BME 4910 Final Report

Assisted Walking Device

Team 3:
Scott Kopp, Andrew Czyzowski, Jason Wang

Project for Annalee Hughes
Susan Lucek,
slucek@nerac.com, 860-872-7000 ext 1008
# Table Of Contents

## Contents

*Table Of Contents*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>2</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>2</td>
</tr>
<tr>
<td><strong>BACKGROUND</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>PURPOSE</strong></td>
<td>3</td>
</tr>
<tr>
<td>OTHER PROJECTS AND PATENTS</td>
<td>3</td>
</tr>
<tr>
<td>REPORT MAP</td>
<td>6</td>
</tr>
<tr>
<td>PROJECT DESIGN</td>
<td>7</td>
</tr>
<tr>
<td><strong>OBJECTIVE</strong></td>
<td>7</td>
</tr>
<tr>
<td><strong>SUBUNITS</strong></td>
<td>8</td>
</tr>
<tr>
<td>PROTOTYPE</td>
<td>22</td>
</tr>
<tr>
<td>REALISTIC CONSTRAINTS</td>
<td>33</td>
</tr>
<tr>
<td>SAFETY ISSUES</td>
<td>35</td>
</tr>
<tr>
<td>IMPACT OF ENGINEERING SOLUTIONS</td>
<td>36</td>
</tr>
<tr>
<td>LIFE-LONG LEARNING</td>
<td>37</td>
</tr>
<tr>
<td>BUDGET</td>
<td>38</td>
</tr>
<tr>
<td>TEAM MEMBER CONTRIBUTIONS</td>
<td>42</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>43</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>43</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>44</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>44</td>
</tr>
<tr>
<td><strong>MECHANICAL DESCRIPTION</strong></td>
<td>44</td>
</tr>
<tr>
<td><strong>ELECTRICAL DESCRIPTION</strong></td>
<td>54</td>
</tr>
<tr>
<td><strong>CODE DESCRIPTION</strong></td>
<td>56</td>
</tr>
<tr>
<td><strong>TECHNICAL SPECIFICATION</strong></td>
<td>61</td>
</tr>
</tbody>
</table>
Abstract

The client has requested a device that will accustom a child with cerebral palsy to a natural walking stride. The device will be designed for Annalee Hughes, a ten year old girl with cerebral palsy, who has a difficult time standing on her own and cannot perform the proper walking technique. The device will be made to mimic the walking motion and keep her legs in a proper walking position in order to develop her muscles. The ultimate goal is for Annalee to get into the device unassisted and to be able to safely walk around in a confined area.

The device will be made from a prefabricated frame that was made for a similar type of walking device. The frame is made of a lightweight metal and it is small enough that it will be easy to maneuver around the home and transport without sacrificing strength or stability. The device will be rear-entry so that she can enter easily. There will also be grips that will allow her to pull herself up into the device from a seated position. The device will support her body weight and assist in standing using supports at the forearms, chest, hips and legs. The user’s legs will be supported by specially constructed braces. These braces will keep the legs in a straight position necessary to mimic walking, and prevent the scissoring of the legs typical of patients with cerebral palsy. The leg braces will be designed to open and close using a combination of both a motor and linear actuator that is user controlled. The device will be adjustable in various locations so that as the user grows in size or progresses in walking technique it may be adjusted.

The budget for this walking device is $1350. This is reasonable when considering the impact the device will have on Annalee’s life as well as the amount that can be saved when purchasing and refinishing used parts. The ultimate goal of the device is to allow her to become a more independent person, and to improve her overall quality of life. By allocating additional funds to motorize the leg braces, we will be able to build a device that requires a minimum of assistance to use.

Introduction

Background

The client for the project is a ten-year-old girl, named Annalee Hughes, who is suffering from cerebral palsy. This medical condition affects her ability to control her body and movements in a natural way. Children with cerebral palsy are often mentally and emotionally developed, but cerebral palsy prevents them from physically responding. She
is confined to a motorized wheelchair and presently lacks the ability to function outside of the chair unassisted. During multiple meetings between the design team, the client and family, and her physical therapist, more detailed limitations were discovered. Annalee and the therapist displayed her tendency to lean forward and her lack of protection reactions, such as catching her balance when falling sideways. Since her back contains many underdeveloped muscles, she tends to have a hard time sitting up.

The major issue related to the project at hand was her ability to walk. Annalee has the tendency to scissor her legs when attempting to walk (her legs cross as she puts one in front of the other). This prevents her from balancing herself throughout attempted walking motion and she requires assistance in this action. Her hamstrings are also in hypertension and prevent her from straightening out her legs. This was caused by the time she has spent sitting in a chair with her knees bent. Due to the underdeveloped muscles in her legs and back, Annalee tends to tire quickly. Another physical issue discovered was the control over her arms. She has capable motor control of her right arm while her left arm is not as functional.

**Purpose**

The main purpose of the Assisted Walking Device is to increase Annalee’s mobility and independence. The client has expressed a desire to walk on her own over short distances. To do this, her body must be acclimated to the correct walking gait. As Annalee gets older, the ability to walk to the bathroom, kitchen, or computer will be extremely beneficial for her and her family. By designing a product which can help support her body and teach her the proper walking motions, she may be able to achieve these skills. There are major issues that the design team must overcome. Some issues include preventing Annalee from scissoring her legs and giving her the strength to support her bodyweight. The Assisted Walking Device must enable her to learn how to walk unassisted. This will give her and her entire family more freedom.

**Other Projects and Patents**

There are some products on the market today which show similarities to the project the team will be designing. The MKII Hart Walker for instance is a product that Annalee has used before with limited success. This product, as seen in Figure 1, does not allow the child to enter the device with ease. One attractive feature is that the MKII Hart Walker allows for a hands free approach to supporting and mobilizing the child. The problem with this device is that it is only a device to get the patient walking in their present condition,
not a training device. Additionally, there are many complicated straps and foot boots which do not allow for easy wearing.

![Figure 1. The MKII Hart Walker](image)

Most common walkers, as seen in Figure 2, do not give enough leg and back support to the patient. The Drive Clever walker is one of these products. This provides the user with a seat to rest on and brakes to use to slow the device and user. This does not provide the leg and back support necessary for Annalee. However, this product does allow the user to enter the device from the rear. This was an expressed desire of the client.
The device for Annalee will incorporate many of the favorable qualities of both of these products, but will accomplish specific goals these devices do not meet.

A patent that was discovered which gives a description of a knee brace joint is United States Patent 6960175. This patent is for an orthopedic leg brace with a joint which involves a spring to give resistance in bending and straightening of the knee. This patent knee joint mechanism allows for the knee to straighten without buckling. US Patent 5634437, the Tie-me-flex ratite leg brace, is a device designed for animal orthopedics. It corrects “cow hook” and “splayed” leg conditions to prevent the need for surgical correction. The design for this patent corrects an outward turn of the leg. In our case, we need to correct and inward crossing of Annalee’s legs.
Report Map

1. Start
2. Determine AnnaLee's needs and limitations
3. Develop project statement of purpose and specifications
4. Build parametric CAD model:
   - Usability
   - Adjustability
   - Realizability
   (Fabrication, Materials, Cost)
5. Get input from family and physical trainer
6. Consult research, faculty, other authorities
7. Revise, refine CAD model
8. Build highly adjustable, standalone components:
   - Arms (stability, comfort)
   - Legs (shape, strength, locking mechanism)
   - Walker Structure (stability, handling)
   - Electrical components
9. Build full prototype
10. Build Final product
Project Design

Objective

The objective of the design is to create a device that allows Annalee to move about independently, while providing enough of a challenge so her muscles can develop a normal gait pattern. As previously discussed, there are several major criteria that the design team must fulfill.

First, the device must give Annalee freedom of movement. The foot, leg, and upper body bracing together must give her enough support to facilitate a normal walking pattern. Large degrees of motion in the hips and legs are not necessary—realistically, she will not walk with long strides, but with small “shuffle” steps with only a few degrees of rotation in each joint. Additionally, to achieve this goal, the leg and foot bracing must prevent the internal rotation tendency of her legs as she swings them. By making the leg braces relatively tight and allowing no lateral rotation in the whole leg assembly, this goal can be achieved.

Second, she must be able to equip and dismount the device with a minimum of outside help. Though we recognize that the hip and chest restraining straps will require help, the legs will be designed to open and close with the touch of a button. Therefore, as she begins to use the device, she will need some assistance to strap into the upper part of the device, but as she becomes more proficient, she may no longer need the upper body straps and can simply equip the leg braces on her own. This will allow her to get from room to room in her home unassisted, a major improvement in her mobility.

Third, the device must not give so much support as to “suspend” or otherwise restrict her. A certain degree of freedom must be available, and the device will require a certain degree of effort from Annalee in order to maintain a walking gait. This is important because the ultimate goal is not only to give her mobility, but to eventually obviate the need for any support at all. While we recognize that she may never be able to walk long distances independently, the device would be considered to be very successful if, for example, she could move between her living room, kitchen, bathroom, and bedroom after practice.

Manufacturing objectives include cost and ergonomics. Overall cost is projected to be approximately $1350, but several crucial parts, including motorization and frame
elements, have already been purchased at costs well under those originally budgeted. Electronic parts will be minimal to reduce cost and complexity—a microcontroller, some basic circuits for motor and actuator switching, and their respective housings are all that is required. All subunits of the device must be easy to equip; for example, the arm rests must be concave she they will naturally hold Annalee’s arms. In addition, the buttons used to control the leg braces must be large and simple to operate in order to accommodate her limited fine motor coordination. Since Annalee has much better control over her right arm compared to her left, all controls will be located on the right side of the device.

Subunits

Frame

The frame is extremely important, as it will serve as the attachment point for all supporting devices. The most important feature of the frame is that it allows entry from the rear, so Annalee can climb into it from a seated position without help. She has demonstrated to us the ability to hoist herself up on her own strength, so this design is realistic. The frame was purchased as a full walker frame which was then stripped down. It has a low center of gravity for stability, with most frame components at the bottom of the device. A bar at the front is the attachment point for all of the walker features, including the hip plate and leg braces, armrests, and chest plate. It is about 40 inches tall at its highest point, an appropriate height for Annalee who is 56 inches tall. It is 23 inches wide, so stability is retained while allowing for maneuverability. Figure 3 shows the gas spring design, and Figure 4 is a photograph of the full frame.
Figure 3. 3-D Model of Gas Spring Attachment – Actual picture of Gas Spring Attachment
The frame will provide the basic structure for the device, but it will be modified with several parts that will support Annalee and enable her to perform a proper walking technique. This requires the frame to be easily accessorized, a factor that depends on the diameter of the aluminum frame, and the available space to modify. Holes can be drilled into the square supporting bar as needed.

Testing of the frame will be done after the whole device is completed, since testing without the actual bracing equipment would yield few meaningful results. For details, see the Integration Testing section.

**Chest Support**

The chest component will be very similar to the hip plate, but is not adjustable. The chest plate will give the client a place to lean against while walking, increasing her stability. It is particularly important because she has very weak trunk muscles and tends to naturally
fall forward, so she will need the extra support to keep her in a walking posture. Ideally, the chest plate will only be a temporary solution while Annalee initially adjusts to the device. As she becomes a better walker, she may be able to achieve a better upper body posture and will no longer need the chest plate.

The team purchased a wheelchair headrest to serve as the chest support. It is made from very durable plastic, yet is lightweight. The chest articulates on a stiff ball joint which allows for periodic angle adjustments while remaining fixed in normal use. In addition, it comes with height-adjustable attachment hardware which only requires a simple rectangular attachment bracket. Figure 5 shows a 3D model and actual picture of the chest support.

Testing of the chest support will simply involve height and angle adjustment. Once the bracket is fabricated, we will bring the frame and chest support assembly to Annalee to find an optimal height. This may be done at both groups’ convenience.

![Figure 5. Left – 3-D Model of the Chest Support. Right – Actual picture of Chest Support.](image)

**Arm Rests**

Through input from the physical therapist as well as observations done by the designers, it has been determined that the handle bars should allow independent lateral positioning, since Annalee’s left arm is substantially less mobile than her right arm. The location of the right armrest will have to be closer to her body. It will also have to be located further back in the design. Annalee’s left arm is not controlled as precisely, therefore, the armrest must be located further from her body. Annalee was kind enough to perform some exercises with her physical therapist where she tried to lift her body from
the seated position by applying force through her elbows. It was clear from this exercise that the handlebars need to be located under her chest, not under her shoulders. This is due to the forward lean incorporated in Annalee’s posture. Figure 6 is the 3-D model and actual picture of the arm rests.

![Figure 6. Left – 3-D Model of Independent Arm Rest. Right – Actual picture of Arm Rest.](image)

Each armrest will be mounted to a sliding bracket to allow for movement in the forward and backwards direction. The lateral movements will be accomplished with multiple locations of attachment. If the rest must be moved away from the body, it will easily be removed from the track and attached from another joint on the bottom of the rest. As seen in the armrest figures, they will each be approximately 13-14 inches long, 4 inches wide and 1.5 inches thick.

The armrests are concave, modeled after some of Annalee’s preexisting devices. This prevents slipping as Annalee leans against the rest. The padding is foam and plastic, and underlying metal bar is lightweight aluminum. The handles are rubber, and are angled to increase comfort.

Testing of armrest positioning will be performed when the rests are attached to the frame. Important metrics will include ease of gripping, reach, stability, and comfort. Testing of the armrest and chest support will be conducted simultaneously because the positioning of these two devices are closely related.

**Hip Support**

The hip component requires only a simple design, but biomechanically it is very important. Since the client must be able to directly equip the device from a sitting position,
the hip plate will be open from the rear so she can pull herself in. A broad strap (described in the Chest and Hip Straps section) will secure her. The inner face is moderately padded and covered in a soft neoprene or similar material. The structure itself is fabricated from a thin, lightweight material. The most likely candidates include parallel aluminum bars, or aluminum mesh on an aluminum frame. Weight of the overall leg assembly (hip, legs, feet) is an important consideration because it will be supported from the frame by springs.

The reason for a flexible, spring-mounted design is based on gait and balance studies. In studies of muscle activation during balance perturbations, it has been shown that the hip is the primary source of balance recovery [5]. Although a rigid hip design would keep the client upright, it would not train her muscles to support and balance her body. The Hart Walker exhibits this limitation. Because its wearers are completely rigid in the device, their gait has a “gliding” characteristic, rather than exhibiting a natural bobbing motion [6]. As such, the Hart Walker can give its wearer’s mobility, but not independence. The Assisted Walking Device aims to remedy this issue by suspending the entire leg assembly from high-stiffness springs, which would provide good support but still require the client to exert small balancing motions in all three degrees. An additional advantage is that as the client improves softer springs can be switched in, providing her with a continual challenge. The springs will be attached to a bar around the perimeter of the hip plate.

Securing the client to the hip plate will be accomplished with a wide elastic strap, attached with Velcro. The client wants to be able to get into the device independently, but to mechanize an opening/closing mechanism may be out of the budgetary and technical restraints of the project. Therefore, the compromise reached is to mechanize the legs, which would substantially increase equipping time, while leaving the hip plate and chest plate to be manually fastened by a helper.

Based on the client’s height of 56” and anthropometric data [1] the following dimensional estimates of her legs are currently proposed:

- Overall width of approximately 13 inches.
- Inner radius of approximately 6.725 inches.
- Outer radius of approximately 7.725 inches.
- Height of approximately 5 inches.

These dimensions are rough, and the project only requires a moderate degree of precision. The design team has repurposed a wheelchair headrest with adjustable width as the hip support. Figure 7 displays the 3D CAD model and a photo of the actual piece.
Testing of the hip support can be delayed until the entire hip and leg assembly has been completed and mounted to the device, since these components interact very closely. Important metrics will include ease of entry/exit, stability, degree of freedom and muscular exertion, and safety. The spring mounting mechanism will be closely analyzed—adjustments for spring stiffness, swing arm length, and bracket height can be made at this time.

**Butterfly Back Support**

To secure Annalee into the device, there will be a strap extending from the hip and chest plates. The strap will be made of high strength nylon and secure using snap in buckles. These straps are extremely important for Annalee’s posture while using the device, as well as her safety. The strap will keep her back straight and give her upper body support. The strap will need to be very tight because it will need to take a lot of the load off of her legs in order for her to use her underdeveloped leg muscles to properly walk. In order to meet these needs, the strap will have a butterfly back support. These can be purchased to order very easily at material fabric stores or online. The strap will wrap around Annalee from one side of chest and hip plate to the other side.

The strap is extremely important in providing support and safety, and thus must be fastened tightly with assistance from someone else. Eventually, as Annalee is more comfortable with the device and progresses with gait technique, she will be able to strap herself in more loosely. She is very limited with her left arm, and thus the loops will be positioned on the right side of the plates so that she can fasten them. Figure 8 shows the type of strap that will be used to harness Annalee into the device.
Testing of the strap will focus on comfort and support. The strap must not dig into Annalee’s back, but also should not be so wide that they allow her to rest against them. The team will also check for ease of attachment.

**Calf and Thigh Restraints**

The leg restraints are the most intricate component of the Assisted Walking Device. These will be critical to correcting Annalee’s gait by providing the appropriate swing path when walking. They must provide enough support to resist her adductive force, while not cutting off circulation in her legs. The designers have developed a clamping design which will allow Annalee to independently mount the device and will provide enough force to stabilize her legs. Figure 9 shows the clamping design of the leg braces. This design will be used for all four of the restraints: the two thigh and two calf restraints.
The exterior leg bars will have three holes for different connect locations. These holes will be set up to allow for lengths between 11-13 inches for the thigh and calf support length. As Annalee grows, these structures can be adjusted accordingly. Aluminum bars and L-brackets will be used to form the frame of each brace.

The motor controlling the back plate is a 360:1 geared DC motor sourced from Robot Marketplace. This model provides suitable torque with low power draw and an adequately slow speed. Pulse width modulation controlled via the microcontroller may provide further speed control. Firgelli PQ12S linear actuators with 20mm of stroke will be used to lock the back plates in place once they are closed. These actuators are extremely small and have low power draw. The motors and actuators have been purchased at well below budget.

The motors and actuators will be controlled by a PIC16 microcontroller. The microcontroller will be programmed in C, and the programming logic flow is illustrated in Figure 10.
Figure 10. Microcontroller logic flow
Running along the side of the users legs will be aluminum braces. These will provide support to prevent Annalee from applying adductive forces. These rods will be attached to the hip plate and all of the leg restraints. Additional support will be added to the leg mechanism if testing shows a need for it. The rods will have a joint located at the knee which will provide approximately fifteen degrees of rotation. Annalee’s knees are already bent at a ten degree angle. For normal gait, knee bending does not exceed fifteen degrees. The lower section of the leg rods will be attached to the ankle-foot orthosis. The above figures show the layout of the leg restraints, including the steel rods that run parallel with the user’s legs.

**Ankle-Foot Orthoses**

Ankle-foot orthoses (AFOs) are a traditionally useful tool for correcting developmental gait problems. Therefore, the Assisted Walking Device will employ a modified open-backed AFO for two main reasons. First, the client has a sufficient level of gross leg mobility, but has difficulty consistent positioning her legs for each subsequent stride. An AFO mounted to the leg brace would keep her legs in a consistent striding pattern. Second, the client tends to internally rotate her legs as she swings them in a walking motion, but not when standing still. This is important, because she can equip an open-backed AFO from a stationary position with relatively little difficulty. Then, as she moves, the sides of the AFO would prevent the internal rotation of her legs.
There are several considerations that must be incorporated into the final AFO design. Notably, gait studies have shown that rigid AFOs can provide a high degree of stability, but change the timing and sequencing of muscles in balance recovery (cite). Therefore, while a rigid AFO would provide good support for the client, it is not compatible with the ultimate goal of training independent gait. A soft, moderately flexible design with a hinged ankle would provide adequate support while avoiding dependency of inappropriate muscle training.

The dimensions for the AFO were base on the client’s height. According to anthropometric data [1] and a height of 56”, the following estimates are currently proposed:

- Ankle brace height of approximately 6 inches.
- Foot length of approximately 8.5 inches.
- Foot height of approximately 2.2 inches
- Foot width of approximately 3.1 inches

Because of the soft material, these sizes do not need to be exact. A standard child-sized AFO should be adequate for the intended purposes. Dimensions will be formalized following a measurement session with the client prior to prototype construction. Figures 11 and 12 display the 3-D rendering and a picture of the AFO with the attachment pieces.

Figure 12. 3-D Model of the AFO
Padding for Restraints

All of the parts that Annalee will have direct contact with will need to be lined with a cushion, for both comfort and fit. These parts include the chest and hip plates, the handlebars, and the calf and thigh restraints. These will be lined with a thick-layer of Neoprene foam. This material is very durable, and also easy to clean because it is water resistant, so it can be wiped with water without damaging. All contact points lining will be 0.5 inches thick to provide enough comfort. This material can be attached to the necessary surfaces by a few different means, including using an adhesive, sewing, or clamping the edges between two plates that are screwed together. Neoprene foam is available in large quantities and in all thicknesses for very reasonable prices [3]. Figure 13 shows the Neoprene material which will be used for the padding. Figure 14 shows the padding mounted on the leg constraints using a glue spray.
Figure 14. Neoprene Padding
Prototype

The prototype achieved all desired goals. The Device supports the client properly, and allows her to stand and walk with a correct gait pattern. With practice, the child will be able to climb into the device from the rear and pull herself into the arm and chest rests. A simple button-operated circuit closes the leg braces, securing the child. For additional support, a broad four-point strap can be attached by an assistant. The device is highly modular. Depending on the child’s abilities and needs, components such as the arm rests, leg closing mechanisms, leg braces, and other parts can be removed by the end user. Also, the Device incorporates a piston-spring mechanism so that it will challenge the user to improve her abilities, rather than simply suspend her.
Figure 16: Final Assisted Walking Device design, rear ¾ view.
By incorporating strong yet lightweight padded leg bracing and ankle-foot orthoses fixed to the braces, the Device provides lateral and rotational support for the client. This design works well in retaining her legs in a standing position, and the allowed range of motion facilitates a walking gait.
However, she can use it initially as a simple standing device in order to strengthen and acclimate her muscles. Our design enables the client to independently lift herself into the device from the rear and press a button to lock the motorized leg braces. A hydraulic piston provides mild spring force, so that she must work in order to remain upright. The client’s physical trainer helped in the planning and troubleshooting stages of the project. Her comments directed the positioning and range of motion of the legs, as well as the positioning of the arm and chest supports. Her help was invaluable in designing and fine-tuning the Device. We feel that this design will provide our client with a platform for developing muscular tone and gait.

Usage
The client can climb into the Device from the rear by first slipping her feet into the foot braces, and then pulling herself up into the leg and upper body braces. She has the muscular strength to achieve this. However, she currently needs some help getting in because she lacks the precise muscular control required to fit into the leg braces. With some help, she can climb into the Device and close the leg braces with a button. Her parent or physical trainer can then equip the rear foot straps and butterfly back strap so that she is completely secured in the walker.

Figure 19: The client being helped into the Device.
Currently, the client can mainly use the Assisted Walking Device as a standing trainer in which she can do squat-like exercises. Her legs are not strong enough to walk in a significant manner. However, she can stand herself up for approximately five seconds at a time. This will certainly improve as she continues to train with the Device, and she will eventually be able to use it for walking around the house. Most importantly, the Device can successfully keep her upright and prevents her legs from internally rotating and scissoring. These were the most major problems we needed to overcome. In addition, the gas spring mechanism offers a suitable amount of support, while requiring her to exert some force to stay upright. If she falls, the Device will sag approximately eight inches but will not fall over. The arm and chest supports perform their desired purposes. The chest support extends to the height of her sternum, and she can grab and hold herself into the arm supports with little to no outside help. Both structures are sturdy enough for her weight and momentum when using the Device.
The entire frame moves smoothly and as one unit. The wheels are very fluid and allow her to push the Device with very little resistance. There is no wobble in the frame, even when force is applied to the far ends of the arm rests. Therefore, we feel that the overall Device is sturdy enough for daily use.

**Development and Testing**

The Assisted Walking Device went through numerous stages of testing and development. Our initial CAD designs provided an outline for the overall design, but they represented only the theoretical solution to our goals. As we progressed through the stages of development, we began to realize each component in a more practical manner.

The frame design was originally modeled after an orthodox walker design. During our early visits with the client, however, we saw that she had tried these types of devices unsuccessfully before. Also, her physical trainer was very concerned about the possibility of tipping in a traditional walker, which has a high center of gravity. When visiting NEAT at Oak Hill, CT, we found an excellent walker base that had both a low center of gravity, wheel
mounts, and an appropriate size. This was a perfect way to address the concerns raised during the previous client meeting. Therefore, we completely revised our frame design to accommodate the new base. Our originally designed leg braces and upper body supports were simply incorporated into the new frame.

![Figure 22: The older CAD Assisted Walking Device design.](image)

![Figure 23: The current CAD design.](image)

Our initial leg brace design was a highly idealized, curved two-piece swing mechanism. As we came closer to manufacturing the pieces, we moved to straight pieces joined by L-brackets, with motors and actuators to create the closing mechanism. However, when we brought the pieces in for testing, we found that they were too large and too heavy for the client to use. At this point, we decided to move to thin, bent pieces. After some practice, we were able to manufacture four new leg brackets, each one made from a
single curved piece of 1/8” aluminum. These were both lightweight and sturdy. However, by moving to a single-piece design, we sacrificed a certain degree of adjustability in exchange. We feel that this was an acceptable compromise. Upon testing, we found that the new design worked exactly as planned. The thinner aluminum still provided enough lateral support to prevent the client’s legs from crossing or rotating, and the sizing was correct while maintaining some room for growth. In the final stages of the design, the braces were painted and upholstered in neoprene foam.

Figure 24: Initial CAD concept of a leg brace.
Figure 25: The older leg brace prototypes.

Figure 26: The new leg brace designs.

The closing mechanism also went through revision during the design process. The initial designs called for two complete sides of the brace to swing closed, with an internal motor or some other type of actuation mechanism. As we moved into the manufacturing stage, we realized that this would be impractical simply because we did not have the manufacturing capabilities to produce it. Therefore, we moved to a complementary motor and actuator system, where the motor would swing a hinge to close the brace, and an actuator would extend to lock the hinge in place. This system may not be immediately used
by the client, because she lacks the muscle strength to stay in the Device for long periods of time. At the current time, it is more practical to remove the hinges and use the braces in an open configuration, until she is strong enough to wear the Device for extended periods. We installed a screw locking mechanism so that the hinges can easily be removed with a single set screw.

Figure 27: Original CAD concept of leg closing mechanism, controlled by hand grips.

Figure 28: Initial prototype of the leg brace.
Realistic Constraints

Building any device for a patient with cerebral palsy will inevitably encounter several restrictions that must be overcome. The strength and abilities of patients with cerebral palsy vary drastically, and the device must be tailored for a high degree of limitations of the disease in order for the product to be manufactured on a mass scale. This is why walking devices that are currently on the market are not ideal, because they overcompensate for the limitations individual cerebral palsy patients, and in doing so inhibit freedom. Walkers such as the MKII Heart Walker, does not promote advancement in walking technique. The Assisted Walking Device will be based on manufacturing feasibility and Annalee’s abilities. This should decrease the number of restrictions on Annalee’s progression in walking technique.

There are several constraints that will be encountered and must be addressed in the design and building process of this walking device. A prefabricated walker frame will be used as the base of the device, and parts will be added as necessary to meet the desired functions. This will save time, money, and issues with manufacturing a structure. However, problems do arise when modifying an existing walker frame for the specifications of this device. There is some difficulty in mounting the parts such as the hip and chest supports. They have different mounting brackets and will have to be treated individually.
Some parts, like the supports and armrests, will require minimal modifications. Other parts, such as the leg braces, will have to be fabricated from scratch. These cannot be purchased because there is little on the market that will meet the demands of the design. There is some restriction in the stock the material that can be used and how it can be shaped, based on what the design team is capable of manufacturing.

For much of her young life, Annalee has been stuck in her power chair. This has limited her social life and has made it hard for her to function as an active young girl. The design must be made portable as to improve upon any travel restraints. Ideally, it will be transported easily, and used with her at her grandparent’s house or anywhere else she will be for an extended period of time. This requires the device to be made of a lightweight material then does not sacrifice strength and durability. It must also be as compact as possible, a feature that will help in its maneuverability, without sacrificing its stability.

Providing a device that is safe to get into, walk around in, and get out of is the most important aspect of this design project. This also provides several complications and limitations for the device. The patient must be able enter the device from the rear, in a sitting position, either from a chair/couch or her chair which is significantly raised from the ground. This provides difficulty in terms of where the hand supports will be placed and how high the device must be to remain stable and allow her to support herself while she is loading into it and prevent tipping. Once in the device, it is important that there is no way for the device to tip over. It must be extremely stable with a low center of gravity, and must support her so that if she loses balance it will not be so rigid that it will tip. This will require a hip brace with some give in it, so that a spring will help bear any change in force.

Probably the greatest limitation that was considered in the design of this device was the lack of muscular strength of the patient. She will require assistance to load and unload from the device until she develops appropriate muscles for lifting and supporting her body. However, it is the goal of the assisted walking device that she be able to move around once she is in it. This requires the device to be light and roll smooth enough so that the patient may push it as she walks. By forcing Annalee to use her muscles, the device will be improving her physical health and functionality. Several aspects of the device will assist in this as much as possible, making it easy to move and ideally allow the patient to walk unassisted and improve her freedom.

With regards to environmental constraints, the device will leave an insignificant footprint. There will be some battery usage to power the motors and actuators of the leg braces. All padding in the device will be removable to increase the sustainability and cleanliness of the device. As stated above, the device will be manufactured from on the
market products with minimal alterations needed. The students have access to a machine shop to make any necessary alterations.

Safety Issues

The device has been designed to incorporate all safety issues expressed by the client and the physical therapist. There were a few issues that were discussed pertaining to Annalee’s abilities and strength. Obviously, balance will be a major issue that must be addressed since Annalee does not have any prevention reactions. Observation of Annalee’s abilities have factored into the design of the device.

As stated above, one major issue for the design team was the balance of the device. The client has expressed the need for the device to be mounted from the seated position in her power chair. This means that she will be pulling on the device from a high point of balance. In order to counteract this force, the device must have a low center of gravity. This low center of gravity will prevent the device from tipping onto Annalee, as well as assist in the overall balance of the device while in use. There are 4 wheels on the side of the frame, as well as two mounted in the front, which make the device stable and difficult to tip over.

Another way the design has addressed the issue of balance was to implement a gas spring in the main frame. A spring will take some of the forces off of the frame and assist in the overall balance of the device, making it more difficult to tip over than a rigid structure. The designers and the physical therapist have discussed this safety issue, and have agreed that this would be the best solution. After doing some research into posture, the design team understands that recovery from a large disturbance of balance is initiated at the hips, so the hip brace will be attached to the spring feedback system.

The frame of the device must be able to carry the load of Annalee’s body and not crumble under pressure. All joints in the device must be strong and the metals used to manufacture the device must not warp or bend after use. To keep Annalee safe, the straps must be strong enough so they do not separate when her weight is applied. The design team has chosen a butterfly back support with buckles to harness her in place.

The leg braces also introduce a safety issue. They must close tightly to secure Annalee’s legs. However, it is important that they do not squeeze or pinch her legs when closing. This will be addressed with the delay of the actuator locking the device, and the strength of the motors.
All safety issues have been discussed with the client and every action will be taken to limit the opportunities for accidents occurring. The designers understand that accidents can still happen if the device is not used properly and will attempt to forecast any misusage.

Impact of Engineering Solutions

The transition from childhood to adulthood is a transition to independence. As a child grows older, more and more skills are learned that contribute to overall self-sufficiency. For many physically disabled children, this process is skewed because they may be mentally and emotionally ready to do greater things, but are limited in their mobility. Our client, Annalee Hughes, is very bright and has many different hobbies. Her cerebral palsy severely limits the activities she can perform, but given the correct practice and equipment, her life has great room to grow.

This is why the Assisted Walking Device is such an important project. It is not a toy or a convenience item, but instead it fills a hole in the market that can genuinely improve the lives of disabled children. The client’s physical therapist has expressed the concern that the devices on the market simply do not provide the training to teach a child to walk. If the client can learn to walk even modest distances, such as from the living room to the bathroom, her quality of life could be greatly improved.

Economically, this device could likely be brought to market at a lower price point than existing walkers. However, this is difficult to ascertain since there is very little overhead in an academic environment. These types of devices have low production numbers, so economics may dictate a higher price in a marketplace situation. Since the current estimated cost is approximately $1000-1700USD, there are some important global implications of the device. First, the Assisted Walking Device is very simple and easy to maintain, and could be manufactured overseas as a substantial cost savings. Second, in many third-world countries, disabled members of the population are hidden away and have little chance to join the greater society. They certainly do not have access to public support systems or physical therapists. For example, in China the quality and availability of devices such as walkers, wheelchairs, and braces is very poor due to lasting societal stigmas. If the Assisted Walking Device were manufactured at a low cost, perhaps well under $1000USD either in the United States of overseas, it may provide an important lifestyle enabler for people with disabilities around the world.
Ultimately, however, large-scale ambitions remain firmly speculative. The bottom line is that the client, her parents, and her physical trainer have an important need to fulfill which is not satisfied by the current marketplace. They have tried several devices with varying degrees of success. If the project is successful, the Assisted Walking Device will improve her life in a tangible, lasting way.

Life-Long Learning

We will learn a great deal from the design process. Determining the client’s needs and expectations will help us understand the needs of disabled children and the challenges they face in daily life. Building and refining the CAD model will be an extensive process involving constant communication with the client and gait research, as well as learning to utilize advanced Autodesk Inventor features such as force analysis. A virtual model of the client will be developed for this purpose, so biomechanical and anthropometrical skills will also be learned. Gait research and consultation with the client’s physical therapist will not only provide a scientific basis for the Assisted Walking Device, but will give us important background knowledge on gait development and pathology.

In addition, a major technique learned will simply be the art of planning and coordinating groups. Microsoft Visio will be used to produce flow charts and diagrams for easy planning. We will need to learn Microsoft Project in order to keep track of project goals and deadlines. Substantial coordination will be required between our team and the client, as well as within our team. All of these skills will be important regardless of each team member’s final career or educational path.

The manufacturing goal for the Assisted Walking Device is to produce a product that achieves all goals using the simplest manufacturing techniques possible. Although the deliverable to the client will be a customized prototype with no plans of future production, manufacturing and materials must be selected with small scale commercial-type production in mind.

As such, we will explore techniques in modifying off-the-shelf components. For the chest and hip plates, we will learn to bend metal bars and attach mesh or similar material in order to create a lightweight, yet supportive structure. Although using an off-the-shelf walker frame would be ideal, we may need to also learn to fabricate larger pieces of bent metal for a customized frame if standard models are found to be unsuitable. The AFO would be a difficult device to manufacture with our capabilities, so we will learn to the features of standard AFOs and select one based on the client’s needs.
Although the current design requires the use of the PIC16 microcontroller. It will be particularly important because the client has limited strength but can operate buttons well. Therefore, C programming skills and circuit development may become an integral part of the project in the future.

The most important skill learned during the manufacturing phase will likely be the process of revision. We will need to develop highly adjustable parts that, through repeated trials with the client, can be adjusted to build an ergonomic final product. Building prototypes and bringing them to the client for feedback are important to ensure the final prototype fits the client well.

**Budget**

Currently, the design team is well under the allotted funding provided to them. The design and building plan in constantly changing, and as the production of the device progresses, the designers are finding more cost efficient materials than they predicted.

The designers started with an allotted budget of $1350.00. This was calculated based on an itemized parts list created by the design team. Table 1 shows the parts lists developed by the team before the project commenced. Some of the parts have been eliminated from the design, which will decrease the total amount spent on the product.
<table>
<thead>
<tr>
<th>Item</th>
<th>Size</th>
<th>Amount</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum Stock – Box</td>
<td>1 ½” x ¾”</td>
<td>8-10 ft.</td>
<td>$50.00</td>
</tr>
<tr>
<td>Aluminum Stock - Rods</td>
<td>.56&quot;/14mm rod- .05&quot; WT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum Stock – Strips</td>
<td>3” x ¾”</td>
<td>6 ft.</td>
<td>$35.00</td>
</tr>
<tr>
<td>Aluminum U-Hole Beams</td>
<td>5” x 3”</td>
<td>4 ft.</td>
<td>$60.00</td>
</tr>
<tr>
<td>Assorted Washers</td>
<td>fit the nuts</td>
<td>50 count</td>
<td>$15.00</td>
</tr>
<tr>
<td>Assorted Nuts and Bolts</td>
<td>All Sizes</td>
<td>100 count</td>
<td>$15.00</td>
</tr>
<tr>
<td>Thumb Screws</td>
<td>Fit onto Bolts</td>
<td>25 count</td>
<td>$10.00</td>
</tr>
<tr>
<td>Neoprene Padding</td>
<td>5’ x 5’ x 1”</td>
<td>2 count</td>
<td>$20.00</td>
</tr>
<tr>
<td>Caster Wheels</td>
<td>5” Diameter</td>
<td>4 count</td>
<td>$25.00</td>
</tr>
<tr>
<td>Walker Frame</td>
<td>30” x 30” x 34”</td>
<td>1 count</td>
<td>$150.00</td>
</tr>
<tr>
<td>Bearing</td>
<td>Pending on wheel</td>
<td>4 count</td>
<td>$6.00</td>
</tr>
<tr>
<td>Ankle Foot Orthosis</td>
<td>Child size</td>
<td>2 count</td>
<td>$120.00</td>
</tr>
<tr>
<td>Velcro Straps</td>
<td>6” x 3’</td>
<td>2 count</td>
<td>$15.00</td>
</tr>
<tr>
<td>Spring Hinge</td>
<td>2” height</td>
<td>4 count</td>
<td>$9.00</td>
</tr>
<tr>
<td>Brake Cables</td>
<td>10 ft.</td>
<td>1 count</td>
<td>$20.00</td>
</tr>
<tr>
<td>Bicycle Handle Bars</td>
<td>N/A</td>
<td>2 count</td>
<td>$15.00</td>
</tr>
<tr>
<td>Sliding Track for Handle Bars</td>
<td>2 ft. long</td>
<td>2 count</td>
<td>$50.00</td>
</tr>
<tr>
<td>Springs</td>
<td>Springs 6” long</td>
<td>5 count</td>
<td>$30.00</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>PIC16F887A</td>
<td>1 count</td>
<td>--</td>
</tr>
<tr>
<td>Linear Actuators</td>
<td>2 in. stroke length</td>
<td>4 count</td>
<td>$300.00</td>
</tr>
<tr>
<td>DC Step Motors</td>
<td>N/A</td>
<td>4 count</td>
<td>$250.00</td>
</tr>
<tr>
<td>PCB Board</td>
<td>N/A</td>
<td>2 count</td>
<td>$100.00</td>
</tr>
<tr>
<td>Batteries</td>
<td>Pending on Motor need</td>
<td>4 count</td>
<td>$50.00</td>
</tr>
<tr>
<td>Wire</td>
<td>insulated</td>
<td>20 ft.</td>
<td>--</td>
</tr>
<tr>
<td>Wire Clamps</td>
<td>Plastic Pull Tie</td>
<td>30 count</td>
<td>$4.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>$1,349.00</td>
</tr>
</tbody>
</table>

Table 1. Itemized Parts list and Cost.

Presently, the team is about four hundred dollars under budget after many major components have been purchased. The walker frame, most of the circuitry, the chest and hip supports, and the armrests have been purchased. This has cost the team a total of $407.00 with shipping. Shipping has been something that must be watched closely due to
the unpredictable. Table 2 shows the itemized expenses the team has accumulated up to this point in the project.

<table>
<thead>
<tr>
<th>Total Budget</th>
<th>$1,350.00</th>
<th>Total Under Budget</th>
<th>$331.23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Spent</td>
<td>$938.07</td>
<td>Total Spent With Shipping</td>
<td>$1018.77</td>
</tr>
<tr>
<td>Total Shipping Cost</td>
<td>$80.70</td>
<td>Remaining Budget</td>
<td>$331.23</td>
</tr>
</tbody>
</table>

Table 2. Budget

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Company Name</th>
<th>Units</th>
<th>Price per Unit</th>
<th>Total Cost</th>
<th>Variance From Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>88935K61</td>
<td>Architectural Aluminum (Alloy 6063) Rect Tube, 3/4&quot; X 1-1/2&quot;, 1/8&quot; Wall Thk, 6' L (Same as 88935K53)</td>
<td>McMaster-Carr</td>
<td>1</td>
<td>$20.21</td>
<td>$20.21</td>
<td>$29.79</td>
</tr>
<tr>
<td>8975K25</td>
<td>Multipurpose Aluminum (Alloy 6061) 1/4&quot; Thick X 1-1/2&quot; Width X 6' Length (Same as 8975K518)</td>
<td>McMaster-Carr</td>
<td>2</td>
<td>$16.58</td>
<td>$33.16</td>
<td>$1.84</td>
</tr>
<tr>
<td>AGT111</td>
<td>Mulholland Gait Trainer (small)</td>
<td>NEAT at Oak Hill</td>
<td>1</td>
<td>$50.00</td>
<td>$50.00</td>
<td>$100.00</td>
</tr>
<tr>
<td>-</td>
<td>2 wheel chair headrests and various hardware (chest, hip, armrest)</td>
<td>NEAT at Oak Hill</td>
<td>1</td>
<td>$50.00</td>
<td>$50.00</td>
<td>(Not in Budget)</td>
</tr>
<tr>
<td>overstock-items</td>
<td>Overstock Item Model PQ-12 S linear actuator</td>
<td>Firgelli</td>
<td>4</td>
<td>$30.00</td>
<td>$120.00</td>
<td>$180.00</td>
</tr>
<tr>
<td>0-GM21</td>
<td>360:1 Mini Metal Sealed Gear Motor</td>
<td>Robot Marketplace</td>
<td>4</td>
<td>$18.99</td>
<td>$75.96</td>
<td>$174.04</td>
</tr>
<tr>
<td>COM-00107</td>
<td>Voltage Regulator - 5V</td>
<td>SparkFun Elect</td>
<td>6</td>
<td>$1.25</td>
<td>$7.50</td>
<td></td>
</tr>
<tr>
<td>COM-00315</td>
<td>H-Bridge Motor Driver 1A</td>
<td>SparkFun Elect</td>
<td>10</td>
<td>$2.12</td>
<td>$21.20</td>
<td></td>
</tr>
<tr>
<td>COM-09341</td>
<td>Concave Button - Green</td>
<td>SparkFun Elect</td>
<td>1</td>
<td>$1.95</td>
<td>$1.95</td>
<td>(Not in Budget)</td>
</tr>
<tr>
<td>COM-09336</td>
<td>Concave Button - Red</td>
<td>SparkFun Elect</td>
<td>1</td>
<td>$1.95</td>
<td>$1.95</td>
<td></td>
</tr>
<tr>
<td>3165727</td>
<td>Battery Alkaline 9V - 12 pack</td>
<td>Mansfield Supply</td>
<td>1</td>
<td>$18.89</td>
<td>$18.89</td>
<td></td>
</tr>
<tr>
<td>272716</td>
<td>2 x 1/2 Mend Brace</td>
<td>Mansfield Supply</td>
<td>4</td>
<td>$0.62</td>
<td>$2.48</td>
<td></td>
</tr>
<tr>
<td>266270</td>
<td>1 x 1/2 Cor Brace</td>
<td>Mansfield Supply</td>
<td>6</td>
<td>$0.62</td>
<td>$3.73</td>
<td></td>
</tr>
</tbody>
</table>

40
<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Company Name</th>
<th>Units</th>
<th>Price per Unit</th>
<th>Total Cost</th>
<th>Variance From Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>266304</td>
<td>1-1/2 x 5/8 Brace</td>
<td>Mansfield Supply</td>
<td>1</td>
<td>$0.62</td>
<td>$0.62</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>6</td>
<td>$0.30</td>
<td>$1.80</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>2</td>
<td>$0.45</td>
<td>$0.90</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>20</td>
<td>$0.12</td>
<td>$2.40</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>20</td>
<td>$0.14</td>
<td>$2.80</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>20</td>
<td>$0.15</td>
<td>$3.00</td>
<td></td>
</tr>
<tr>
<td>B0015TESE4</td>
<td>Dorsal Night Splint</td>
<td>amazon</td>
<td>2</td>
<td>$42.50</td>
<td>$85.00</td>
<td>$35.00</td>
</tr>
<tr>
<td>190-117-CL</td>
<td>Small Butterfly Safety Belt - Black</td>
<td>ocelo</td>
<td>1</td>
<td>$37.50</td>
<td>$37.50</td>
<td>-$22.50</td>
</tr>
<tr>
<td>--</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>1</td>
<td>$5.68</td>
<td>$5.68</td>
<td>Not Done Buying</td>
</tr>
<tr>
<td>--</td>
<td>Hardware/Paint</td>
<td>Mansfield Supply</td>
<td>1</td>
<td>$12.29</td>
<td>$12.29</td>
<td>Not Done Buying</td>
</tr>
<tr>
<td>2750710</td>
<td>On-Off-On Toggle Switch</td>
<td>Radio Shack</td>
<td>2</td>
<td>$3.99</td>
<td>$7.98</td>
<td>Circuit Parts</td>
</tr>
<tr>
<td>2701803</td>
<td>Circuit Box</td>
<td>Radio Shack</td>
<td>1</td>
<td>$3.69</td>
<td>$3.69</td>
<td>Circuit Parts</td>
</tr>
<tr>
<td>2337T25</td>
<td>Black Hard Tread Wheels 5”x15/16&quot; and 5/16&quot; Axle</td>
<td>McMaster-Carr</td>
<td>4</td>
<td>$4.00</td>
<td>$16.00</td>
<td>($3.00)</td>
</tr>
<tr>
<td>overstock-items</td>
<td>Overstock Item Model PQ-12 S linear actuator</td>
<td>Firgelli</td>
<td>1</td>
<td>$30.00</td>
<td>$30.00</td>
<td></td>
</tr>
<tr>
<td>Misc</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>1</td>
<td>$25.00</td>
<td>$25.00</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>PCB</td>
<td>PCB Express</td>
<td>2</td>
<td>$21.01</td>
<td>$21.01</td>
<td></td>
</tr>
<tr>
<td>8461K117</td>
<td>2”X1/2”X36” Soft Adhesive neoprene</td>
<td>McMaster-Carr</td>
<td>1</td>
<td>$22.42</td>
<td>$22.42</td>
<td></td>
</tr>
<tr>
<td>8461K115</td>
<td>2”X1/4”X36” Soft Adhesive neoprene</td>
<td>McMaster-Carr</td>
<td>1</td>
<td>$11.93</td>
<td>$11.93</td>
<td></td>
</tr>
<tr>
<td>4138T56</td>
<td>Gas Spring with Ball Joint Fittings - 17.13&quot; 50lbs</td>
<td>McMaster-Carr</td>
<td>1</td>
<td>$14.25</td>
<td>$14.25</td>
<td></td>
</tr>
<tr>
<td>RD5x1-1/4GS</td>
<td>5” x 1 1/4&quot; Gray Rubber Crown Tread Wheel</td>
<td></td>
<td>4</td>
<td>$6.86</td>
<td>$27.44</td>
<td></td>
</tr>
<tr>
<td>RF3x1-1/4PS</td>
<td>3” Gray Rubber Wheel - Ball Bearing</td>
<td></td>
<td>2</td>
<td>$5.00</td>
<td>$10.00</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>Hardware</td>
<td>Mansfield Supply</td>
<td>1</td>
<td>$10.04</td>
<td>$10.04</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Itemized Expenses.
Team Member Contributions

Scott Kopp
- Design based on research of cerebral palsy
- Circuitry Design and Implementation
- Fabrication of metal components
- PCB Design and ordering
- Parts research and ordering
- Assembly of components and PCB
- Refinish Frame and Components

Andy Czyzowski
- Research on cerebral palsy
- Circuitry design
- Physical work on frame
- Refinish Frame and Components
- Research and design of AFO
- Design of leg braces and constraints
- Parts research

Jason Wang
- Research on gait development
- Construction and maintenance of CAD models
- Development of microcontroller code
- Formal communications with client via periodic progress reports
- General design work, parts research, and construction

42
Conclusion

Independent mobility is one of the most important aspects of a child’s development. Many advances have been made to maximize the mobility of children with disabilities, but gait rehabilitation is often a long and difficult process requiring substantial personal attention and customization of equipment. Annalee Hughes, our client, has excellent access to a physical trainer who can coach her, and the Assisted Walking Device aims to fulfill the second need for customized equipment.

Because independence is the ultimate goal, most of our design efforts are focused towards this. Current devices on the market such as the Hart Walker require large time commitments from parents or other helpers to equip and de-equip them, compromising independence of the child. The Assisted Walking Device will incorporate important concepts of gait rehabilitation, based on research and consultation with Annalee’s physical trainer, and will apply these concepts in a way that Annalee can equip and de-equip the device by herself. She will be able to do things she was never able to. For example, when she is watching television, she could hoist herself into the Device and move to the bathroom on her own. These small changes can make a profound difference in her life.

The ultimate goal of the Assisted Walking Device is to gradually train Annalee to walk short distances unassisted. To realize this, the Device will have adjustable and detachable subunits such as the chest rest, arm rests, etc. As her physical trainer monitors her progress, she can make the decision to remove successive levels of support, thereby transferring more and more load to Annalee’s body.

This project will provide a great benefit to Annalee, with a low cost and a high degree of ergonomics and customization. To us, the design team, it will teach many lessons in design and manufacturing considerations. As the year progresses, we will continue to work hard to meet the needs of Annalee and her family.

References


Acknowledgments

Dr. Enderle
James Paolino
Eric Leknes
Katrease Gerace
N.E.A.T. at Oak Hill
MaryAnn Tuttle
Ocelco
Sunstone PCB

Appendix

Mechanical Description

This section will give a general description of the parts used in the device. It will provide size specifications and dimensions in a technical drawing design. These drawings will separate out the dimensions of individual portions of the device including the frame, leg braces, mounting bars, and swing arms. The entire frame was made from lightweight aluminum. This was also the case for the fabrication of the leg bracing system, locking arms, and arm mounting bars. Please refer to the technical drawings below for all detailed dimensions of the listed parts.
Walker Frame

Castor Wheels (4 large wheels)
Front Pressure Clamp

Front Vertical Mounting Bar
Gas Spring

Second Vertical Mounting Bar
Thigh Leg Brace

Calf Side Bar for Leg Braces
Calf Leg Brace

Hip Support and Leg Brace Connector
Arm Support Base

Arm Support Padding and Structure
Electrical Description

This section of the manual will display the circuit diagrams and equations used for the design of the electrical system. As seen in the figures and illustrations below, many simple and common components are used in the design of the circuit board. The diagrams were designed in National Instruments Software, specifically Multisim and Ultiboard. In this section, you will find circuit schematics and PCB diagrams which were used in the fabrication of the circuit. All voltages and currents are displayed in the steady state and functioning device.
In order to calculate the appropriate resistors to use for the H-Bridge voltage regulator, the following equation was required. The mathematics used for this device can also be seen below.

\[ V_{out} = 1.25v \times \left(1 + \frac{R_2}{R_1}\right) + I_{adj} \times R_2 \]

For the voltage regulator used, certain intrinsic characteristics were used to calculate the appropriate resistors. If was necessary for \( V_{out} \) to be 6.53 colts, \( I_{adj} \) to be 100 µA, and \( R_1 \) was chosen to be 240 Ω. This allowed for the second resistor to be calculated.

The parts used for the Circuit consisted of the following:

a) 4 x 2N222A Transistors
b) 13 x Resistors (various resistance)
c) 1 x Quad H-Bridge driver
d) 1 x PIC16F874 Microcontroller
e) 2 x Push Button Switches
f) 1 x DPST Power Switch
g) 2 x Voltage Regulators
h) 1 x 6.35 MHz Crystal Oscillator
i) 2 x 40µF Ceramic Capacitors
j) 2 x Green Polar LEDs
k) 1 x Custom Fabricated Dual Layer PCB Board

**Code Description**

The coding for the microcontroller can be seen in this section of the operator's manual. Programming of the device was done using a Qik Start Board to mount the code to the PIC16F874 microcontroller. MPLab software was used to write the code which uses timing to control when the motors and actuators start and stop moving. Below, the code that has been written and mounted on the device being used for The Assisted Walking Device can be reviewed.

```c
#include <stdlib.h> //standard include files
#include <pic.h>
#include <htc.h>
__CONFIG(DUNPROT & PWRTDIS & XT & WDTDIS & BORDIS & LVPDIS);
#ifndef _XTAL_FREQ
```
// Unless already defined assume 4MHz system frequency
// Used to calibrate __delay_us() and __delay_ms()
#define _XTAL_FREQ 6550000
#endif

int motorPos;
int forwardButton, reverseButton, advar;
int i=0;
int j=0;
int max=2;
int actuatorsDeployed=0; // This variable will change when the actuators are extended,
int deployLength=120; // since they don't respond well to PWM.

void Initial(void)
{
    ADCON1 = 0x00; // Setup A/D converter and enable PORTA as digital I/O
    ADCS0 = 1; // Use A/D FOSC/8

    TRISA = 0b00000011; // Set PORTA as inputs
    TRISB = 0b00000000; // Set PORTB as inputs
    TRISC = 0b00000000; // Set PORTC as outputs
    TRISD = 0b00000000; // Set PORTD as outputs
    TRISE = 0b00000000; // Set I/O for PORTE
    PORTD=0b00000000;
}

int adConvert1(void)
{

    CHS0 = 0; // Read channel AN0
    CHS1 = 0;
    CHS2 = 0;
    ADON = 1; // Turn A/D on
    __delay_us(30); // delay 30 usec to settle A/D acquisition
    ADGO = 1; // Start conversion
while (ADGO); // wait for ADGO to go off signalling end of conversion

if(ADRESH <= 200)
{
    advar=0;
}

if(ADRESH > 200)
{
    advar=1;
}

return(advar); // return the A/D result from the ADRESH register

int adConvert2(void)
{

    CHS0 = 1;    // Read channel AN1
    CHS1 = 0;
    CHS2 = 0;
    ADON = 1;    // Turn A/D on
    __delay_us(30); // delay 30 usec to settle A/D acquisition
    ADGO = 1;    // Start conversion

    while (ADGO); // wait for ADGO to go off signalling end of conversion

    if(ADRESH <= 200)
    {
        advar=0;
    }

    if(ADRESH > 200)
    {
        advar=1;
    }

    return(advar); // return the A/D result from the ADRESH register
}

void listenButtons(void)


{  
    // This function will monitor channels AN0 and AN1 for button inputs.

    // 1.) Listen for both channels
    forwardButton = adConvert1();
    reverseButton = adConvert2();

    // 2.) Respond to individual buttons
    if(forwardButton==1) // Forward button
    {
        if(motorPos<200)
        {
            forwardMotors();
        }
        if(motorPos==200)
        {
            forwardActuators();
        }
    }

    if(reverseButton==1) // Reverse button
    {
        if(motorPos<=200)
        {
            reverseMotors();
        }
        if(motorPos>200)
        {
            reverseActuators();
        }
    }

    // if(forwardButton==1 && reverseButton==1) // Reset positions
    // {
    //     motorPos = 0;
    // }
void forwardMotors(void)
{
    if(motorPos<=200)
    {
        PORTD=0b00000011;
        __delay_ms(5);
        PORTD=0b00000000;
        motorPos++;
    }
}

void reverseMotors(void)
{
    if(motorPos>=0)
    {
        PORTD=0b00001100;
        __delay_ms(5);
        PORTD=0b00000000;
        motorPos--;
    }
}

void forwardActuators(void)
{
    if(motorPos!=255)
    {
        PORTD=0b00110000;
        for (int i=0; i < deployLength; i++)
        {
            __delay_ms(10);
        }
        PORTD=0b00000000;
        motorPos=255;
    }
i=0;

void reverseActuators(void)
{
    if(motorPos==255)
    {
        PORTD=0b11000000;
        for (int j=0; j < deployLength; j++)
        {
            __delay_ms(10);
        }
        PORTD=0b00000000;
        motorPos=200;
        j=0;
    }
}

int main(void)              //This is the main body of the program
{
    //All functions of the program start here and are called
    //either by the endless FOR loop or a subsidiary.

    Initial();                   //This function initializes necessary registers

    motorPos=0;
    PORTC=0b00000001;
    while(1)
    {
        listenButtons();
        __delay_ms(10);
    }
}

Technical Specification

Physical:
Body: - Structure based on common walkers with lightweight aluminum metal

Wheels: - Caster

Harness: - Neoprene/Nylon harness with back and stomach supports

Handles and Elbow Pads: - Handles and rests that attach to crutches

Leg Supports: - Support to allow for proper walking posture and prevent legs from crossing (braces; straps; bars; plastic shell)

Motors and Actuators: - Attached at individual leg brace; mounted directly to brace

Mechanical:

Height elbow rests: adjustable between 30-50 inches from floor
Width: less than 30 in
Length: less than 36 in
Weight: less than 50 lbs

Electrical:

Battery Voltage: 2 x 9 Volt
Battery Current: less than 5 Amps
Battery Life: based on 9 volt disposable batteries

Environmental:

Operating Battery Temperature: Running at less than 120°F
Storage Temperature: 30-100°F
Operating Environment: Indoors (Tile, Carpet, Wood)

Indoor Limitations:

Wood sills from room to room; rough pattern carpet with uneven (indented) pattern; counter tops

Safety:

- Maximum user weight for the device not to exceed 150 lbs
- Not meant for staircases
- Indoor use only
- Avoid use on inclines greater than 10 degrees
• May require assistance to get into device until comfort level reached
• (support for loss of balance)
• Keep battery and electronics away from moisture
• Do not touch battery terminals

Maintenance:
• Replace batteries as needed
• Possible need for replacement motors
• Adjustments necessary to allow for proper form for walking assistance.
• Remove parts as necessary as walking ability improves