two subunits. Another alternative to using an adhesive substance would be to weld the two pieces together. The tall grey
subunit U pieces will be run the length of the entire uprights of the lower base unit. The reason for this is because each corner will accommodate a spring/dashpot combination that will have to apply upright force to the unit. If the aluminum plate that is on the side is too much to deal with and is overly pricey an alternative to this can be seen below. This alternative is not a revision of the mechanism of how this subunit works or is integrated but is simply the result of cutting out excess between material that does not provide any additional function, as well as creating more weight for the device to compensate for.

**Alternative to Above Subunit**

![Diagram](image)

**Figure 1.5- Alternative design to the one above. Is not a total revision of design is just a reduction in mass.**

The figure above again shows the attachment of the upper functional uprights to the base container for the monitor itself. This is in no way a new mechanism being employed and should not be thought of as a completely different design from the subunit above. Instead this is the result of cutting out the middle section of that piece depending on where the spring/dashpot subunits will be located as well as cost and weight constraints. Regardless of this option to change the means of connection will still be the same and will function in the same way.

**Total Subunit With Monitor in Place**
Figure 1.6- A depiction of the side view and the side cross section with monitor in place.

The above figure depicts the placement of the monitor and where the described subunits fall into place in relation to where the monitor will sit. The height of the grey uprights, that are the functional part of the device, is slightly lower than the monitor by a fraction of an inch. This means that the limiting factor of the height of the total unit is not the device itself but is the monitor. Since the monitor dimensions cannot be changed we are able to mask the height of our device under the higher monitor itself.

The above figure shows how the monitor will sit within the platform and how the uprights will not come in contact with the monitor at all. The grey uprights will not hinder the motion of the monitor and will not physically come in contact with the monitor. The lower L bar will in fact come into intimate contact with the monitor so as to prevent sliding and other motion during operation. The lower frame will most likely be covered with an adhesive tape or a latex rubber so as to not damage the monitor. If the monitor were to constantly be in contact with the aluminum metal it could scratch the device resulting in damage to the monitor and a potentially unsafe environment could develop.

The above figures describe the upper structural section of the device piece by piece. Describing the device in such a way will give us a good guide to constructing the device next semester. The thorough nature of the description also allows for an outsider to gain a good understanding of the device and as a result an intimate knowledge of how the device will work and should work.
1.2.6 Spring Raising System

The main component of our device responsible for lifting the heavy monitor is the use of four springs. These springs are in the four corners of the device, and wound around the metal guide bars. Because of their location around the guide bars, their motion will be entirely restricted to the z axis, only allowing for up and down motion. The critical idea of our device is spring equilibrium. In combination with the platform, the monitor will weigh approximately 84 lbs. Our goal is to distribute that weight evenly to all four springs so there is a near equilibrium reached in the compression. Ideally the springs will be in equilibrium when the monitor is almost all of the way down. At this lowest position the springs will have stored all of the force from the weight of the monitor and platform. When the user wishes to lift the monitor to its highest position they need only to apply a minimal amount of force upward and the stored energy in the springs will take care of the rest.

For this design to work, it is imperative to choose the correct springs. If the springs are too rigid or too compressive, the user will not be able to slide the monitor up or down. Equilibrium is the key. Hooke’s law can be used to find the constant, k.

\[
F = -kx
\]

Using Hooke’s Law for the springs involved in our design, it is possible to mathematically determine the type of spring needed for our system. Below, Figure 16 shows springs at different lengths during compressive stretching.

A. 1"  B. 2"  C. 4"

Spring Length VS. Tension
Figure 1.4: Using Hooke’s Law

Obeying Hooke’s Law, the springs will deform linearly. Part A shows a spring sustaining 1” deformation. If we assign an arbitrary value of $k = 2.5 \text{ lbs/inch}$, we could calculate the force on the spring being 2.5 lbs. Next, we examine the spring in part B. The spring has deformed 2”. Using the same value of $k = 2.5 \text{ lbs/inch}$, we can determine that a force of 5 lbs is being carried. Finally, in part C, the spring has stretched 4 inches. This would require 10 lbs of force.

Determining the amount of weight required to deform a spring a specific distance is useful in instances where the spring has already been purchased or placed into a device. Graph 1 shows the relative weights and distances a spring with a constant of $k = 3 \text{ lbs/inch}$ would deform. The force vs. deformation forms a linear line for a linear spring.

![Graph 1: Deformation of a spring with $k = 3 \text{ lbs/inch}$](image)

A scenario that is more pertinent to our design rather than determining how much weight deforms a specific spring, would be to determine which type of spring we need to buy. We know that our monitor and platform will weigh around 84 lbs. Optimally, our design would allow the sheer weight of the platform to stretch the springs a certain distance. This is the equilibrium position, and we want it to be at the monitor’s lowest height. We can manipulate Hooke’s law to solve for $k$. 
Equation 2: Solving for k \[ k = \frac{-F}{x} \]

Since we know both \(x\) and \(F\), we can solve for \(k\). The deformation, \(x\), is 12 inches. \(F\), the force deforming the spring is 84 lbs. So if we use equation 2, we can solve for \(k\), which is \(84 \text{ lbs}/12 \text{ inches} = 7 \text{ lbs/in}\). Now if we distribute that to all 4 springs the \(k\) for each spring would be 1.75 lbs/inch.

1.2.7 Spring System Continued

Our design currently revolves around the nature of springs and their restorative nature. The springs will allow for an assisted manual lift of the monitor and will also provide a safety mechanism in the event of a failure. The type of springs that we must choose is crucial to the ability of the lift to function. If the springs do not provide enough restorative force then the lift will be too heavy to operate and will not be practical. If the springs provide too much force vertically then the monitor will remain elevated in its equilibrium position, opposed to at a zero desk level position. The springs must be finely chosen to allow for the monitor to be on the cusp of raising itself without the help of an assistant. The person thus must provide very minimal force to the machine to allow for the effective raising of the monitor. Since the springs are on the cusp of equilibrium and do not exceed the downward force of the monitor, it is essential to have a mechanism that will hold the monitor once in the elevated position. The use of dash-pots allows for the temporary suspension of the monitor so that locks can be put into place mechanically to stop the downward motion of the device. Dash-pots will be talked about later in this paper. The springs upon release of the locking mechanism will allow for the supported dash-pot lowering of the monitor in a safe and effective manner.

The springs that we are going to use are easily obtainable through various catalogs and manufacturers. The abundance of springs and their varying characteristics allows for us to customize our machine to whatever it must lift. Our design using springs allows for the monitor lift to be adapted to other monitors that might be used in the future. The simplicity of the springs and their mechanical workings means that they are cheap and easily replaceable if needed. The laboratory thus can have multiple springs so as to never have downtime with the lifting device. The springs are also easily manufacturable and allow for great versatility with our device.

Figure 1.5 below shows the calculations that went into finding what spring will be tailored to the safe and effective operation of our device. As previously described Hooke’s law is used in calculating the desired spring constant of our springs.
We currently know two of the three variables in Hooke’s law. The total downward force of all the upper components was calculated. Each of the individual subunit’s contribution to the total downward force are documented and described below. The total downward force that must be countered by the springs was found to be 445.79 Newton's. The monitor lift only has to have two settings, zero and twelve inches, even though our lift can accommodate a range of motions and stopping positions. Knowing that the desired height of the lift is twelve inches we were able to calculate the desired spring constant. It was also taken into consideration that the springs will only have to counter a quarter of the total downward force since there are four springs implemented. For an individual spring the spring constant would have to be 37.15 but since we are using four springs the spring constant that we require is only 9.29 which is easily within the realm of manufactured springs on the market today. Seen below is a schematic of what went into calculating the spring constant.

**Springs**

**Spring in Equilibrium**

Hooke’s Law

\[ F = Kx \]

**Spring Compressed**

\[ F = \text{Force} \]

\[ K = \text{Spring Constant} \]

\[ X = \text{Distance Traveled} \]

Total Downward Force in Newtons = 445.79
Four Springs Total = 111.45 Newtons per spring

Using Hooke’s Law

(Knowing springs must travel 12 in.)

\[ 111.45N = K (12\text{in.}) \]
\[ K = \frac{111.45N}{12\text{in.}} \]
\[ K = 9.29 \]

Desired spring constant of 9.29 per spring

For safety parameters could design so that one spring could withstand the whole downward Force by itself. Work Seen below

\[ F = Kx \]

\[ 445.79 \text{N} = K (12\text{in.}) \]
\[ K = \frac{445.79\text{N}}{12\text{in.}} \]
\[ K = 37.15 \]

**Figure 1.5** - Displays the nature of springs and the resultant desired spring constants for our particular lift design.

A free body diagram has been included for the spring system. Free body diagrams are a crucial first step in considering how a system might react to inherent and applied forces. Figure 1.6 shows two free body diagrams of our system. The left diagram
shows the springs resting in their equilibrium state. The only force on the system is the inherent weight of the platform and its components.

When the user wishes to raise the monitor, a minimal amount of force can be applied to the platform. The force applied will break the equilibrium state of the springs and the stored energy in the springs will be released upwards. So the user will only have to apply a small amount of effort to raise the monitor because most of the force will come from the springs.

But once the monitor is raised, what will keep it in its maximum height? Common sense would say the monitor weight will again compress the springs and it will be lowered downward. This is where the dash-pot comes into use, which will be described in more detail in its own subunit section.

One last important note to consider is the linearity of springs. A spring can only be stretched elastically to a certain length. After a certain length the linearity of springs no longer exists and a significant amount of extra force is required to deform the spring. While purchasing springs we must be careful to consider the manufacturer’s maximum deformation of the spring. Exceeding this value will not only require an excess amount of force but can also damage the springs.

1.2.8 Sub Unit Breakdown of FBD

The force body diagram below delves into the internal subunits of the upper platform. These subunits contribute to the total downward force of the device and are essentially what the lift has to overcome in order to function. The lift upper unit is composed of a flat surfaced Aluminum square panel with stated dimension, as well as a U shaped metal frame, also made of Aluminum, which the lift will function on directly creating the upward force. The U shaped nature of this upper platform allows for the monitor lift to descend to almost zero, or table surface, which was requested from the customer. In order to figure out the total downward force we first had to figure out how each individual piece contributed to that total. The top platform was constructed of Al which has a density of .0027kg/cubic cm. and in the dimensions of the monitor given. Volume of the platform was calculated with the dimensions of the monitor base being considered as well as a desirable thickness of the metal, resulting in a volume of 48.75 cubic inches which converts to 798.69 cubic centimeters. We must convert to centimeters since the density is in cm and allows us to convert to Newton’s. Multiplying the density of the material by the volume we are able to get the mass of the entire plate which came out to be 2.156 kg. Knowing that the calculation of Force comes from the mass * the acceleration of gravity (9.8m/sec squared) we were able to obtain the downward force contributed solely from that
sheet of Al metal, which came out to be 21.14 Newton’s. The calculation of the side U rails was done in the same exact way since they were made out of the same material. These subunits were found to contribute 53.12 Newton’s and 15.89 Newton’s between the four subunits. The only other material that is contributing to the total downward force of the machine depends on the weight of the monitor. Our monitor that we are designing our lift for weighs 80 lbs. We had to first convert this weight into kg’s which resulted in a weight of 36.29 kgs. Using the acceleration of gravity we were then able to calculate the force which it exerted downward, which came out to be 355.64 Newton’s. Through the addition of all these subunits a total downward force was calculated to be 445.79 Newton’s which the monitor lift would have to counter to perform the desired function. Figure 1.6 below shows this breakdown and the calculations that went into figuring out the total force.

**Force Body Diagram of Subunits**

**Figure 1.6-** Shows the breakdown of the individual components that contribute to the downward force on the springs and the dashpots.
1.2.9 Entire Monitor Lift Force Body Diagram

The force body diagram referenced earlier can be seen below. Figure 1.6 shows the entire unit in its maximum elevated position as well as in its lowered “zero” position. The monitor had to be lowered to as close to the table as possible, which is why we went with the U shaped design allowing for the whole unit to be with the height of the compressed springs, from the table. It is important to note that at no time are the springs in tension and are thus supplying no downward pulling force to the unit. The amount of force being applied varies linearly as the unit is raised and the spring elongate out, trying to reach an equilibrium state. The left picture shows the unit in its base position. At this point the entire units downward force is being supported by the four springs placed at the corresponding corners of the square base unit. The dash-pots are not in effect and the valves are open on them allowing for air flow in and out. Having the valves open in the dash-pots allows for variation and movement with the monitor lift without a vacuum or compression being made within the devices. Since the dash-pot valves are open no restorative force is applied in either direction resulting in a quarter of the entire load being carried by the springs. The total downward force of the monitor, frame bars, and base platform is 445.79 Newton’s. A quarter of this downward force is 111.44 Newton’s which each individual spring will uphold. This quarter of downward force results in spring constants, previously calculated, of 9.29 to hold the entire unit in equilibrium. With such springs in place the unit will be extremely close to self elevating thus allowing for very little upward force to start motion in that direction. The forces at this point cancel each other out with the right springs in place and thus essentially the monitor and the unit upper parts goes to zero, or weightless. Figure 1.6 below demonstrates schematically both positions and the resultant force body diagram. It is important to mention also that the dashpots take over with regards to the quarter fraction of total downward force once the springs are elevated and have expended most, if not all, of their upward resorting force. As the springs linearly decline with regards to the force they supply in the vertical direction, the dashpots take over and do what they were designed to do. The dashpots function will be touched upon later in a different section concerning the subunits.
Figure 1.7- Shows the FBD of the lift in upright position and in lowered position. The total downward force switches between the four springs and the four dashpots.

1.2.10 The Dash-Pots

Dashpots are very simple yet effective mechanisms that rely on air or a viscous fluid to slow the rate of motion down. The dashpots we use will be run on the expulsion and the influx of air into a chamber that can be sealed or opened manually. The dashpots simply work by reducing the ability for air to enter or leave the chamber the dashpot encloses. A piston is attached to the moveable piece that alters the volume of the inner functional compartment. The dashpots have an air vent path that is attached to a screw. By turning the screw one is able to alter the flux of air flowing into or out of the middle chamber resulting in more or less resistance. The way these mechanisms work is that the piston has a long bar that is attached to some sort of load. The pistons ability to move in response to the load is determined by the rate of motion of the piston which is governed by the air pressures forces on the inside chamber. The air pressure is determined by the valve that is near the screw head. The more air the vent allows to enter and exit, meaning the more open the vent is, the faster the piston will respond to the load that is applied. With the valve open and the air being able to enter and exit with minimal resistance at the vent, the load will alter the pistons motion with little or no resistance and at the speed of gravity. With the vent completely closed the chamber in the middle becomes a cushion of air.
Depending on the compressibility of that gas results in the spring like motion of the piston in response to a load stimulus. If the air cannot be released through that valve the dashpot will hold that load in definitely because of the pistons inability to compress the gas within anymore. The device will be in equilibrium with the dashpot inner chamber providing the necessary force upward to counter any downward force. Whether the dashpot will sustain this load relies on the nature of the air vent and the stability of the materials used, particularly at any joint pieces or gaskets (weak points).

With regards to the dashpots functioning within our monitor lift the idea is simple. The springs will provide the help to lift the monitor from the base level position. Because of the previously described functionality of the springs the force to lift the monitor will be minimal. The dashpots vent valve will be set to a desired opening size so as to allow an influx of air into the chamber and the piston to move upward, since the piston is connected to the upward moving U shaped top subunit. Once the unit is at the desired height, 12 in., the dashpot chambers are closed off so as to seal the chamber and not allow for any air to escape. The feedback force from the compression of the air results in a countering upward force that is equal to that of the total downward force. Since the springs are almost at equilibrium with themselves, their upward force is negligible and is a minute subtraction from the force exerted by the now supporting dashpot units. Relying on the dashpots to completely close off after being completely open to allow the inflow of air is somewhat hard to accomplish. Thus a desired influx of air will be set with minimal resistance to the upward motion of the lift will be determined. The resultant of the dashpots vent not being completely open will be that the upward motion will be hindered by a resistive force created by the friction of the piston and the slight vacuum trying to be created within the chamber. This problem can be solved when designing for the springs. The partially open vent will allow the user to operate the lift without adjusting the dashpots from an open and closed position every time they raise and lower the lift, but at the same time the lifting of the monitor will require a little more force and will take a little longer as the chamber tries to counter that vacuum trying to form. The payoff of the slow incremental raising of the lift is that when the lift is at its highest point all that force downward will be on the pistons resulting in a decrease in volume of the chamber and an increase in pressure as the air attempts to vacate through the vent. With this resistance to downward motion the operator of the lift can set the safety holding brackets into place which will mechanically hold the monitor in place for the endurance of the testing. The dashpots left to hold the entire monitor would eventually lower the lift to the original position as the air slipped past the partially closed vent and reduced the pressure in the chamber, thus reducing the upward force. The safety support levers will be attached to the frame and will not contribute to the downward force of the total upper unit. These support bars will be described in a later section of the subunits.
Once the test has been completed using the monitor lift the dashpots are ineffective because all the upward force they once supplied is gone due to the slow release of air over time. The dashpots air valve could then be closed allowing for no downward motion, for reasons explained previously. With no downward motion and the force of the monitor being carried by the dashpots, the support bars can be released allowing the full weight of the device to be on the dashpots and the springs. The dashpot air valves are slowly opened to release air, and thus pressure, from the chamber resulting in a restricted downward motion due to the imbalance of the forces. As the dashpots allow the monitor to be lowered the springs gradually take and bare some of the load as they are compressed. The dashpots load decreases and thus the release of air does as well, this results in a slow and safe means of lowering the monitor from its maximum height. As the last of the air is expelled from the dashpot the springs bare all the weight and are in equilibrium in the “zero” position that we started with. The resultant position is obtained by the natural workings and mechanisms of the dashpot and springs mechanical function, thus no external assistance is needed to get the monitor down, as well as the monitor being able to revert back to its original position. Figure 1.8 shows the dashpot in its entirety in both extended and compressed phase.

**Figure 1.8- Dashpots side view in a mechanically supporting position and a rest equilibrium position. All essential subunit pieces are labeled above.**
Above pictured in Figure 1.8 is a dashpot in two positions. All the subunits of the dashpot are labeled and their function within the mechanism are relatively self explanatory. The upper exposed piston will be attached to the load and will be the means of contact between the application and this device. The low friction housing is made in a cylindrical manner and contains the sealing push block which varies the volume of the inner air chamber.

The mechanisms workings are explained using the Ideal Gas Law, PV=nRT. It is important to understand this equation to understand how the dashpot works. We are concerned with the P, pressure, and the V, volume, variables in the equation since the n, number of molecules, R the gas constant and the T temperature will remain constant concerning the upper and lower actions of the device. Altering the equation gives us P=nRT/V, and since nRT part of the equation remains constant in regards to the functioning of our mechanism we can replace this value with a 1 for simplicity sake. Now we have P=1/V which is very significant in the functionality of the dashpot. We can now see that when the volume is decreased by pushing the piston down the pressure will increase due to the inverse relationship seen in the simplified equation. Now in regards to our lift one can see that when the load is applied to the piston arm by the weight of the lift the piston will depress the sealing push block and result in a smaller volume in the chamber. The pressure will then increase as a result of this decrease in volume yet no decrease in the amount of air in the chamber. In the case of the valve being open slightly the air will not be expelled at a rate fast enough to counter the decreasing volume and increasing pressure thus the lift will be lowered slowly and provides an unforeseen safety mechanism built in to the workings of the dashpot.
Figure 1.8b: The Airpot Dashpots

Figure 1.8b shows the actual dashpots that we will be purchasing from the Airpot Corporation. Airpot is a local company that can make custom dashpots and actuators to the specifications their customer needs. Because our system has to extend a considerable distance, we will have to order custom dashpots which will have at least a 12 inch stroke.

The specifications for the Airpot dashpots are shown in the following table. It shows what the dashpot is capable of and what the stroke lengths are. They also include specifications for their custom products.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>2K56</th>
<th>2K95</th>
<th>2K160</th>
<th>2K240</th>
<th>2K325</th>
<th>2K444</th>
</tr>
</thead>
<tbody>
<tr>
<td>BORE (inches)</td>
<td>0.22</td>
<td>0.36</td>
<td>0.627</td>
<td>0.945</td>
<td>1.281</td>
<td>1.75</td>
</tr>
<tr>
<td>STROKES AVAILABLE - STOCK UNITS (inches)</td>
<td>0.5,1,0,0</td>
<td>0.5,1,0,0</td>
<td>0.5,1,0,0</td>
<td>0.5,1,0,0</td>
<td>0.5,1,0,0</td>
<td>0.5,1,0,0</td>
</tr>
<tr>
<td>STROKE RANGE - CUSTOM</td>
<td>.125-.125-.125-.125-.125-.125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>UNITS</strong> (inches) (any x.xxx)</td>
<td>11.0</td>
<td>11.0</td>
<td>13.0</td>
<td>-12.0</td>
<td>-10.0</td>
<td>-8.0</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>-------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td><strong>FIXED STROKE FOR SNUBBER MODELS</strong> (inches)</td>
<td>N/A</td>
<td>N/A</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FORCE CAPACITY GUIDELINES</strong>**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PULL DAMPING DIRECTION</strong></td>
</tr>
<tr>
<td>lbs force (Starting from fully retracted position)</td>
</tr>
<tr>
<td><strong>PUSH DAMPING DIRECTION</strong></td>
</tr>
<tr>
<td>lbs force (Starting from fully extended position)</td>
</tr>
</tbody>
</table>

**Note: Best performance for each model will be achieved at or below input forces shown above. Maximum force capability is higher and is based on % of available volume displaced.**

<table>
<thead>
<tr>
<th><strong>APPROXIMATE ENERGY CAPACITY AT REFERENCE STROKES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STROKE</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td><strong>PULL DAMPING DIRECTION</strong> (inch-lbs)</td>
</tr>
<tr>
<td><strong>PUSH DAMPING DIRECTION</strong> (inch-lbs)</td>
</tr>
<tr>
<td><strong>SNUBBER MODELS TO STANDARD STROKE</strong> (inch-lbs)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>DAMPING COEFFICIENT RANGE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FORCE/VELOCITY:</strong> lbs/(in/sec)</td>
</tr>
</tbody>
</table>

**Note: Higher damping rates available. Please consult an Airpot applications engineer. engineering@airpot.com or (800) 848-7681**

<table>
<thead>
<tr>
<th><strong>OTHER SPECIFICATIONS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FRICTION COEFFICIENT</strong></td>
</tr>
<tr>
<td><strong>PISTON FRICTION</strong></td>
</tr>
<tr>
<td>(without side load) : grams</td>
</tr>
<tr>
<td><strong>OPERATING TEMPERATURE</strong></td>
</tr>
</tbody>
</table>

57
### RANGE

<table>
<thead>
<tr>
<th></th>
<th>55°C to +150°C</th>
<th>55°C to +150°C</th>
<th>to +150°C</th>
<th>55°C to +15°C</th>
<th>55°C to +15°C</th>
<th>55°C to +15°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>55°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to +150°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*NOTE: If operating at temperatures over 70 degrees C (158 degrees F) please advise factory.

### COMPONENT WEIGHTS

<table>
<thead>
<tr>
<th>Fixed mass in grams</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>(cylinder, bottom, etc.) =</td>
<td>1.2</td>
<td>2.9</td>
<td>6.1</td>
<td>11.5</td>
</tr>
<tr>
<td>(C1 x Stroke) + C2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movable mass in grams</td>
<td>C3</td>
<td>C4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(piston and rod) =</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>(C3 x Stroke) + C4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1.2.11 The Base Platform

The final subunit of the device is solely for safety. Safety was a big issue in all of the previous designs, in particular the stability of the monitor off of the table. The catastrophic event of the monitor falling on the patient has been taken into a great consideration and certain safety measures have been taken with regards to counterweight balancing as well as safety harnesses. These measures taken to secure the monitor to the lift itself are useless if the whole monitor lift and monitor fall over. This final means of protection against such an event anchors the whole mechanism, which up to this point is all securely anchored with its subunits, to the table or fixture it is being placed on. The idea is simple in that it relied on the use of metal clamps. The clamps will be screwed direction into the bottom platform of the monitor lift as shown in figure 1.5b. The nature of the design relies on the use of relatively heavy laboratory table, therefore, we need four clamps in total to keep the bottom platform in place, shown in figure 1.5a.
The clamps can be made of aluminum which enhance durability and excellent in reducing corrosion. The dimensions of the steel clamps are shown in figure 1.5b. These clamps are very easily machined that can be made in a machine workshop without going through the ordering process. The screws can be in any size, preferably 1/8in in radius. Total of 16 screws and four screws for each clamp will be used for our secure clamp system.
1.2.12 Testing of the whole system

Suggested method and procedure of how to test the whole system is following. We need to test functionality of the spring. Since we putting the springs on top of each other, the springs might be out of place. Before test the support of the spring, we need to take the dimensions of the spring when they are in full compressive form. We need to make sure that the springs will not retract so much that the monitor of the platform will be right on the top of the table. If so, it is not safe because the collision between the table and the monitor platform will cause the monitor to be shaky. And this factor might affect the patient’s consciousness also.

Then, we will need to test the support of the spring by place some weight around 40 pounds on the monitor platform. We will try to find the maximum force the springs at each corner can withstand. During this procedure, we also need to absorb how stable the base platform on the top of the table. It is necessary to prevent any imbalance which might cause severe damage and injury.

After testing of the spring, we will then test the functionality of the dashpot. Because we have four dashpots at each corner, it is very important to balance the dashpot. If the dashpots are not balanced, the monitor might tilt and fall of the platform. We have to be able to adjust the equal amount of air in each dashpot. To test the dashpot, we will apply the same procedure as we used to test the spring. We will place some weights on the top of the platform. Since the springs are already attached to the frame, it might be harder to balance the dashpot since the spring might cause up or down moment of the platform. One method to do this is to insert four bars at each corner of the L bars. By doing this, we will keep the monitor platform at one level. We will be able to observe the level of each dashpot by standing a foot away. Again we have to make sure the base platform is stable and sturdy during the procedure.

The last step in testing the device is to have an object that weighs 100 pounds or more to be on the top of the monitor platform. The reason why we perform this is because we want to maximize safety for both user and person sitting on the front of the device. If we use some object that weight exactly 80 pounds, the weight might fail when the monitor is not exactly 80 pounds or random objects were placed on the top of the monitor platform. During lowering or raising of the monitor, the user might assert his or her force on the monitor platform, that also add weights to the monitor platform. The device should be able to lower or raise the monitor smoothly and without any distracting factors such as noises and wires sticking out.
Paint Cap Remover

2.2.1 Objective

Our goal is to be able to build a paint cap removal device that is small in size and easy to operate. There many other products that can open bottles’ cap or cans. Our product is specially made to open the cap of the Grumbacher paint tube. Our customer is an artist who can only use one hand with limited dexterity. We want to provide him a device that can twist open the paint tube with minimal amount of works. The main goal is to provide the artist the comfortable feeling at work where he does not need to rely on other person. Being independent will boost up his confidence in his career life as well as normal daily life.

Throughout all the alternative designs, we have come up with the final design that will maximize the reliability of the device. We make sure that the user will satisfy with our product. In case if unexpected problems occurred, we will fix it to fully satisfy the user. So far, our final design is based on the optimal design, which was greatly improved from the previous design. We have added some other features to maintain safety and effective functionality of the device.

There were little changes that we made for this final design to make it the most effective and safe device for our client. Our final design is shown in its entirety in Figure 2.1, below. Our client has limited dexterity, and it is difficult for him to grip the paint tube. In our previous design, the clamp was needed to be placed right into the clamp groove. Our new implemented “clamp securing mechanism” will allow our client to place the clamp over the paint tube easily without concerning whether it was in a right place. This mechanism will make sure the clamp is sturdy and will not vibrate and fall off the top of the enclosure. In the previous designs, the motor used was large that makes the device bulky. The new motor has been replaced which is very small and reliable that which helps to reduce the entire size of the device. The smaller the device, the lesser amount of mechanical and electrical inputs and outputs the device withstands. This will enhance safety to the client. In addition, failure of the small device will not cause much damage. The chart below shows the diagram of our design.
Chart 2 – Paint Cap Remover

1. Plug the power cable
2. Insertion of paint tube
3. Insertion of clamp
4. On/Off Switch
   - ON
   - Spinning / Opening of paint cap
     - Power ON
     - Motor ON
     - Cap twisting
   - OFF
5. On/Off Switch
2.2.2 Subunits

2.2.2.1 The base unit

The base unit of our device includes the enclosure, the enclosure’s cover, the clamp securing system, and the rubber feet for stabilization. We finally came up with the detailed description of this unit which included the exact measurements and the locations of all components inside the enclosure.

The Enclosure

The material being used for the enclosure is Flame Retardant ABS plastic, see Figure 2.2a. This material is suitable because it offers flame retardancy with excellent mechanical strength and impact resistance. With the motor being mounted inside, the material needs to be excellent in mechanical strength to hold the running motor sturdy.

The dimension of the box is 4" thick x 3" wide x 4" long, see Figure 2.2b. This size of the box will fit all the components perfectly. The enclosure is securely sealed by tightening the four screws into threaded brasses at each corner of the enclosure, as shown in Figure 2.2a. Screws will ensure the cover is closed tightly because the cap...
head is rotating through a hole on the cover. Therefore, the cover needs not to be loose while the motor is rotating the cap head.

**Figure 2.2a – The plastic enclosure**
Can be customized at Polycase.com [19]

**Figure 2.2b – The base unit layout**
The Enclosure’s Cover & Clamp Securing System

Two features were added to the enclosure’s cover. One of these features is the hole that allows the cap head to be visible. As the cap head is exposed outside of the box, the user can easily know where to insert the paint tube. The hole on the enclosure’s cover has a diameter of 1.25 inches. The cap head is 1in diameter. The 0.25in space is necessary for smooth rotation of the cap head without in contact with the enclosure’s cap. This gap, however, needs not to be too wide in case the paint might spill inside the motor and cause electrical failure. Electrical failure of the motor (or electrical components inside the enclosure) might be harmful to the user. The figure 2.2c below illustrates the position of the cap head at the enclosure’s cap and how much of a height it will be exposed outside of the enclosure.

The second feature is the clamp securing system, which attached to the surface of the enclosure’s cover, see Figure 2.2d. This mechanism will hold the clamp in place. During operation, the spinning of the motor might cause the device to shake slightly, with this clamp securing mechanism in place, the clamp will be staying sturdy. The material used to make this mechanism is polypropylene.
Rubber Feet for Stabilization

The paint cap remover has been designed to be unobtrusive and light. To keep it from moving around while in operation, each corner of the base unit sits upon a rubber foot, see Figure 2.2e. Each foot is cylindrical with slightly rounded edges. This provides the paint cap remover with some added traction. There will be one rubber foot aligned with each corner. The amount of traction that these feet provide is based is dependent upon the coefficient of friction of the rubber on the table surface and the weight of the base unit.

![Black rubber foot w/adhesive, 2.25cm round base, bowl shape](image)

*Figure 2.2e - Rubber Foot*
2.2.3 The electronic circuit

AC Adapter
The motor in our application is very simple that it can operate with a small DC voltage supply. In the previous designs, we use batteries as the supplied voltage to the motor. However, upon our suggestions, the client agrees with the idea of using power outlet instead of batteries. The power plug provides many advantages to the user, in this case an artist with limited strength of only one hand. The artist will not have to change the batteries every time it runs out. Changing batteries involve the use of both hands, which is a biggest constraint to our customer. We will use 120VAC as our AC power supply. The AC voltage will be converted to DC voltage using the AC adapter shows in the figure below. This AC adapter is a multi-voltage control. The purpose of using this particular adapter is to vary the speed and torque of the motor with various voltages. For right now, the required torque and speed to twist open the cap is unknown due to the small size of the cap leads to difficulty in taking accurate measurements. The advantage of using this adapter is able to control smallest voltage of 1.5V and largest voltage of 12V. Economic advantage is no need to purchase a new adapter of different voltage when needed. It is safe to work with smallest voltage and increase it up if the voltage is not suitable for the motor. The adapter is small in size, the user can easily plug it in the wall without using much of strength. In addition, the long cable will allow the user to move the device around without being constraint to one spot. There are 12 adapter plugs included in the package. The picture below shows the image of the AC adapter that we used in our application.
The adapter plug is connected to the power jack which carries the current to the protoboard, see figure 2.4b below.

**Protoboard**

The voltage coming out of the AC adapter will be the voltage supply for our simple circuit. The circuit includes the resistors, the fuse, the switch, and the compact fiberglass protoboard that can be placed inside the base unit. The figure 2.4a below shows the picture of the protoboard.
Our circuit contains switch, fuse, motor, and resistors. The role of the resistors is to reduce the voltage and current going through any particular components in the circuit such as the switch or the motor. These components are different in voltage supplies. In other words, each component will be operate with different voltage supply. The voltage needed to operate the switch is 12V. Therefore, we have to use the 12VDC from the AC adapter. We also need more voltage supply for the fuse as well. The motor is the only component that operates under a low voltage supply. We implemented the voltage divider circuit (which we will mention later), that will reduce the voltage supply to the smaller voltages.

We do not know the particular voltage needed for our application because we need to build the cap head and attach it to the motor, then try to twist the cap in order to know the specific torque and speed. Therefore, we have to vary our circuit to accommodate with the specification of the motor. It is not a difficult task to do. The first voltage supply that we tested is the 1.5V. The output voltage is 1.5V and the current output is 35.71mA. The motor that we used in this application is adjustable that we could vary the voltage and current to adjust the desired speed and current, respectively. The table below display 12VDC input, and various voltage and current outputs for the motors, and various resistors that can drive those motor voltage outputs.

<table>
<thead>
<tr>
<th>Input Voltage (V)</th>
<th>Input Current (A)</th>
<th>Output Voltage (V)</th>
<th>Resistor 1 (Ohm)</th>
<th>Resistor 2 (Ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.0357</td>
<td>1.5</td>
<td>280</td>
<td>40</td>
</tr>
<tr>
<td>12</td>
<td>0.0432</td>
<td>3</td>
<td>208.3</td>
<td>69.4</td>
</tr>
<tr>
<td>12</td>
<td>0.0476</td>
<td>4.5</td>
<td>157.6</td>
<td>94.5</td>
</tr>
<tr>
<td>12</td>
<td>0.05</td>
<td>6</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>12</td>
<td>0.055</td>
<td>9</td>
<td>54.5</td>
<td>163.6</td>
</tr>
</tbody>
</table>
The schematic 1 below was drawn and simulated in PSPICE. For this circuit, we used 12V input and resulted in 1.5V and 37.5mA which goes into the motor. The schematic 2 has 12V input and 9V and 55mA outputs.

The schematic 3 below gives an overview of how the circuit connected together with the motor and the switch.
The Fuse
For safety of our user, we implemented the fuse, which is a type of over-current protection device. The fuse [Figure 2.6b] contains a wire designed to melt and open the circuit when there is a high electric load occurs. This will protect the circuit’s components from getting burnt or exploded.

Switch
The switch will be a toggle switch that will not require much dexterity to operate. The user turns on a switch in the motor circuit which begins operating the motor. This happens because the switch closes the circuit, allowing for the flow of current from the power supply into the motor, driving the rotation of the motor’s shaft. The shaft of the motor will be attached to the cap head. So when the switch is turned to the “ON” position, the cap head will continuously turn which twists opened the paint cap. Below is the figure of the switch for our application.
Figure 2.6 – The toggle switch

Mini Toggle switch  
Type: SPST, ON-OFF 24" Leads  
Rating: 6A 12VDC  
Mounting hole: 0.250" (1/4")  
Maximum panel thickness: 0.156" (5/32")

This switch is operated with 12VDC. This brings up the case where we need to convert the AC voltage directly to 12VDC. In the section below, the motor needs not to use 12VDC because it might increase the speed of the motor. We will use another method to convert 12VDC from the supply to a small voltage that is suitable for the motor only.

2.2.5 The motor

To open the cap of the paint tube, the motor must have a low amount of rotations per minute. Most small DC motors spin at a high rate. DC motors are easy to operate and vary the speed and torque. Since this device is going to be used to remove a paint cap, which does not take many rotations to do, we do not want the motor to be spinning too fast. Skycraft Parts company provides a small 12 volt motor with relatively low voltages and RPMs.

Figure 2.7a - DC Motor  
Can be purchased at Skycraft Parts & Surplus. [17]
Motor’s specifications:
Various voltages with no-load:
@ 6VDC: 970rpm [50mA]
@ 9VDC: 1500rpm [55mA]
@ 12VDC: 1920rpm [60mA]
@ 24VDC: 4280rpm [65mA]
Dims (Excluding Shaft): 2-3/8"H x 1-3/8"Dia.
Shaft Dims: 11/16"L x 1/8"Dia.
Weight: 0.45lbs

Due unknown torque and speed parameters, we chose a motor that has various voltage and current parameters. For this particular motor, the lowest voltage is 6VDC that induces 970rpm, which considered fast for our application. For DC motors, the output torque is proportional to current, and the output speed is proportional to the voltage. To reduce the speed, we just have to limit the voltage, and do the same procedure for the torque. Because 970rpm is still high, we want to limit the voltage to achieve a lower speed and torque. To do that, we performed estimation by creating the graph that shows the relationship between the voltage and the current. Since the line is not linear, it is hard to predict the output current. To solve this problem, we applied logarithmic equation to solve for the relationship. The dash line is the logarithmic equation used to find the current for any arbitrary voltage. For example, we want to use 1.5V, the output current will be 35.7mA, for 3V, current is 43.22mA, for 4.5V, current is 47.62mA. We can obtain 1.5, 3, 4.5, 6 and 12V easily from the AC adapter.
Graph 3 below shows the linear equation estimated from the data given by the motor company. We estimated the speed of the motor when we reduced the voltage to 1.5V, 3V and 4.5V, and the speeds are 87rpm, 366rpm, and 642rpm respectively. The 87rpm speed might be a suitable speed for our application, however, we cannot predict as of right now. Reducing the voltage is not a difficult task. We can always add resistors to our circuit to reduce the voltage to a desired value. One method is to use voltage divider, shown in figure 2.7b. The reduced voltage is the Vout which will be connected to the motor. Vout is the voltage across R2. We want to select the R1 and R2 values so that we will drop to the desired voltage at R2. In accordance with Ohm’s Law, the ratio of voltage across these resistors will be equal to the ratio of the resistance values themselves. We just need to find the ratio of the voltage supply (E) and the output voltage (Vout). The smaller the resistors’ values, the smaller then loading effect from this voltage divider.

![Voltage divider](image)

**Figure 2.7b – Voltage divider**

![Voltage Vs. Speed](image)

**Graph 3 – The relationship between the voltage and the speed of the motor**

\[
y = 184.94x - 190.48
\]
2.2.6 The Cap-Head

The cap head was originally on a descending platform and was put on the tube’s cap by the device. To make sure that the cap head does not miss the cap, the cap head is now located in the base unit and the paint tube’s cap is placed into the cap head by the user. The shape and dimensions of the paint cap is shown in Figure 2.8a. Our cap-head design is shown in Figure 2.8b. The cap-head remover is a plastic rod that can be purchased at Plastic International. There are small teeth in the bore which will fit around the cap snugly. Since the type of paint is specific, we can design this cap head to fit our cap precisely. Upon request, we could also design multiple sized cap heads for different types of paint. We can make a bore easily by drilling a hole through the plastic rod and then using a utility knife and a file to make the teeth. The final product is a specialized cap head with small grip-teeth that perfectly matches the cap of the paint tube. The cutout portion will be thinly lined with rubber so that there will be a smaller chance of the cap head being stripped. The plastic of the cap head is very soft and it is imperative that the shape of it is maintained so that our device can remove the cap more than once. When it is rotating, the grooves of the cap-head will lock into the cap, spinning both the cap and tube counter-clockwise.

![Diagram of Paint Cap's Dimension](image)

**Figure 2.8a - The Paint Cap's dimension**
2.2.7 The Clamp

If the tube were uninhibited, our device would not accomplish the goal of opening the paint tube, since the tube could simply rotate endlessly. Think about trying to unscrew a nut from a bolt. If the bolt is free to rotate, the nut will be nearly impossible to twist off since the bolt would spin too. The same is true for our paint cap and to prevent the tube from spinning along with the head, the tube must be restricted from spinning. Our original design used a tight clamp to secure the paint tube from spinning. One major drawback that we were asked to consider was that a tight clamp might put too much pressure on the paint tube. This could result in the tube expelling paint superfluously. Not only would this be a waste of paint but it would be very messy and would require unnecessary cleaning of all parts involved in the device. Our design is unique because it will secure the paint tube without expelling the paint. The key to our design is that it takes advantage of the ovular shape of the paint tube. If you look at the tube from a birds-eye angle you can see that its width is larger than its depth, resulting in an oval shaped tube. This can be seen in the figures below. Figure A shows a top view of a full paint tube after it has been
placed into the box-shaped clamp. The clamp fits around the outside of tube without applying any pressure to the tube. These simple clamps are cheap and come in many sizes at local hardware stores or online stores. It will be easy to find or even fabricate one that will fit into the grooves cutout on the base for it since it is just a plastic rectangular cylinder. As mentioned earlier in the other section, we implemented the clamp securing mechanism for the purpose of holding the clamp in place without creating a dent on the cap of the enclosure. The cap of the enclosure is very thin, so we cannot make a groove into it.

**Figure 2.9a** - the front view of the paint tube inside of the clamp.

**Figure 2.9b** - The different stages of the paint tube in the process of cap removal. Figure B shows what happens once the cap head remover begins to rotate. When the cap head is locked into place over the cap of the tube, both the tube and the cap begin
to rotate counterclockwise. However, since the tube is wider than it is deep, it is
prevented by the clamp from rotating fully. The clamp stands firm and holds the tube
with minimal pressure, and this allows for the cap to be twisted counterclockwise.
After several rotations the cap will be removed. At this point there is no pressure at
all on the tube because nothing is twisting it. Also, when the cap is being unscrewed,
the tube will travel upwards a bit. The clamp is does not have a top to it; it is just a
rectangular cylinder so there is no concern that the tube will be squished that way.
The user can now turn off the device and remove the clamp. The paint tube is upside
down at this point, but since there is no pressure on the tube when it is opened and
the paint is rather viscous, there should be no mess. The user can pick up the open
tube, pick the cap up out of the cap head and begin to paint.

Figure C shows a paint tube with less paint inside of it. One important concept to take
into consideration is that the paint tubes change size as they expel more and more
paint. The specific type of paint, Grumbacher Oil Based Paint, comes in small 1.25 oz
containers. These containers are shaped like a toothpaste tube, except the paint tube is
made out of a thin metal. What is unique to the shape of the tube is that it is sealed at
a flat line at the very bottom of the bottle. This means that no matter how much paint
is already used, the width of the tube will never be less than its original width. Figure
C shows this concept: that although the depth of the tube will decrease as the paint
gets used up, the width will remain nearly the same.

Figure D shows the tube with less paint in it once the cap head remover comes into
direct contact with the cap. Even though the tube has less paint in it and the depth
has decreased, the width of the tube cannot change because it is sealed in a flat line at
the bottom. The metal tube retains its rigidity and when the tube begins to rotate it
comes into contact with the clamp. The clamp prevents the tube from rotating in a
complete circle and therefore the cap is allowed to be unscrewed counterclockwise.
After several rotations the cap will be removed. Just like with the full tube, at this
point there is no pressure at all on the tube because nothing is twisting it. The user
will once more let go of the depression handle enabling the springs to retract the
descending platform. The descending platform returns to its steady-state resting
height, and the motor can be turned off. The final result again leaves the paint tube
sitting loosely in the square clamp with its cap removed. The tube can be picked up
out of the device and the user is ready to use the paint.
Bending of the paint tube case

The artist might encounter the case where the paint tube will bend or deform in shape when the paint is running out. This problem might cause difficulty for the artist when he wants to insert the paint tube into the cap head. The two figures below illustrate the shapes of the paint tubes in the described conditions.

![Figure 2.7a – Bending and deformation of paint tube.](image)

No matter how little paint is left over inside the tube, the width of the tube will not change in length. The tube can be well fitted inside the clamp as long as the artist keeps the tube straight in its full length. The figure 2.7b below proves how the clamp can still hold the tube regardless its size:

![Figure 2.7b – Clamp](image)

The unique feature of this simple clamp is that it will work properly and efficiently for the paint tube no matter how much paint is remaining in it. Because of the distinctive sealing of the tube at the base of the bottle the width of the tube will not
be variable. Therefore since the clamp is rectangular shaped it will prevent the tube from rotating no matter how full it is. Even if the tube is almost completely empty, it will still have relatively the same width as when it is brand new.

In the previous designs the clamp was to be made of metal. Since the clamp is being placed over the tube and covering it entirely in this design it will instead be made of a strong, clear plastic. Polystyrene would be suitable since it has high clarity and is very durable. This will allow the user to see when the cap has been loosened and know that they should stop the motor.

2.2.8 Testing of the whole system

Trials of testing are needed for our application. Testing involves several steps. The first part is to test the circuit board. We want to make sure to have the right resistors’ values. As of right now, we need two resistors to get the desired current value. We need to test the current that goes through the resistor R2 (see Schematic 1). The current cannot exceed the input current to the motor. The current controls the torque of the motor; therefore, it is important not to have either too high or too low current input. We have not been able to find out the torque needed to twist open the paint cap. However, this can be accomplish by apply many trails using different torques. The speed of the motor needed to twist open the paint cap is also unknown. We will also need to supply different voltage to the motor and to verify the suitable speed for the cap head. Because we have a motor and AC adapter that are adjustable, we will be able to know the exact torque and speed values. Next, we will insert the variety of paint tubes of different sizes, and try to open each cap. If the clamp cannot hold the tube in place, then we will think of a different way to build a clamp that can hold all sizes of tube in place. Another consideration is to see whether different forces are needed to open caps that have paint around them. All the data with variables will be kept to further implement our device.
3 REALISTIC CONSTRAINTS

Monitor Lift

Engineering standards from IEC provide guidelines to make sure that products are reliable, durable, manufacturable, economical and safe. The following are a couple of standards our monitor lift must meet.

IEC 60812 Ed. 2.0: Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA). This standard requires that our system be reliable. It must function reliably and if it is to fail, it must have a back up system and “fail safe”. The PVC tube-guide rods, dashpots and springs all counteract the others to a degree if one of them was to fail. This standard requires this be proven through analysis of forces and specifications.

IEC 60605-3-4 Equipment reliability testing. This standard must be met to make sure that our design is durable. It requires that the device’s operation be put through low simulation and passed under a number of cyclic loadings.

Realistic constraints exist for the manufacturability of this device. The manufacturability of the parts of the monitor lift faces some constraints. It should be relatively simple. Parts cannot be custom made by an outside company since we are working on a timeline and they would probably take too long to receive. If a custom part is needed, it must be thoroughly planned out, absolutely necessary, and ordered far in advance from when it is needed. Any pieces we order that are not already welded or put together should be materials that are easy enough to assemble that we can do it ourselves. The tools available to us in the machine shops and labs constrain which pieces we will and will not be able to assemble ourselves. Another manufacturability constraint is that the parts ordered must meet specifications calculated (i.e. springs must have proper force constants). Time is a major manufacturability constraint on the project.

An economical constraint for the monitor lift is our budget. The sum of all of the parts needed to build the lift must not exceed the preset budget. Shipping and handling and tax must also be considered in the budget. Our budget for this prototype is $750 and it is required that all other expenses including shipping and handling should not exceed this limit.

An ethical constraint regards the use of budget money. The budget money should not be spent “just because it is there”. Materials should be researched and shopped around
for before purchasing to make sure that the money provided by the sponsor is not wasted on overpriced goods. If there is a sale, or a different company can provide the same quality part at a lower price, the lower priced piece should be purchased. Concern for safety is another ethical constraint. It would be unethical to design a lift that could support only 80 lbs. The monitor lift is going to be used in a clinical setting. An object weighing 80 lbs could seriously harm somebody if it fell on them for instance. If the lift failed while it was raised, it would most likely also crush the eye tracking device (which is most likely very expensive) underneath it. It would be unethical and reckless to not incorporate a variety of safety measures.

The monitor lift has no set constraints when it comes to sustainability. Wear is impossible to avoid forever but, keeping safety in mind, it should not be made of a material or in a fashion that would increase its likelihood of breaking suddenly. The springs may wear and need to be replaced every so often. It will probably not be used or moved too often, so we hope the device sustains for at least 5-10 years.

Health and safety constraints for the monitor lift include the safety of the patients and users. There are no electrical devices to pose a threat. The balance of the monitor and the risk of it falling or the joint failing are the only real potential problems. Safety measures (clamp, strap, raised edges on the platform) have been taken to meet these. If a spring or dashpot broke, the direction of the fall would be managed by the guide bars and cylinders. It would not fall towards a subject. The other dashpots and other springs would lessen the impact of the failure of a single component.

There are no political constraints for the monitor lift but the social constraints include the status of the patients and the environment. The lift must not disturb the patients while they are being tested. This means that the lift cannot be aesthetically distracting (it will be all black and is designed to house the wires for the computer in a tube) and it cannot be noisy. It needs to make looking at the screen comfortable for the patients. It will also make testing the patients easier for the technicians. The implementation of the monitor lift will help make the patients more comfortable while being tested, and will also make the test results more accurate/easier to obtain. These test results may help uncover solutions to a variety of neurolinguistic problems.

The monitor lift is going to be used in a laboratory or clinical setting. It needs to be quiet so it will not disturb the patients. It cannot emit any kind of pollution or mess that may harm those around it (this is not a problem for this design since it is not powered). It must be able to stand on a desk and be compact. When it is raised, it must leave the smallest possible footprint on the desk so that a tracking device may be stored underneath it. Temperature of the room should not affect this design, though it may have an impact on the functionality if hydraulics were still being used.
Oil Paint Cap Remover

Engineering standards require that the oil paint cap remover be reliable, durable, manufacturable, and most importantly the product must satisfy the customer and be safe.

In addition to the engineering standards that must be met for the monitor lift, the paint cap remover must follow many standards concerning its electrical components.

IEC 61360 - Component Data Dictionary. The component data dictionary provides classifications, characteristic properties and conditions for which the property values are valid. All of our electrical components will be checked against the component data dictionary.

IEC 60529- Degrees of Protection provided by enclosures (IP code). This standard classifies the degree to which our enclosure box (base unit) will serve as protection against electrical injuries.

IEC 60364-4-41 Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock. Our device will be enclosed within a plastic box (non-conducting material) shielding it from the user. No loose wires or live components will be in contact with any material that could indirectly transfer electric shock to the user. A fuse will be incorporated to guard against power surges. The circuit and all components should be grounded.

IEC 60512- Connectors for electronic equipment - Tests and measurements. The plug will be purchased from a manufacturer so it should pass this standard for mechanical and electrical endurance of electromechanical endurance. The specifications for the plug and our circuit have been run through PSpice to make sure that the voltages and currents are the desired values.

The device is less bulky and relies on a smaller frame to operate further reducing the risk of being unstable and falling off the table. The design relies on a simple gear and motor combination that can easily be altered to get a desired speed and a safe operating motion. The nature of the design allows for the client to set the tube in the device and then leave it until complete, resulting in less risk of the client becoming endangered during the operation of the machine. The moving parts of the machine will be contained but further precaution will be able to be observed if the client can remove themselves from the area during the working operation of the device. The paint cap remover design safety has been addressed in the design through the housing of electrical components in a box. All electrical components will be grounded and the
user will not come into contact with them during regular use (only when changing batteries, but those will still be separated from the rest of the electrical components. The wires used will meet engineering standards. Since the output current is relatively small, the thickness of all electrical wires that will be used in our application is small within a range of 0.254 – 0.28702 mm of diameter. These wires can also be enclosed in PVC electric conduits that are light-weight and have high impact resistance, safe and low flammability, and long lifespan. The motor will be powered by 600 mA current (14.5V DC output by the transformer of the outlet plug) which is relatively low in power input and output. The fuse will safeguard against power surges or excessive current, which could be dangerous.

The main manufacturability constraint on the paint cap remover is the timeframe given to build it. The oil paint cap remover has a wide variety of parts; it has electrical components, structural components, and springs. Not all of these parts will be easy to find at one company. This may increase the amount of time spent waiting for parts to arrive since sometimes companies take longer to ship smaller orders.

An economical constraint for the paint cap remover device is the cost to run it. Especially since it is a device for personal use that will be used often, the cost to power the machine should not be excessively high. The budget is the main economical constraint on the paint cap remover device design. Particularly for our first prototype, the budget is $750 and it is required that we will not go over this budget.

The same sorts of ethical constraints apply to the paint cap remover. The budget money cannot be used recklessly or for anything other than the development of the project. The safety of the client is also an ethical constraint since it would be entirely unethical to develop a product for a client that might harm them in any way. Thorough testing and planning will be done to make sure the device is safe for constant use.

The paint cap remover has no set constraints on sustainability. It is no longer battery operated so maintenance of the power supply is unnecessary. The device should function for as long as the individual components last. We expect the device to be used often so it we hope it sustains for at least 1-3 years.

The paint cap remover has more health and safety constraints because it has more types of parts. The electrical components must be grounded at all times. The client/user should not ever come into direct contact with any live wires or components. They will all be housed in a box. The motor and the cap head are moving parts. They should not be easy to get things such as hair tangled in, or fingers
caught in. The device should be sturdy so that it will not fall over or wobble when it is being operated. The client may not have the strength, dexterity, or reflexes left to be able to react accordingly in such a situation. The device should be of a stable nature so that it can withstand a variety of forces without falling to the ground or becoming a projectile. The device should at no time expose the individual’s eyes, or mucous membranes to the paint which is contained in the container. The device must be designed to effectively remove the cap without removal of any of the paint which would cause exposure to the individual's own person and their environment.

The paint cap remover does not have any political constraints but it has more social constraints. The client has multiple sclerosis and as a result can only use one hand, and with little force or grip. The paint cap remover must be simply operable with only one hand. It must be mostly automatic. The objective of the paint cap remover is to give the client back his independence. Since the client is in a wheelchair there is the constraint of accessibility. The device must be readily accessible to the client so as not to promote an unnatural stance or posture during the use of the machine. Any reaching or unnatural posture during the operation of the device could lead to the device malfunctioning or becoming a falling object. The client should not have to leave a comfortable relaxed position in their chair so as to operate this device.

Since the paint cap remover is being designed with the goal to give back a sense of independence to a person, it should not be confined to a certain space. It must be not only easily operable but also easily accessible even in a wheelchair. By having the paint cap remover run on power from an outlet, the painter may be confined to use the device in only certain areas, but he will not have to maintain the device. Changing batteries may be a difficult task for he client as a result of his condition. Since the device will most likely be stored in an art room, the probability that it will get messy is a constraint. The device will either have to function when it is dirty (maybe has paint from the client’s hands built up on it), or be easy to clean. Rubber sealants may be used to further contain the inner workings of the device so as to protect them from contamination.

4 SAFETY ISSUES

The first and most important consideration all engineers must revolve is safety issues. Overlook in identifying any mechanical, electrical, or other failures might lead to many downfalls associated with financial, social and economic problems, and possible lawsuit. In medical system, patient safety is the primary concern, and it is extremely substantial to understand fully all the known risks of any device that will be used both in vitro and vivo. All medical devices must be approved by the Food and Drug
Administration (FDA) before expose it to the market. For any new medical products, FDA will goes through processes that evaluating the safety, efficacy, and use of medical products [8]. Errors and device failures are unavoidable. It takes numerous trials of testing in order to successfully remove all the possible hazards from the device. IEC provides standards and guidelines that outline proper ways to do this. It is essential to pay a very close attention to every small detail as much as possible to limit the severe damage to both designers and users.

**Monitor Lift**

The environment is very important in this design. The monitor lift will be placed on top of the laboratory table and is in the front of the patient. The laboratory table surface is larger than the dimensions of the monitor’s base. The laboratory table cannot be modified in any way to accommodate the monitor lift. The monitor itself is very large with the dimensions of 19.25 inch tall x 19.5 inches wide x 10 inches long and 80 pounds. Failure of the lift might cause severe injury to the patient and possibly persons who are performing an experiment. There are several methods being implemented to prevent unnecessary risks. The raised side bars are a safety measure to help keep the monitor from sliding and moving during operation. The monitor platform will be tailored to the dimensions specified in the project thus further increasing the safety of the device. Tie down accessories will be placed on either side of the platform allowing for a multitude of straps to be implemented in tying down the monitor, again further anchoring the monitor to the solid frame design. Previous designs of such a lift had a problem with unsightly wires. This was taken into consideration in that a hole will be machined in the back of the top platform so as to allow the discrete exiting of the wired down the backside of the lift in a bundled fashion.

Should a spring or dashpot fail in the device, the remaining dashpots and springs would lessen the impact of the failure. The load carried by the failed spring or dashpot would be transferred to the remaining ones. Since there would be three remaining if one were to fail, the device should still be reasonably stable/level. The PVC tubes-guide bars also aid in keeping the platform level in the event that a dashpot of spring fails.

This design does not require any power source. It is moved manually with the help of dashpots and springs.
In using materials that are durable and have high melting temperatures the threat of fire consuming the device is minimal. In the event that the monitor or surrounding machinery was to catch fire the lift device itself would provide no extra fuel to the fire. In the event of a fire the mechanism will not fail mechanically for some time. The probability that a patient or care taker will be near the fire at the time of mechanical failure is almost zero.

**Oil Paint Cap Remover**

For any device that is connected to a battery or AC power supply, electrical hazard might happen at any time during or after operation. Our device, the oil paint cap remover, is considered a simple electrical application that does not involve complicated electrical component and wire network. Our system encompasses a DC motor that can be operated using a plug that converts the AC power to 14.5V DC. The relatively low in power input and output that will reduce the high risk of electrocution. The output current from the DC motor is 0.57Amp, which is critically safe. In addition, choosing the right size of the electrical wire and cable is crucial in reducing the heating up and causing fire during the performance [2]. Since the output current is relatively small, the thickness of all electrical wires that will be used in our application is small within a range of 0.254 – 0.28702 mm of diameter. The fuse makes sure that the current running through the circuit is not too high. This is very important because not only would it overload, break and possibly cause the other electrical components to explode; it could potentially harm the user. The circuit and its components must be grounded for this reason also. All of the electrical components are small and if they were to explode, it would be mild. Because all the electrical components are in close proximity to moving parts (the shaft of the motor and the cap head), all the wires should be held in place firmly. These wires can be enclosed in PVC electric conduits that are light-weight and have high impact resistance, safe and low flammability, and long lifespan [11]. Because all the electrical components are kept inside the ABS plastic box, the user is safe from being in contact with wires and all other electrical components.

The mechanical functioning of the device allows for safe operation at a distance. The low torque and slow adjustable nature of the spinning head allows for mistakes to be made when operate the machine without injury or harm occurring. The housing unit
not only protects the client from the inner workings but also protects the inner workings from the messy paint. The paint has the ability to short out electrical devices, potentially causing harm to the device itself or surrounding persons. The encasement does not allow for any casual paint contact as well as any casual mistaken human contact. The high walls of the paint tube containment unit will easily contain a jostling paint tube, even though we do not expect much movement of the tube other than at the cap head. The rubber feet implemented in this design not only provide traction but also ground the device of any unwanted stray currents. The anti-slip nature of the rubber will accommodate any ordinary table surface and will prevent motion of the device. The device is designed so that no outside torque needs to be applied thus the stationary nature of the device is reaffirmed by the simple yet effective rubber feet. The low bulk and lightweight features of this device reduce the risk of injury if this device was to fall on the client, even though no such risk of fall is immediately present. Since the device is easily carried from one place to another the client can bring the apparatus to a location of his choice. By allowing the client to operate the machine in a comfortable and familiar environment within his studio we are reducing the risk of him having to maneuver within his chair and potentially falling out. If the device can be placed at the most convenient location at that time the natural positioning of the client is inevitable. Knowing that art studios surroundings often change to accommodate various artwork and artwork supplies, the mobile nature of the device again proves useful.

5 IMPACT OF ENGINEERING SOLUTIONS

Monitor Lift

Our device has shown a great improvement in the dimension of the whole system. This has a great environmental impact for our client. We are trying to create a compact device which does not take up space on the laboratory table. Our client wishes to have a device that does not produce a lot of noises. In our design, the use of the spring and air pump has its advantage in which noise is limited. Other features such as wires, shape, and color will be developed based on our clients’ desires. The patients being tested have neurological disorders; therefore our goal is to create a device that is simple enough to prevent any distraction to the patients.

In the neurological laboratories, many benefits will be gained through the use of our device. Upon achieving all the requirements, our device will help in bring more accurate and effective discoveries or solutions to the laboratorial experiments. Once the results are obtained from successful experiments, new solutions such as drugs,
devices, or methods will be given to patients, helping them to recover their illness and complications. There are a large number of populations who are suffering from neurological disorders, new discoveries and findings will have such a great social impact on mankind. It will reduce many burdens for families and friends. Life will be much easier than it always is.

Globally, there are a large number of companies producing monitors/television lift. Those include LCD lift from ActiveDesign [13], monitor lift from Flex-Y-Plan [14], monitor lift from Starfield Group [6], LCD lifter from ChuangGD in China [15], monitor lift from Fox Bay Sit – Solutions for Human [7], and many more. These companies’ purpose is to provide people easy access to the monitor. Our device, with a similar purpose, can be successfully deliverable in the near future. With our additional safety straps and clamps, we will add more benefits, also success, to the monitor devices in general.

Economically, our device is cost effective in a way that it can be manufacture in bulk with cheap budgets. Many people, not necessary industries, hospitals, or laboratories only can afford one.

Our device leaves little impact on our natural environment. The consumption of electricity is used to fuel an air driven system in which no exhaust is created, and thus not emitted from the device. The corrosion resistance of the materials chosen will reduce particle flaking and thus reduce pollution of surrounding laboratory. The environmentally friendly nature of such a device will ultimately add to its appeal and effectiveness in the future.

**Oil Paint Cap Remover**

Approximately 250,000 to 350,000 people in the United States have been diagnosed with MS [12]. MS can occur between the ages of 20 and 40 and causes many sorrows for those young people. Among these are the young and ambitious painters who are struggling with their careers due to the limitations of physical abilities. Our design, which is the paint cap remover, has the great impact in improving both career and social life of many painters. This device will provide him with more confidence in achieving his career goal since he will not worry about such a small task. The users can be independent whereas he will not need any help from an assistant. They will feel much comfortable in a sense that they can use it any time without asking anyone for help. According to psychologists, humans tend to feel much confident in their work when they have a full control over it. The painters will gain back his confidence and positive determination in achieving their ultimate life and career.
goals. Socially, upon the full control of his painting tasks, the painters can raise his self-confidence and self-esteem. This behavior will lead to many positive impacts such as communication, social involvement, and human relationship and partnership.

The lifespan for people with MS is nearly the same as for those who do not have MS. Because of this fact, expense of diagnose, treatment, and daily health care is a big problem; billions of dollars are spent annually. Economically, the price of our device is reasonable for it can last for a long period of time. Our future implementation of the device will bring down the cost. Nevertheless, the painter is able to save a good amount of money since he does not need human assistant or any other aids.

Our ultimate goal is to be able to provide the client the maximal convenience and comfort in his working environment: less strength and easy-to-operate, compact device. There are numerous devices in the industry that allow users to open bottle, can, or lid [3][4][5][9][11] that our client might possibly use. However, those devices do not give him a maximal comfort and minimal use of hand grip. Our device’s impact is that we satisfy every request our client asked for and it is specific made to accommodate the needs of our client.

6 LIFE-LONG LEARNING

Our projects have expanded our knowledge much further in engineering discipline. Every part of our designing process allows us to gain much valuable experience that we will use in our future career. The purposes of the projects are incredibly relevant to our career that is being able to improve health and life of mankind using technological aids.

So far, we have learned different types of mechanical systems that could be used in our monitor lift. The systems included hydraulic, pneumatic, spring, air and dashpots. Through some investigation of each system, we are able to discover the advantages and disadvantages of each system regarding our unique application. For our optimal design, we have decided on using the spring and dashpot system for our device for many reasons. The advantages of this system are flexible and adjustable vertical height adjustment without the degrees of freedom in other directions, avoidable unnecessary sound, compact, reliable, and simple design and manufacture. The bar integration of spring mechanism and the integration of arm bar and pivot joint allow a very smooth and substantial lowering and raising manipulation. Most devices in the world today use springs and dashpots in their applications. With this
knowledge about springs and dashpots, we will be able to understand how other devices work and learn from it.

As mentioned, because we have used spring in our monitor life project, we are able to proceed through our optimal project easily. The cap removal device also used spring system in previous designs to descend the cap head to be fitted directly on top of the oil paint cap. The spring and the weight of our motor compartment together create advantages in which reduce the amount of work the user has to apply to push the head downward. However, the degrees of freedom in every direction we learned was a downside to springs. As simple as springs are, we were able to make the design for paint cap remover even simpler by cutting them out of the design. This project has developed the basic knowledge of motor among the team members. Acquiring a right motor is not such an easy task as it sounds, thus it requires a good amount of knowledge about gears, rotation speed in relation with voltage supply, current in relation with the torque, size, and many other important factors. Almost all technologies operated by motors, therefore motor comprehension will serve a very important and beneficial foundation in our career lives.

This is a design project that based on the need of the client. In the past months, we have learned the skills and steps in achieving the needs of our client. As engineers, it is very important to provide all of the engineering standards and specific needs that are required from the clients. It is useless to produce a device that does not encompass all the basic specifications requested. Therefore, we have learned step by step in approaching and solving problems that are given. For instance, our oil paint cap remover project’s requirements are non-manual labor, compact, and easy to operate. At first, we did not fulfill all the conditions because it was difficult to put together a perfect device in the first try. However, through the help of our client, professors, advisor, and classmates, we are able to identify and solve the problems. As of right now, we are able to have a control over our projects because we have spent a good amount of time researching and solving for any issue that come along with the design process. We have learned that for any design, it is necessary to obtain all the information, to identify all the possible problems, and to collect feedbacks from all the surrounding sources.

We have learned that it is never an option to sacrifice the safety of the patient for a more easily manufactured/cheaper product. The patient’s safety must come first when dealing with medical devices. The patient relies on that device to perform a task to promote healing and a safe environment. If the environment is not safe the device will not be effective in what it is employed to do, even if it never ends in catastrophic failure. We have learned that all aspects of safety must be taken into consideration, no
matter how plausible they may be. Safety must never be sacrificed for the sake of the devices creation.

Time constraints are a big factor when producing such products. Without being on time and having an organized schedule the devices design will suffer and the nature of the project will be lost in efforts to just play catch up.

Learning will never end. We acknowledge that we will have to learn more in depth about every part in our designs. Learning is not only through successful trial, also through failures in both hardware and software designs. Our projects might fail, but failure does not mean the termination of our goals. With the goals set in mind, we will accept any failure, learn, implement, and improve from it. In the future, besides our ultimate goals of which producing a working device, we also look forward to acquiring important education and expertise related to engineering.

Besides academics, we have learned a lot about team work. Our team is incorporated of four members and we are responsible for two projects. It was challenging when there are more members in a group. Initially, we struggled in dividing the tasks equally among the members of the group, setting up meetings, and putting together ideas. However, as we go along with the projects, we are able to communicate and compromise on everything that we are doing. We hope in the future, with our hard work, we will be able to deliver products that will fully satisfy our customers.
## BUDGET AND TIMELINE

### 7.1 Budget

#### Monitor Lift

<table>
<thead>
<tr>
<th>Parts</th>
<th>Companies</th>
<th>#</th>
<th>Price of all pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aluminum sheet</strong></td>
<td>Aaluminum</td>
<td>2</td>
<td>$24</td>
</tr>
<tr>
<td><strong>Spring</strong></td>
<td>LeeSpring</td>
<td>28</td>
<td>$115.92</td>
</tr>
<tr>
<td><strong>Round Bar</strong></td>
<td>Metalsdepot</td>
<td>4</td>
<td>$58.56</td>
</tr>
<tr>
<td>R438 4 foot 3/8 inch Dia. 304 Stainless Steel</td>
<td><a href="http://www.metalsdepot.com">http://www.metalsdepot.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PVC Tube</strong></td>
<td>Mansfield Supplies</td>
<td>1</td>
<td>$2.00</td>
</tr>
<tr>
<td>7/16&quot; inch PVC tubing 1 foot tube</td>
<td><a href="http://www.mansfield-supplies.com">http://www.mansfield-supplies.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dashpot</strong></td>
<td>Airpot Corporation</td>
<td>4</td>
<td>$601.92</td>
</tr>
<tr>
<td>12-inch Stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Metal corner brackets for frame</strong></td>
<td>Mansfield Supplies</td>
<td>4</td>
<td>$20</td>
</tr>
</tbody>
</table>

**Total** $822.4 + shipping
## Paint Cap Remover

<table>
<thead>
<tr>
<th>Parts</th>
<th>Companies</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Case</td>
<td>Polycase</td>
<td>$5.00</td>
</tr>
<tr>
<td>Plastic Clear Clamp</td>
<td>US Plastic</td>
<td>$2.44</td>
</tr>
<tr>
<td>Acrylic Sheet 12” x 12” x 1/8” (.118) Thick. Item No.44290</td>
<td>US Plastic</td>
<td>$7.11</td>
</tr>
<tr>
<td>Plastic Sheets</td>
<td>US Plastic</td>
<td>$7.11</td>
</tr>
<tr>
<td>(for securing clamp mechanism) HDPE 24” x 48” 1/16” Thick</td>
<td>US Plastic</td>
<td>$10.81</td>
</tr>
<tr>
<td>Plastic Rods</td>
<td>US Plastic</td>
<td>$10.81</td>
</tr>
<tr>
<td>(for cap head)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1” HDPE Rod</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC Adapter</td>
<td>Universal Estore</td>
<td>$4.87</td>
</tr>
<tr>
<td>300mA. The voltage is switchable for 1.5, 3, 4.5, 6, 7.5, 9, and 12V.</td>
<td>Universal Estore</td>
<td>$2.88</td>
</tr>
<tr>
<td>Power Jack</td>
<td>Vetco Electronics</td>
<td>$2.88</td>
</tr>
<tr>
<td>Protoboard</td>
<td>Vetco Electronics</td>
<td>$4.39</td>
</tr>
<tr>
<td>Fiberglass 1.75” x 1.75”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper plated traces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td>Vetco Electronics</td>
<td>$1.49</td>
</tr>
<tr>
<td>SPST-On/Off-2 screws-Model No.379340-Manu.# 54100-BP</td>
<td>Vetco Electronics</td>
<td>$4.50</td>
</tr>
<tr>
<td>DC Motor</td>
<td>Skycraft Parts &amp; Supplies</td>
<td>$4.50</td>
</tr>
<tr>
<td>Electrical components</td>
<td>Mansfield Supplies</td>
<td>$10.00</td>
</tr>
<tr>
<td>Resistors, wires, fuse, fuse holder</td>
<td>Mansfield Supplies</td>
<td>$6.00</td>
</tr>
<tr>
<td>4 rubber feet</td>
<td>Mansfield Supplies</td>
<td>$1.50/each</td>
</tr>
<tr>
<td>Epoxy Glue</td>
<td>Mansfield Supplies</td>
<td>$1.84</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$61.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ shipping</td>
</tr>
</tbody>
</table>
### 7.2 Timeline

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Paint Cap Remover</td>
<td>4 wks</td>
<td>8/27/2007 8:00</td>
<td>9/21/2007 17:00</td>
</tr>
<tr>
<td>2 Preparing the parts</td>
<td>5 hrs</td>
<td>8/31/2007 8:00</td>
<td>8/31/2007 14:00</td>
</tr>
<tr>
<td>3 • Open up all part packages</td>
<td>1 hr</td>
<td>8/31/2007 8:00</td>
<td>8/31/2007 9:00</td>
</tr>
<tr>
<td>4 • Count all parts to make sure everything is accounted for</td>
<td>1 hr</td>
<td>8/31/2007 8:00</td>
<td>8/31/2007 9:00</td>
</tr>
<tr>
<td>5 • Verification that the correct parts have been received and if the wrong parts have been received, fill out the necessary paperwork to return them</td>
<td>1 hr</td>
<td>8/31/2007 8:00</td>
<td>8/31/2007 9:00</td>
</tr>
<tr>
<td>6 • Divide all the parts into similar categories</td>
<td>1 hr</td>
<td>8/31/2007 8:00</td>
<td>8/31/2007 9:00</td>
</tr>
<tr>
<td>7 • Take the exact measurements of all parts</td>
<td>1 hr</td>
<td>8/31/2007 8:00</td>
<td>8/31/2007 9:00</td>
</tr>
<tr>
<td>8 Design the circuit</td>
<td>5 hrs</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 14:00</td>
</tr>
<tr>
<td>9 • Lay out the protoboard and circuit components</td>
<td>29 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:29</td>
</tr>
<tr>
<td>10 • Following the circuit diagram, insert each resistor</td>
<td>29 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:29</td>
</tr>
<tr>
<td>11 • Insert the switch</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>12 • Insert the fuse</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>13 • Attach the power jack</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>14 • Using a digital voltmeter, test the voltage output</td>
<td>1 min</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:01</td>
</tr>
<tr>
<td>15 • Using a digital voltmeter, test the current output</td>
<td>1 min</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:01</td>
</tr>
<tr>
<td>16 • Make sure the amount of voltage coming into the motor is suitable</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>17 • Apply an extremely large amount of current directly through (a replaceable) fuse to test that the fuse works and other components will not be harmed in the event of a power surge</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>18 • Test the motor at different voltages to determine how voltage affects rotational speed and torque</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>19 • Pick a voltage that minimizes RPM but maintains an acceptable torque</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>20 Designing the cap head remover</td>
<td>5 hrs</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 14:00</td>
</tr>
<tr>
<td>21 • Start with a solid plastic rod that is 1 inch in diameter</td>
<td>1 min</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 8:01</td>
</tr>
<tr>
<td>22 • Cut the plastic rod horizontally with a saw to create a 1 inch thick cylinder</td>
<td>30 mins</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 8:30</td>
</tr>
<tr>
<td>23 • Take the cap head and place it on the top of the cylinder</td>
<td>1 min</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 8:01</td>
</tr>
<tr>
<td>24 • With a permanent marker, trace the exact shape of the paint cap onto the top of the cylinder</td>
<td>10 mins</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 8:10</td>
</tr>
<tr>
<td>25 • Bore a 0.217 inch deep hole into the top of the cylinder that is 0.242 inches in diameter</td>
<td>10 mins</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 8:10</td>
</tr>
<tr>
<td>26 • Using a file and a knife, and following the traced shape of the cap, form the plastic to fit exactly over the paint tube cap</td>
<td>3.5 hrs</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 11:30</td>
</tr>
<tr>
<td>27 • Test the cap head remover to make sure it fits over</td>
<td>1 min</td>
<td>9/14/2007 8:00</td>
<td>9/14/2007 8:01</td>
</tr>
</tbody>
</table>
the cap and cannot spin without the cap spinning.

- Bore a small hole in the bottom of the cap head remover (for the shaft of the motor) that is 1/8 inch in diameter and 0.5 inch deep.
- Open a dual-component bottle of strong setting epoxy glue.
- Mix the two separate chemicals of epoxy for 30 seconds.
- Coat the shaft of the motor with epoxy and insert into the cap head.
- Hold in place until the epoxy has set, forming a tight, plastic fit around the shaft.
  - After 24 hours test the strength of the bond. Because the epoxy will become as strong as plastic, it should hold tightly to the shaft of the motor and not allow for any slippage.

**Attaching the circuit to the motor**

- Connect the motor into the circuit.
- Test the speed of the motor as it is regulated through the circuit.
  - Adjust speed if necessary by changing resistors in the circuit or changing the input voltage on the universal adapter.
- Make sure the switch functions properly.

**Building the Plastic Box**

- Drill a 0.7 inch hole in the center of the plastic box for the cap head remover.
- Drill a 15/32 inch hole in the side of the box for the switch.
- Drill a hole for the AC power cord.
- Insert the circuit and the motor into the plastic box.
  - Secure the motor to the base of the plastic box using screws.
- Install the switch in the side of the box.
- Connect the power supply.
- Close the plastic box.
  - Make sure all parts fit into the box without causing electrical interference with each other.
  - Out of a sheet of 1/2 inch thick plastic, cut a rectangular “Clamp securing mechanism.”
  - Screw the clamp securing mechanism to the top of the plastic box.
  - Attach the rubber feet to the bottom of the plastic box.

**Prepare the Monitor Lift**

- Open up all part packages.
  - Count all parts to make sure everything is accounted for.
<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Time</th>
<th>Start Date 1</th>
<th>Start Time 1</th>
<th>End Date 1</th>
<th>End Time 1</th>
<th>Start Date 2</th>
<th>Start Time 2</th>
<th>End Date 2</th>
<th>End Time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>Verify that the correct parts have been received and if the wrong parts have been received, fill out the necessary paperwork to return them</td>
<td>1 hr</td>
<td>9/28/2007 8:00</td>
<td>9/28/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Divide all the parts into similar categories</td>
<td>1 hr</td>
<td>9/28/2007 8:00</td>
<td>9/28/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>Take the exact measurements of all parts</td>
<td>59 mins</td>
<td>9/28/2007 8:00</td>
<td>9/28/2007 8:59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Obtain an 80 lb weight from a recreational facility to simulate the monitor</td>
<td>1 min</td>
<td>9/28/2007 8:00</td>
<td>9/28/2007 8:01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td><strong>Designing the descending platform</strong></td>
<td>10 hrs</td>
<td>10/5/2007 8:00</td>
<td>10/8/2007 10:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Drill two holes in each of the two top plates for the PVC guide tubes</td>
<td>30 mins</td>
<td>10/5/2007 8:00</td>
<td>10/5/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>Drill two holes in each of the two top plates for the top of the dashpot strokes</td>
<td>30 mins</td>
<td>10/5/2007 8:00</td>
<td>10/5/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Cut 4 small PVC sections for the guide tubes</td>
<td>1 hr</td>
<td>10/5/2007 8:00</td>
<td>10/5/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Bore a small groove into the tubes to fit into the metal plates</td>
<td>1 hr</td>
<td>10/5/2007 8:00</td>
<td>10/5/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>Insert the tubes into the top of the two plates</td>
<td>1 hr</td>
<td>10/5/2007 8:00</td>
<td>10/5/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>Secure the tubes to plates with brackets</td>
<td>1 hr</td>
<td>10/5/2007 8:00</td>
<td>10/5/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>Weld the two top plates to the two side frames</td>
<td>1 hr</td>
<td>10/12/2007 8:00</td>
<td>10/12/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>Weld the side frames to the main platform</td>
<td>1 hr</td>
<td>10/12/2007 8:00</td>
<td>10/12/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Secure the tubes to plates with brackets</td>
<td>1 hr</td>
<td>10/12/2007 8:00</td>
<td>10/12/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>Install a triangle bracket on all right angle corners of the system for extra stability</td>
<td>30 mins</td>
<td>10/12/2007 8:00</td>
<td>10/12/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>Drill holes for tie-down strap</td>
<td>30 mins</td>
<td>10/12/2007 8:00</td>
<td>10/12/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>Drill a hole in the center of the backside of the descending platform for the wires to be threaded through</td>
<td>30 mins</td>
<td>10/12/2007 8:00</td>
<td>10/12/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>74</td>
<td><strong>Designing the bottom platform</strong></td>
<td>5 hrs</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 14:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Make sure the bottom platform stays flat and balanced on the top of the laboratory table</td>
<td>30 mins</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Bore 4 divots in the corners of the bottom platform for the guide bars</td>
<td>30 mins</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>Drill 4 holes near the corners for the bottom of the dashpots</td>
<td>30 mins</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>Insert the guide-bars into their respective divots</td>
<td>30 mins</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>Weld the guide-bars to the platform</td>
<td>1 hr</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Insert the bottom of the dashpot into their holes</td>
<td>30 mins</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>Secure the dashpot to the platform with metal brackets</td>
<td>1 hr</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 9:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>Secure the bottom platform to the laboratory table using two metal clamps</td>
<td>30 mins</td>
<td>10/19/2007 8:00</td>
<td>10/19/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>83</td>
<td><strong>Designing the springs and the guide bars</strong></td>
<td>5 hrs</td>
<td>10/26/2007 8:00</td>
<td>10/26/2007 14:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>Ensure that the guide bars are in the correct location to match up with the guide tubes of the descending platform</td>
<td>30 mins</td>
<td>10/26/2007 8:00</td>
<td>10/26/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>Slide the four springs around each of the four guide bars</td>
<td>30 mins</td>
<td>10/26/2007 8:00</td>
<td>10/26/2007 8:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Duration</td>
<td>Start Date</td>
<td>End Date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------</td>
<td>------------</td>
<td>-----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>•Put the descending platform over the guide bars and springs</td>
<td>1 hr</td>
<td>10/26/2007</td>
<td>10/26/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>•Apply weight/force to the descending platform so it compresses the springs partially</td>
<td>1 hr</td>
<td>10/26/2007</td>
<td>10/26/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>•Put metal cap on the top of the rod to stop the platform from ever extending past the top of the bars</td>
<td>1 hr</td>
<td>10/26/2007</td>
<td>10/26/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>•Weld the metal cap to the top of the platform</td>
<td>1 hr</td>
<td>10/26/2007</td>
<td>10/26/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td><strong>Designing the dashpots</strong></td>
<td>5 hrs</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>•Ensure that the dashpots are in the correct location to match up with the holes in the top plates of the descending platform</td>
<td>30 mins</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>•Release pressure from the dashpots to allow them to slide freely</td>
<td>30 mins</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>•Extend the strokes completely</td>
<td>30 mins</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>•Slide the strokes through the hole in the top plates</td>
<td>30 mins</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>•Secure the top of the stroke to the top plate by tightening the nuts</td>
<td>1 hr</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>•Weld the stroke to the top plate</td>
<td>1 hr</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>•Check to make sure are at a 90 degree angle</td>
<td>30 mins</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>•Check to make sure the strokes slide freely</td>
<td>30 mins</td>
<td>11/2/2007</td>
<td>11/2/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>•Put the 80 pound weights on the descending platform to simulate the monitor</td>
<td>1 hr</td>
<td>11/9/2007</td>
<td>11/9/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>•Use a screwdriver to tighten the dashpot pressure</td>
<td>1 hr</td>
<td>11/9/2007</td>
<td>11/9/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>•Make sure to match the dashpots with each other</td>
<td>1 hr</td>
<td>11/9/2007</td>
<td>11/9/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>•Dashpots can be kept in synch by turning them all the same degree of rotation. If you turn one a quarter turn, turn them all that much</td>
<td>1 hr</td>
<td>11/9/2007</td>
<td>11/9/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>•Find the perfect equilibrium so that the user has to use little force to lift the monitor</td>
<td>1 hr</td>
<td>11/9/2007</td>
<td>11/9/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>•The remaining weeks are for Thanksgiving Break and Testing of the projects</td>
<td>16 days</td>
<td>11/16/2007</td>
<td>12/7/2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8 TEAM MEMBERS CONTRIBUTIONS TO THE PROJECT

Our team met each week after class (usually on Mondays) to brainstorm and collectively decide on a design for each project. Then the units of the reports were divided up between members, alternating who worked on which parts from week to week. We emailed each other our parts as we finished them and allowed our team members to edit/give feedback on our work before compiling and submitting it. We even created a team email account where we could all upload our pieces, view each other’s work, and store our drafts for future references.

- **Patrick Keating**
  - Patent search and previous work for the proposal
  - Monitor lift subunits for Alternative design 1
  - Subunits for the monitor lift for Alternative design 2
  - Introduction, Realistic constraints, and safety issues for the paint cap remover for alternative design 3
  - Monitor lift subunits with Dan for the optimal design
  - Abstract, conclusion, subunits, additional patent searches for the final design

- **Thuy Pham**
  - Methods for the paint cap remover in the proposal
  - Safety Issues, Life-Long learning and compiled everybody’s pieces for Alternative design 1
  - Safety Issues, Life-long learning and compiled everybody’s pieces for Alternative design 2
  - Monitor lift subunits for alternative design 3
  - Paint cap subunits for the optimal design
  - Subunits, timeline, budget for the final design

- **Daniel Zachs**
  - Executive summary in the proposal
  - Subunits for the monitor lift for Alternative design 1
  - Subunits for the paint cap remover for Alternative design 2
  - Introduction, Realistic constraints, and safety issues for the monitor lift for alternative design 3
  - Monitor lift subunits with Pat for the optimal design
  - Subunits, timeline, budget for the final design

- **Katie Zilm**
Methods for the monitor lift in the proposal
Introduction and Realistic Constraints for Alternative design 1
Introduction and Realistic Constraints for Alternative design 2
Paint Cap remover subunits for Alternative design 3
Edited/updated all parts besides subunits for the optimal design
Subunits, timeline, team member contributions, design alternatives, acknowledgements, specifications, and compiled the report for the final design

9 CONCLUSION

The designs presented to you in this paper are the result of four students’ hours or critical thinking and teamwork. The devices that have been set into motion with the schematics and explanations in this paper will be put to the test next semester as fabrication begins. The needs and safety of the patients was the main concern with regards to the designing of these devices. All aspects of a products development were taken into consideration and thought upon for hours and hours to develop what is our final report.

The monitor lift will rely on the simple spring dashpot mechanisms, as well as their ability to accommodate each others functionality to achieve the lifts main purpose, vertical elevation of the monitor. The previous designs relied on various mechanisms to function including pneumatics, hydraulics, springs alone, and a combination of various apparatus. After careful consideration to the functionality of the device and its potential to be fabricated we settled on the most effective design which was our optimal design. The simple nature of the device allows for a safe and effective means to operate the lift as well as easy continual maintenance. By combining the best features from each of the designs we were able to capitalize on the strengths while weeding out the weaknesses. The hydraulic was deemed to be hard to work with and adjust, as well as expensive. The hydraulic design did not allow for the fully flush resting position of the monitor. However the platform and safety devices on the unit were good and could be salvaged. The next design that worked on springs was not feasible because the springs would not provide either enough help lifting or pushing down, it was one way or the other. However the springs did seem quite functional and were easily implemented into a design. The problem was that if the springs were to help in the lifting they would hinder the compression. Thus we came up with the idea of using dashpots as well as springs. The dashpots would be able to make up where the springs lacked.

As a result of this trial and error many kinks were worked out as well as many functional designs were discovered. Our optimal design fits the requirements of the
client and is within our budget that we have to work with. The most important part of the device is that it is safe to operate and at any point of catastrophic failure would pose no threat to human life.

The paint cap removal aid was the second project that we tackled. This project went through the same design process as the monitor lift. Through the various testing and thinking about designs we were able to compile all the good ideas from the three designs and combine them into our optimal design. As of this moment the design fits all the necessary guidelines and looks to be a great product for the application it is intended for. Our design progressed from a hinge system with a faulty clamping device to an easily operational device that accommodates the ever changing size of the paint tube. The great thing about our device is that it requires little effort on the part of our client. The cap remover allows for the easy placement of the tube into the holding area and then the safe and effective way of removing the cap. The same standards were held as with the monitor lift when it came to constraints, budget, safety, and functional effectiveness. The time that was put into the planning of the project was immense but as a result will produce an effective marketable product that will help many lives.

With regards to our two projects it is important to see the individual parts that go into the creation of the whole piece. Without taking into consideration the minute details all the hard work that went into the major components could be put in jeopardy. The process of creating a device from scratch has demonstrated to us the ever present nature of life long learning and how much of an impact it has on every aspect of our lives.

10 REFERENCES

Subunits:


Paper Body:

11 ACKNOWLEDGEMENTS

We would like to thank our sponsor Dr. Brooked Hallowell, not only for giving us this opportunity but also for her enthusiasm and feedback.

Thanks to Dr. John Enderle for his constructive criticism and advising throughout the design process.

Thanks to Bill Prueschner for his advice and feedback on our designs throughout the entire project. His knowledge of materials and mechanical devices has been very helpful.

12 Appendix

12.1 Updated Specifications

Monitor Lift

As described in earlier sections of this report, the monitor lift must be able to lift an 80 lb monitor from approximately desk height, up vertically 12 inches. The lift is
being designed so that it can be used in a neurolinguistics laboratory at the University of Ohio. It will be used in conjunction with an eye-tracking device to monitor and record eye movements of patients with neurological disorders in response to stimuli. The device is to be used in a laboratory/clinical setting so it must be safe and must not be distracting to patients. An eye-tracking device is placed underneath the monitor lift when it is raised off of the desk so the lift must accommodate for this by having enough open space underneath it when raised. While there are monitor lifts currently on the market, this lift must be able to accommodate a bulkier, heavier monitor than most are designed to handle. The need for it to have space for storage underneath it when raised is also unique. It must sit upon the desk but not be permanently fixed to it, and the desk cannot be modified in any way.

Mechanical Parameters
  Adjustable height
    Max. height  at least 12”
    Min height   no more than 2-3”
  Portability  no permanent fixation
  Stability
  Noise level during operation  low
  Minimum Load  100 lb
  Footprint 10”x12” clear area when raised
  Execution speed min-max height in 1 min or less
  Manual Force for Operation Maximum force 15 lbs
  Low wear
  Platform minimum 20”x18”
  Direction movement up, down
    max 5” any direction not vertical
  Operating Temp  -20 to 600 F
  Storage Temp  -20 to 300 F
  Storage sits on top of a laboratory table
  Weight light enough to be held by a table

Aesthetic Parameters
  Nondistracting
  Keep wires from user’s sight

Paint Cap Remover
  The paint cap remover is being designed to remove the caps from paint tubes. There are no products on the market for this specific application at the moment. The need for a paint cap remover has been found by our client: a painter who has
multiplesclerosis. This degenerative disease makes it difficult for him to perform this simple task. The paint cap remover must be able to automatically remove the paint cap from the specific type of paint tube that this client prefers to use. It must be able to do this without requiring the user to apply any significant amount of strength in any way, and must not require the user to use more than one hand since he only has use left in one of them. It cannot puncture the tube since the client will not use an entire tube of paint the first time he opens it, and the device must have a long operating life under frequent use.

### Electrical Parameters

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Torque</td>
<td>2-10 lb-in</td>
</tr>
<tr>
<td>RPM</td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
</tr>
</tbody>
</table>

Power Source: frequent-continuous operation life of 6 months minimum

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuse</td>
<td></td>
</tr>
<tr>
<td>Switch Size</td>
<td>0.5”x0.5” min</td>
</tr>
<tr>
<td>Force to operate</td>
<td>minimal~ 0.25 lb max</td>
</tr>
<tr>
<td>Execution time</td>
<td>40 sec max</td>
</tr>
<tr>
<td>Resistors</td>
<td></td>
</tr>
</tbody>
</table>

### Mechanical Parameters

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit size</td>
<td>min 2”x2”x1”</td>
</tr>
<tr>
<td>Specificity</td>
<td>fit Gumbacher brand 1.25oz tubes</td>
</tr>
<tr>
<td>User ability</td>
<td>cannot use more than 1 hand</td>
</tr>
<tr>
<td>Strength level</td>
<td>low</td>
</tr>
<tr>
<td>Dexterity level</td>
<td>low</td>
</tr>
<tr>
<td>Stability</td>
<td></td>
</tr>
<tr>
<td>Efficient</td>
<td></td>
</tr>
</tbody>
</table>

### 12.2 Purchase Requisition Forms

Refer to the attachments.
PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

<table>
<thead>
<tr>
<th>Date:</th>
<th>April 20, 2007</th>
<th>Team #</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name:</td>
<td></td>
<td>Total Expenses:</td>
<td></td>
</tr>
<tr>
<td>Ship to:</td>
<td>University of Connecticut</td>
<td>Lab Admin only:</td>
<td></td>
</tr>
<tr>
<td>Attn:</td>
<td>Biomedical Engineering</td>
<td>FRS #</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U-2247, 260 Glenbrook Road</td>
<td>Student Initial Budget</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storrs, CT 06269-2247</td>
<td>Student Current Budget</td>
<td></td>
</tr>
<tr>
<td>Project Name:</td>
<td>Monitor Lift</td>
<td>Project Sponsor</td>
<td></td>
</tr>
</tbody>
</table>

**ONLY ONE COMPANY PER REQUISITION**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC 041GG 13</td>
<td>Compression Spring</td>
<td></td>
<td>28</td>
<td>115.92</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

Comments

Price Quote: $0.00

Vendor Accepts Purchase Orders?

Yes or No: Lee Spring

Vendor: Lee Spring

Address: 245 Lake Avenue
          Bristol, CT 06010

Phone: (888-777-4647)

Contact Name: General Sales

File Name: Total: $115.92

Shipping: $0.00
**PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB**

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

| Date: | April 20, 2007 |
| Team #: | 4 |
| Total Expenses: | |

**Ship to:**

University of Connecticut  
Biomedical Engineering  
U-2247, 260 Glenbrook Road  
Storrs, CT 06269-2247

**Attn:**  

**Project Name:** Monitor Lift

**ONLY ONE COMPANY PER REQUISITION**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>7075T6</td>
<td>Aluminum Sheet</td>
<td>1</td>
<td>1</td>
<td>$2.40</td>
<td>$2.40</td>
</tr>
</tbody>
</table>

**Comments**

**Price Quote**  

**File Name:**  

**Yes or No**  

**Vendor Accepts Purchase Orders?**  

**Vendor:** Aaluminum Sheet & Wire

**Address:**  

26 Colvin Crescent  
Thornhill Ontario Canada L4J 2N8

**Phone:** (905)764 2245

**Contact Name:** General Sales

**Lab Admin only:**

<table>
<thead>
<tr>
<th>FRS #</th>
<th>Student Initial Budget</th>
<th>Student Current Budget</th>
<th>Project Sponsor</th>
</tr>
</thead>
</table>

**Authorization:**

**File Name:**  

**Total:** $2.40

**Shipping:** $0.00

**Price Quote:**

**Files:**

**Yes or No:**

**Vendor Accepts Purchase Orders?**

**Vendor:** Aaluminum Sheet & Wire

**Address:**  

26 Colvin Crescent  
Thornhill Ontario Canada L4J 2N8

**Phone:** (905)764 2245

**Contact Name:** General Sales

**Authorization:**
Instructions: Students are to fill out boxed areas with white background.
Each Vendor will require a different purchase requisition.

<table>
<thead>
<tr>
<th>Date:</th>
<th>April 20, 2007</th>
<th>Team #</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Expenses:</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Ship to:</td>
<td>University of Connecticut</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomedical Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U-2247, 260 Glenbrook Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storrs, CT 06269-2247</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab Admin only:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRS #</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Initial Budget</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student Current Budget</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attn:</th>
<th></th>
<th>Project Sponsor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name:</td>
<td>Monitor Lift</td>
<td></td>
</tr>
</tbody>
</table>

**ONLY ONE COMPANY PER REQUISITION**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>R 438</td>
<td>Stainless Steel Round Bar</td>
<td>1</td>
<td>4</td>
<td>$14.64</td>
<td>$58.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments

Price Quote: [ ] Yes or No [ ] Vendor Accepts Purchase Orders?

Vendor: Metals Depot

Address: 4200 Revilo Road
          Winchester, KY 40391

Phone: 1-859-745-2650

Contact Name: General Sales

Authorization:
Each Vendor will require a different purchase requisition

<table>
<thead>
<tr>
<th>Date:</th>
<th>Team #</th>
<th>Total Expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 20, 2007</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

| Student Name:       |        |                |

<table>
<thead>
<tr>
<th>Ship to:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Connecticut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomedical Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-2247, 260 Glenbrook Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storrs, CT 06269-2247</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Attn:                |        |                |

<table>
<thead>
<tr>
<th>Project Name:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor Lift</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| FRS #                |        |                |

<table>
<thead>
<tr>
<th>Vendor:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mansfield Supplies Co.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Address:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1527 Storrs Rd.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mansfield Connecticut, 06250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phone:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(860) 429-2990</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contact Name:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>General Sales</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Comments              |        |                |

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/16&quot; PVC tubing</td>
<td>1</td>
<td>1</td>
<td>$2.00</td>
<td>$2.00</td>
<td></td>
</tr>
<tr>
<td>Metal Corner Brackets for Frame</td>
<td>1</td>
<td>4</td>
<td>$5.00</td>
<td>$20.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shipping</th>
<th>Total: $22.00</th>
</tr>
</thead>
</table>

Vendor Accepts Purchase Orders: Yes

Price Quote File Name: 

Authorization: 

108
Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

<table>
<thead>
<tr>
<th>Date:</th>
<th>April 20, 2007</th>
<th>Team #</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name:</td>
<td></td>
<td>Total Expenses</td>
<td></td>
</tr>
<tr>
<td>Ship to:</td>
<td>University of Connecticut</td>
<td>Lab Admin only:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomedical Engineering</td>
<td>FRS #</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U-2247, 260 Glenbrook Road</td>
<td>Student Initial Budget</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storrs, CT 06269-2247</td>
<td>Student Current Budget</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attn:</th>
<th>Project Sponsor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Name:</th>
<th>Monitor Lift</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ONLY ONE COMPANY PER REQUISITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalog #</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>2K240</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Price Quote</th>
<th>Shipping</th>
<th>Total:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.00</td>
<td>$0.00</td>
<td>$601.92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comments</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>File Name:</th>
<th>Vendor Accepts Purchase Orders?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes or No</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Authorization:
### PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

| Date:          | April 20, 2007 |
| Student Name:  |               |
| Ship to:       | University of Connecticut |
|                | Biomedical Engineering |
|                | U-2247, 260 Glenbrook Road |
|                | Storrs, CT 06269-2247 |
| Attn:          |                |
| Project Name:  |                |

**ONLY ONE COMPANY PER REQUISITION**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>44290</td>
<td>Acrylic Sheet 12&quot; x 12&quot; x 1/8&quot; (.118) Thick</td>
<td>1</td>
<td>$2.44</td>
<td>$2.44</td>
<td></td>
</tr>
<tr>
<td>42585</td>
<td>HDPE 24&quot; x 48&quot; 1/16&quot;</td>
<td>1</td>
<td>$7.11</td>
<td>$7.11</td>
<td></td>
</tr>
<tr>
<td>46164</td>
<td>1&quot; HDPE Rod</td>
<td>1</td>
<td>$10.81</td>
<td>$10.81</td>
<td></td>
</tr>
</tbody>
</table>

**Comments**

<table>
<thead>
<tr>
<th>Price Quote</th>
<th>Shipping $7.59</th>
<th>Total: $27.95</th>
</tr>
</thead>
</table>

**Vendor:** United States Plastic Corp.

**Address:** 1390 Neubrecht Rd. 
Lima, Ohio 45801-3196

**Authorization:**
PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

<table>
<thead>
<tr>
<th>Date:</th>
<th>April 20, 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name:</td>
<td></td>
</tr>
<tr>
<td>Ship to:</td>
<td>University of Connecticut</td>
</tr>
<tr>
<td>Team #</td>
<td>4</td>
</tr>
<tr>
<td>Total Expenses</td>
<td>$15.93</td>
</tr>
</tbody>
</table>

**Ship to:**

Biomedical Engineering
U-2247, 260 Glenbrook Road
Storrs, CT 06269-2247

FRS #
Student Initial Budget
Student Current Budget
Project Sponsor

<table>
<thead>
<tr>
<th>Attn:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name:</td>
<td></td>
</tr>
</tbody>
</table>

**ONLY ONE COMPANY PER REQUISITION**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>44061</td>
<td>Philips USA PH-62061 Universal AC Adapter</td>
<td>1</td>
<td>$4.87</td>
<td>$4.87</td>
<td></td>
</tr>
</tbody>
</table>

**Comments**

Price Quote: $11.06

<table>
<thead>
<tr>
<th>File Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes or No</td>
<td></td>
</tr>
<tr>
<td>Vendor Accepts Purchase Orders?</td>
<td></td>
</tr>
</tbody>
</table>

**Vendor:**
Universal Estore

**Address:**
UNIVERSESTORE.COM

Authorization:
PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB

Instructions: Students are to fill out boxed areas with white background
Each Vendor will require a different purchase requisition

<table>
<thead>
<tr>
<th>Date:</th>
<th>April 20, 2007</th>
<th>Team #</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ship to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Connecticut</td>
<td>Biomedical Engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-2247, 260 Glenbrook Road</td>
<td>Storrs, CT 06269-2247</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attn:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Name:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ONLY ONE COMPANY PER REQUISITION**

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK1159</td>
<td>0-24VDC Motor</td>
<td>1</td>
<td>$4.50</td>
<td>$4.50</td>
<td>$4.50</td>
</tr>
</tbody>
</table>

**Comments**

- Price Quote: $0.00
- Shipping: $8.20
- Total: $12.70

**Vendor:** Skycraft Parts & Surplus
**Address:** 2245 West Fairbanks Ave.
**Winter Park, FL 32789**

**Authorization:**
**PURCHASE ORDER REQUISITION - UCONN BME SENIOR DESIGN LAB**

**Instructions:** Students are to fill out boxed areas with white background

Each Vendor will require a different purchase requisition

---

**Date:**

**Student Name:**

**Team #**

**Total Expenses** $18.38

**Ship to:** University of Connecticut

Biomedical Engineering

U-2247, 260 Glenbrook Road

Storrs, CT 06269-2247

**Attn:** Project Sponsor

**Project Name:**

---

### ONLY ONE COMPANY PER REQUISITION

<table>
<thead>
<tr>
<th>Catalog #</th>
<th>Description</th>
<th>Unit</th>
<th>QTY</th>
<th>Unit Price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH-12-603</td>
<td>Protoboard Fiberglass 1.75&quot; x 1.75&quot; QTY: 2</td>
<td>1</td>
<td>$4.39</td>
<td>$4.39</td>
<td></td>
</tr>
<tr>
<td>PH-P209</td>
<td>2.1mm DC Jack</td>
<td>1</td>
<td>$2.88</td>
<td>$2.88</td>
<td></td>
</tr>
<tr>
<td>PH-30-10005</td>
<td>SPST Mini Toggle Switch w/leads</td>
<td>1</td>
<td>$1.49</td>
<td>$1.49</td>
<td></td>
</tr>
<tr>
<td>CES-ZGMAFW</td>
<td>GMA Fuse Holder</td>
<td>1</td>
<td>$0.69</td>
<td>$0.69</td>
<td></td>
</tr>
</tbody>
</table>

---

**Price Quote**

**File Name:**

**Shipping** $7.05

**Total:** $16.50

---

**Vendor Accepts Purchase Orders?**

**Vendor:** Vetco Electronics

**Address:**

12718 Northup Way - Suite 100

Bellevue, WA 98005

**Phone:** 425-641-7275

**Contact Name:**

**Authorization:**

---