Project(s) for Carolyn Martin: Final Report
Team 10: Nishant Patel and Eric Puffer

Project 14
Sponsor Dr. Enderle
Client: Carolyn Martin
1 Wheatfield Circle Shelton, CT 06484
Phone: 203-225-0123
Email: Carolyn8289@sbcglobal.net
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Abstract

The project features two distinct products custom built to fit the needs of our client, Carolyn Martin. Our client has Multiple Sclerosis (MS) which limits her mobility and has rendered her reliant on a power wheelchair for the last ten years. This disease has affected our client’s mobility more specifically she has lost most motion from her hips down. Carolyn has full brain function and has full strength on her upper body.

The first project is a 2-in-1 exercise machine that incorporates two distinct exercising mechanisms. The exercises are a pedaling system and a stretching mechanism each of which will help Carolyn in her rehabilitation endeavors. This machine is being built because Carolyn currently cannot exercise using her standard exercise bicycle. This is due to the fact that mounting and dismounting from the exercise bike is difficult due to her current condition. This custom built machine will allow Carolyn to remain comfortably seated in her wheelchair while still getting all the physical activity she desires.

Project number two is a mobile stander which involves the customization of a mechanical stander to become fully mobile. This involves equipping a stander frame with a joystick, microcontroller, motor(s), and battery mechanism to allow for full motion. The stander frame already features a hydraulic pump which the client will use to mount and dismount to and from the stander. This stander will allow our client to stand upright and navigate throughout her kitchen. Carolyn desires to cook and clean in her own kitchen, but she has a hard time doing so while confined to the dimensions of her power wheelchair. This stander will allow her to comfortably be erect and have full function of her upper body to do what she pleases.

1. Introduction

1.1: Background

Carolyn Martin is a 42 old woman who is currently diagnosed with Multiple Sclerosis (MS). Carolyn has been using the aid of a powered wheelchair for the past ten years. She is only able to walk very short distances with the help of an assisted device such as a walker. She lives with her mother in a home in Shelton, CT which has been slightly modified to be easily accessible to her.

Multiple Sclerosis (MS) is an inflammatory disease in which the fatty myelin sheaths around the axons of the brain and spinal cord are damaged. MS affects the ability of nerve cells in the brain and spinal cord to communicate with each other effectively. Studies show that MS usually occurs in young adults, and it is more common in women. Although much is known about the mechanisms involved in the disease process, the cause remains unknown. Theories of how MS occurs include genetic or infectious causes. There is no known cure for multiple sclerosis. Treatments attempt to return function after an attack, prevent new attacks, and prevent disability.
1.2: Purpose of the Project

Due to Carolyn’s Condition and her continual use of a powered wheel chair for the past ten years she has developed much atrophy in her legs. She has a great desire to reverse this condition and rehabilitate herself back to health. In order to solve this issue we suggested exercise for our client. She currently has a standard exercise bicycle which does not fit her needs. She has a difficult time mounting and dismounting from said exercise bike which is very discouraging and limits how much exercise our client gets. To solve this issue we decided to construct a custom exercise machine that our client will be able to use from the comfort of her own wheel chair. This machine will not only employ a pedaling exercise but also incorporate a stretching system that will only further help our client in her rehabilitation process. Rehabilitation is our client’s first priority so this project will help her achieve this goal.

A secondary desire our client expressed is being able to cook, clean, and reach items in her kitchen. Due to her current dimensions and constraints of her powered wheelchair Carolyn is unable to do much in the kitchen area. She is unable to reach things that are not on the edge of her countertop and using the stove is simply out of the question. Carolyn is able to use her walker to stand and get a better reach but this only allow hers to use one hand at a time which once again limits her. To solve this issue we proposed designing a mobile stander which will not only keep her in an erect position, but it will allow full use of both her hands. She will be able to move her powered wheelchair up to the stander fasten a harness around her midsection and hydraulically pump herself up in an erect position. Once upright and secure our client will be able to move the stander via joystick and navigate throughout her kitchen. With the use of this machine our client will be able to reach anything on her countertop, use the high cabinets without the help of others, and finally be able to cook for herself. Dismounting from the stander is as simple as holding the hydraulic pump up and it will slowly place her back in her power wheelchair. This system will make our client more independent which has been a one of her great desires.

1.3: Previous Work Done by Others

1.3.1: Products

The EasyStand Evolv (model # NG50084 Evolv Large) is a stander developed for adults with special needs. The stander accommodates users that are up to 82” and 350 lbs. The entire design was to make the sitting to standing transition as easy and pain free as possible. The image of the machine can be viewed on Fig. 1.

![Figure 1: EasyStand Evolv XT](image)
To use this stander the user will have to manually transfer to the seat provided by the EasyStand Evolv. Once secure on the seat the user will place his/her feet in the footrests and make sure the knee stabilizers are properly adjusted. Using the hydraulic actuator, as mentioned on the website, the user will easily be able to pump his/her self to the upright position while maintaining support on the back and knees. The seat that the client was originally seated on doubles up as back support when the client is erect. This product is fully customizable with an additional fifty accessories that include features for further support to assist seat transfer.

One major optional configuration is also available. The Evolv Mobile feature changes the stander from a stationary stander to a manually mobile machine. It's designed for people who can push a manual wheelchair because it allows the user to stand upright and self-propel the stander. This can be done by pushing set of wheels that resemble wheelchair wheels and that located directly to each side of the stander when in the erect position as seen on Fig. 2.

![Figure 2: EasyStand Evolv: Mobile](image)

The mobile feature in the EasyStand Evolv (model#PNG50025) is controlled by highly efficient chain drives, and is controlled by the pace at which the user rotates the drive wheels. A braking system is also featured so stopping the stander will never be an issue.

The Rifton Large Dynamic Stander is a mobile standing aid designed for use by children and adults with lower extremity disabilities as seen on Fig. 3.

![Figure 3: Rifton Large Dynamic Stander](image)

The stander comes with a contoured padded body support, straps, seat pad, and fleece, and contoured padded body support that can be adjusted to accommodate users. Its wide standing platform helps the user to spread his or her legs for hip development, or to accommodate leg braces. The platform is free of obstruction to facilitate placing the user in the stander. Lockable
rear casters enable the stander’s use outdoors on hard, level terrain. Additionally a mobile option is available that includes large drive wheels and a one hand pumps to navigate and move the stander.

The Theracycle 100 is an adaptive exercise bike built specifically for users who have lower body disabilities. It allows users in wheelchairs to exercise without mounting or dismounting as seen on Fig. 4.

Figure 4: Theracycle 100

Unlike traditional leg exercise machines and other stationary exercise equipment, Theracycle 100 takes the strain off the user’s joints and muscles with motorized technology that assists you through the cycling motion so you can continue to move your legs. The structural steel frame, wide legs, and low center of gravity are ideal for users in wheelchairs. It features several different settings that will allow the user to exercise at their own pace. The only issue is that the dimensions of the actual machine are 25" W x 45" L x 37" H which may be too large for some customers.

1.3.2: Patent Search Results

Recumbent bicycle for disabled users has been patented by a Michael N. Mann. The bicycle includes a seat unit that it adjustable in both the horizontal and vertical directions. The recumbent bicycle features a pedal unit that has a motor for controlling both the time and rotational speed of the pedals. Straps are located both on the pedals to secure the users feet and on the seat to secure the users midsection. The pedals also feature a heel engaging ledge for further support. The overall system has a very low center of gravity so a disable user will be able to mount and dismount with assistance.

A mobile prone stander with positioning chair has been patented by a Talton C. Kendrick. The mobile inclinable stander with positioning chair includes a mobile frame and a body support frame mounted to the mobile frame for movement between upright and reclined orientations. Chest, waist, and knee supports are mounted to the body support frame. A removable seat is mounted to the body support frame below the waist support so that the waist support acts as a back and arm rest of a positioning chair for a user seated on the seat. The positioning chair is table to be tilted with the body support frame. The seat frame has two sides pivotally attached to each other to permit opposed clamp plates. The knee supports include a horizontal support post
mounted to the body support frame and a pivot tube mounted over the support post. This stander is completely mechanical but as previously mentioned does feature mobility.

1.4: Map for Report:
The remainder of the report further describes each project in detail, focusing on major objectives and the subunits which are associated with each design. Each project has its own set of alternative designs and ultimately a final design. The report will thoroughly cover each alternative design as well as the reason and details of selecting the optimal design. After the technical aspects of each project, the report will outline constraints and solutions that are associated with each project. Finally the report will discuss the updated budget and a rigid timeline responsible for outlining the work needed to complete the project on time.

2. Project Design

Project 1: 2-in-1 Exercise Machine

2.1.1: Introduction
The design of the 2-in-1 exercise machine is divided up into three distinct mechanical sections: the base, the rotating plate, and the upper structure as seen on Fig. 5.

Figure 5: Solid Works design of 2-in-1 exercise machine
The entire mechanical design will be constructed with aluminum rods and plates. Aluminum was chosen due to its light weight features, low cost, and good strength properties. The base consists of eight distinct square pipes and all need to be cut and welded to meet our Solid Works specifications. The rotating plate is made up of one square plate that is 3/8 in thick. This plate will be the mounting plate for both of the attachments. This plate will also be the item that will be rotating via stepper motor. The base, the rotating plate, and the upper structure will all be cut, according to our specifications, and welded together so that there are no moving parts in terms of the mechanical design of the exercise machine.

The rotation system will be achieved by the use of a stepper motor which is a brushless electric motor that can divide a full rotation into a large number of steps. This stepper motor will come with a controller that will take inputs such as direction, number of steps, speed, torque, and acceleration. This control is easily programmed and will be set to meet the designs needs. With these properties assigned to the input, a push button will initiate the rotation of the system. Our system is such that it needs to rotate 180 degrees every time the push button is pressed. So each time the user presses the button the system rotates 180 degrees and a different exercise apparatus will be directly in front of the user.

The exercise attachments will be mounted the rotating of the exercise machine for ease of use. The pedal system will be attached to any one side of the rotating. As can be seen on Fig. 5 we will be keeping the length of the pedal so when it is mounted to the rotating plate it will stick out towards the client for ease of use. The stretching mechanism will be located on the opposite side of the pedal system as depicted on Fig. 5. To use the stretching exercise our user will place her feet into a set of footplates and pull on a set of rubber coated galvanized steel ropes which will be attached to the head of each plate. This will stretch the user’s calves and hamstrings in an effective manner. The attachment of the footplates will be such that they hang on to each side of the upper structure giving enough spacing for the user to stretch properly.

The optimal design is far more practical, cost effective, and useful than any of the alternative designs proposed in the next few sections. It features two distinct exercises, all in one system, and allows the clients to perform these exercises from her wheelchair. The two exercises are essential to our client’s rehabilitation process because they provide both physical and passive stimulation via the peddler and stretcher respectively. The rotation system will allow the user to remain stationary when she has the desire to perform the other form of exercise. This feature provides additional convince to the client. The mechanical design is ergonomic which is essential to our client due to her living situation. She already has many medical and exercise machines accumulated so saving space with this design is a priority.

**Alternative Design 1**

This alternative design requires splitting the machine into two distinct parts essentially creating two different standing structures for each exercise. The design structures would need to be very compact since they will be taking up more space being two separate entities instead of one machine. The lack of extra space in our client’s home will also come into play with the design of the two machines. Each mechanism will be mounted to the wall to save space because the rotation system will not be required in this particular design.

The pedal machine would involve using a simple peddler because the wall will not be able to support something as heavy as the Chattanooga Deluxe Pedal Exerciser, Fig. 6, which
weighs upwards to 30 lbs. The Instride XL Peddler, Fig. 7, would be a better fit due to ergonomic design and lightweight properties while still offering resistive pedaling.

A heavy duty chrome shelf bracket system can be used as the mounting structure for the pedal system. Two of these pieces, as seen on Fig. 8, can be drilled on the wall in parallel to each other to make a sturdy structure. The hooks will be encompassing an additional steel rod that will go across the system. With this rod enclose by the hooks and welded for additional safety the pedal system can be mounted to the rod. Some modifications need to be made to the attachment on Fig 8.

The support beam may need to be replaced with a thicker piece of steel due to the stress that it will face when the user is pedaling.

The same structure as mentioned prior will be created for the stretching mechanism. For the stretching exercise our client will require full foot plates to be installed. The plate will only be attached to the wall structure, Fig. 8, from the back portion of the mounts, i.e the portion corresponding to the heel of a human foot. The attachment type will allow the plates to have full motion radially. Our client will be able to place her feet in these mounts, use the pulleys attached to the front the mounts, and pull back. This will allow for stretching of the ankles, calves and hamstrings to the extent at which our client desires.

This design lacks the use of any electronics that can be seen in the other alternative designs. It is a very simple but an effective design that will help our client in her rehabilitation process. Space will be an issue as to where the systems can be mounted without being a
hindrance. Also mounting can be a problem if the walls in our clients home aren’t strong enough to support the weight of the machines. Additionally our client lives with her mother who is doesn’t like the idea of having any permanent changes being made to her home.

**Alternative Design 2**

The second alternative design involves buying and modifying a recumbent exercise bicycle for our client Carolyn Martin. A recumbent bike provides all the benefit of a regular exercise bike but the design is built with a lower center of gravity as seen on Fig. 9 with the Schwinn 240.

![Schwinn 240 Recumbent Exercise Bicycle](image)

This will allow for the user to mount and dismount from the exercise bike with having to struggle climbing onto a traditional bike. The system features a padded ergonomic seat and dual-position lumbar support essential for users with disabilities. It features oversized stabilizers and levelers that are built-in for a stable workout platform.

The major modification that needs to be made involves changing the pedals themselves. The pedals are designed to be flat and the only support they feature is a flimsy strap going over the top of the user’s foot. This will not suffice for our client due to her current condition. The pedal itself will need to replaced with full foot plates where the client will be able to place her entire foot into. This plate will then have to be covered with a case so when the client places her foot on the plate it will be fully enclosed. This will ensure full safety for when out client wants to exercise.

The problem with this machine is that it’s too bulky. It will take up too much room in our client’s home which is a problem. The machine will also only allow the user to perform a single form of exercise. The peddler is a highly physical exercise that will surely help our client in her rehabilitation process. This being said it’s not the only form of exercise she needs. The benefits of passive exercise that involves different ways of stretching will not be achieved by using a recumbent bicycle. Finally, even with the Schwinn 240 low center of gravity design our client will have a tough time transferring to the machine. She will still have to get off her power wheelchair and manually transfer herself to the recumbent bike. We want to avoid this process at all cost because our client has expressed becoming very tired after this process.

**Alternative Design 3**
The final alternative design will be a single machine that is completely stationary. This will implement a pedal exercise system and a stretching exercise system on opposite ends of a single machine. Since the system is stationary the client will have to move from one side of the machine to the other if she wants to perform each of the exercises. This design will create a higher stability for the system because all the parts will be welded together leaving no moving parts.

The base will consist of 10 aluminum tubes that are strategically placed to ensure sturdiness, as observed on Fig. 10.

![Figure 10: Steel Base](image)

Another four steel tubes will be vertically welded to the top of the base which will make up the portion of the machine. Four horizontal rods will be welded at the top of the vertical rods essentially make a rectangle on top of the base. These horizontal rods will be where the exercise mechanisms will be welded on.

The pedal system is connected to the base of the attachment where the primary exercise will be done. On the opposite side of the pedal system movable footplates will be implemented for a stretching mechanism. The plates will be pulled via a pulley system so Carolyn can stretch her calves without much resistance. The footplates will resemble the notion of ski bindings as seen in Fig. 11.

![Figure 11: Ski bindings (footplate model)](image)
This system allows our client to exercise from her wheelchair. The stationary aspect does mean our client will have to move to the opposite side of the machine when she want to perform another exercise, but her power wheelchair does allow for this action to be done.

2.2.1: Optimal Design – 2-in-1 Exercise Machine

2.2.1.1: Objective

The 2-in-1 exercise machine is a custom built device for our client Carolyn Martin. The exercise machine, as seen on Fig. 5, is divided into three distinct mechanical parts known as the base, the rotation system, and the upper structure. Each of these parts plays a key role in comprising the machine as a whole to ideally fit the needs of our client. The machine will serve as a platform for exercise that our client is not currently getting from any other source. The upper structure will be host two forms exercise which will be attached on its own body of work. These attachment points will be welded to the upper structure so that there are no moving parts.

The first attachment will be an exercise peddler the Instride XL Peddler, as seen on Fig. 6, which will be modified to fit the upper structure. When mounting the modified peddler an extender piece that brings the peddler closer to the user needs to be installed, this can be viewed on Fig. 5. The extender, which is already featured on the instride XL design itself, is so the user will not hit the base when exercising. The peddler itself will be bolted to the rotating plate.

The second attachment will require the use of additional footplates and its attachments making up the stretching apparatus. This will be mounted directly on the opposite side of the foot peddler for spacing purposes. The head of the foot pedals will be attached with galvanized rubber coated steel ropes. The ends of the ropes, which are not attached to the foot pedals, will feature handles for pulling. The attachment of the footplates to the upper structure will be made at the bottom of each plate. The style of attachment will allow for the plates to rotate freely with some tension. When the client places her feet on the plates she will pull on each rope to cause her toes to rotate towards her thus stretching her legs. This exercise can be done at any stress level the client desires based on how far back the rope it pulled back.

The rotating plate system will be achieved via one single square aluminum plate. A push button will initiate the rotation 180 degrees each and every time the user pushes the button. This will ensure one of the two exercise machine will be directly facing the client at all times.

The stepper motor will be set to rotate 180 degrees by setting the device to the correct number of steps. This can be done via the controller which takes inputs of speed, torque, number of steps, acceleration, and direction. Connecting the motor to the inner plate requires the use of a drive shaft. This piece will be in direct connection with the stepper motor and rotate the metal plate according to the control settings. A basic layout of this process can be seen in a flow chart on Fig. 12.


2.2.2.1: Subunits

Base

The frame of the exercise machine was designed with three main objectives in mind. The first objective was to provide enough support that a person’s body weight could be supported while the machine was in use. The second objective was to prevent the machine from tipping or sliding while being used. The final objective was to allow optimal overhang for the attachments so the rotating plate could rotate unhindered.

Addressing the first objective, the frame needed to be sturdy enough, but not be overwhelming in terms of weight. 6063 Aluminum square tubes were selected for their mechanical strength to weight ratio. The aluminum would be more than sufficient to support a significant load while being light enough for easy transport. The aluminum square tubes that construct the base and frame contain the dimensions of 1 ½ “ x 1 1/2 “. The square tubes provided optimal thickness for welding as well as providing optimal surface area to prevent tipping and sliding.

For the second objective, the machine could not tip or slide during use, the base was designed accordingly with the aluminum tubes. The bottom of the frame, the base, was designed to be rectangular, as seen in Fig. 13, in order to create the largest amount of surface area contacting the ground without impeding on the limited space constraint applied to the project. The rectangular shape will prevent the machine from tipping forward and backwards when in use with the majority of the load being present on the top portion of the frame on the rotating plate. In order to prevent sliding, the bottom of the base was rubberized to increase the friction between the floor and the base. The rubber also serves another purpose of preventing scratching of the flooring during movement and usage.

The final objective was to make sure that each attachment could be rotated while on the rotating plate and have enough overhang so that the exercises could be completed in their entirety. In order to achieve this objective the top section of the frame, as seen in Fig. 13, is smaller than the rectangular base and is a 1’ x 1’ square. The square provides optimal overhang and for both the exercise attachments and the overhang can be seen in Fig. 14.
The dimensions of the base of the exercise machine is 2’ x 1’ x 8’’ and was designed according to ergonomic and user limitations. Keeping the device small allowed for lighter weight and to be used in any room in a home. Keeping the device at 8 inches in height conformed to the height of the feet of a user in a wheelchair.

The frame was created with an open design to create ideal ventilation which will prevent the stepper motor from overheating while in use. The frame will also remain uncovered by cloth or other obstructing material to keep the ventilation system. The open system of the frame also allowed for mounting brackets to be welded onto the frame to attach both the stepper motor and the rotating system.
**Stepper Motor Mounting Plate**

The stepper motor mounting plate is a custom built plate made out of aluminum that mirrors the bracket of the stepper motor. The bracket had a 1.5 inch diameter circle cut out of it, as shown below in Fig. 15, to allow room for the motor shaft and its rotating system. Four holes were threaded on the corners to allow the motor to be held to the plate via screws. The plate was then welded directly onto the frame at a height that will keep both sprockets parallel.

![Figure 15: Stepper Motor Mounting Bracket](image)

**Lazy Susan Mounting Plate**

The rotating mechanism works based off of the design that one end of the lazy Susan rotates the plate while the other end is held stationary to the frame. This sandwich effect of the the plate sprocket and lazy Susan prevents the rotating plate from falling off. The rotating system ideally would be found in the center of the plate to allow for even rotation each time it is rotated. In order to do this, custom mounting plates were built and welded to the inside of the frame so that the lazy Susan could be directly attached to the frame, Fig. 16. From there the bolts would be placed through the other end of the lazy Susan through the sprocket and into the plate.

![Figure 16: Lazy Susan on Mounting Brackets](image)
Attachments

Besides the frame, the main component of the exercise machine are the attachments that provide both designed exercises. One of the attachments provides the user with the ability to stretch their calves, hamstrings, and legs, while the other attachment allows for a resistive controlled peddling workout.

Peddler Attachment

The peddler attachment is a modification of an In-stride XL peddler and was used to provide resistive peddling to the exercise machine. The resistance is controlled by rotating the knob either left or right to decrease or increase the resistance. The peddler base is comprised of steel and therefore could not be welded directly to the aluminum rotating plate. Due to this the ends needs to be modified. Parts of the frame were removed and angle iron was welded onto the ends of the peddler. The angle iron was then bolted directly to the frame which keeps the attachment in place.

![Peddler Attachment](image)

Figure 17: Peddler Attachment

Stretching Attachment

The stretching mechanism is a custom made footplate that acts upon a hinge and spring system to work. The footplate itself, as shown in Fig. 18, is attached to the rotating plate by use of a piano hinge. A piano hinge is a long hinge that allows nearly 360 degrees of motion. The way the hinge is attached to the rotating plate and the footplate allows it to have an ideal range of motion for a stretching workout. The footplate itself is a custom built plate built of a sheet metal. A rectangular piece that is 10 inches wide by 12 inches tall serves as a platform for the user to put one or two feet. A piece of metal was bent to mimic the curvature of a heel and provide support to the users feet during usage. The bent metal is welded onto the plate to create a single strong piece.
Other components of the stretching mechanism are the spring system and stop plate. The stop plate is welded directly onto the rotating plate and serves as a stop for when the plate is not in use. The stop keeps the plate at an ideal angle for the user to place their feet onto the footplate. The other component of the mechanism is the spring, both seen in Fig. 19. The spring is attached to a piece that is welded directly to the rotating plate and the other end is attached to a piece welded to the back of the footplate. The spring provides sufficient tension in returning the footplate to its original position while not inhibiting the user from completing the stretch.
**Rotating Mechanism**

The rotating mechanism is a mechanism designed to shift the weight of the load of the exercise machine from the shaft of the stepper motor onto the frame of the exercise machine. The rotating mechanism consists of two sprockets, a lazy Susan, a rotating plate, and a ¼ inch chain. The rotation is powered by a stepper motor and is covered later in this section. As for the mechanical aspect of the rotating mechanism the design allows for complete rotation of the plate while also providing support so the plate will not be tip or be knocked off during use.

The first component of the mechanism is the lazy Susan. The lazy Susan consists of two rotating disks that run off oiled ball bearings. By securing one end of the lazy Susan to the frame and preventing it from spinning it will provide support to the rotating plate as well as only allow the plate to be rotated. The next component is the large sprocket which goes on top of the lazy Susan and is connected to the free moving end and then bolted directly into the aluminum plate. Fig. 20 shows the sandwich effect of the three and how they are assembled. From there Fig. 21 shows the bottom end of the lazy Susan being connected to the mounting brackets to make it stationary. Also in Fig. 21 the chain can be see connected to the larger sprocket and onto the sprocket attached directly to the stepper motor shaft. When the motor is prompted by a switch, the stepper motor activates rotating 2 complete rotations which rotates the chain and the larger sprocket 180 degrees. Once the rotation is completed the motor draws power for the brake to keep the plate from rotating unnecessarily during use.

![Figure 20: Lazy Susan, Sprocket, and Plate Connection](image-url)
Stepper Motor

The stepper motor selected to power the rotating mechanism is an Excitron AU-57 stepper motor with gold motor controller, Fig. 22. This motor features a max speed of 6900 rpm and a torque of 280 in-oz which will be able to rotate a 45 lb structure which is more than the 20 pound load that is exerted onto the motor. The motor is programmed using CNC and is programmed to respond to the input of an ON pushbutton switch. As seen in Fig. 24 the command prompt shows the saved program of the motor that will run once prompted by the pushbutton. The ON pushbutton switches the input from occasionally closed to occasionally on causing the motor to run its programmed commands. The rotating mechanism uses two sprockets and because of this the sprockets create a 4 to 1 gear ratio. Due to this ratio it is calculated that the motor would need to turn two full rotations to cause the system to turn 180 degrees. The stepper motor was altered in order to have a sprocket placed onto its shaft. The motor had a flat ground into it and the sprocket was fastened with a set screw to keep it in position.

In order to use the stepper motor, the AC adaptor needs to be inserted into PWR pin 8 which is shown in Fig. 22. The AC adaptor also contains the serial port needed to plug the motor into the computer. When the motor is plugged into the computer use a program, PUTTY, to access the programming. The correct serial port needs to be determined and the Baud needs to be set to 57,000. Once these parameters are set PUTTY will be able to connect with the motor.
Figure 23: Solidworks rendition of the Stepper Motor

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Figure 24: Command Prompt
2.2.1: Prototype – 2-in-1 Exercise Machine

The 2-in-1 Exercise Machine, Fig. 25, is a product designed and created to our client’s need to perform her physical therapy. The machine offers the user both the ability to stretch and perform a pedding exercise without leaving their wheelchair. Once one of the exercises is completed a push button controlled stepper motor along with a rotating mechanism will allow the user to rotate between exercises without having to move their wheelchair. The machine was professionally painted white and is furnished with rubber coating on the bottom to prevent any scratching to the flooring it will be subjected too.

The exercise machine is fashioned with a sheet metal cover that was professionally painted white. The cover seen in Fig. 26 was created in order to both protect the user from the mechanics of the machine during use as well as hide the attachment points of each exercise mechanism.

Figure 25: Completed 2-in-1 Exercise Machine

Figure 26: Cover for Exercise Machine
As shown in Fig. 27 below, the cover is removed and the rotating aluminum plate is exposed. The plate serves as the attachment point for both the peddling and stretching mechanism. The plate has threaded holes that hold both the bolts for the sprocket underneath as well as the peddler attachment and piano hinge for the footplate.

![Figure 27: Rotating Plate](image)

Attached to one end of the rotating plate is the peddler attachment seen below in Fig. 28. The peddler attachment is a modified In-stride Xcitor peddler that provides resistive peddling by use of the black rotating knob. In order to attach the peddler the ends were modified by having angle iron being welded to the steel frame of the peddler and then having the angle iron being directly bolted into the rotating plate. The attachment method allows optimal overhang for the user to complete a peddling exercise.
Attached to the other end of the rotating aluminum plate is the stretching mechanism. Fig. 29 below shows the custom footplate that was made to support one or both of the user’s feet. Once the feet are placed onto the plate, the handle and rope can be pulled to as far as a desired stretch is wanted.

The footplate is attached to the rotating plate by use of a piano hinge Fig. 29. The piano hinge allows the footplate to be attached to the rotating plate but allow the plate to bend. The bending motion is a key component in the motion of a calf stretch.
After the footplate is bent forward, a spring system, as seen below in Fig. 30, will be connected to the back of the footplate and the tension will pull the plate back to its original position.

In order to keep the footplate at a proper angle and position before use and after use, a stop plate was welded onto the rotating plate as seen in Fig. 31. The stop plate is made out of aluminum sheet metal and is cut to an angle that allows the user to be at rest when the plate is not being pulled.
Figure 31: Stop Plate for Stretching Mechanism

Below the rotating plate is the rotating mechanism which can be seen in Fig. 32. The rotating mechanism consists of a stepper motor and a sprocket that rotates a larger sprocket and a lazy Susan and in turn rotates the aluminum rotating plate.

Figure 32: Rotating Mechanism

Directly below the aluminum plate is the larger sprocket, Fig. 33, and is directly bolted to the aluminum plate. The sprocket has ¼ treads and is rotated by the stepper motor and ¼ chain. The rotation is possible by the lazy Susan it is connected too.
The lazy Susan, Fig. 34, is the main component of the rotating feature of the rotating mechanism. One end is made stationary and bolted to the frame while the other end is connected to the larger sprocket and rotating plate. This free end provides for the rotating potential while the direct connection of the lazy Susan to the sprocket to the plate keeps the entire system together as seen in Fig. 35.
The other end of the lazy Susan needs to remain stationary and therefore mounting brackets were built into the frame for the lazy Susan to attach too. These brackets are shown in Fig. 36.

Fig. 37 shown below shows the smaller sprocket which is responsible for turning the larger sprocket in the rotating mechanism. The smaller sprocket is attached to the stepper motor shaft by grinding down a flat end and inserting a set screw to hold the sprocket in place.
The stepper motor, Fig. 38, is the main power source for the rotating system. The motor is programmed to function by the input of a push button switch. Once prompted the motor rotates 720 degrees in order to turn the larger sprocket 180 degrees. The degree of rotation is determined by the gear ratio between the two sprockets 4:1.

![Figure 38: Stepper Motor](image)

The stepper motor attaches to the frame by connecting to the custom built mounting plate that was welded directly onto the frame. The mounting bracket, Fig. 39, was welded at a specific level in order to make sure that both the smaller sprocket and the larger sprocket were parallel.

![Figure 39: Stepper Motor Mounting Bracket](image)

The final component of the 2-in-1 Exercise machine is the base, Fig. 40. The base is comprised of square aluminum tubes that were welded together. The top section is a square and is so to provide optimal overhang for the attachments during rotation. The bottom part of the base is a rectangle which provides more stability to the machine during use. The bottom is also lined with rubber to increase friction to prevent sliding during use and to also prevent scratching of flooring.
2.2.1.1: How to use

1. Pull wheel chair up to the exercise machine, making sure that your feet and chair are clear of the rotating apparatus.
2. It is recommended that you perform the stretching exercise prior to the peddling exercise. First grab the handle of the rope and then place one or both of your feet onto the footplate.

3. Once your feet are secured pull the rope to the desired distance to attain the desired stretch.
4. Slowly return the plate back to its original position and remove your feet once the footplate is back in its secured position.

5. Before using the rotating function of the machine please make sure all body parts and obstructions are clear from the machine.
6. Once the area is determined to be clear press the pushbutton in order to make the machine rotate.

7. Please wait until the machine completes its 180 degree rotation before touching any of the attachments.
8. After the machine has stopped place your feet into the footstraps and begin the peddling exercise. The black knob may be turned to adjust resistance.
Project 2: Mobile Stander

2.1.2: Introduction

The second project being designed for Carolyn Martin is a mobile stander that will allow her to move freely around in a standing position. The design hinges on the modification of an immobile stander by transposing components of a powered wheelchair to make the stander fully mobile via joystick control. The design contains several subunits which will solve the three major objectives of the project. The first objective of the stander will be to lift Carolyn from her wheelchair and bring her from a sitting to erect position. The second objective is to have Carolyn be able to control the stander via joystick so she can move about her kitchen. The final objective was to have it so Carolyn will be able to reach her counter tops by limiting the distance of the stander being between Carolyn and her counters.

![Figure 41: Mobile Stander model](image)

The design shown in Fig.41 was selected for the optimal design because it best fit the time, monetary, and size constraints that accompany the project. Also the design completed each objective. By leaving the lifting mechanism as a hydraulic pump the design can overcome the project constraints. The hydraulic pump is smaller and already attached to the stander frame. By changing it with a linear actuator, a significant amount of changes would need to be made. A strong enough actuator would need to be purchased as well as a separate power source and microcontroller. The more attachments needed, the larger the frame would be which would exceed practicality when being used in the kitchen, and also it could exceed the standard 3 feet space for doorways. The hydraulic pump was tested and can support over 500 lbs of weight, far
exceeding our client’s weight, and use of the pump is fairly easy and within the range of our client’s physical ability.

The stander cannot have a drive shaft, which prevents the use of a one armed drive; the wheels must turn the device by alternating spinning. The C program is very intensive time allotted to finish the project. Instead the controller and code will be taken from a powered wheelchair and the components of the wheelchair will carefully have to be transcribed to the stander. Several modifications will be needed to house the DC motors, batteries, and electronics. Also the wiring will need to be extended because it is going from a condensed wheelchair to a more spread out stander frame.

The necessary modifications will be added directly to the stander frame itself. By directly connecting the DC motors to the stander frame, space can be saved in terms of width of the final product. The base will need to be extended in order to serve as the mounting bracket for the motors. The extension will come in the form of attaching angle iron that will hold the motors in place. A shelf will also be built to house the batteries and electronics; the shelf will be located in the front of the stander.

**Alternative Design 1:**

The design focuses on altering a currently immobile stander frame and making it fully mobile via joy stick and automating the lifting mechanism. Currently the frame cannot be moved by the user and must be pushed around in order for the user to move. The first objective of this design will be to bring mobility to the user via joy stick control. In order to achieve fully controlled mobility two DC motors, a power supply, wheels, a microcontroller and a joystick will need to be installed to the frame. Mounting brackets for the DC motors will be made of steel and will fasten to the side of the frame and directly attached to each of the powered wheels. The powered wheels and motors will be placed as far in front of the frame as possible in order to minimizing the torque forces of the standing client and the frame, minimizing the potential of the device tipping. The flow chart shown in Fig. 42 outlines the line from the joystick to final movement of the device. A PWM motor controller and an H-bridge are needed in this design to make the motors move both forwards and backwards. The flow chart will serve as the basis for the C program that will be written in order to code the microcontroller to send proper outputs based on the joystick inputs.

**Figure 42: Microcontroller Flow Chart**
The second objective of the design is to change the hydraulic pump lifting mechanism with a linear actuator in order to automate the lifting process. The actuator purchased will have to be able to support the client and will need its own custom mounting bracket to fit in place of the hydraulic pump.

![Linear Actuator](image)

**Figure 43: Linear Actuator**

The linear actuator, as seen in Fig. 43, will function by the use of a switch. The switch will require a microcontroller and will function very similar to the flow chart seen in Fig. 42. The H-bridge is required in order to reverse the actuator to be able to bring the client both up and down.

**Alternative Design 2**

This design deals with the customization of an already existing stander frame. Unlike alternative design one, as previously mentioned, this design makes the entire stander mechanical as opposed to electronic. The frame would utilize four wheels on each end of the base and would be linked together and controlled using a one armed drive. A one armed drive is a mechanical device which allows the user to move the stander by cranking the drive with one hand forward and backwards and turning by rotating the arm drive. In order for the drive to be in working order each wheel needs to be connected so the drive can control all wheels at once.

![One Armed Drive Wheeldrive](image)

**Figure 44: One Armed Drive Wheeldrive**
The design will prevent the needed adaptation to the already mechanical design of the stander to make it electronic friendly. This design requires no electronics thus making the stander more compact in size.

The problem with the design lies in the fact that with a one armed drive there cannot be a lifting mechanism. The connection of each wheel, seen in Fig. 44, will block the passage for Carolyn to wheel her wheelchair up inside the stander. Without the lifting mechanism the design fails to be independent for Carolyn to get safely in and out of the stander.

**Alternative Design 3:**

The final design differs from the first two as it is an adaptation to a powered wheelchair. The change to the wheelchair will focus on having the seat bring a user from sitting to standing. The main components of the sitting to standing wheelchair are the linear actuators that will lift the seat to an upright position. In order to do this a powered wheelchair will need to be purchased and reconfigured to make from for the actuators. The actuators will work via button control and with the use of an 8 bit microcontroller and an H-bridge. The button will give the input to the microcontroller which the H-bridge will ultimately determine the polarity of the input changing whether the actuator goes up or down.

![Figure 45: Comfort Hero-1 Wheelchair](image)

The second component of the sitting to standing wheelchair is the chair. The conventional chair will have to be removed from the wheelchair in order to put in a new chair. The new chair will have to be two separate pieces that are connected by a hinge in order to be able to bend from a chair to a straight line. The chair will also have its own actuator in order to complete the straightening process simultaneously as the seat is being raised so the client does not get hurt in the raising process.
The problem with this design compared to the optimal design is after the client is in the raised position she will remain immobile. Do to safety concerns standing wheelchairs lose their functionality to move via joystick control after they are fully raised. This because the balance of the wheelchair is completely altered and torques from a much greater height are being applied.

2.2.2: Optimal Design – Mobile Stander

2.2.2.1: Objective

The mobile stander is a customization of a pre-existing stander frame in order to give the user complete mobility via joystick. The design is catered towards Carolyn Martin and her desire to perform tasks in her kitchen. Currently Carolyn has difficulty doing anything in her kitchen due the constraints from her powered wheelchair. The stander will hoist her out of her wheelchair and allow her to be able to move from station to station across her kitchen in order to use whatever appliance she wishes.

The design of the stander involves taking key components of a powered wheelchair and mounting them onto a stander frame. In order to properly mount the components, DC motors, batteries, joystick, and microcontroller attachments and modifications need to be made to the stander frame. To mount the DC motors the base needs to be extended in order to match the width of the motor’s mounting plate. The extension will come in the form of welding and bolting steel to each side and drilling holes in the steel for the screws of the motor’s mounting plate to attach too. The motors will be directly under the frame, which will prevent widening the entire device as well as making it easier to conceal the motors to make the final device physically appealing. The other alteration will be to build a shelf which will be responsible for holding the electronics as well as the batteries.

The main component of the mobile stander is the full mobility control for the user by use of a joystick. By using the joystick and microcontrollers from the power wheelchair, the motors will function the same. The inputs affect how each wheel turns individually. Turning is made possible by alternating the direction each wheel spins.

The final component of the design is the lifting bar and mechanism that will lift Carolyn from her seat onto the stander. The lifting mechanism is a hydraulic pump that lifts a steel bar up. Attached to the steel bar is a harness which Carolyn will attach herself too. Once in the harness she will be able to crank the pump and be brought to a secured erect position.

2.2.2.2: Subunits

Base

The base shown in Fig. 46 is made of steel in which the load of the device and the user will be supported. The base resembles an open ended rectangle giving a wide surface area so the stander has a lot of room to balance on. At the bottom of the four ends of the base are wheels with the front wheels each of them being caster. Also on the sides of the base there are 2 drive wheels which are powered and give the overall system full mobility.
The base, as previously mentioned, is comprised of steel which provides needed weight and strength in order to support the constant load on the device. The back half of the base is extended in order to allow the user to pull his/her wheelchair as close as possible to the frame. The front wheels and support also feature a short design in order to allow Carolyn to move as close as possible to her countertop while providing her with maximum reach. The front and back of the base are furnished with caster wheels in order to maximize mobility and allow for controlled and more precise movements. The drive wheels being in the middle of the stander allow for balanced control and even weight distribution.

The base also serves as the attachment site for the DC motors. The base will need to be widened in certain area by attaching angle iron into either side. The motors will be mounted to this angle iron.

Frame

The frame, Fig. 47, of the design is the frame of an already existing immobile stander.
The frame contains two major functional pieces. The function of the frame is to provide stability and support by transferring the load of hoisting and supporting the user down the stem and onto the base. The frame also serves as a major attachment point for the devices that provide dynamic functionality. Attached to the body is the lifting mechanism and bar and attached to the desk rest will be the joystick which will control the movement of the stander. The frame will also house a shelf which will hold the electronics and battery supply needed to use and run the stander.

The stander frame was stress tested in order to see if the frame can support the load of an individual as well as the load from hoisting an individual out of a wheelchair and onto the stander. The testing was performed using Solidworks and the results gave back high coefficients of safety dealing with stresses heavier than of a 250 lb. man, showing the frame is safe for usage.

### Foot Support

The foot supports shown in Fig. 48, came built in with the mechanical stander and feature hard plastic base Velcro straps for additional safety.

![Figure 48: Foot rests w/ Velcro straps](image)

The foot pedals will be attached to the base and provide an area in which the user can stand as well as secure their feet.

### Shin Pads

The shin pad is located directly above the foot rests as seen on Fig. 49.
Figure 49: Shin Passing

The pads feature a smooth leather finish giving an attractive look while also providing the support the user will need when operating this device. The shins pads are also horizontally adjustable so they can be adjusted to the user’s preference.

**Hip supports**

The leg supports are made of hard plastic and padded molds that are attached to the upper section of the frame as seen on Fig. 50.

Figure 50: Hip Support

The hip supports provide a comfortable and structural support in which the user will rest her legs against while upright in the machine. The width of the supports will be adjustable so over time continued use of the device is possible regardless of physical changes to an individuals’ body.
Desk Rest

The desk rest located at the top of the stander is a highly important feature of the automated stander. The surface area is also large enough as seen on Fig. 51 to place various items and accessories.

![Figure 51: Desk rest](image)

The height of the desk is also adjustable according to the user’s preferences. Mounted on the desk is the joystick that controls the entire mobile system. The joystick features an on/off knob and speed change knob as seen on Fig. 51.

Lifting Bar

The lifting bar or hoisting bar is a staggered bar made of steel, Fig. 52, that will be fastened at a joint on the front of the frame.
The bar will support the entire weight of the user during the lifting phase, and will be the main support unit during the standing phase. The bar will be attached to a pivot point at the front of the frame to allow for range of motion as well as support from the frame and base of the load of the client. The bar underwent stress tests like the frame and resulted in similar safety results.

**Lifting Upper Back Harness**

The lifting harness is a nylon upper back harness, shown in Fig. 53, which is attached to both ends of the lifting bar.
The harness will attach at points on the upper back and shoulder and will provide a safe and comfortable transition from wheelchair to the mobile stander. Once in the standing position the harness will remain on and be the main personal support for the user’s body weight. By relieving the user’s lower body from a significant portion of her weight the user will be able to stand and use the mobile stander without having to support herself with her upper body. Prior to purchasing a harness, its strength was researched, ensuring that the load experienced from the hoist points and user’s body weight will be enough. Further physical testing was implemented in order to confirm the harness system is safe.

**Wheels**

There are two types of wheels used in the automated stander. First there are four caster wheels, as seen on Fig. 54, on each of the four ends of the base. The casters are meant to give the system better balance and guide the stander while in motion.

![Caster wheel](image)

Figure 54: Caster wheel

Secondly the drive wheels, which are attached to each of the DC motors, will fully mobilize the stander.
DC Motors

The DC motors used to run this system were taken from a powered wheel chair bought at the NEAT Market place in Hartford, CT. The motor assembly can be viewed on table 1.

<table>
<thead>
<tr>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axle key 0.236W x 0.236H x 1.566L</td>
</tr>
<tr>
<td>Brake cap, E610</td>
</tr>
<tr>
<td>Brake solenoid, E610</td>
</tr>
<tr>
<td>2 x Motor, brush (MTS: 62400001)</td>
</tr>
<tr>
<td>2 x Motor, brush cap (MTS: 62400013)</td>
</tr>
<tr>
<td>3 x Screw M6-1.0 x 16 mm</td>
</tr>
<tr>
<td>3 x Screw M6-1.0 x 30 mm</td>
</tr>
</tbody>
</table>

Table 1: Assembly of Quantum Q1103 Ultra motors
Two of these high speed electric motors can be found on the frame of the automated motor as seen on Fig. 56.

![High speed electric motor](image)

Figure 56: High speed electric motor

**Power Supply**

The power supply for the power stander will be based of two 12 V Deep Cell Marine batteries as seen on Fig. 57.

![Ever Start Deep Cell Battery](image)

Figure 57: Ever Start Deep Cell Battery

Deep cell batteries are needed because they can be recharged using an electric charger. This provides the user an easy way to charger the automated stander. The batteries will be the main supply of power to both the motor and the control circuit. The design requires taking the microcontroller from a powered wheel chair, changing the code to control the speed will not be possible. By limiting the voltage from the battery to the motors the amount of power will be limited, slowing the device down.

**Microcontroller/PIC/Joystick**
The microcontroller is the key electrical component to the power stander. The microcontroller will receive inputs from the joystick and timely be responsible for the overall speed and direction of the power stander. The 16 bit microcontroller along with motor controller will be taken from the powered wheel chair. The joystick will be attached to the right arm rest of the power stander and will be taken from a scrapped power wheelchair. The joystick will be attached to the right arm rest due to our client’s preference of being right hand dominate and desiring more precise control. The joystick will be the client’s main method of controlling the speed and direction of the stander. The turning function of the stander relies on the inputs from the joystick/ microcontroller. Because the wheels are directly connected to the motors the stander will turn by opposite spinning. The motor controller along with the microcontroller will cause one wheel to spin backwards and one wheel to spin forwards which will allow for the stander to turn either left or right, depending on the joystick input.

2.2.2: Prototype – Mobile Stander

The top of the mobile stander features a rest desk where the user can rest his/her hands while operating the device. The surface area is also large enough as seen on Fig. 59 to place various items and accessories.
The height of the desk is also adjustable according to the user’s preferences. Mounted on the desk is the joystick that controls the entire mobile system. The joystick features an on/off knob and speed change knob.

Going down the central pipe several attachments can be found as seen on Fig. 60.

The first attachment is the hip cushion which provides support and protection when using the mobile stander. Next the shin pads also provide similar support and protection. Finally, the foot
pads will allow the user to place his/her feet in a secure location when standing erect in the mobile stander.

Also attached to the central pipe is the lifting mechanism which features a steel bar and a hydraulic pump. This system as seen on Fig. 61 will lift the user onto his/her feet via a harness which is also visible on Fig. 61. The pump has the lifting capacity of 400 lbs.

Figure 61: Lifting mechanism
Two dc motors are mounted to the lower back portion of the frame are seen on Fig. 62.

Figure 62: Mounted dc motor
The dc motors will power the two drive wheels which intern will make the system mobile. The mobile stander features 4 caster wheels that help keep the system balanced when operational. These casters are free moving while the drive wheels are in neutral until the joystick is operated. The entire system can be viewed on Fig. 63.

![Figure 63: Dc motor, drive wheel and caster wheel](image)

Towards the front of the mechanical frame, as seen in Fig. 64, of the stander a custom built battery shelf was put in place to hold the two 12 volt batteries that power the mobile stander.

![Figure 64: Closed/grounded battery case](image)

The batteries are mounted in-between the two pieces of angle iron and are securely held in place. Covering the batteries is a custom built case with a removable top, as seen on Fig. 65, which allows access to the batteries. In between the two batteries the microcontroller is mounted and its job is to relays the signal from the joystick to the dc motors.
Connecting the motors, batteries, microcontroller, and joystick all must be done through the surge box featured in Fig. 66.

From left to right the input include joystick, dc motors (middle three) and the charger. For the charger as seen on Fig. 67 a simple three pin plug needs to be attached and plugged into an outlet to charge the batteries.
The batteries need to be connected to the dc motor with the positive and negative wires which are colored red and black respectively. These wires, Fig. 68, will be providing the power from the batteries to the dc motors which will rotate the drive wheels.

Then connecting the microcontroller to the dc motors requires plugging in the pin seen on Fig. 69.
Each of the two motors has this connection associated with it and the wires are labeled as to which motors they belong to. Each and every one of these connections leads back to the surge box which organizes this system while keeping it safe.

2.2.2.1: How to use??

1. Place feet in foot rests

2. Place harness over your body
3. With one hand on the hydraulic and the other holding onto the desk rest slowly pump yourself up.

4. Fasten the safety belt
5. Turn on the mobile stander by flipping the left switch down

6. Adjust the speed accordingly by rotating the right knob (spin left to slow down and spin right to speed up)

7. Using the joystick to control the motion
8. To turn off mobile stander flip the left switch down

9. To dismount remove safety belt and hold hydraulic pump all the way up so the lifting bar can slowly release.
3. Realistic Constraints

Constraints come with the engineering of any product, new or old. The fewer the constraints a product faces the more likely it will be a successful invention. One of the largest constraints is our client’s condition, multiple sclerosis. This disease has rendered our client to have very little function in her lower extremities. The purpose of creating a customized exercise machine for Carolyn is to cater to her specific limitations. The design was primarily made to function for the specific needs our client requires. The flexibility of the design is clearly limited by Carolyn’s physical condition and ability to actually use the device with ease.

Economically we are restricted to the budget which stands at 1500 dollars. We do not have an endless sum of capital so some parts preferred parts may not ideally suit the design. Specifically, Aluminum will be used in our design for the framework of the attachment. Aluminum is a high sturdy and reliable metal that will increase the product's sustainability. It also comes in a glossy finish which is appealing to most customers.

Our client lives in her mother homes in Shelton, CT. This being said she has expressed the need to keep her equipment as much “out of the way” as possible. She wants to be able to keep everything in her bedroom which is already filled with other medical devices like her wheelchair, walker, etc. This intern limits the size of the machines being designed. The design needs to be compact enough to fit into her living quarters, but still be able to support the force they endure while the client is using them.
The sustainability of the product will be determined by the parts used to piece this exercise machine together. The Chattanooga deluxe pedal exerciser as seen on Fig. 8 was initially the pedal exerciser of choice because of its impeccable design and two year warranty. With this being said the cost was nearly $140 and weighed over 30 lbs so it was not practical for our exercise machine design. Instead the design went with the instride XL peddler.

Safety is the largest issue when it comes to designing any sort of product for a client with disabilities. The entire design is based around the fact that the client will not be able to use a conventional exercise machine safely so a custom version will be built to fit her specific needs. The rotating central apparatus will be slowed down considerably so injury is not an issue when the client decides to perform the second form of exercise associated with this attachment.

Socially we face one major problem, the distance the client is from our working quarters. The hour and fifteen minute drive cannot be made on a weekly basis so email communication is essential. We would like to visit her more often and get feedback, but it just isn’t practical.

4. Safety Issues

One of the most important features of each product will feature is top notch safety for the user, Carolyn Martin. Due to Carolyn’s current condition she does not have much function from the hips down so she is very limited in her ability to move without a wheelchair.

Several safety issues were addressed with the exercise machine. The machine will be stationary in her home in an easily assessable location for her wheelchair. She will then be able to navigate to this location, by the use of her wheelchair, and use the machine without the help of others. Ensuring that the machine is fully stationary and safe to use is essential. Since she will be pedaling the framework will need to endure a certain stress and strain, but after 3D testing the design has shown it can withstand the load.

Since Carolyn has very little leg function she will have to insert her feet into the pedals by the use of her arms. This may lead to difficulty and potential injury for the client if the pedals aren’t placed in an easy to reach position. The rotation mechanism to switch between exercises is also another cause for concern. She needs to be able to reach the push button, but also must not be able to accidently hit it during use of the machine.

Once again overall sturdiness of the frame will come into question. Aluminum is the ideal choice because of its strong and light properties and price compared to steel. It is easily manipulated and can be shaped to nearly any shape. Having a strong and sturdy framework for the attachment is essential for the safety of the user.

For the mobile stander that will be customized for Carolyn some safety issues did arise. The strength of the hydraulic pump as well as the harness needed to be determined. The harness is rated for over 1000 pounds of force, far exceeding the weight of our client. Also the hydraulic pump can lift over 500 pounds without significant effort. Due to Carolyn’s strong upper body and the ease of using the pump, lifting herself will not be a strenuous activity.

The other major safety issue associated with the mobile stander is tipping. By using four caster wheels and two larger wheelchair wheels the stability of the stander is assured. The power wheels will be placed as far forward on the stander as possible and will be accompanied with a set of caster wheels. This will limit the torque force from Carolyn reaching her cabinets while in the stander. The other set of caster wheels will be place in the back which will help with balance as well as increase range of motion.
5. Impact of Engineering Solutions

2-in-1 Exercise Machine

5.1.1 Global:
The global impact of the design can apply to all physical therapy fields. By creating exercise equipment that is catered towards those with disabilities it is possible to further active approaches against degenerative diseases. Although physical therapy is not a cure, leading an active healthy life has shown signs of slowing disease as well as other physical benefits associated with exercise.

5.1.2 Economical:
It is hard to judge the device as a whole on the economic level. There are not any machines out on the market to compare the device too. Although the device cost slightly more than higher end leg peddlers and leg stretching devices. The overall product is affordable by almost all physical therapy clinics and is not a large strain for most families to purchase individually.

5.1.3 Environmental:
The environmental impact of this device is of small concern. The device is electric and its usage is minimal compared to other exercise machines. The device is not a large or heavy piece of exercise machinery, meaning shipping and handling efforts are reduced, reducing the carbon footprint of the vehicle required to move it. Disposing of the device also causes minimal environmental concern. Due to the frame being comprised of aluminum the scrap metal can be reused in the future. The devices’ power source is from an outlet as opposed to a battery, eliminating the hazardous removal required with batteries.

5.1.4 Social:
The social aspect of the solution is catered directly towards our client, Carolyn Martin. The device is custom equipment that is specialized to her needs. It allows minimal effort for her to use while in her wheelchair, while allowing her to perform her required physical therapy as well as further her physical therapy with the addition to stretching. Carolyn wishes to be able to walk on her own power some day and she feels that her best route to that destination is through physical exercise.
Mobile Stander

5.2.1 Global:

Power standers are already on the market, but most power standers have the same physical design, to create a device to help an individual to stand and give them a workspace. The design built is catered to interacting with the world around the individual, not making a world for them to interact with. By minimizing the front of the device the user will be able to use and reach objects without obstruction. In the case of our client, Carolyn, she will be able to use her appliances throughout her kitchen.

5.2.2 Economical:

For an automated stander with an automatic lift, the price range starts at a 2,000 dollar minimum. Our finished design will cost no more than 1,000 dollars, and will contain all the functions of a top of the line model. For most owning a stander provides a much needed convenience and change from just a wheelchair, but the steep price range prevents most potential buyers from ever purchasing one. By providing a cheaper and comparable quality product, the device will affect the market as a more affordable stander is introduced.

5.2.3 Environmental:

The stander does not cause any immediate environmental concerns in both the building and using phases. The only major concern environmental wise is the disposal of the batteries. The batteries are lithium which is easier and safer to dispose of, but each battery contains its own environmental risks. The steel that the frame and base are made up of can be reused as scrap metal. As far as the electronics they leave a smaller carbon footprint than gasoline powered motors, but also need proper disposing action.

5.2.4 Social:

Socially, this device was created in order to improve the quality of life of our client. Carolyn has stressed how important cooking and using her kitchen is to her, but she is unable to use it while in a wheelchair. The stander will allow her free range of motion with her reach and access to all her kitchen appliances. Standing, even assisted, is a healthy passive form of exercise and will hopefully provide a healthier life for her.
6. Life Long Learning:

6.1 Mechanical:
Each project needed a strong supporting base in order to ensure the safety and functionality of the device. The bases were made of metal and it was an important skill learning how to join and weld different metals. Steel and aluminum require different skill levels, with aluminum not turning red hot before it melts. It was vital to have experience welding steel first before moving on to the more challenging aluminum. Despite just using strong metals, the bases for each project had to be built in a manner which disperses the load, preventing any mechanical failures, specifically at the joining points.

Each device also contains a motor, it was important that each motor was correctly connected. One of the motors is a stepper motor and needs to be controlled by a microcontroller in order to rotate the needed 180 degrees. Learning the proper steps to achieve a 180 degree rotation is needed. The other motor, stander motors, are controlled by a joy stick and will be used in a kitchen. It is important to limit the amount of power from the DC motors to keep the speed of the stander to a minimum. Along with the electrical components and the machine shopping skills associated with the welding and cutting of metal, soldering is another important technique that was earned when dealing with the electrical components.

6.2 Social:
The entire design project brought forth many educational lessons with one of the most important experiences being the social aspect. The team needed to be able to cooperate and trust each other while constantly keeping communication open. The group members all had strengths and weakness and in some instances in the projects were both members’ weak points. It was vital to work together to overcome the harder aspects of the project, specifically with the electronics, and to keep level heads.

The other social aspect that the project entailed was communicating with the bosses and the client. The client had to be kept up to date just like the bosses. No member could slack in responding to an email or updating the status of the project. Learning how bosses want results and concise work in order to quickly catch them up to speed with an idea is a skill that will carry over into the workforce. The design project showed that a boss that you represent demands quality work just like a client would. As for the client communication and understanding is essential. By learning as much about the client as possible and understanding their needs and wants, better devices can be made oriented to them. Especially dealing with clients with disabilities, by understanding their conditions better the greater understanding of the final goal can be understood.

6.3 Computer Software:
Computer Software was another essential in completing the designs. CAD designs as well as SolidWorks designs helped create a visual picture and a theoretical testing model. By
using SolidWorks to help show how each component connected, the experimental success rate greatly increased, creating a theoretically perfect blueprint.

7. Budget & Timeline

7.1: Budget

<table>
<thead>
<tr>
<th>Product</th>
<th>Cost($)</th>
<th>Shipping($)</th>
<th>Total Cost($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamina 15-0120 Intridy Cycle XL Pedal Exerciser</td>
<td>40.00</td>
<td>Free</td>
<td>40.00</td>
</tr>
<tr>
<td>36’ 1.5x1.5x.25 Aluminum Square Tubing</td>
<td>143.00</td>
<td>Free</td>
<td>180.00</td>
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<tr>
<td>1 1x1x.375 Aluminum Plate</td>
<td>38.00</td>
<td>Free</td>
<td>38.00</td>
</tr>
<tr>
<td>Excitron Au28-32 -- NEMA11 Gold Stepper Motor + Controller</td>
<td>459.00</td>
<td>15.00</td>
<td>474.00</td>
</tr>
<tr>
<td>Angle Iron, bolts, nut, washers ect. From Mansfield Supply</td>
<td>40.00</td>
<td>Free</td>
<td>40.00</td>
</tr>
<tr>
<td>4 1.5 inch caster wheels</td>
<td>60.00</td>
<td>10.00</td>
<td>70.00</td>
</tr>
<tr>
<td>Miscellaneous ( i.e. Anti-scratch pads, handles, welding costs)</td>
<td>100.00</td>
<td>Free</td>
<td>100.00</td>
</tr>
<tr>
<td>Stander Frame</td>
<td>250.00</td>
<td>Free</td>
<td>250.00</td>
</tr>
<tr>
<td>Koch 7425100 Roller Chain, #25, 10 Feet</td>
<td>11.02</td>
<td>10.93</td>
<td>21.95</td>
</tr>
<tr>
<td>Arduino Duemilanove</td>
<td>22.75</td>
<td>10.75</td>
<td>33.50</td>
</tr>
<tr>
<td>USB to Serial Adapter - Professional</td>
<td>34.95</td>
<td>9.30</td>
<td>44.25</td>
</tr>
<tr>
<td>Martin Roller Chain Sprocket 5.876”</td>
<td>27.54</td>
<td>10.04</td>
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<tr>
<td>USB to Serial RS-232 DB9 Adapter Cable</td>
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<td>11.97</td>
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<td>Martin Roller Chain Sprocket 1”</td>
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<td>12V LIGHTED PUSHBUTTON, 1” BLUE LENS</td>
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<td>7.00</td>
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<tr>
<td>Rubber</td>
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<td><strong>109.61</strong></td>
<td><strong>1389.61</strong></td>
</tr>
</tbody>
</table>

Figure 34: Budget

8. Individual Contributions

8.1: Nishant Patel

I have been steadily working over the past two semesters to make sure both of the projects have been going according to our Microsoft project plan. This plan assigned individual tasks to me and Eric which we have been following on a weekly basis. My major focus last semester was to designing a 3-D Solid Works model of the 2-in-1 exercise machine based on our specifications. I also focused heavily on materials needs and part ordering for the 2-in-1 exercise machine. Based on my own preference, our client’s opinion and the advice given to me I made detailed decisions on the layout of the machine. I have also been a key contributor to the design ideas behind the automatic stander which will be built using parts from a power wheelchair.

Solid Works was a brand new program for me so designing the model, at first, was highly challenging. I ended up working several weeks on the model but the final design is perfectly to
scale of what the actual machine should be, as seen on Fig. 5. Stress testing on the model was
done in order to prove it is a successful design and it managed to pass every single test.
Sustainability testing was also done on the design giving many favorable results.

Deciding what material to make the mechanical design of the 2-in-1 exercise machine
and choosing which parts to implement are part of my contribution to the overall project. Steel
was my first metal of choice until my advisors diverted me away from the idea. Steel happens to
a highly dense and heavy metal that would make my design unpractical. It also is highly
expensive which would really hurt our budget. Aluminum seemed to be a viable replacement
with its good strength characteristic and lightweight design. Also cost wise aluminum is far less
expensive than steel. Welding the machine together seemed to be a potential issue seeing that
aluminum will go from the solid to liquid state rather quickly. Upon further research at the
machine shop building we the shop featured an arc welder system which would help with
welding the aluminum making it a viable option. Parts such as the XL instride peddler, Fig. 6,
were chosen with my design in mind. Many other peddlers featuring built in resistance weighed
upwards to 30 lbs. and cost upwards to $130. The XL instride peddler is light weight at 9.8 lbs.
and cost significantly less.

This previous semester I helped implement the both of the solid works designed as
previously mentioned. I first helped motorize the mechanical stander frame we had previously
bought from the Neat Market place. We attached several pieces of angle iron to the side paneling
of the stander frame and installed both of the motors and drive wheels. To the front of the stander
we also attached solid angle iron inter making a shelf for the two 12 volt batteries we would need
to power the system. For the batteries and electronics I worked on constricking custom casing
that would not only protect the parts but give the user easy access to them. All the cases where
then painted to give an attractive finish.

For the 2-in-1 exercise machine I worked on customizing the parts to fit the overall
machine. The instride XL pedal attached was cut in such a way that would fit onto the metal
plate with simply two bolts. I helped design and built the base which was all constructed from
aluminum square rods.

8.2: Eric Puffer

Over the course of the semester the major focus was following the outline and tasks given
on the Microsoft project outline. Following the budget and conferring with the other group
member of specifics about the project was necessary in completing individual work. The main
focus of the individual report was to handle the mobile stander, specifically with the Solidworks
drawing. A majority of time was spent creating the stander as well a human model on
Solidworks. The Solidworks design consisted of creating the stander frame, caster wheels,
wheelchair wheels, DC motors, and an actuator. The Solidworks model of the projected final
product was useful in both determining how the product was going to be built as well as testing
to see if the additional weight and the clients weight will be supported.
After discussion with the other group member stripping a powered wheelchair and using the
parts became the ideal method in completing the stander. In order to do so the stander frame and
wheelchair had to be purchased and picked up from the NEAT market. After the wheelchair was
purchased, measurements of the stander frame were taken and the wheelchair was brought home.
At home the wheel chair was stripped down to its key component parts and each part was tested
to see if the motor, microcontroller, and joystick were in working order.
The DC motors were assembled onto the mechanical stander frame by making custom mounting brackets. The brackets were made out of a composite as well as angle iron to sit flat on the frame of the stander. The stander was then wired and tested to see if it ran properly. Because the way the motors were mounted special casters had to be put on which involved making new caster treads. The frame was cut in and new treads were machined and welded onto the frame.

The other task given was to be responsible for the making and upkeep of the website via Dreamweaver. The overall design and function was a task that involved learning on the go. Being new to website design and Dreamweaver improvement on the website was made as more experience was gained with use of the program.

In regards to the 2-in-1 exercise machine I was responsible for designing and machining the frame as well as making the attachments of the peddler and the stretching plate. Machining also needed to be done to create special mounting brackets for the lazy Susan and stepper motor. Also the rotating mechanism was designed by myself and implemented by making changes to the sprockets lazy Susan and rotating plate. Finally the last task I was responsible for was programming the stepper motor to make sure the system rotated 180 degrees.

9. Conclusion

Two projects were designed and specialized so Carolyn Martin, a 42 year old female who has Multiple Sclerosis, could further her physical therapy treatment and be able to use her own kitchen. Two separate projects have been designed, with the first project being a dual exercise machine and the second being a mobile stander. Each of the machines is specialized to fit our client’s specific needs.

The first project focuses on the necessity for Carolyn to further her physical therapy. Exercise is our client’s first priority and will be the major theme of the first project. The machine design incorporates the ability to both stretch and do resistive peddling without the client having to leave or move from her wheelchair. The design consists of three major components, the base, stepper motor/controller/push button system, and the upper structure. The base is comprised of a square aluminum base which is used to support the exercise apparatus and the motor. Aluminum square tubes are used to fasten and secure the peddling system and the stretching mechanism to the frame and the rotating plate. The pedaling and stretching systems will be mounted on opposite ends of the machine. With the use of a button a stepper motor and controller the plate will turn 100 steps to rotate the plate 180 degrees allowing the user the ability to exercise using the equipment.

The second project focuses on the desire Carolyn had for cooking and using all of her kitchen appliances. Our design of the mobile stander has the ability to hoist the client from her wheelchair via a harness and hydraulic pump onto the stander in a secured standing position. Once she has reached the standing position, the stander can be controlled via joystick. The joystick gives inputs to the microcontroller and is directly responsible for moving and directing the wheels. The joystick and controller will be transferred from a powered wheelchair and the speed will be changed by limiting voltage to the motors from the battery. By making the stander automatic, Carolyn will be able to navigate around her kitchen as she pleases. By turning the joystick left or right, one wheel will rotate forward while the other wheel will rotate in reverse, causing her to turn in the desired direction with a high turning radius. The stander frame and base are both made from steel to compensate for the high load and stress placed on the system. Unlike normal standers, the design allows a user to interact with the surroundings around them by minimizing the length of the structure in the front.
10. References


11. Acknowledgements

- Dr. Enderle – Our professor whom advised us with the overall project

- Marek Wartenberg – Our TA whom advised us with the overall project

- Don Hoerman – Works at the Neat Market Place and helped us pick out parts.

- Serge Doyon – Machine Shop

- Pete Glaude – Machine Shop

- Carolyn Martin – Our Client
12. Appendix

Figure 70: Pin Data Sheet for Stepper Motor
10A-RS232 Controller/driver

This controller has an RS232 (+10 vdc) serial interface built-in, therefore no external adaptor is required to connect to PCs, notebook, R/C, and other computers.

Its very small size allows easy mounting, yet the 10A-RS232 can drive 57mm (NEMA 23) or smaller stepper motors.

You can serially communicate using the Tx232 and Rx232 pins, which are RS232 (+10v) signals. Connect these directly to an external computer’s RS232 lines as shown. The 10A-RS232 includes a 12” shielded jacketed cable with a female DB9 RS232 connector and metalized plastic shell.

Note that the input signals IN3, IN4, IN5, and Reset are TTL (0 to +5v). Maximum allowable voltage is +5.5, minimum is -0.5. See Controller Manual for how the inputs can control your motor motion. All inputs are protected to +15kV.

The power supply filter is inside. The controller or the motor may be ordered separately. Suggest our 24 volt 80 watt encapsulated power supply with this controller.

Figure 71: RS232 Controller Data Sheet
New! GOLD Controllercoders

"Control-lo-sunder"—stepper motor controllers with optical encoders built-in. Each Controllercoder is fully integrated with the stepper motor, producing the most compact and powerful intelligent motor drive available. Complete family can drive stepper motors from 15mm diameter to NEMA 42, and perfectly matches drive amperage with the motor size. The absolute optical encoder and Index give position feedback for optimal motion control. These units offer the first total 100% motor drive solution, allowing easy plug-n-play for machines, CNC robots, actuators, robots, and off equipment.

Features common to all Au Gold Controllercoders

- Special optical encoder built-in-no external messy wires, no physical hard-to-align modules! Closed-loop feedback ensures motor motion.
- Gold plated connectors, printed circuit boards, and covers for ultimate reliability, heat flow, and performance.
- Easily change directions, number of steps, speed, acceleration, and torque.
- On-board RS232 serial communication port.
- 8 input pins (2 analog), and 1 output pin for external standalone motion control.
- +5V shutdown, 3.3 Volt logic, +5 Volt tolerant. Easily change speed-on-the-fly.
- Dual microprocessors with enough memory and speed for full automatic and robotic motion control. Multi-axis capability eliminates DOSs and PCs.
- CNC Driver mode using step and direction pins. Contains all the electronics required for complete motor control—nothing else needed except power supply, regulated 4 to 30 VDC.
- Temperature and voltage monitoring, thermal shutdown control.
- Extremely high efficiency, only uses 80%, controller run cool.
- Exact same connectors for all motor sizes gives total compatibility. Cables exit tightly against motor for superb cable management.
- Full backwards compatibility with previous Excitron Controllers.
- Optional 2 Aktor SM64NH and unique internet address for worldwide remote control, diagnostics, updates, and status.

All 57 series motors are industry standard NEMA 23, 0.45 deg/full step, and are rated at 2.3

Inching. All 56 series motors are industry standard NEMA 23, 0.9 deg/full step, and are rated at 2.3

Inching. The Au50-Au57 series motor handles 3 amps and needs a 5 amp heat sink, while the Au60-Au67 series motor handles 5 amps and needs a 15 amp heat sink, while the Au60-Au67 series motor handles 5 amps and needs a 15 amp heat sink.

Motor/Controller: L: L03 Wt: Torque
Au57-40M 1.54 1.16 84 in-lb
Au57-66M 2.66 1.9 220
Au57-76M 3.06 2.2 280
Au60-45 1.83 1.4 140
Au60-86 3.44 3.1 380

Figure 72: Motor Controller Data Sheet