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

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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 the linear actuator and the guide rails. 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 affect one’s 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 the body of the paint tube which is held by the tube holder. The motor will spin at a slow rate allowing for the tube to be placed inside the tube holder, 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 ones 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 ones 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.

Patent #5,732,919 A Stowable Monitor Lift Apparatus: January 13, 1997 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 the 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.
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.
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.

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 80 lbs (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 $\cos(45) \cdot 355.642$ 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.
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.

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.

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.

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.

![Figure 2d](image)

Figure 2d- View of attachment. Aerial and side views are shown to get an idea of how attachment will occur.
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 2e- The monitor lift middle functioning (moving) subunits are seen in maximum and minimum positions](image)

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.

Oil Paint Cap Remover
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.
The platform again 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.

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 2g- Descending Platform
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.

![Figure 3a - An overview of the monitor lift.](image)

**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 maximum extension and retraction](image)

**Figure 3c – Left: Maximum extension; Right: Maximum retraction**

A) Steel plate  B) Sliding frame with 3 members B1, B2, and B3.  C) Slot  D) Pins  E) Spring.  
F) Body  G) Weld

### 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.

![Linear Pneumatic Slide - HBT15](image)

**Figure 3d – The Linear Pneumatic Slide - 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 80lbs + 4.76lbs = 84.76lbs, 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.

Figure 3e – the bottom tool plate and dowel pin holes

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](image)

**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.
2.2.2 Subunits

Monitor Lift

The Monitor lift is a device that is to be implemented into an Ohio State University Neurolinguistics laboratory. There is no current device within the laboratory that can move the monitors they test with. They require that a device be created that will raise a 27 inch flat panel monitor 12 inches off of the table surface and then back down. This device must allow for the complete resting of the bottom of the monitor with the desk as this is crucial for their studies. The monitor lift must be able to lift the monitor with no hesitation as well as with ease in the event of any load or change of monitor. The device must be controlled by a switch that has the options for vertical motion in both directions. The monitor lift must have the ability to stop at any position and either continue in its original motion or reverse directions. The lift must also be safe at its highest position as well as at it lowest. The lift should not bind and should provide solid controlled vertical motion of the monitor. Below is a picture of the main power component of the monitor lift, the linear actuator. This along with the frame will provide the necessary motion and stability that will allow for the safe and effective movement of the monitor lift.
Figure 1.1- Main working component of lift (linear actuator)

Overall Image
Many constraints had to be met when choosing a base platform to house the entire monitor lift and all its subunits. We needed a material that was heavy enough to withstand the constant repetitive motion of the monitor lift as well as support the various loads applied in static position as well as in motion. This platform had to be sturdy enough to provide a good base for all the working components of the device while at the same time be light enough that it will not hinder the relocation and support of the finished product. We initially thought that steel would be a good choice but upon locating a piece and finding out how much it would weigh we abandoned that idea and searched for a new piece of metal. A large piece of 1/8 inch aluminum was located and was thought to provide a sturdy enough base for the monitor lift while still keeping the weight of the overall project down. The piece was 3X4 feet and was later cut down to a piece that was 2X2 ft. The 2X2 piece was then brought back to the laboratory and measured for accuracy and was mocked up with various
parts. The 2 foot depth allows for support of all the moments that the device will experience. We calculated that this size piece would allow for the mounting of all the subunits behind the center line thus preventing any real forward flipping motion. With this piece of aluminum we would be able to mount all the subunits on the rear of the platform and thus allow for adequate support of any forward flipping moments as well as any backward moments that would not be a problem if the rest of the subunits did not extend past the back of the plate. The figure below shows the monitor lift aluminum base plate with the HDPE polymer piece attached. This was the very beginning of the project and is essentially the foundation of which the rest of the project would be built. Without the proper base the rest of the project would not be successful and would not function properly. It was important to see past the initial phase and into the later steps when choosing the material and the size. We had to consider how the plate would accommodate the other subunits and how they would be affixed. Another important component would be the idea of the environment this piece will be in and how the material will react. This is an indoor environment and the monitor will not see any harsh or varying environments but still we chose a non corrosive material to stand the test of time. This material is also strong enough that it will not flex under reasonable loads as well as it has the ability to support drilling holes as well as affixing nuts and bolts through the device. The thickness of the material is engineered to safety specs in that it will support beyond reasonable conditions that will be implemented in affixing the various subunits to the final piece.

Figure 1.2- Monitor lift aluminum base subunit. Very foundation of project.

The base unit was later cut along the left side to create a more sleek and uniform symmetrical look. The excess aluminum was not being used to affix any subunits and did not provide any real additional support in that it was not preventing any moment from happening unless from the side, which is unlikely would ever happen. The corners of the
aluminum sheet were rounded to create a safer more finished design. The surface of the aluminum was also sanded with 3M paper to do away with the scratches that accumulated as well as any imperfections in the metal. The sanding of the surface gave a uniform look and created a better looking mount for the other subunits.

This base platform then had holes drilled near the back corners of the platform. The holes were to mount the L brackets that were to hold up the guide rails and the actual monitor mounting unit. These holes were done with a drill press and were done using a 5/16 drill bit. Again the material that was chosen for the base was ideal for this type of machining and allowed for clean and precise holes to be drilled.

Another important fact about this base subunit was that it was completely flush with the surface of the table. The nature of our project, its functioning design and implementation in the lab, requires that it be flush with the surface of any flat level table it is placed on. This is not only to project the table from being scratched but also provides a safer, more stable, platform for this device to function. As a result of mounting the linear actuator to the base there were flat head screws protruding from the underside of the device. In order to get these to be flush with the surface the underside holes where any type of flat head screw would be placed, had to be countersunk with an appropriate bit and hand drill. This was done and allowed for a flush overall surface to be maintained after all subunits were attached to the base unit.

1.2.2 Linear Actuator Subunit

Working up from the base the very next essential piece that was attached to the previously talked about base unit, would be the monitor lift. The monitor lift is a linear actuator that was purchased with a 400lb vertical lifting force. This Linear actuator is a simple tube in tube design that allows for the inner tube to move axially. The design is simple in that it relies on the threading of a middle bar that is attached to the inner tube. A stepper motor that is attached to the side of the linear actuator rotates the inner threaded bar and when a nut is held in place it will travel along this rotating bar until it reaches its maximum height and minimum depth. When the bar turns the nut will want to move either up or down along the threads of which it is attached. When the nut is affixed it will not free spin and will transfer this motion to which it is attached, that being the inner tube. This inner tube is allowed to move in a vertical motion and will do so with regards to which way the stepper motor is turning the threads in relation to the nut. The figure below shows an x-ray of the inner workings of the main linear actuator.
Figure 1.3- Inner workings and dimensions of Linear actuator courtesy firgelliauto.com.

The outer encasement of the linear actuator is a hard aluminum cylinder with an attached fully enclosed stepper motor that is encased in a hard dye cast metal. The Linear actuator had internal limit switches that cut the power to the device so that it will not lock down and bind in its maximum and minimum positions. This internal limit switch is activated when the device reaches it limits and cuts it off before the device starts to fight itself in going beyond the maximum and minimum position. This was important in that we did not want the device to lock down and be immobile if it were to reach its highest height or lowest low.

Our linear actuator is a 12V DC motor equipped mounted directly to the linear actuator itself and is completely encased. The device will draw up to 5 amps at its maximum load but we do not foresee it reaching this unless the device gets bound or hung up within itself or as a result from some outside source. The outer tube is a IP43 Aluminum allow that resists denting as well as corrosion and any outside electrical buildup. The linear actuators operating temperature range is from -26 degrees Celsius to 65 degrees Celsius, well beyond what any of the labs will see in which our device will be implemented in. The linear actuator stands 24.88 inches in its lowest setting and 42.88 inches at its maximum height, fully extended (range of motion equaling 18 inches.) Below is the linear actuator that has been described above.
Figure 1.4- Linear actuator subunit.

This subunit was tested the day of arrival. The cord that was attached to the linear actuator was that of a microphone headphone jack. It did contain the means to hook it up to a power supply and test it. We were able to hook up the positive and negative terminals to the jack and then lift the actuator. To lower the actuator we simply reversed the connections made with the jack and lowered it. It was important to find out if the actuator did indeed contain internal limit switches. The way in which this was tested was by bringing the actuator to its maximum and minimum heights to see if it would bind up. If the actuator did not bind up it meant that the limit switch stopped it before it reached that point. We simply attached the actuator to the power supply and ran it until it reached that maximum and minimum point and then continued to run it. The actuator turned itself off before going past its maximum and minimum points. We also had to test to see how well it reversed directions and did this by raising the actuator and then at random points reversing the voltage and then lowering it. If the actuator could reverse direction mid cycle we knew we had the correct machine for our device. The linear actuator was able to do this and later was integrated with the double pole subunit switch.

1.2.3 Monitor Lift/ Base Unit Larger Subunit (attachment)
The two previous subunits, the linear actuator and the base platform, are all subsets of the larger combination of the two. The linear actuator base unit component is a crucial subunit of the whole device as it will support most of the load and will be the main functioning unit in the elevation of the monitor. The Linear actuator base was an odd design and did not allow for standard mounting to any type of flat surface. The bottom of the linear actuator directly below the vertical axis line of the tubes was a metal protrusion that had a hole in the middle of it. This was a coated metal that was of a different shape and strength than the other part of the device. This extension is a subunit of the linear actuator itself but is crucial in integrating the two subunits to create the larger Base/Actuator Subunit. The way in which the two subunits were mounted to each other was simple in design and provides a very suitable, safe and effective means to joining the two pieces. Below is a figure of the extension piece that will mount the actuator to the base.

Figure 1.5- Bottom fixture of linear actuator.

Since the aluminum base was too thin we could not employ the machining technique to mount this directly to the metal base plate. Instead we mounted the actuator to a HDPE polymer subunit that was flat on both sides and then could be mounted indirectly to the aluminum base through the direct mounting of the polymer to the metal. Pictured below is a visio drawing of the means in which the actuator base is to be mounted to the HDPE base block.
This HDPE subunit integrates the whole working piece of the linear actuator to the actual base itself. This HDPE polymer is a polyethylene thermoplastic that is very dense and does not deform well. The reason it was chosen was because it offered the desired support coupled with the workability and machining capabilities we needed. Pictured above one can see that the plastic can be drilled through and was drilled through in the four corners of the top. These clearance holes were then carried through to the aluminum base, long screws with bolts were carried through thus linking the base aluminum unit to the HDPE which will then be attached to the linear actuator. A hole was then drilled through perpendicular through the side in line with the actuator mounting hole so that the linear actuator will face the open longer base side of the platform. This hole was then joined up with a hole coming from the topside down into the material. This hole allows for the placement of the protruding piece seen in figure 1.5. The linear actuator is placed in the pressure fit hole from above. The hole in the linear actuator bottom mounting subunit is then lined up with the perpendicular hole that was drilled from the side. A rod representing another subunit piece is then inserted through the hole from the side and then through the hole of the linear actuator bottom piece. This prevents the pulling out of the linear actuator as well as any twisting within the HDPE. The tilting motion of the device is prevented by the fact that the bottom of the actuator is square and is flush with the HDPE surface. This cannot pull out at all and thus cannot tilt at all. This completes the creation of the very basic subunit known as the Base/Actuator Subunit. All the other components as well as the working nature of the device rely heavily on the subunit created and picture below in figure 1.7.
The subunit created above provides a means to implementing the structural base of the aluminum sheet to the functional mechanism of the linear actuator. The materials that are used are hand selected for their implementation and provide a very sturdy and useable interface of the lift to work. The subunit described above provides a sleek and efficient means of providing a solid foundation for the rest of the subunits to be attached.

The way in which this was tested was by rocking the upper linear actuator back and forth to note any loosening of the junction point. A hammer was also taken to the material to test the relative hardness of the material. The HDPE was exposed to various temperatures that would never be reached in a laboratory setting, both at the high and low end. The material functioned fine during all the tests and appears to be a suitable material for the application.

1.2.4 Uprights

The creation of the next larger subunit piece will later be implemented onto the platform created as well as attached to the linear actuator. The next subunit created was the upright steel bars that will provide support to the guide rails as well as the lifting unit. These uprights will have to be mounted to the base plate and must also be strong enough to prevent the bending moment of the monitor. With this subunit we could not sacrifice strength for weight, we had to stick with the heavier material so as to provide a good solid foundation for vertical linear motion. We found two hollow square bent steel uprights. These uprights are pictured below in figure 1.8.
This subunit must function two ways. It must first be mounted to the platform and provide a means of integrating the lifting guide subunit with the actuator and the base subunit. The uprights must also be able to accommodate the guide rails and provide a track for the motion to occur. This subunit must be rigid and not collapse or bend under intense load. The more rigid and durable this material is, as well as how well it is mounted onto the base determines how well it will function and how direct and precise the motion of the rest of the machine will be. This subunit is part of a larger unit which is the integration of these uprights to the guide rails that we purchased. One can see that there are smaller holes drilled into this face seen above. This will allow screws to be set through and then into factory pre drilled holes in the guide rails themselves. The connection of these to subunits to create a larger subunit is crucial because the direction of motion is determined by how well these two subunits are connected as well as how level they are connected. If the two are not fused together properly it could result in binding of the machine as well as many other different malfunctions.

The main purpose of the guide rails is to provide a safe, sturdy effective means of mounting the functional guide rails to the base unit/ actuator. The way in which this is
accomplished is by choosing a symmetrical sturdy piece of steel that resembles the shape of the guide rails and is adaptable to them. The uprights are a means to combine the lower subunits to the beginning of the upright vertical lifting piece.

The way in which these uprights was tested was by performing bending tests within a vice in the workshop and noting any changes in shape or characteristics. The uprights did not bend at all and no deformation was noticed. Also a point force test was conducted in which a hammer was taken to various areas of the metal to test its impact force as well as how hard it was. The material used passed all the tests we feel were needed to justify its use and implementation as a structurally crucial part of our monitor lift design.

1.2.5 Guide Rails

The guide rails are a crucial subunit for the device in that they are the very basic means of lifting the monitor in a controlled structured fashion. Without the guide rails there would not be a uniform constant direction and rate of motion. The monitor would be all over the place and any slight force imposed on the device would throw off the whole upper subunit and could be catastrophic. The guide rails provide a good means of keeping the monitor in plane during the lifting phase of the devices operation. The guide rails are mounted so that they face inward and are perpendicular to the linear actuator. In mounting the guide rails this way they prevent the bending forward motion that the monitor will stress on the device. The function of the guide rails greatly reduces the bending moment of the device and focuses the forces in a more uniform and normal to the ground fashion on the linear actuator. The linear actuator was designed to lift objects directly overhead in plane with the y axis of lifting. Our monitor imposes a moment on the linear actuator that causes the actuator arm to want to bend in the direction of the monitor. The guide rails offer support in that direction because of how they are mounted and the forces that the material and function of the rails provides in that direction. Below is a picture of the guide rails.

![Figure 1.9- guide rails that are to be mounted onto the uprights. As seen in the above picture the guide rail offers a wide range of motion due to their telescoping mechanism of action.](image)

The guide rails above work in a simple manner of action. The rails are a system of three subunits that make up the whole. The first piece of metal is flat and bent on the edges
to hold within it the second and third subunit of the guide rails. The second and third piece within the initial piece are smaller and telescope within the initial piece. The third piece telescopes within the second piece, which then telescopes into the third piece. The mechanism by which they are able to slide over each other is a system of ball bearings. These ball bearings which are present along the interface of subunit one and two and then subunit two and three allow for the reduction of friction along these two joining surfaces. The rolling nature of the bearings allows for the movement of each of the subunits over one another thus allowing each piece to slide over one another and results in a 16 inch range of motion.

The guide rails offer tremendous support when subunit three has a force exerted against that of subunit two and three. This is because the material itself is pressing against the next. When the subunits are pulled out towards the face there is little support and the subunits separate from each other. When the subunits have a force exerted from the side they offer even more support than the first type of force, thus this is how they were mounted. The guide rails were mounted so that the direction of the greatest force would be in the direction pushing on the sides of the guide rails. Thus the moment of the monitor is greatly reduced and that problem is solved.

The testing of the guide rails was done by applying forces in various directions by hanging weights and noticing any loosening or deformation of the rails. Testing was also done at various stages as opportunities arose. Once the upper subunit was functional the guide rails were indirectly tested as they are a functioning part of the whole upper subunit. As the upper unit progresses it becomes harder to test the individual subunits as the entire unit functions with the help of all the subunits integrated into the device up to that point.

1.2.6 Upright/Guide Rail Integrated Subunit

The next step in creating the larger subunit from the two previous ones was to mount the guide rails to the uprights. The guide rails already had factory drilled holes in them which fit a flat head screw. The flat head screw allowed for the movement of the smaller subunits within the guide rails and did not hinder them. The flat head of the screw was to come through the front side of the guide rails and then into the upright. The uprights had to have holes drilled into them at strategic places that allowed for alignment of the holes with the pre drilled ones found in the guide rails. The guide rails were then affixed to the uprights with the use of threaded bolts which were to pass through the clearance holes on the guide rails themselves and then straight through the holes that were drilled onto the front face of the uprights. The nuts were then fasted tightly on the back side of the uprights thus affixing the guide rails to the uprights in a manner that provides solid safe movement of the rails. This larger subunit then can be affixed to the larger base and thus begins the making of the center body subunit that the monitor will be attached to and then attached to the linear actuator itself. The part of the guide rails that remains stationary is flush with the uprights and has holes of attachment evenly spaced throughout the entirety of that stationary part.
Below is a picture of the holes that were drilled as well as the point of attachment with the flat head screws.

Figure 1.10- Shows attachment of guide rails to the uprights as well as drilled hole placement

In figure 1.11 one can see the guide rail fully extended on upright. The upright will then be attached vertical to the base unit with the help of another L bracket subunit that will be talked about later. Also seen in the picture is a bracket at the top end of the guide rail that will allow for the integration of the T aluminum sheets that will house the mounting bracket and eventually tie in the whole guide rail system with the main lifting system.

Figure 1.12- Guide rail attached and extended to maximum height on the upright. Not pictured is the identical piece that will be mounted opposite this piece and create the interface for the monitor mount and eventually the monitor itself.

1.2.7 L Brackets

A crucial subunit for the mounting of the newly created upright/guide rail subunit is the L bracket in which the uprights, with the guide rails attached, will be permanently affixed to the bottom base plate and will provide a means for constructing the cross member piece and eventually the upright perpendicular piece that ties in everything structurally to
the functionally operation linear actuator. These L brackets are standard 1/8 inch steal that are bent into a 90 degree angle and then have holes drilled in them to affix screws through and eventually bolts. On our steel uprights we have two flat faces that are perpendicular to the plane created by the face that contains the mounted guide rails. These flat faces are where the L brackets will be mounted and attached to the uprights. Once they are attached they will then be attached on the other end to the base plate. The major function of these L bracket subunits is to provide a means to attach the uprights to the base plate and provide structural strength in both the forward and reverse moments, as well as any torsion forces the structure will encounter throughout its daily functioning. Below is a picture of the L bracket as well as how the bolts and screws will be affixed to both the base plate and the uprights.

![L bracket for joining the lower subunit to the uprights/guide rail subunit.](image)

The bottom most part of the L bracket for the ones facing forward was left as is, in that it was not cut or modified. The bolts seen facing up are through the base plate clearance holes that are countersunk and screwed through. Once through the clearance hole of the base plate the bolts then go through the factory drilled holes on the L bracket. The nuts are then tightened down on the bolts and the L brackets are thus affixed to the base plate. The same thing is done for the uprights and one can see in the picture the flat head screw side, the side that would be seen on the underside of the base plate. The torsion that this device will encounter is not enough to cut the bolts and the bending moment will never be enough to bend the actual L brackets. The reason they won’t bend is because there would be compression absorbed by the front two brackets and a tension that would be absorbed by the back two brackets. In the event of a large forward moment, all four brackets would take on a
relatively equal load. The purpose can thus be seen in that the support for the device at the joint of the upright subunit with the base unit is strong enough to maintain a vertical and level platform for this monitor lift to function.

Figure below shows the side view of how the uprights are mounted as well as the other side of how the guide rail is mounted to the upright. The two L brackets can be seen on either side of the upright. Notice that the L bracket in the back is shorter on the leg that is affixed to the base. The L bracket was cut short in order for the placement of the uprights as close to the back of the plate as possible. As a result of cutting off and modifying the L bracket we lost two holes and had to drill another one in so as to not sacrifice any support. The L bracket was cut with a metal saw and the hole was then drilled with the drill press. The bolts were used in the same manner as in the forward facing L brackets. One can see how these brackets will offer support in both the forward and backward moment forces that will be applied. For the two uprights to be separated from the bottom base plate the six forward facing bolts would have to fail and the L bracket pushed through the base metal, as well as the rear facing L bracket bolts to be pulled up through the base. The event of this subunit failing the other two is very unlikely and thus shows the importance of this simple subunit.

Figure 1.13- Shows L bracket subunit and how it is implemented into the fusing of the top and lower main subunits.

The testing of the connection of these subunits was done by manually applying a force in different directions and watching for loosening or deformation. None was observed
in the trials. Later testing was conducted as the upper main subunit came together and the weights could be attached.

1.2.8 Corner Bracket Subunit

The next subunit of the monitor lift is important in integrating the mounting platform to the guide rails. We now have the uprights and the guide rails mounted to the base unit. The linear actuator is also mounted to the base unit. Now we need a way to mount a cross piece of aluminum to the guide rails so they can offer support to the movement of the monitor. The form of these brackets is a simple 90 degree bend that creates two mountable faces. These brackets can be used in a variety of ways and are similar in function to the L brackets. Because the corner brackets are not holding the entire weight of the upper unit they do not have to be as heavy duty as the L brackets that attach the uprights to the base. The function of these corner brackets is to bridge the gap between the horizontal face plate, which will be talked about later, and the uprights that house the guide rails. This cross piece will mount the monitor to it and thus must be able to move. We therefore did not want to mount the corner bracket to the stationary part of the guide rail or the stationary uprights. Therefore the corner bracket must be mounted to the third subunit of the guide rail that offers the greatest amount of movement, as the monitor is to move at least 12 inches. The corner brackets were mounted in a similar way as the guide rails to the uprights. The corner brackets had pre drilled holes in them from factory. We then had to drill corresponding holes into the guide rail subunit and mount that face with nuts and bolts. We then had to drill clearance holes through the cross plate that corresponded to the corner bracket. Nuts and bolts were then used to affix the corner bracket to the cross piece and ultimately link the uprights to the cross member piece which will house the Samsung monitor bracket.

Figure 1.14- Corner bracket seen above mounted to upright and cross piece.
Below is a picture of the corner bracket and how it was mounted to the guide rail. This was before implementation of the aluminum cross piece. One can see that the bolts and screws were used as well as washers to provide ultimate security in their placement and load bearing capability.

The corner brackets were made out of 1/16 inch aluminum and were factory drilled with various mounting holes. The guide rails had holes that corresponded and that allowed for the mounting without hindering the motion of the guide rails themselves. The corner bracket does offer impedance of the moment that will occur if there is any force towards the middle or sides of the whole lift itself. For this subunit to fail the bolts would have to be pulled through the material or the threads would have to be stripped over by the nuts. To test this piece the cross piece was attached and a heavy motor was mounted to the cross piece to test the strength of their attachment and to test the inherent nature of the material.

1.2.9 Aluminum T Piece

This piece is a crucial subunit of the upper components. The previous pieces depicted the power structural supporting half. This piece is a little less supporting and more of a mounting platform and integration piece for the many workings and various areas of the device as a whole. The monitor lift must adapt a monitor to it somehow. The mounting of a monitor is done with the placement of a bracket, which can adapt a monitor to itself, on a flat surface that will move with the actuator. This subunit is the piece that combines the
functional moving part with the structural guiding part. Here is where the linear actuator will indirectly contact the guide rails and support system through the T piece. Without this piece the monitor lift would either be lifted without any guidance or immobile with plenty of guidance and support.

Throughout the course of the project it was evident that aluminum was a good metal to use throughout the device because of its mixture of lightweight as well as high strength properties. The purpose of the T piece is to have a flat surface to mount the monitor bracket too as well as have a plate that will mount to the bare face of the previously mounted corner brackets, which are mounted to the upright/guide rail subunit. This then allows for the connection between the uprights and the monitor itself. Later the T piece will be affixed to the lift completing the major upper subunit of the linear actuator. Below is a picture of the aluminum T piece.

![Figure 1.16- Aluminum T piece consisting of two joined aluminum sheets cut to size.](image)

The aluminum sheets were cut from larger sheets with the metal press cutter. The two pieces then had corresponding holes drilled through them. The holes were lined up with each other and then nuts and bolts joined the two pieces. The subunit itself is simply two pieces of metal but is crucial to the working of the device. The two 9.5 inches of the lower cross piece were attached to the corner brackets that are on the upright/guide rail subunit. The corner bracket was attached in that corresponding holes were drilled in the cross piece
of aluminum and then nuts and bolts were inserted through and the cross piece and was integrated into the lower part of the devices subunit. The material itself is susceptible to slight bending but will never really be exposed to a torsion force. The T piece must only not sheer within itself to be effective. As long as the monitor does not introduce dislocations within the material then the subunit will be effective, and safe. The type of force that will be on the cross piece is a simple pulling force within the material. The material itself is strong enough that a 23 pound monitor will not pull the metal atoms apart. The amount of force needed to rip the material apart from itself would cause more problems elsewhere within the project before this type of catastrophe happened.

The way in which we tested this subunit was to try and pry to the two pieces apart with forces that are above anything that would be experienced by the unit as a whole. Once the project progressed with the other subunits we were able to test the hanging force that it would experience during normal operation. The material itself is rated far beyond any tensile force that could be exerted on it by a monitor of reasonable size. Figure 1.17 shows the T piece on the linear actuator, its attachment will be discussed in a later subunit that deals with the upper part of the project.

Figure 1.17- Shows the T piece connected to the linear actuator.
Looking at the above figure one can see how the T piece will be lifted by the linear actuator. It is evident that when the T piece is lifted so will anything connected to it. The guide rails will help keep the T piece moving in a particular vertical plane, but the main function is to provide a means for the monitor to be mounted to the mechanically functioning unit, the linear actuator. The visio below shows the subunits up to this point and where the monitor lift is after the base is mounted to the uprights and the linear actuator as well as the guide rails mounted to the uprights and the cross piece. It is important now to explain the subunit in which the cross piece is connected to the guide rails which ties in the bulk of the functioning product.
1.2.10 Aluminum T Piece Connection to Guide Rails

The next crucial subunit of the piece which builds directly from the upper major subunit (T piece and actuator) and the lower major subunit (uprights, guide rails, linear actuator mount) is the connection of the two major units. We had to connect the T piece to the guide rails in order to offer only one plane of motion for the linear actuator. The linear actuator itself will only function in the vertical direction but under various loads can stray from this plane due to bending of the components and the material it is made out of. The lower subunit of the monitor lift is structurally rigid in nature because of the materials and allows for limited movements other than that in the direction of interest. Thus this subunit which involves the connection of the T aluminum piece to the uprights through the corner brackets can couple this range of motion of the linear actuator with the rigid base subunits. The mechanism of attachment was simple in that it involved the placement of the nuts and bolts through the various clearance holes that were pre drilled either by factory or by us. The attachment of the pieces was then tested by manually moving the T piece up and down on the guide rails without any attachment to the linear actuator. Once we successfully tested the motion and the range of motion on the new macro unit we then hooked the entire assembly up to the linear actuator and carried on as before when we were testing the linear actuator by itself. This time the actuator was to follow the guide rails without binding or snagging on any workings of the lower sub unit. The test was performed and our machinery passed. The next subunit to describe is the attachment of the T piece to the linear actuator.
1.2.11 Linear Actuator Attachment to T Piece Subunit

It was commented on earlier that the linear actuator was attached to the T piece during the testing of the device, but no information was given as to how. The linear actuator connection to the T piece was simple and involved the use of a simple purchased subunit that is made for our particular linear actuator head. At the top of the linear actuator head there is a slice down the middle of the round tube head. On either side of this hollow slice are two upright walls that contain holes. These holes allow for the insertion of a bolt and a cotter pin. This bolt passes through a purchased piece that allows us to adapt the linear actuator to the T piece. Pictured below is the piece described above.

![Figure 1.20- Shows bracket for mounting T piece to linear actuator.](image)

The bracket is designed to be used in a variety of scenarios and offers us a flat surface to do whatever we want with. The flat surface works out perfectly in that we can mount the flat plat to the flat face of the bracket by the same means of mounting all the other components. Three holes were drilled in the aluminum plate in the corresponding position as the bracket. Bolts were then passed through the holes through the bracket and then fastened by means of nuts. The bracket was then affixed to the linear actuator as it was designed to. The rod seen above passes through both uprights on the linear actuator top piece with the bracket hole in the middle. A cotter pin is then inserted at the other end so that the bar cannot be pulled out through the holes, thus affixing the T piece to the linear actuator. In the picture below is the bracket attached to the top of the linear actuator.
The bracket has approximately a 270 degree range of motion over the linear actuator. We only require that the bracket stay perpendicular to the surface of the base unit. The free movement of the bracket does not matter as it does not have to guide the monitor. The guide rails do all the guiding of the monitor and the free range of motion of the bracket allows for adsorption of any movement errors that may be encountered and inhibits any binding that may occur.

The Bracket was tested and it was determined that the metal at the corner is malleable with a great amount of force. It was determined that that force and in that direction would never be encountered and thus is not a problem. The bracket was tested by attaching the T piece to the bracket while it was attached to the linear actuator. The actuator was then lifted and lowered numerous times to ensure proper functioning. Later testing occurred when we hung the motor from the mount to simulate the presence of the monitor. All tests were passed and the next subunit was encountered.

1.2.12 Monitor Bracket Subunit

The next subunit is the monitor bracket which will hold the monitor to our device. The function of this device is simple, it musts securely hold the monitor in place and must provide a firm attachment to the linear actuator T plate. The model bracket we chose was designed with the Samsung monitor in mind. This is good to know that the monitor will be easily adapted to this mount because we do not have access to the monitor and it will be up to the customer to mount it. Knowing the mount will easily accommodate the monitor we are using will help the consumer mount the monitor in a safe and secure manner. The bracket was mounted by drilling three holes in the T plate that corresponded to the factory holes in the mount. The mount was then secured to the T plate by means of bolts and screws.
that were received with the purchase of the mount. The tests that were performed were done so to prevent any failure of the mechanism. A 23 pound motor was attached to the mount while it was on the linear actuator device. The linear actuator then was raised and lowered in various increments as well as to its maximum and minimum heights. The linear actuator performed without flaw and proved to be a suitable and effective device. Pictured below is the monitor bracket with and without the monitor attached. The second picture depicts the bracket attached to the T piece.

![Mounting bracket with and without monitor attached.](image1)

![Mounting bracket attached to the T piece of monitor lift.](image2)

The mounting bracket was the final piece of the entire top subunit that completes the upper half, which in turn completes the entire structural part as the lower part is complete as well.
1.2.13 Circuitry Subunit

The final subunits of the project consist of the circuitry and how it is housed. The switch that was chosen for this project had to do a couple things. First the switch had to reverse polarity so the linear actuator had the ability to go in two different directions, up and down. And second it had to have three physical positions so that it could have an up, down and neutral off state. We also wanted the switch to automatically go to the off position when not depressed. This meant we needed a switch that was a single throw, meaning that the switch has to be depressed in order to function. When the switch is not depressed the toggle will revert back to the neutral middle position, which is off. This is a safety mechanism that requires an attendant to be present during the entire operation of the device, and thus the device can not be left to its own accord once set in motion. The switch we found is pictured below. The switch itself was tested the day it was received by soldering it as shown and then crudely hooked up to the linear actuator and tested. Through this test we were able to determine which way was up and which way was down. The test went as planned and demonstrated that the switch would work and that it functioned according to the double pole single throw.

Figure 1.24- Double pole single throw switch both unwired (left) and wired (right)

The toggle switch was chosen because of its ease of use and the common knowledge people have regarding the working function of such a switch. The toggle was tested preliminarily by crudely hooking it up to the linear actuator, and then was finally tested after the linear actuator wire was cut and the toggle switch was soldered semi-permanently
to the linear actuator wire. Both tests that were performed resulted in positive working results.

Figure 1.25- Linear actuator double pole single throw toggle switch.

1.2.14 Circuitry Encasement

The next and final subunit of the project was the encasement for the toggle switch. We decided to use a leftover EKG box that provided an easy platform for the use of the switch as well as a tough protective case to house the sensitive circuitry inside. The wires as shown will reverse the polarity of the voltage resulting in a reversal of the direction of the linear actuator. This was tested before as well as on the final project after to make sure that the rewiring and encasement of the switch did not alter anything. The switch was mounted by drilling a hole in the upper encasement and then pushing through the toggle switch. A nut was then tightened down from the outside to ensure that the toggle switch could not be pulled through. The encasement seen below offers great protection and durability for the switch and allows for safe easy use of the device. The wires were fed through a hole and then they were attached to the appropriate terminals on the switch. Before the wires were soldered heat shrunk rubber was placed over so that once the soldered dried the heat shrink could be placed over the exposed metal parts and then secured. This allows for safe operation and prevents any crossing of, or shorting out of, the circuit.
Figure 1.26- EKG box which houses internal circuitry for switch.

The outward cord to the linear actuator was bundled and wrapped with electrical tape. The hole to the opening was also finished with a rubber grommet to secure the wires and give a more finished look.

The tests that were performed both under load and without load, at various heights and currents were all successful and demonstrated the successful integration of all the subunits into macro units and all the macro units into a whole working device.

Paint Cap Remover

2.2.1 An Overview

The design of the paint cap remover must be simple and easy enough for a person with multiple sclerosis to operate. Additional features must be satisfied such as small in size and portable for the ease of relocation of the device. The first prototype does satisfy all of these criteria and is proven working properly. The figure 2.2.1_1 illustrates the overall configuration of the device. All of the components include the clamp with a lever, paint tube holder, motor, motor plate, motor encasement, electronic component, back wall, platform, and the AC adapter. Our main goal is to provide comfort to the client while using the device. The client does not have to use a lot of strength in the arm and hand at anytime during operating the device. A little effort is needed to tighten the cap to the clamp fingers, however, it is only required a very slight push against the lever of the clamp. The paint tube is accessible to be taken in and out manually without any force. A momentary switch button allows the client to twist open the paint tube’s cap in a few second. The device functions upon connect the AC adapter to the wall plug. The AC adapter allows the client to run to device endless and to avoid changing batteries when they are running out. A more clear and detailed description of the device are written in the following sections.
2.2.2 The Base Unit

The base unit is a platform that has to be sturdy to support the entire device. Every components of the device are metal; therefore the base unit needs to be very strong and rigid. The basic unit is made of Aluminum. Aluminum is a soft, lightweight metal that is suitable for our design. It has a very strong corrosion resistance due to its thin surface layer of aluminum oxide that forms when the metal is exposed to air. This layer also prevents the oxidation. Because Aluminum is a good thermal and electrical conductor, seals or additional components that protect the users from in contact with electrical shocks are needed. In addition, Aluminum has a silvery color, which resembles all of the other colors from other components. With a uniform color of silver, the device looks neat and professional.

The dimension of the platform is 7 ¼ inches long x 7 ½ inches wide x 0.5 inches thick. With this dimension, the platform can support the entire device sturdily. The figure 2.2.2_1 shows the image of the platform in front view. The front side of the platform is slanted at 45 degree. The purposes of this slanted side are for a better image and avoidance of pointed corners that can cause unnecessary pain to the users. All of the other corners were filed so
that they are nicely rounded. The original platform was not smooth, handheld orbital finishing belt was used to finely smoothen the surface of the platform. The surface is smooth and shiny after this process.

![Figure 2.2.2_1 – The platform of the paint cap remover](image)

### 2.2.3 Felt discs for Base Unit Stabilization

It is possible that the device will move while it is in operation. To prevent any movement during operation, felt pads are used. These felt pads are adhesive and attachable. Four of these felt pads were attached underneath the platform at each corner. These non-slip felt pads are made of rubber than can prevent movements of the device. Another purpose of having these felt pads is to prevent any interference as the device is being placed on top of any object. The platform is Aluminum and Aluminum is well known as a good conductor, electrical current leakage from surrounding area can be absorbed by our device. These felt pads act as barriers to prevent electrical current transmission. The figure 2.2.3_1 below shows a picture of the felt pads that are being used in the paint cap remover.

![Figure 2.2.3_1 – Felt pads](image)

### 2.2.4 The Device Back Wall

The paint cap remover has a stand up position, where every component is supported by the vertical back wall. This back wall is also made of Aluminum, the same as the bottom
platform. The initial dimension of the back wall was 10.5 inches tall and 3.5 inches wide. The figure 2.2.4_1 bellow shows the back wall how where it will be attached to the bottom platform. The next figure 2.2.4_2 illustrates the mechanism used to attach the back wall to the bottom platform. Three holes were drilled on the bottom of the back wall, and three holes were also drilled through the platform. The top three holes have to be lined up with the other three in the bottom platform. The three screws were inserted from the bottom of the platform; these screws keep the back wall attached to the platform sturdily.

Figure 2.2.4_1 – The back wall in the initial stage

Figure 2.2.4_2 – (Right) Attachment of the back wall to the bottom platform, (Left) The bottom view of the platform after applied the screws.

There is no need of countersink the bottom platform due to the simple shape of the three screws. These screws do not have any head; therefore they are totally fitted within the
bottom platform. The device is proven to be smooth and leveled after these screws were inserted in.

In the final stage, the back wall was cut in an L shape as shown in the figure 2.2.4_3 below. The cutoff area was 1.9 inches wide and 6.7 inches tall. The purpose of this step was to enable the client to easily rotate the lever. The cutoff area would prevent the lever to rotate a larger range of degree. Cutting off this area also helped to decrease the weight of the device.

Figure 2.2.4_3 – L shape back wall.

2.2.5 The Motor Compartment

The motor compartment is the main functional part of the device. It is compose of motor, motor parallel plates, motor encasement, tube holder and cushion piece, switch, and the electronic circuit components. Each of these components will be explained in detailed in the sub sections bellow.

2.2.5a – Motor

Due to the portable and compact specification of the device, the suitable motor has to be small and strong enough to twist open the paint cap. Although the cap of the paint tube is small, a good amount of torque is required to open the paint tube’s cap. The first motor was purchased with a purpose to determine the suitable torque of the paint tube’s cap. This first motor was too weak for the paint tube’s cap. The functional torque is in a range of 2-7 lb*in. The Lynxmotion store provides a gear head motor that can perform maximum of 14.5 lb*in torque. The specifications of this gear head motor is as follows:
Gear Head Motor Specifications:

1. Testing Conditions:
   Temp: 25° Celsius
   Humidity: 60%
   Motor Orientation: Horizontal
2. Rated Voltage: 12vdc
3. Voltage Operating Range: 6-12vdc
4. Rated Load at 12vdc: 1.50Kg-cm (1.3 lb-in)
   Do not exceed rated load. Damage may occur!
5. No Load Speed at 12vdc: 152 RPM +/- 10%
6. Speed at Rated Load (1.50Kg-cm): 132 RPM +/- 10%
7. No Load Current at 12vdc: < 155mA
8. Current at Rated Load (1.50Kg-cm): < 466mA
9. Shaft End-Play: Maximum 0.8m/m
10. Insulation Resistance: 10Mohmat 300vdc
11. Withstand Voltage: 300vdc for 1 Second
12. The gear motor is not intended for instant reverse.
    The gear motor must be stopped before reversing.
13. The gear motor does not include protection from water or dust etc.

The figure 2.2.5_1 below shows the drawing of the motor with dimensions in mm. In general, the motor has a dimension of 80.6mm long x 37 mm diameter (3.17 x 1.46 in.)

![Figure 2.2.5_1 – Drawing of gear head motor.](image-url)
The figure 2.2.5_2 shows the drawing of the bottom view and top view of the gear head motor. The bottom view of the drawing shows where positive and negative potentials of the motor. The top view of the drawing shows the location of the motor shaft together with the locations of the set screws. These set screws are not relevant to our device because the motor is situated vertically with the shaft facing upward.

![Figure 2.2.5_2 – Drawing of (a) bottom view and (b) top view of gear head motor.](image)

The figure 2.2.5_3 below displays a real image of the gear head motor. The shaft of the motor is flat on a side. This flat region can be used with many purposes. In this design, the flat region was used to apply set screw to secure the tube holder to the motor shaft itself. A more detailed description of the set screw application will be explained in later section.

![Figure 2.2.5_3 – The gear head motor.](image)
2.2.5b – Motor parallel plates

The position of the motor is vertical, where the shaft of the motor faces upward. The polarity connection of the motor is located at the bottom of the motor. If these connections happen to be in contact with the bottom platform, the metal platform will conduct the leakage current throughout the entire surface area. This condition is very dangerous to the client in case of electrical shock. Therefore, the motor is raised to a level where it is safe from current transfer. Figure 2.2.5_4 displays the clearance between the motor polarity connection and the platform.

![Figure 2.2.5_4](image)

Figure 2.2.5_4 – The clearance between the motor’s polarity connection and the platform.

The image on the left in the figure 2.2.5_4 is the true presentation of the distance between the motor connections to the bottom platform. To mount the motor to the motor plate, a 1.5” hole was drilled that fits the upper part of the motor (see figure 2.2.5_5 – right). It is important for this hole to fit the motor’s diameter perfectly because any slight movement of the motor must be eliminated. The hole also cannot be too tight because several adjustment of the correct position of the motor in the hole might be necessary prior to final assembly of
the device. Additional mechanism, set screw, was added to the motor plate to ensure the motor does not move. Set screw is very small and almost invisible (see figure 2.2.5_5 – left). The small set screw was pressed against the wall of the motor’s body, preventing it from move in any direction. Set screw can be removed easily; therefore, we had no problem in relocating the location of the motor shaft.

Figure 2.2.5_5 – (Left) 1.5” motor mount hole, (Right) Set screw in the motor plate.

As shown in figure 2.2.5_6, there are two motor plates in parallel. The reason for this is that the motor needed to be in the axis of the clamp. The plate that has a motor mounted to if attach to the back wall, the shaft will point up to some point that is not directly under the fingers of the clamp. In other words, the clamp’s fingers, paint tube, tube holder, and motor have to be vertically lined up. One of the criteria of the design is to make sure the device is easy to use. The client only needs to put the paint tube into the holder in one step and turn on the device by pressing against the button. The client does not need to do any adjustment such as line up the paint tube with the clamp’s fingers. The figure 2.2.5_7 is the mockup of the device (this step was done prior to building the real device). This image shows how the paint tube needs to be right below the clamp’s fingers when the client first inserts the paint tube into the paint tube holder.
To secure the parallel plates to the back wall, two long 11-in screws were used. The figure 2.2.5_8 and figure 2.2.5_10 show the locations of the two long screws in front view and side view. In this image, the screws might seem to be long, however, in the final stage (image shown in figure 2.2.5_9 and figure 2.2.5_10), there is no extra length of the screw showing. Two steps needed to be done to achieve this. The first step was to cut the screws shorter by \( \frac{1}{4} \)", the second step was to insert washers and motor encasement (which are the later steps in the design process).
Electronic components are needed to have the device as a whole functional. The motor will be connected to the other electrical components, such as AC adapter, fuse, push button, etc. These components cannot be seen by users due to several reasons. First, it is dangerous to have electronic components fully exposed and accessible to users. It is important to prevent any unnecessary harm to users at any time. Second, if electronic components are not sealed and separated completely from any other interference such as EMI, explosion or any other hazardous conditions might happen. For these reasons, it is strongly recommended to have a enclosure that creates a barrier between the electronic components and the outside interferences. The encasement is made of Galvanized Aluminum. The dimension of the
sheet is 12.5 inches long and 3.25 inches wide. The sheet was divided into three segments: 4.5”, 3.5”, and 4.5”. The 3.5” is the middle part with its face facing the front view. The sheet was bent using the manual metal bender so that it has an L shape with three faces. The back wall covered the back face, so there is no need to have the 4-sided encasement. The figure 2.2.5_1 shows the drawing of the encasement with specified features such as switch hole and wire hole. The wire hole is for the AC adapter wire, which is coming out of the circuit and into the power outlet in the wall. To attach the encasement to the device, two holes were drilled on the encasement. The two long 11” screws then secure the encasement to the motor plates. On each side of the encasement, one screw was inserted to ensure the encasement is totally closed. The switch button has to be external where the user presses easily. A 0.9” tall x 0.55” width square area was cut out to put the switch button in place. The wire hole has a diameter of approximately ¼” and it is 0.13” above the platform and 0.57” in from the back wall. The two front long screws are 2.6” apart. The side screw is 1.55” up from the bottom platform and 0.2” in from the back wall.

![Diagram of the motor encasement.](image)

**Figure 2.2.5_11 –The motor encasement.**

### 2.2.5d – The Tube Holder

The paint tube is always in an upward position, or standing up position. The tube holder for our paint cap remover design is made of Aluminum. Aluminum is suitable for the tube holder material because it is light in weight and easy to mill. We obtained a rectangular solid piece of Aluminum and milled it so that it has a U shape. The paint tube has a length of 4”, the tube holder, therefore, must be at least half the length of the paint tube. Our tube holder, as shown in figure 2.2.5_12, has a length of 2.17” and 1.3” wide. The area that was milled out can hold the paint tube and keep it in place.
The drawing in the right of figure 2.2.5_12 shows the hole that was drilled for the purpose of inserting the motor’s shaft through it. The diameter of the hole is 6mm and it located at the center of the bottom face of the tube holder. It is very important to ensure the drilled hole is in the middle. Figure 2.2.5_13 gives the scenarios of motor shaft positioned at different locations in the tube holder’s bottom surface. Scenarios A1 and A2 are standard position that works for both stationary and rotating stages of the device. The B1 is the scenario in which the shaft is not positioned in the middle, this leads to failure during rotation of the motor’s shaft.
Although the location of the shaft in the bottom of the tube holder is important, secure the shaft to the tube holder is crucial. There should be no movement of the tube holder while the device is operating. We used set screw mechanism to completely eliminate all movement. The figure 2.2.5_15 show how set screw was used in this step. Set screw was drilled on the side of the tube holder and the hole elongated until it reaches the motor shaft. The screw presses tightly against the motor’s shaft to prevent spin or rotation of the motor’s shaft. The shape of the motor’s shaft aid this mechanism in which its shape is flat on one side, allows the set screw to safely and securely press against the flat surface area.

(A)

Figure 2.2.5_15 – Set screw to secure the motor shaft to the tube holder.
The figure 2.2.5_16 below is the image of the complete step of putting the motor and the paint tube holder together. Many trials were done in which individuals attempted to pull the tube holder out, and the result was that no one can successfully remove the tube holder from the motor’s shaft by simply pulling. They need to remove the set screw using the specific T-Handled wrench.

The pink foam that attached to the tube holder prevents the paint tube from being squeezed down once the cap is twisted open. This flaw was noticeable right from the first trial of opening the paint cap. The pink foam gives a clearance between the bottom of the paint tube and the tube holder, so that when the cap is twisted open, the entire paint tube will move downward within the clearance distance.
2.2.5e – The Switch

(ON)-OFF
Push-to-make = SPST Momentary

The image above is the schematic presentation of the Push-To-Make button.

In the figure 2.2.5_17 A, the circuit in the initial stage is an opened circuit due to the switch is in opened (OFF) stage. As the user presses the button, the upside down T' bar will create a closed circuit and current coming out of the fuse and rushes through the closed switch, and the motor will then be activated (Figure B).

![Figure 2.2.5_17 (A) Schematic of the opened OFF switch](image)

![Figure 2.2.5_17 (B) Schematic of a closed ON switch](image)
The two images below in the figure 2.2.5_18 are the real presentation of the button. The image on the left (A) is the top view of the button and the image on the right (B) is the side view of the button. Image B is the button during the OFF stage, and the image C is the button during the ON stage (being pressed by the user).

Figure 2.2.5_18 – Push-to-make switch button

A push-to-make switch returns to its normally open (off) position when the user releases the button. This type of switch is used in our design is for the purpose of easy to operate. The client does not have a lot of strength in one hand, a very little effort to turn on the device is necessary. This switch is a keyboard type of switch that is very light and easy to press. Its structure and function are resembled to the regular keyboard buttons. The amount of force needed to press down a key on the keyboard is the same of the amount needed to press this particular button of our device.

The size of the switch (0.7” x 0.7”) is standard that can either be pressed using one, two, three, or all five fingers. There is no noise produced by this button. The top surface of the button can also be labeled or colored by removing the clear plastic top. The button is located only 0.2” above the bottom platform. At this height, the user can rest his or her hand on the bottom platform and press the button.
In figure 2.2.5_19 (A), it shows a large area where the user than rests his or her hand to activate the device. Our purpose for this area is stabilization of the device, and also the space for the user to rest his or her hand. From the testing trials, it takes approximately 3-6 cycles or rotations of the tube holder to twist open the paint cap. The time frame is around 2-5 seconds. Although the duration is not too long, the user will feel more comfortable if he or she can rest his or her hand on the platform. Another situation where the hand resting area is needed is that the tube holder sometimes does not stop at a desirable location. The user might need to spend a little more time to adjust the stopping angle of the tube holder. Having this area will provide the user comfort in doing this step.

2.2.5f – The Electronic Circuit

The paint cap remover is a simple electronic device that relies entirely on the rotation of the motor. The motor runs on a DC voltage supply. DC voltage was converted from 120AC voltage from the AC adapter that connects to the wall. The circuit of the conversion of AC to DC is already configured inside the AD adapter cable wire. The unique feature of the AC adapter is the multiple options of voltage value can be selected: 1.5, 3, 4.5, 6, 7.5, 9, and 12V (picture in figure 2.2.5_20a).
For our application, we chose the 3V supply. The maximum current of the AC adapter is 300mA. To detect the amount of current running through the motor, we connected the voltage supply in series with the motor. Using the multimeter with its probes across the positive and negative connections of the motor, we obtained 83.33mA across the motor. According to the Ohm’s Laws:

\[ V = IR \]  

[Eq. 1]

The resistor (R) is 36Ω. The motor acts as a resistor in this case. Therefore, 83.33mA is the current that goes into the motor. 3V is relatively small; this small voltage produces a very low RPM. With 3V supply, the motor rotates approximately 2 revolutions in one second.
Figure 2.2.5_20 – The current of the circuit.

The schematic in figure 2.2.5_21 is the entire schematic of the device with all the electronic components, voltage supply (AC adapter), fuse, switch, and motor. This design does not have a very complex circuitry because the only object that is in motion is the tube holder. The tube holder is connected to the motor, therefore rotating the motor will automatically spinning the tube holder. The rotating motion does not need a complex control since the paint cap can be opened by several twists. The most important factor in our circuitry is the torque of the motor. Once we figured out the needed current that is required to twist open the paint cap, the only parts left for the circuit works are connecting all the components together.

Figure 2.2.5_21 – The whole schematic of the paint cap remover.

The schematic in figure 2.2.5_21 shows how to wire all the components together. Figure 2.2.5_23 and 2.2.5_24 are the captures of the real circuits. For safety of our user, we implemented the fuse, which is a type of over-current protection device. The fuse [Figure 2.2.5_22] contains a wire, which was designed to melt when there is back flow of high current into the circuit in case of blackout. Once the fuse is activated, the circuit will be
opened and no current flow throughout the circuit. This will protect the circuit’s components from getting burnt or exploded. The fuse is glued on the wall of the encasement.

![Image of the fuse](image)

Figure 2.2.5_22 – The fuse.

To prevent the current from leaking out of the circuit, heat-shrink cables were used to cover all of the exposed metal wires. As shown in the figures 2.2.5_23 and 2.2.5_24, there is not sight of any metal wire inside the encasement.

![Image of the circuit inside the encasement](image)

Figure 2.2.5_23 – Capture of the circuit inside the encasement.
2.2.6 The Clamp

The clamp that is being used in the device is the Panavise. However, only the top part of the vise is used. The job of the vise is to hold the paint cap in place prior to activate the motor. The lever is long and easy to turn due to the extra lubrication, or oil, applied to the device.
The following series of figures (2.2.6_2 – 2.2.6_6) show the dimensions of the vises. The length of the lever is 3.5”. The length of the top vise is 4.5” and the handle part, which connected to the back wall, is 2.2”. The distance from the back wall to the clips of the vise is 3.7”. It is important to put the paint tube so that its cap fits right into the vise’s clips. In figure 2.2.6_4, the top view of the device shows that the clips’ gap is right underneath the tube holder. Once the cap is in the middle of the vise’s clips, a small number of turns are needed to tighten the clips to the paint cap. A detailed description of how to use the vise is clearly written in the operator manual of the device.
A 0.63” hole was drilled in the top region of the back wall to mount the clamp to. The figure 2.2.6_6 shows the location of the hole from the back view of the device. To prevent the clamp from rotating, set screw mechanism was used. Set screw located on the right side of the back wall.
2.2.7 **Assembly of the device**

The device can be assembled in the following order:

1. Attach the bottom platform to the back wall.
2. Mount the motor to the motor plate.
3. Assemble the tube holder and the motor’s shaft.
4. Insert the motor encasement into the two long screws.
5. Insert the long screws with the encasement into the parallel motor plates; through the back wall (remember to put the lock washers at the ends of the long screws.
6. Mount the clamp to the back wall, tighten the set screw.
7. Tighten all the screws.
The following figures show the pictures of the device in many views:

Figure 2.2.7_1 – The front view of the device.
Figure 2.2.7_2 – The left side view of the device

Figure 2.2.7_3 – The right side view of the device
2.2.8 Testing of the device

The final product does work properly after several trials of testing. The figure 2.2.8_1,2 below show the rotation of the tube holder at different angle. The device does not produce loud noise. The cap was loosening up after the tube holder rotated about 2 or 3 revolutions in 3 or 4 seconds.
2.3 PROTOTYPE

This section provides a description of the prototype and its operation with photographs. Describe prototype testing with clients (or persons pretending to have the disabilities of the clients).

Monitor Lift

The monitor lift is extremely easy to use. It has a footprint of 18” wide and a depth of 24”. The platform sits flush on top of a desk. The monitor lift itself weighs only 32.4 lbs so it is very easy for it to be relocated if necessary. The monitor lift’s design, especially the shape and size of the platform, provide excellent stability so no clamps, straps or other securing devices are necessary. It simply rests on top of the desk’s surface. Rubber grips on the bottom of the aluminum platform keep it in place and prevent any possibility of the monitor lift sliding around on the desktop.

Once the monitor is attached to the wall mount (there are directions for how to do this in the operator’s manual) the monitor rests approximately 0.7” above the surface of the platform at the lowest height and is level with the desktop. To operate the device
the user only has to plug the adapter into a wall socket and then use the switch to raise the monitor up or down. The switch is a DPDT momentary switch meaning. It defaults to the ‘off’ setting, which is the middle position. Labels clearly indicate which way to hold the switch to move the monitor up or down. The lift will only operate while the switch is being held one way or another. This is for safety reasons. The lift cannot be left moving when somebody may not be paying attention. An internal limit switch keeps the shaft from rotating outside of its movement range, which is 18”. If the momentary switch is held in the downwards position when the lift is already completely lowered, the limit switch will safeguard the actuator from being damaged or getting locked up. The same is true for the upper limit of the shaft range. If the switch is held in the up position when the actuator has already extended the full 18”, the internal limit switch prevents it from moving any further and from being damaged. The adapter supplies the monitor lift with a 9V power source. This particular voltage level was selected to provide the monitor lift a steady speed that the team members feel is safe and desirable. It is slow enough to provide a steady motion moving the delicate monitor, and the slow speed allows the user to be able to stop the lift at the precise height they want more easily. The speed is fast enough though that is does not take an excessively long time to lift the monitor 12 or more inches.

The monitor lift has been tested periodically throughout the building process as well as extensively as a final product. The linear actuator has been tested since the day of its arrival since it is the sole component driving the motion action of this device. This was done rather informally by simply touching the ends of the cord to a power source to be sure that it would operate. Group members tried to physically stop the actuator from moving by applying pressure to it as it rose. The actuator overpowered all attempts to be manually stopped (as would be expected since it is rated to be able to lift 400 lbs). The speed with which the actuator rose was slightly impeded by these actions and the noise level that it operated with also rose. Even under the best efforts of some, the change in speed and noise level observed during the operation of the linear actuator was not significant. The group was satisfied that the actuator would not have any problems lifting (at this time the monitor lift was being designed for an 80 lb monitor) a heavy monitor.

Clearly, the monitor lift could not be powered by touching wires to a power source and switching terminals to switch direction. The DPDT momentary switch was assembled. The wires were soldered to the terminals of the switch as depicted below and ultimately attached to the cord of the actuator.
When the switch was connected to the power source, the actuator would raise or lower depending on which way the switch was held. The group had established that the switch was wired correctly and once the structural components were assembled the switch would be ready to be permanently attached without any worries that the actuator would be operable. Notice below the switch is being pushed towards the left and the actuator lowers (picture on the left side). When the toggle switch is pulled in the other direction, the actuator rises (picture on the right).
The electronic aspects were tested continuously as they were developed so that troubleshooting would be much easier if a problem was encountered. If the group had not tested the switch or actuator continuously throughout the building process, it would have been very difficult to determine what component was causing a fault if the system did not work in the end. Continuous testing of the actuator and its controlling devices reduced possible work in the long run. For example, if functional testing of the actuator and switch had not been performed until the monitor lift had been fully assembled, it would be very time consuming and frustrating figuring out if the problem was that the actuator was broken, the switch was wired incorrectly, the circuit was shorted somewhere, a component or wire was not attached well enough or if there was interference once everything was packaged. The process of examining each of these and having to disassemble parts to do this could in turn cause more problems. Continuous testing saved the team possibly a great deal of time and energy.

The electronics are only one aspect of the monitor lift. It also had to be proven that the actuator and the lift system’s frame would provide enough support and stability to raise and lower a monitor. The lift system needs to be effective both statically and dynamically. Just as with the electronics, the structural components were tested periodically throughout the fabrication process as well. This was done so that the group was confident that each piece would be sufficiently strong and durable, and so that if any piece did not satisfy these requirements, it could be modified prior to its incorporation in the system.

The actuator was secured to the motor base. In order to be sure that the material selected for the motor base was indeed strong enough, mechanical testing was performed when the actuator was secured in the motor base (as depicted on the next
A piece of wood with the dimensions 1.5” x 3.5” x 36” and weighing 2.8 lbs was secured to the bracket on the shaft of the actuator. Holes were drilled at interval spaces down the length of the beam and different weights were hung at different distances from the actuator. This created different moment situations to test the linear actuator’s behavior. By testing the linear actuator before the guide rails or supports were installed, the team could be assured that if the actuator could handle a similar moment force as would be generated by the monitor, that the lift system would be extremely reliable, safe and durable once the guide rails were set in place. If each individual piece could sustain the forces created by the monitor alone, a comfortable factor of safety would be obtained.
when everything came together. Four moment situations were created using a variety of materials found around the lab.

Materials:

Wood - 2.8lbs
Metal ‘superstruts’ - 3.6 lb each
Motor – 22 lbs

Situation #1:
Only wood → 2.8lb load, 18” away → 50.4 lb-in moment

Situation #2:
Wood + 2 ‘superstruts’, 30” away → 50.4 lb-in + 2*3.6lb*30” → 266.4 lb-in

Situation #3:
Wood + motor, 7” away → 50.4 lb-in + 22lb*7” → 204.4 lb-in

Situation #4:
Wood + motor, 7” away + 2 ‘superstruts’, 9” away → 204.4 lb-in + 2*3.6lb*9” → 269.2 lb-in

Diagram of Linear Actuator With forces Loaded as in Situation #

The linear actuator raised and lowered both effectively and smoothly under all four of the simulated moment conditions. Even if the monitor is directly attached to the
actuator and no support or guide rails were used, the moment force generated by a 23lb monitor approximately 6” away (the monitor will most likely actually be much closer than 6”) is far less than most of the above situations (only 138 lb-in) and the linear actuator effectively managed this stress both statically and dynamically.

The finished product was tested for reliability, wear and strength. The electronics were also tested again. The monitor that this lift has been designed for weighs 23 lbs. A motor that weighs nearly the same as the monitor (the motor weighs 22 lbs) was attached to the wall mount to see if any problems would arise when the lift was operated under a similar load. The team kept a keen eye out for any signs of binding, flipping or other such things during the operation of the lift. Any binding issues would need to be resolved promptly, not only because they impede the functionality and effectiveness of the lift, but because binding issues could damage parts if they are left to persist. Fortunately no binding issues were observed. No strength or stability issues were observed either. The lift was loaded with more weights up to 40 lbs (nearly double what it will be actually loaded with) and cycled multiple times. No signs of binding, instability or difficulty in operation were observed.

The team agreed that the weakest state the lift is ever in is when it is fully raised and loaded. In order to test the sustainability/reliability of the weakest point of the monitor lift, the motor (‘mock monitor’) was left attached to the mount support and the lift was fully raised. The monitor lift was left in this position from Friday to the following Monday afternoon. No signs of deformation or fault were observed. The shaft of the linear actuator and all other components were still in perfect condition after this 60+ hour testing period.

In order to test the wear the monitor lift was cycled multiple times with the ‘mock monitor’ attached. Many people tested the lift and then the team completely raised and lowered the lift 50 consecutive times. The monitor lift raised and lowered with the same behavior each cycle. No signs of wear were observed to any part of the lift.

The current was monitored as the lift was raised under each of the loading conditions. The highest spike in current occurred at the point where the lift starts to move from the lowest height level. This is due to the ‘locking’ mechanism of the guide rails at this height. The spike only goes up to 1.77 amps. The actuator is rated for up to 5 Amps and this current will only be experienced when a 400 lb force is exerted on the actuator. This means that the factor of safety load-current wise is above 10 (even when adding in the weight of the supports) when this device is used for its intended application.

The monitor lift is easy to operate and all tests have shown that it is reliable. Granted no binding issues develop and the device is handled with care during transport, it should be operable for many years.
Paint Cap Remover

The Oil Paint Cap Removal Aid is another device that has been designed with the goal of making it very easy to use. It is not very large – about the size of a shoe box and weighs only 7.4 lbs. The paint cap remover sits flush on a desktop and can be stored virtually anywhere.
This paint cap removal aid was designed specifically for Grumbacher 1.25 oz oil paint tubes. However, any tube of the same general geometry and size will fit this device. In addition (and this is a specific problem that was encountered with the Grumbacher 1.25 oz tubes) caps with different designs, such as round with teeth versus round with no teeth, can be easily removed.

The tube on the left is the old cap design. Grumbacher has recently begun to make cap heads without the distinctive teeth as seen on the right in the above picture. The paint cap removal aid has been designed to accommodate both of these cap styles. In addition to being so accommodating to paint tube designs, the paint cap remover features a footprint size of only 7.25” x 7.75” so it does not take up much space. This is
important for its application because no artist wants their supplies taking up all for their
desk space and getting in the way. Artists need ample space to exercise their creative
abilities. The only constraint with placement/storage of the paint cap remover is that is
has to be plugged into a wall. The cord is 5' long. While the cord is a constraint in one
sense, it is also liberating because the user does not need to worry about batteries
running out, having to change them or needing to have a certain size of battery on hand if
they run out. Simply plug the paint cap remover into the wall. The adapter only has two
prongs so it can be operated using any wall socket. The paint cap remover features a
momentary switch located just above the base. The switch will only allow the motor to
spin when it is manually depressed and held there. The location of the switch is key— it
promotes safety and easy use of the device. It is located far enough away from any moving
parts so that fingers will not contact them and it is located close near the surface of the
base so that the user can even have their hand rested on the surface while holding the
button. The user does not need to hold their hand in the air while trying to keep it steady
enough to contact the button. In three easy steps, a person with limited strength and
dexterity can remove the cap from a paint tube. Place the tube in the tube holder. Close
the vise (which can be done by simply hitting the lever and it does not need to be
tightened with any significant amount of force). Push the button. Most people who tested
this device found it very easy to use and loved the simple design. The device is so user
friendly that almost everybody who tested the paint cap remover could also figure out
how to use the device even if they had no instructions on how to do so.

In order to determine just how easy the paint cap remover is to use, and if a person
with multiple sclerosis will have difficulty operating it, subjects were asked to use only
one hand when trying out the device. Some were told how to use the device and others
were not. Some were asked to use their right hand, others used their left hand and a few
were asked to try it using each hand. Further testing was done by asking a subject to try
to use the device using only one hand covered by a sock. The idea being that the sock
would impede the user’s dexterity and grip in an attempt to simulate some of the
characteristics of multiple sclerosis since no subjects who actually have multiple sclerosis
were available to test the device. While the monitor lift required more testing for possible
functional or structural problems (because its operation only involves flipping a switch),
results from testing of the paint cap remover is more subject to opinion since the user is
required to do more. As with the monitor lift, the paint cap remover components were
tested as they were fabricated to ensure that they would each perform as intended. This is
especially true for the motor, the switch, the vise and the tube holder.

The motor was tested for functionality from the day it was received just as the
actuator was. The speed with which the shaft of the motor rotated was examined as well
as the torque with which it rotated. Team members were able to stop the motor shaft
from turning by holding it still. However, it took a significant amount of effort to be able
to do so (more effort was needed to stop the shaft than was needed to remove the paint
cap). Since it took more effort to manually stop the shaft of the motor from rotating,
than it did to remove the paint cap, the team could be sure that the motor would have no
problems supplying sufficient torque to remove the cap. This had been a problem with
the motor ordered initially.
The circuit for the switch controlling the motor was tested during every step of its fabrication as well. A key board type key was found and used for the switch. The circuit was first built on a breadboard for preliminary tests before soldering the wires together. This made it easy to determine which wires should be connected to which terminals to obtain not only control of the motor by the switch, but also the correct polarity so that the motor spins the shaft clockwise when the switch is pressed. The shaft must turn clockwise so that the paint cap will be removed when the tube holder spins rather than tightened.

The tube holder was tested when it was attached to the motor and even before it was ever attached to the motor. The theory behind the paint tube holder’s design is that the tube would be held in place enough to unscrew the cap and once the cap loosened, no force would be exerted on the tube anymore (this way no paint would be expelled from the tube when the cap is loosened). The geometry of the tube and mechanism by which it turns the tube also allow it to accommodate the ever-changing size of a paint tube as it is used. Below are some pictures of the tube holder being tested before it was attached to the motor. This was done ensure that it would not have to be redesigned once the entire project had been built.
This manual testing of the tube holder did bring to attention the fact that as the stationary cap is unscrewed, the tube is forced downwards by the threads. A piece of foam was incorporated into the design of the tube holder as a result of the finds from this testing. The foam allows the tube to move downwards as the cap is unscrewed. This is one example of preliminary and periodic testing that helped the team avoid problems with the prototype at the end of the fabrication process.

As can also be seen in the previous pictures of the tube holder being tested, the vise was extensively tested manually as well. Both cap heads were tested in the vise to ensure the artist would be able to use the device for both old and new tubes of paint.

Each set screw was tested as they were put in place for stability of the device. When the set screws are tightened, the tube holder cannot be pulled off of the motor, the motor cannot be manually forced out of motor plate A and the vise cannot be forced out of the back wall. Once the individually tested pieces were assembled together into the final product the team tested the device to make sure each component was still working properly. Each piece did indeed still function as previous testing had seen and the device worked properly as a whole. Functional testing was an immediate success. The next step was to have other people test the paint cap remover to see if it was indeed easy and simple to use.

The prototype underwent extensive testing by random subjects, most of (but not all of) whom were volunteers from other BME classes. The subjects were asked to fill out a series of 6 questions after they had tested the paint cap remover. The questions are as follows:

1. On a scale of 1-10 (where 10 is extreme difficulty), how difficult was it to use this device overall?
2. On a scale of 1-10, how difficult did you find it to load the paint tube into the tube holder?

1 2 3 4 5 6 7 8 9 10

3. On a scale of 1-10, how difficult was it for you to manage the vise?

1 2 3 4 5 6 7 8 9 10

4. What do you like about this device?

5. What would you do to improve this device?

6. Would you use this device?

The average response to the first question, how difficult was it to use the device overall, was 2 (where 1 is no difficulty and 10 is extreme difficulty). While this is not ideal and it means that there is room for improvement, it is still a very good and satisfying response. The average answers to questions two and three were 2.3 and 1.5 respectively. Subjects had the most difficulty loading the tube into the holder and almost no difficulty using the vise.

All subjects were instructed prior to testing the device that they should use only one hand (it was not specified which hand they had to use) and not much force. These instructions were given in an attempt to have subjects mimic the abilities of the client. Three subjects tested the device using only their right hand. Two subjects used their left hand only. One subject tested the device wearing a sock over their hand to further prevent dexterity and grip. This subject used their right hand to test the device and then tested it again using their left hand.

The minute amount of difficulty experienced using the vise was experienced by individuals who used their right hand to close the vise. This is most likely due to the fact that the lever is located on the left side of the device. However, these individuals who used their right hand to operate the device were still able to do so with ease. By rotating the entire paint cap remover device 90° counterclockwise, so that the lever was directly in front of the user and the opening of the vise on the right side, some of the right-handed users were able to eliminate any difficulty they had experienced when using the device before. In addition, most of the right-handed users made this adjustment without it ever being suggested to them.
Right-Handed User Loading Tube into Tube Holder

Right-Handed User Tightening Vise
In the event that a right-handed user still experiences difficulty using the vise this way, the set screw can be loosened and the vise can simply be rotated 180° so that the lever is on the right side. The set screw should then be tightened to hold the vise securely in place.

Another variable that was explored when testing the paint cap remover was how subjects operated the device when they were not given any explicit directions on how to do so. These subjects were simply told that the device was designed for the purpose of removing the cap from paint tubes and were asked to see if they could operate it. Approximately one half of the subjects were not told how to use the device. The individuals each responded by looking over the device and even touching a few parts like the vise and button before loading the paint tube into the tube holder. After a short period of deliberation, each individual successfully figured out how to use the device and did not appear to have difficulty doing so. Only one individual did not use the device correctly the first time. The individual was unsure on which way to load the paint tube and began to load the tube cap side down into the tube holder. It was suggested that the open area on the base in front of the enclosure be used as space to put pictorial directions on how to use the device. This suggestion has been taken into consideration and a series of three Visio drawings depicting the steps – first load tube into paint tube holder (showing the correct orientation), secondly rotate lever to close clamp, thirdly push button- will be drawn. The pictures will be placed next to each other and form a strip, like a comic strip, that can be stuck to the base of the device if the user wishes. This will give the user or area the choice to have the directions displayed for widely easy use or to have a neat, clean looking device.

After the device had been tested by both right-handed and left-handed individuals, the next subject was asked to try to operate the device under further restriction than only one hand and not much force. The last subjects hand was physically restricted by placing a sock over it. The aim of this was to try and make sure that the amount of force and dexterity used was truly limited as it is in the conditions produced by multiple sclerosis. Tremors which are another characteristic of multiple sclerosis were harder to manipulate except by asking an individual to consciously do so, in which case they are not the same as when they are uncontrollable. The subject placed a
sock over their right hand and proceeded to use the paint cap remover. The subject exhibited some difficulty picking up the paint tube from the table. This demonstrated that the grip and dexterity of the healthy individual was indeed hindered by the sock as intended.

The subject displayed less difficulty placing the tube in the tube holder than they did in picking the tube up off of the table.
Tightening the vise did not pose any difficulty either. Although a picture depicting which way to turn the lever may be helpful and can be a future addition to this device.

The subject had no difficulty operating the switch. Notice how the subject was able to rest their hand on the table surface while holding the button down. The placement of this button makes it very convenient for people who may experience tremors.

The subject easily removed the tube from the tube holder once the cap had been rotated off of the tube.
The subject was then asked to repeat use of the paint cap remover using their right hand instead. The level of difficulty experienced may have been slightly higher using the right hand instead, but the subject was still capable of effectively removing the paint cap by use of the paint cap remover.
Placing tube in tube holder → tighten vise

Press and hold button → loosen vise
Remove paint tube from tube holder → paint cap is removed. Use Paint!

Through constant preliminary tests and many final tests, it can be seen that the paint cap remover works reliably and effectively. When subjects were asked what they liked about the device, all of them reported that they like how simple it was. Some went as far as to say that they felt the design was ‘fool proof’. Future models of this device should include a mechanism for placing the cap back on top of the paint tube. While the client has specified that this prototype does not need to do this, the main response from subjects who tested the device answered question #5 on the survey (What would you do to improve this device?) by saying that they would like a way to put the cap back on. Overall the paint cap remover has been proven to be very reliable and easy to use. While none of our subjects have multiple sclerosis, the limitations that this condition incurs was simulated as best as possible when subjects were testing the device. Assuming the testing conditions were appropriate, the client should be satisfied with this easy-to-operate 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 that the 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 the system be reliable. It must function reliably and if it is to fail, it must have a backup system and “fail safe”. The set of guide rails, guide rail supports and the brackets are all support systems for the failure of the linear actuator, whether it is the actuator itself or the junction of the actuator and the mount support that fails. No piece of this system is secured with only a single bolt. If one bolts or point of attachment fails, other bolts/screws will compensate for the loss. 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. The monitor lift has been loaded with weights similar to and greater than the monitor’s weight. It has been left under loaded conditions in the raised position for over sixty consecutive hours and exhibited no faults. It has also been cycled over 50 times repetitively with no signs of wear or change in performance.

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 a timeline is in place 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 be assembled by a group member. The tools available for use in the machine shops and labs constrain which pieces the group will and will not be able to assemble. Another manufacturability constraint is that the parts ordered must meet specifications calculated.

Time is a major manufacturability constraint on the project. An economical constraint for the monitor lift is the 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. The 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 23 lbs. The monitor lift is going to be used in a clinical setting. An object weighing 23 lbs could 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 probably 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. It will probably not be used or moved too often, so the team hopes that the device sustains for a minimum of 5-10 years.

Health and safety constraints for the monitor lift include the safety of the patients and users. The lift is electrically powered and plugs into a wall. The adapter is permanently attached to the switch/actuator and the actuator can accommodate levels of current that would only be experienced under loading conditions well above the intended application. All wires and even the cords have been covered in heat-shrink or electric tape for safety. Common safety practices/caution should be used so that users do not trip over cords. The balance of the monitor and the risk of it falling or the joint failing are the only real potential problems. Safety measures (guide rails, brackets, large platform, locking washers) have been taken to meet these. Both guide rails and the actuator or the mount support-actuator joint would all have to fail for the monitor to fall forwards towards a patient.

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 has a very simple look and it all one color) 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 device since it is electrically 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.

IEC 60529- Degrees of Protection provided by enclosures (IP code). This standard classifies the degree to which the 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 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. All wires/soldered areas will be coated with heat-shrink. 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 adapter features a switch where the user can change the voltage level. This will allow the user 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 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. 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 and structural components. 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. It requires that the cost to build the prototype does not exceed $750.

The same sorts of ethical constraints that apply to the monitor lift also 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 the user comes into closer contact with moving 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 individuals 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 the client as a result of their 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 could lead to many downfalls associated with financial, social and economic problems, and possible lawsuit. In medical systems, patient safety is the primary concern, and it is extremely important 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 large (a 27” screen) and weighs 23 pounds. Failure of the lift might cause injury to the patient and possibly persons who are performing an experiment. There are several methods being implemented to prevent unnecessary risks. The guide bars are a safety measure to help keep the monitor from sliding and moving (twisting) during operation. The monitor platform will be tailored to the dimensions specified in the project thus further increasing the safety of the device. The monitor will be attached to a mount that is commercially available (for attaching monitors to the wall) and designed for the specific model, effectively 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. There are only two wires protruding from this system (the one to the switch and the one to the plug) and they have been neatly fastened together into one cord near the lift so that they do not get tangled or look unsightly/distracting. Should a guide rail or support or bolt fail, the remaining guide rail, supports and bolts will lessen the impact of the failure. The load carried by the failed guide rail or support would be not only minimal but transferred to the remaining ones.

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 since it is made out of metal and plastic. 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. The oil paint cap remover, is considered a simple electrical application that does not involve complicated electrical components or wire network. The system encompasses a DC motor that can be operated using a plug that converts the AC power to direct current. The relatively low in power input and output that will reduce the risk of electrocution. The output current from the DC motor is 0.083A, 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 this application is small within a range of 0.254 – 0.28702 mm of diameter. The fuse ensures 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 serve as protection to 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 of 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 coated in heat shrink, especially at the points of attachment where live wire would be otherwise exposed. 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 adjustable voltage on the adapter allows the user to operate the device at a speed they feel comfortable (none of the allowable voltage settings produce an unsafe speed of rotation). 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

The monitor lift has shown a great improvement in the dimension of the whole system. This has a great environmental impact for our client. Effort and conscientious planning has been put forth to create a compact device which does not take up space on the laboratory table. The client wishes to have a device that does not produce a lot of noises. Using a linear actuator satisfies the low noise requirement and is also compact. While actuators do produce more noise when operating at high speeds and under excessive loads (but more under high speeds), this particular application involves neither. Other features such as wires, shape, and color will be developed based on the clients’ preference. 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 the device. Upon achieving all of the requirements, the monitor lift will help in bring more accurate and effective discoveries or solutions to the laboratorial experiments. Once 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 is a large number of populations who have neurological disorders; new discoveries and findings will help to improve the quality of life.

Globally, there are a large number of companies producing monitors/television lift. These 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. The monitor lift that is being designed for the sponsor, with a similar purpose, can be successfully deliverable in the near future. With our additional safety guide rails and supports, this prototype will add superior benefits and 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 necessarily industries, hospitals, or laboratories can only afford one.

The monitor lift leaves little impact on our natural environment. The consumption of electricity is used to fuel an actuator system in which no exhaust is created, and thus not emitted from the device. The corrosion/rusting 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 day to day use.
Oil Paint Cap Remover

Approximately 250,000 to 350,000 people in the United States have been diagnosed with multiple sclerosis (MS) [12]. MS can occur between the ages of 20 and 40 and prevents the affected individuals with numerous limitations. The paint cap removal aid being designed will have a great impact in improving both career and social life of many individuals. This device will provide them with more confidence in achieving his career goal since they will not worry about such a daunting task as opening a paint tube. The users can be independent whereas they 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 more confident in their work when they have a full control over it. The painters regain back their confidence and positive determination in achieving their ultimate life and career goals. Socially, upon the full control of painting tasks, the painters can obtain superior self-confidence and self-esteem. This behavior will lead to many positive impacts on things 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 treatment and daily health care can be a problem; billions of dollars are spent annually. Economically, the price of our device is reasonable because 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.

The ultimate goal of the paint cap removal device is to be able to provide the client the maximal convenience and comfort in their 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 them with maximal comfort and minimal use of hand grip. The paint cap removal aid's impact is that it will satisfy every request our client asked for and it is customized to specifically meet the needs of our client.
6 LIFE-LONG LEARNING

Spring 2007

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.

Fall 2007

This semester continued with our life long learning theme. We learned many various things this semester that will help us in our future jobs as well as personal lives. This semester was heavily team based and relied on the collaborative thinking of four people. It is not always easy to work with other people who have other ideas and agendas. The ability to work in a team will extend too many aspects of our lives from here on. In whatever job one pursues there will always be a team aspect and this semester gave us a foundation to work in a team effectively and respectfully.

Another aspect of BME 291 that will extend to our future lives is the ability we have to work on a project from the ground up. We have started from scratch and have learned all the various methods to obtaining the correct parts, assembling and testing a device. It is interesting to see how much work goes into just ordering parts and machining parts. Which brings me to the next topic of life long learning that we all experienced this semester, that is the ability to machine a piece using various machines. As engineers it was good to finally get some hands on experience with making parts from raw materials. The art of machining is making a useable piece by removing material from a raw piece of material. After this semester we are all proficient in using a milling machine, drill press, threading device, belt sander, vertical saw, cutting press, portable sander, cordless drill and metal bender to name a few. Even if we do not ever come in contact with these devices again we will have gained a great understanding of how such machines are operated that can carry over to other devices that we will be sure to come in contact at a later time.

Another aspect of life long learning that we will definitely carry over to future projects is the topic of time management. It is important in a project such as this where you have a long amount of time to complete, not to get to comfortable with where your project is at any current moment. We all learned that to be on schedule we often times had to work as if we were behind schedule. A steady working regiment as well as well as thought out time line to adhere by was the key to success in this project and ultimately taught all of us how to complete a project on time. In future projects that we come across in work and in our personal lives will have a time frame to be completed in, with the knowledge that we have gained we are now better suited for tackling such projects no matter what the circumstances.

Overall we have gained a greater sense of who we are and our abilities as engineers. The team in which we worked on this project grew as a whole and will carry these life long lessons into the future wherever we may end up as engineers and as people.
### 7.1 BUDGET

Monitor lift & Paint Cap Remover

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<td>5/30/07</td>
<td>Skycraft Parts and Surplus</td>
<td>$12.73</td>
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<td>6/4/2007</td>
<td>Philips USA ph-62061 adapter</td>
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<tr>
<td>5/30/07</td>
<td>Universalestore.com, Cyber Gift Center.com</td>
<td>$15.93</td>
<td></td>
<td>6/6/2007</td>
<td>18&quot; stroke 400 lb force linear actuator</td>
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<tr>
<td>9/10/07</td>
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<td>9/18/2007</td>
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<td>9/17/07</td>
<td>LynxMotion, Inc.</td>
<td>$38.45</td>
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<td>Firgelli Automations</td>
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<td>9/24/2007</td>
<td>PnanVise stand head vise</td>
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<td>10/8/07</td>
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<td>$25.23</td>
<td></td>
<td>10/11/2007</td>
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<td>10/22/07</td>
<td>Bestpricemounts.com</td>
<td>$44.00</td>
<td></td>
<td>10/25/2007</td>
<td>9-VDC 4.1 amp adapter</td>
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<tr>
<td>11/4/07</td>
<td>Action Electronics</td>
<td>$57.51</td>
<td></td>
<td>11/7/2007</td>
<td>Returned Lee spring order. $23.18 restocking fee.</td>
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<td>10/16/07</td>
<td>CREDIT FROM LEE SPRING</td>
<td>$92.74</td>
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<td></td>
<td>2'x2' aluminum sheet, bolts, washers, nuts</td>
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<tr>
<td>11/30/07</td>
<td>Uconn Machine Shop Labor</td>
<td>$60.00</td>
<td>N/A</td>
<td></td>
<td>labor</td>
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<tr>
<td>11/30/07</td>
<td>Uconn Machine Shop parts</td>
<td>$15.00</td>
<td>N/A</td>
<td></td>
<td></td>
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</table>

**Beginning budget** $1,500.00  
**Total expenses** $652.33  
**Total credits** $92.74  
**Total cost** $559.59  
**Remaining Budget** $940.41
## 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 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>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 proto board 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 Using a digital voltmeter, verify that all resistors are within acceptable variance from assigned values</td>
<td>30 mins</td>
<td>9/7/2007 8:00</td>
<td>9/7/2007 8:30</td>
</tr>
<tr>
<td>17 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>18 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>19 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>20 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>21 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>22 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>23 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>
</tbody>
</table>
• Take the cap head and place it on the top of the cylinder 1 min 9/14/2007 8:00 9/14/2007 8:01
25
• With a permanent marker, trace the exact shape of the paint cap onto the top of the cylinder 10 mins 9/14/2007 8:00 9/14/2007 8:10
26
• Bore a 0.217 inch deep hole into the top of the cylinder that is 0.242 inches in diameter 10 mins 9/14/2007 8:00 9/14/2007 8:10
27
• 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 3.5 hrs 9/14/2007 8:00 9/14/2007 11:30
28
• Test the cap head remover to make sure it fits over 1 min 9/14/2007 8:00 9/14/2007 8:01
96
• 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 15 mins 9/14/2007 8:00 9/14/2007 8:15
30
• Open a dual-component bottle of strong setting epoxy glue 1 min 9/14/2007 8:00 9/14/2007 8:01
31
• Mix the two separate chemicals of epoxy for 30 seconds 1 min 9/14/2007 8:00 9/14/2007 8:01
32
• Coat the shaft of the motor with epoxy and insert into the cap head 1 min 9/14/2007 8:00 9/14/2007 8:01
33
• Hold in place until the epoxy has set, forming a tight, plastic fit around the shaft 10 mins 9/14/2007 8:00 9/14/2007 8:10
34
• 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 10 mins 9/14/2007 8:00 9/14/2007 8:10
35
• Attaching the circuit to the motor 1 hr 9/21/2007 8:00 9/21/2007 9:00
36
• Connect the motor into the circuit 15 mins 9/21/2007 8:00 9/21/2007 8:15
37
• Test the speed of the motor as it is regulated through the circuit 15 mins 9/21/2007 8:00 9/21/2007 8:15
38
• Adjust speed if necessary by changing resistors in the circuit or changing the input voltage on the universal adapter 15 mins 9/21/2007 8:00 9/21/2007 8:15
39
• Make sure the switch functions properly 15 mins 9/21/2007 8:00 9/21/2007 8:15
40
• Building the Plastic Box 4 hrs 9/21/2007 8:00 9/21/2007 12:00
41
• Drill a 0.7 inch hole in the center of the plastic box
for the cap head remover 30 mins 9/21/2007 8:00 9/21/2007 8:30
42
• Drill a 15/32 inch hole in the side of the box for the
switch 30 mins 9/21/2007 8:00 9/21/2007 8:30
43 • Drill a hole for the AC power cord 15 mins 9/21/2007 8:00 9/21/2007 8:15
44 • Insert the circuit and the motor into the plastic box 15 mins 9/21/2007 8:00 9/21/2007 8:15
45
• Secure the motor to the base of the plastic box
using screws 15 mins 9/21/2007 8:00 9/21/2007 8:15
46 • Install the switch in the side of the box 15 mins 9/21/2007 8:00 9/21/2007 8:15
47 • Connect the power supply 15 mins 9/21/2007 8:00 9/21/2007 8:15
48 • Close the plastic box 15 mins 9/21/2007 8:00 9/21/2007 8:15
49
• Make sure all parts fit into the box without causing
electrical interference with each other 15 mins 9/21/2007 8:00 9/21/2007 8:15
50
• Out of a sheet of 1/2 inch thick plastic, cut a
rectangular “Clamp securing mechanism” 30 mins 9/21/2007 8:00 9/21/2007 8:30
51
• Screw the clamp securing mechanism to the top of
the plastic box 30 mins 9/21/2007 8:00 9/21/2007 8:30
52
• Attach the rubber feet to the bottom of the plastic
box 15 mins 9/21/2007 8:00 9/21/2007 8:15
53 • Monitor Lift 10 wks 9/28/2007 8:00 12/6/2007 17:00
54 • Preparing the parts 5 hrs 9/28/2007 8:00 9/28/2007 14:00
55 • Open up all part packages 1 hr 9/28/2007 8:00 9/28/2007 9:00
56 • Count all parts to make sure everything is
accounted for 1 hr 9/28/2007 8:00 9/28/2007 9:00
57 • Verify that the correct parts have been received
and if the wrong parts have been received, fill out
the necessary paperwork to return them 1 hr 9/28/2007 8:00 9/28/2007 9:00
58 • Divide all the parts into similar categories 1 hr 9/28/2007 8:00 9/28/2007 9:00
59 • Take the exact measurements of all parts 59 mins 9/28/2007 8:00 9/28/2007 8:59
60
• Obtain an 80 lb weight from a recreational facility
to simulate the monitor 1 min 9/28/2007 8:00 9/28/2007 8:01
61 Designing the descending platform 10 hrs 10/5/2007 8:00 10/8/2007 10:00
62
• Drill two holes in each of the two top plates for the
PVC guide tubes 30 mins 10/5/2007 8:00 10/5/2007 8:30
63
• Drill two holes in each of the two top plates for the
top of the dashpot strokes 30 mins 10/5/2007 8:00 10/5/2007 8:30
64 • Cut 4 small PVC sections for the guide tubes 1 hr 10/5/2007 8:00 10/5/2007 9:00
65
• Bore a small groove into the tubes to fit into the
metal plates 1 hr 10/5/2007 8:00 10/5/2007 9:00
66 • Insert the tubes into the top of the two plates 1 hr 10/5/2007 8:00 10/5/2007 9:00
67 • Secure the tubes to plates with brackets 1 hr 10/5/2007 8:00 10/5/2007 9:00
68 • Weld the two top plates to the two side frames 1 hr 10/12/2007 8:00 10/12/2007 9:00
69 • Weld the side frames to the main platform 1 hr 10/12/2007 8:00 10/12/2007 9:00

70 • Reinforce the platform and the side frames with brackets 1 hr 10/12/2007 8:00 10/12/2007 9:00
71 • Reinforce the side frames and top plates with brackets 30 mins 10/12/2007 8:00 10/12/2007 8:30

72 • Install a triangle bracket on all right angle corners of the system for extra stability 30 mins 10/12/2007 8:00 10/12/2007 8:30
73 • Drill holes for tie-down strap 30 mins 10/12/2007 8:00 10/12/2007 8:30

74 • Drill a hole in the center of the backside of the descending platform for the wires to be threaded through 30 mins 10/12/2007 8:00 10/12/2007 8:30
75 Designing the bottom platform 5 hrs 10/19/2007 8:00 10/19/2007 14:00
76 • Make sure the bottom platform stays flat and balanced on the top of the laboratory table 30 mins 10/19/2007 8:00 10/19/2007 8:30
77 • Bore 4 divots in the corners of the bottom platform for the guide bars 30 mins 10/19/2007 8:00 10/19/2007 8:30

78 • Drill 4 holes near the corners for the bottom of the dashpots 30 mins 10/19/2007 8:00 10/19/2007 8:30
79 • Insert the guide-bars into their respective divots 30 mins 10/19/2007 8:00 10/19/2007 8:30
80 • Weld the guide-bars to the platform 1 hr 10/19/2007 8:00 10/19/2007 9:00
81 • Insert the bottom of the dashpot into their holes 30 mins 10/19/2007 8:00 10/19/2007 8:30

82 • Secure the dashpot to the platform with metal brackets 1 hr 10/19/2007 8:00 10/19/2007 9:00
83 • Secure the bottom platform to the laboratory table using two metal clamps 30 mins 10/19/2007 8:00 10/19/2007 8:30
84 Designing the springs and the guide bars 5 hrs 10/26/2007 8:00 10/26/2007 14:00
85 • Ensure that the guide bars are in the correct location to match up with the guide tubes of the descending platform 30 mins 10/26/2007 8:00 10/26/2007 8:30
86 • Slide the four springs around each of the four guide bars 30 mins 10/26/2007 8:00 10/26/2007 8:30
87 • Put the descending platform over the guide bars and springs 1 hr 10/26/2007 8:00 10/26/2007 9:00
88 • Apply weight/force to the descending platform so it
compresses the springs partially 1 hr 10/26/2007 8:00 10/26/2007 9:00

89

•Put metal cap on the top of the rod to stop the
platform from ever extending past the top of the
bars 1 hr 10/26/2007 8:00 10/26/2007 9:00

90 •Weld the metal cap to the top of the platform 1 hr 10/26/2007 8:00 10/26/2007 9:00

91 Designing the dashpots 5 hrs 11/2/2007 8:00 11/2/2007 14:00

92

•Ensure that the dashpots are in the correct location
to match up with the holes in the top plates of the
descending platform 30 mins 11/2/2007 8:00 11/2/2007 8:30

93

•Release pressure from the dashpots to allow them
to slide freely 30 mins 11/2/2007 8:00 11/2/2007 8:30

94 •Extend the strokes completely 30 mins 11/2/2007 8:00 11/2/2007 8:30

95 •Slide the strokes through the hole in the top plates 30 mins 11/2/2007 8:00 11/2/2007 8:30

96

•Secure the top of the stroke to the top plate by
tightening the nuts 1 hr 11/2/2007 8:00 11/2/2007 9:00

97 •Weld the stroke to the top plate 1 hr 11/2/2007 8:00 11/2/2007 9:00

98 •Check to make sure are at a 90 degree angle 30 mins 11/2/2007 8:00 11/2/2007 8:30

99 •Check to make sure the strokes slide freely 30 mins 11/2/2007 8:00 11/2/2007 8:30

100 Calibrating the dashpots 5 hrs 11/9/2007 8:00 11/9/2007 14:00

101

•Put the 80 pound weights on the descending
platform to simulate the monitor 1 hr 11/9/2007 8:00 11/9/2007 9:00

102 •Use a screwdriver to tighten the dashpot pressure 1 hr 11/9/2007 8:00 11/9/2007 9:00

103 •Make sure to match the dashpots with each other 1 hr 11/9/2007 8:00 11/9/2007 9:00

104

•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 1 hr 11/9/2007 8:00 11/9/2007 9:00

105

•Find the perfect equilibrium so that the user has to
use little force to lift the monitor 1 hr 11/9/2007 8:00 11/9/2007 9:00

106

•The remaining weeks are for Thanksgiving Break
and Testing of the projects 16 days 11/16/2007 8:00 12/7/2007 17:00

8 TEAM MEMBERS CONTRIBUTIONS TO THE PROJECT
Over the past year, the team has spent countless hours brainstorming and building two projects with the needs of the clients in mind. Each member has played a vital role in the fabrication of these devices and has added put a lot of creativity and work into them. Having four people in a group did not make it easy to meet all of the time but everybody made conscious efforts to meet regularly and work around each other’s busy schedules. The work load was distributed very evenly and team members were never reluctant to lend a hand to another when problems arose or setbacks encountered. Much of the fabrication process was done in pairs, no one person was ever assigned to a large portion of the project by themselves. The group adapted well and rose to the occasion when plans had to be changed and deadlines met. Each member played an integral role in this group though none were necessarily well defined.

- **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
    - Constructed back wall and base plate for paint cap remover
    - Milled a hole into motor plate A for motor
    - Secured motor into motor plate A with a set screw
    - Milled hole into back wall for clamp
    - Secured clamp in place with a set screw
    - Helped make tube holder out of a block of aluminum
    - Attached back wall to base
    - Attached motor plates to back wall
    - Attached tube holder to motor shaft with a set screw
    - Wired switch for monitor lift
    - Moment testing of the actuator
    - Counter-sunk holes on bottom side of platform of monitor lift
    - Cut excess side off of platform of monitor lift
    - Rounded edges of monitor lift
    - Subunits for monitor lift

- **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

- Worked on circuits for both projects
- Drilled holes in platform for brackets.
- Drilled holes in guide supports for guide rails.
- Secured guide rails to guide supports
- Built mount support
- Cut HDPE to size for motor base
- Secured guide rail-mount support system to platform
- Drilled holes for wall mount on mount support.
- Taped cords of monitor lift together and made them look neater
- Drilled holes in top of mount support for attachment to bracket on linear actuator
- Attached mount support to actuator
- Attached wires for to button for paint cap remover.
- Found button for paint cap remover and attached it to the enclosure
- Moment testing of the actuator
- Life-long learning section and subunits for paint cap remover.

**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
  - Constructed back wall and base plate for paint cap remover
  - Milled a hole into motor plate A for motor
  - Secured motor into motor plate A with a set screw
  - Milled hole into back wall for clamp
  - Secured clamp in place with a set screw
  - Made tube holder out of a block of aluminum
  - Attached back wall to base
  - Attached motor plates to back wall
  - Made an enclosure out of galvanized aluminum to house motor and electronics
- Attached tube holder to motor shaft with a set screw
- Soldered wires together
- Drilled holes in guide rail supports for platform brackets
- Drilled holes in box for switch for monitor lift.
- Taped cords together and made mires from monitor lift look neater.
- Documented disassembly and reassembly of both projects
- Moment testing of the actuator
- Operator’s Manual

- **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
- milled hole into HDPE motor base for monitor lift
- drill and lathed a hole into the motor base for the pin
- secured the linear actuator in the motor base with the pin
- drilled holes in guide rail supports and attached guide rails
- Drilled holes in guide rail supports for brackets that secure supports to platform
- Built mount support
- Inserted a tight fitting washer into the space where the shaft of the actuator attaches to the bracket. Made the bracket fit in the slot of the shaft more securely.
- Attached mount support to brackets on guide rails. Put locking washers in between mount support and brackets to prevent binding
- Measured and drilled holes in mount support for wall mount
- Attached wall mount
- Measured and drilled holes in top of mount support for bracket that attaches mount support to top of monitor lift.
- Attached mount support to linear actuator (by means of the bracket)
- Measured where to drill holes in platform for the guide support-platform brackets with a large L-ruler to ensure that the mount support would be perpendicular to platform to avoid binding.
- Attached mount support-guide rails system to platform.
- Rounded edges of platform
- Brushed the top of the platform to remove scratches and blemishes. Result- much nicer, neater looking platform surface
• Found box to use for switch enclosure
• Applied heat shrink to all wire connections as they were soldered
• Tested moment force capabilities of actuator
• Tested final monitor lift prototype for strength, wear and reliability
• Prototype section of final report and sections 3-12.
• Made models of each cap head (old and new designs) for paint cap remover project
• Tested paint cap remover prototype
• Created a survey for people to answer after testing the paint cap remover
• Disassembled/reassembled paint cap remover for instruction manual
• Soldered wires in place
• Applied heat shrink to all wire connections

9 CONCLUSION

The designs presented to you in this paper are the result of four students’ hours of 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 were 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 manifest the optimal design and final report.

The monitor lift will relies on the abilities of a linear actuator with the aid of proper structural support and guide rails to achieve vertical elevation of the monitor. The previous designs relied on various mechanisms to function including pneumatics, hydraulics, springs alone, dashpots 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 satisfies the client’s needs. 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 and noisy. 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. However, this design did not seem to be secure or stable enough to safely maneuver a large monitor in a precise direction. Linear actuators seemed to have the most properties that were found
desirable in the other mechanism while lacking the undesirable characteristics so the prototype has ultimately been built using a linear actuator as the mechanism for motion. As a result of this trial and error many kinks were worked out as well as many functional designs were discovered. The optimal design satisfies the requirements of the client and can be fabricated within the available budget. The most critical 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 endeavored. This project went through the same design process as the monitor lift. Through the various testing and thinking about designs the group was able to compile all the good ideas from the three designs and combine them into the optimal design. The design fits all of the necessary guidelines and looks to be a great product for the application it is intended for. The 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 the design 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 means of removing the cap. The paint cap remover design was held to the same standards 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 improve the quality of life for a number of individuals.

With regards to both projects it is important to see the individual parts that go into the creation of the whole piece. Without taking into consideration each minute detail, all the hard work that went into the major components could be jeopardized. The process of creating a device from scratch has demonstrated to the group the ever present nature of lifelong learning and how much of an impact it has on every aspect of our lives.

10 REFERENCES

Subunits:

Paper Body:
11 ACKNOWLEDGEMENTS

Special thanks to 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 this year-long design process.

Thanks to Bill Prueschner for his advice and feedback on our designs throughout the planning phases of this project. His knowledge of materials and mechanical devices was very helpful.

Thank you to Dave Price whom has been very helpful while we built our projects.

Thank you to Serge and Rich who helped us in the fabrication process of some parts in the machine shop and were very accommodating of our conflicting schedules.
Thank you to Lisa and Jen who were always very helpful with shipments, orders and scheduling to say the least.

Thank you to the individuals who volunteered their time and tested our design projects.

12 Appendix
12.1 Updated Specifications

Monitor Lift

As described in earlier sections of this report, the monitor lift must be able to lift a 23 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 raise the monitor higher than is normally available and in a different setting. 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 at least 10”x12” clear area when raised
Execution speed min-max height in 1 min or less
Maximum force 15 lbs if manual
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**
Non-distracting
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 multiple sclerosis. 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**
Motor
Torque 2-10 lb-in
RPM
Voltage
Current
Power Source: frequent-continuous operation life of 6 months minimum
Fuse
Switch
Size 0.5”x0.5” min
Force to operate minimal~ 0.25 lb max
Execution time 40 sec max
Resistors

**Mechanical Parameters**
Unit size min 2”x2”x1”
Specificity fit Gumbracher brand 1.25oz tubes and *any* generally round shaped cap
User ability cannot use more than 1 hand
Strength level low
Dexterity level low
Stability
Efficient
### Purchase Requisition Forms

**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

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<td>425-641-7275</td>
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Each Vendor will require a different purchase requisition

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Biomedical Engineering  
U-2247, 260 Glenbrook Road  
Storrs, CT 06269-2247     |
| **Attn:**             |                    |
| **Team #**            | 4                  |
| **Total Expenses**    |                    |
| **Lab Admin only:**   |                    |
| **FRS #**             |                    |
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| **Student Current Budget** |              |
| **Project Sponsor**   |                    |

### Project Name:

**ONLY ONE COMPANY PER REQUISITION**

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**Yes or No**

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**Vendor:** Firgelliauto.com

**Address:**

3888 sound way  
bellingham, WA 98227 USA

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**Attn:** Project Sponsor

**FRS #**

**Student Initial Budget**

**Student Current Budget**

**Lab Admin only:**

**Project Sponsor**

**Student Name:** Thuy Pham

**Ship to:** University of Connecticut

**Biomedical Engineering**

**U-2247, 260 Glenbrook Road**

**Storrs, CT 06269-2247**

**Date:** October 11, 2007

**Team #:** 4

**Total Expenses:**
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- University of Connecticut
- Biomedical Engineering
- U-2247, 260 Glenbrook Road
- Storrs, CT  06269-2247

**Attn:**

- Project Sponsor

**Project Name:**

**ONLY ONE COMPANY PER REQUISITION**

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- Yes or No: ____________

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**Authorization:**

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