

**CHAPTER 9**  
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# **Cerebral Palsy Bicycle: An Adapted Bicycle for a Twelve Year Old with Cerebral Palsy**

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## **INTRODUCTION**

Dr. Mollendorf teaches a graduate and senior level undergraduate course in the Mechanical and Aerospace Engineering Department entitled Assitive Device Design. This class is also taken by students from diverse departments such as environmental design and architecture. The goal of

the course is to design and build an assistive device for a handicapped person. Several design projects were offered in the beginning of the course, but only one could be chosen. Our choice was to design a bicycle for a twelve year old boy, Mark Engle, who has Cerebral palsy. The above-named students, as a team, set off to design and build this bicycle for our client, Mark Engel.

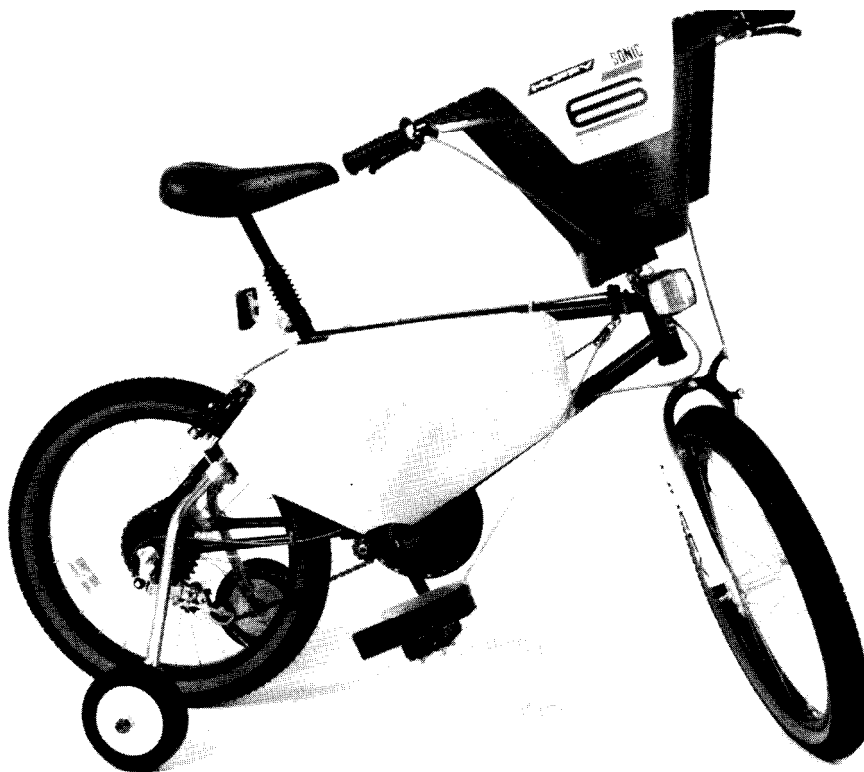


Fig. 9.1. Cerebral Palsy Bicycle.

Cerebral palsy is a disorder caused by brain damage usually before or during birth and marked especially by defective muscular control. The first objective of the project was to determine the severity of Mark's disorder. After a meeting with Mark's father, Dave Engel, and his physical therapist, Amy France, we determined that Mark's muscular coordination was good in the upper half of his body, and fair in the lower half. Mark's ability to walk on his own, moreover, suggested that he might be able

to power the bicycle using his legs. We also determined that Mark wanted a bicycle that looked like everyone else's, namely a BMX bicycle. This request reflected the undesirability of the various adaptive bicycles on the market that Mark's parents had already investigated. We knew then that our design goal was to modify a bicycle to fit the needs of Mark.

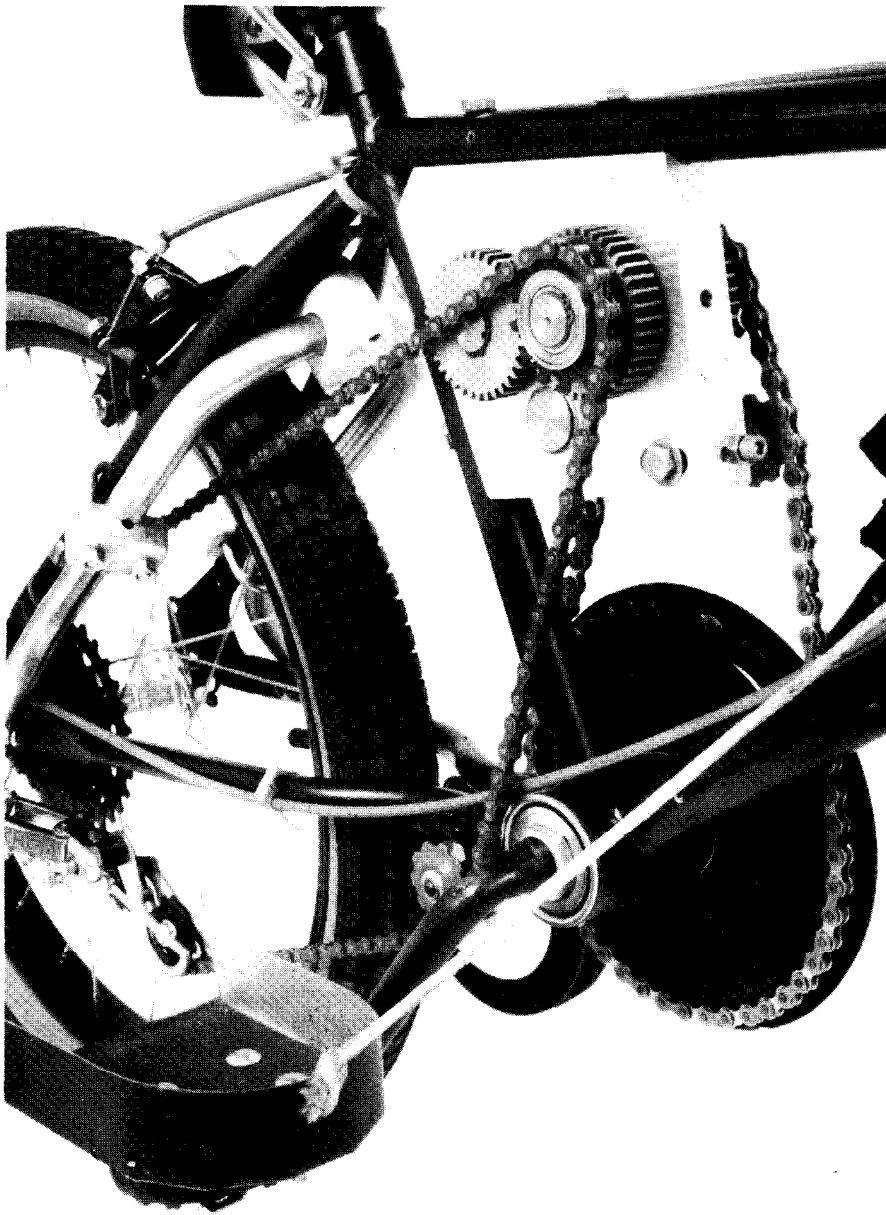


Fig. 9.2. Close up view of Cerebral Palsy Bicycle.

Logically, the first item we purchased for this project was a five speed BMX bicycle. The five speeds would give Mark a selective range of speed and power necessary in the development of his leg muscles. Our next goal in the project was to get Mark up onto the bicycle and determine what modifications were necessary. After a dry run with Mark on the bicycle, we encountered several unexpected obstacles.

The first obstacle was Mark's inability to pedal forward. His legs tended to lock up when one pedal was at the maximum height of travel and the other at the lowest. However, remarkably, Mark could pedal backward with no locking. After consulting with Amy France, we decided to design a device that would allow Mark to pedal backward, but still have the bicycle move forward. This goal was reached by designing and building a reverse transmission.

The second of our unexpected obstacles was Mark's inability to keep his feet on the pedals. Mark's toes tended to point inward toward the frame of the bicycle and his heels pointed outward. Not only did he have difficulty keeping his feet on the pedals, but interference occurred between the front of his foot and the frame of the bicycle. We therefore decided to design a proper pedal that would also prevent his feet from sliding off. A "semi-pedal" that attached to the original pedal was designed and built.

Our next concern was to design a device that would stabilize the bicycle. The team thought of using two rear wheels. This design consideration was rejected because it resembled the adaptive bicycles on the market. The group did, however, determine that a training wheel system would be the best solution because it would stabilize the bicycle and also be more aesthetically pleasing and normal looking. The conventional training wheels on the market do not, however, provide the necessary strength for mounting and dismounting. The final design that we conceived allowed Mark to mount and dismount safely which would also help develop Mark's balance skills. To further enhance Mark's balance skills, a spring mechanism was incorporated in the design. When Mark becomes comfortable with the bicycle, he will then be able to adjust the training wheels so that the bicycle could tilt to a prescribed angle. This tilting effect should help the user develop his or her balance. This is the same principal that a conventional training wheel

uses, however, our design incorporated a damping spring that compresses upon tilting which aids in the stabilization of the bicycle.

## **SUMMARY OF IMPACT**

The current adaptive bicycles on the market are not aesthetically pleasing, especially to children. Most of them appear to be adult bicycles. Children tend to want to go with the norm and not appear to be different in any way. This was the case of our device user, Mark Engel. Mark wanted a bicycle that looked just like his friends'. At a glance, our Cerebral Palsy bicycle does not appear to be any different from a normal BMX bicycle with training wheels. This was due to creative additions to the bicycle that allowed a twelve year old boy with Cerebral palsy to ride a "normal" bicycle.

The primary component that was added to the bicycle was the training wheel mechanism. This mechanism allowed Mark to mount and dismount without the bicycle falling over. Conventional training wheels would not be able to handle the stress caused by the user's weight. This device should also act like a conventional training wheel in that it would help develop Mark's balance. This was accomplished by a spring mechanism incorporated into the structure. When the user becomes comfortable with riding a bicycle, a simple adjustment can be made to allow the spring to be activated. As the bicycle tilts, the compressed "self-righting" spring will help the user regain the vertical position of the bicycle. Thus, this device supports the bicycle and aids in the development of the user's balance skills.

The most provocative device on the bicycle is the reversible transmission. The purpose of the reversible transmission is to allow the user to pedal backward and permit the bicycle to move forward. This device was necessary for our client because of his poor muscle coordination when pedaling forward. Pending other considerations, this device could be applicable to other people.

The final devices added to the bicycle were the adaptive pedals. These pedals keep the user's feet in a parallel position with respect to the frame of the bicycle. A pulley and a length of rope were added to the pedal adapters to facilitate balancing. This keeps the pedals in an upright position at all times. These pedals are easily attached to almost any type

of bicycle pedals and would be suitable for bicyclists who have poor leg control.

This bicycle proved to be successful in the first few minutes of testing. Our device user was able to ride a bicycle for the first time in his life. Mark enjoyed it so much that he did not want to stop riding. It is expected that this bicycle will bring happiness to Mark and will also help develop his leg muscles. Our team believes that with the device we developed, other children with similar conditions to Mark's could be able to experience the freedom of riding a bicycle.

### **TECHNICAL DESCRIPTION**

The training wheel mechanism incorporates a bent piece of tubing with rods that have wheels affixed to them. Inside the tubes are springs that compress as the rods move inward inside the tube. Collars and a pin allow the user to adjust the distance of each wheel from the ground which thereby changes the amount of spring compression. The training

wheel mechanism is attached to the bicycle by modified clamps.

The pedal adapters were attached to the original pedals. These were made of sheet metal and were easily fabricated. A pulley and a rope prevented the pedals from tilting upside down. Non-skid tape was affixed to minimize slippage.

Basically, the reversible transmission consists of five spur gears, two sprockets, four roller bearings, and an aluminum block. Brass bushings were incorporated into the block to prevent the gears from riding up against the block itself. Two idler sprockets were affixed to the bicycle to guide the chain to its original path before the installation of the transmission. This allowed the use of the five speed system already on the bicycle. A chain guard was also installed to prevent any contact between the user and the gears.

This bicycle was recently featured on CNN television. Total project cost was about \$445.

# Redesign of a Lower Extremity Abductor: A Device to Faciliate Proper Leg Separation While Sitting

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## INTRODUCTION

The devices that are currently on the market are not optimally designed. They lack adjustability, strength, and are unsuitable for a wide range of clients and seat types.

The device itself, which typically attaches to the base of a wheelchair seat, is used to maintain leg separation for individuals with spasticity. The device should be easily adjustable and be able to withstand constant pressure from abnormal muscle tone and corrosion from water and cleaning solvents.

## SUMMARY OF IMPACT

The mechanisms for pad width adjustment, height adjustment, and length adjustment should, optimally, be easily made with common tools, and yet withstand fatigue stresses. Furthermore, the angle of the pads does not always fit a person's legs correctly. Additionally, asymmetry of pad angle adjustments are sometimes necessary to accommodate differences in leg length and width measurements.

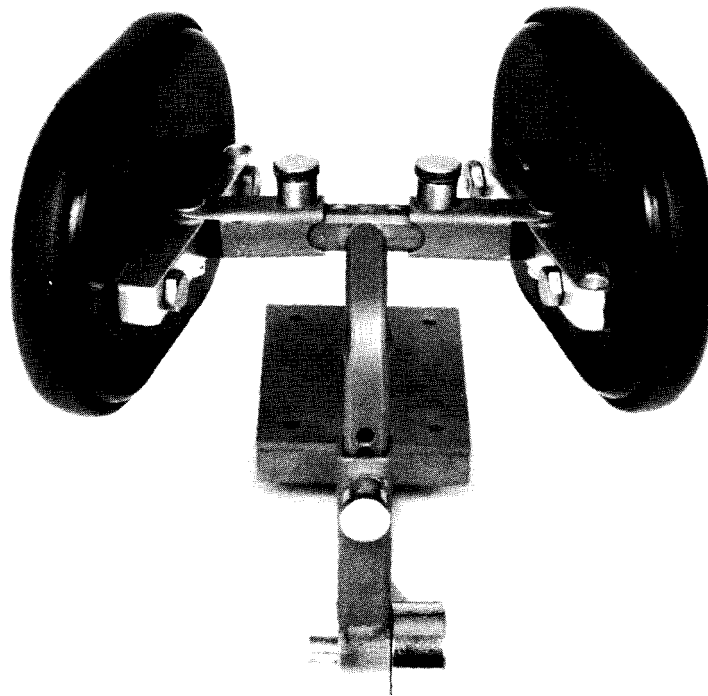


Fig. 9.3. Leg Separation Device.

The pads should also be able to swing down easily to allow access for transfer of client to or from the wheelchair. Also, when swung into functional position, the device must automatically lock in place.

The first step in resolving the problems was to obtain a device that is currently on the market.

The next step was to disassemble the swing-away mechanism of the device. It was decided to use the same mechanism currently being used for this because of its simplicity. The current swing-away mechanism was disassembled to find the part that is continually breaking. This part of the mechanism was then redesigned.

Another important step was to obtain the dimensional requirements of the device. In order for the device to be used by a wide range of clients, the amount of adjustability had to be determined. We obtained these dimensions by meeting with the professionals who would be implementing such a device.

## **TECHNICAL DESCRIPTION**

By evaluating many different proposed designs, a final design was reached. The resulting device contains four main mechanisms that will address the problems of adjustability. These are the pad width adjustment, the height adjustment, the swing-away mechanism, and the length adjustment. The parts in the original device were made of chrome-plated

steel that provides the necessary corrosion resistance.

The pad width adjustment mechanism involves two considerations. The first is the angle of the pads. The angle of the pads is adjusted by placing the pads in the desired orientation and tightening down the bolt that holds the pads to a hollow tube. The second is the pad width adjustment mechanism itself that consists of a solid square steel bar that slides inside a hollow square tube. A series of holes drilled in the bar allows the spring plunger to hold the bar in the desired location. Because this adjustment is made on both the left and right, it very advantageously permits an asymmetric setting. The height adjustment mechanism works in the same way.

It was decided that the current swing-away mechanism was to be retained in the final design. This mechanism was simple and easy to use. A minor design change was necessary, however, to make it stronger.

The length adjustment mechanism utilizes the same sliding tube and bar idea as the height and pad width adjustments.

The final design satisfied all of the adjustability requirements. It is also strong enough to withstand the stresses encountered in use.

Total project cost was about \$100.

# **Cervical Control Orthosis (CCO): A Device to Facilitate Upright Head Support**

*Designer: Lillian A. Pascale  
Client Coordinators: Drs. Pendergast, Fisher, Chutkow and Carolyn Teter  
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## **INTRODUCTION**

The main objective of this project was to develop a device that would hold a person's head upright. The problem was suggested by Dr. David Pendergast and Carolyn Teter. The patient, Anna Wilson, has difficulty holding her head up and is currently using a Philadelphia Cervical Collar. Her main complaints about the cervical orthosis are: it's too warm in the summer, too bulky, uncomfortable around the ears, and it is not symmetrical.

## **SUMMARY OF IMPACT**

An orthosis that is comfortable is critical. Anna Wilson must wear it all day but does not use it

when sleeping, but she must be able to eat with it on. She also wanted it to be smaller, better looking, lightweight, and washable. It is desirable to form the orthosis directly from a mold of the patient to assure a good fit.

A critical factor involved in the design of the orthosis was that of the mobility of the skeletal system. The scapula cannot be constrained and the region of the lumbar vertebrae should not be restricted. Satisfying these requirements would assure greater mobility for the patient.



Fig. 9.4. Device to facilitate upright head support.



## TECHNICAL DESCRIPTION

During brainstorming with Dr. Mollendorf and Tonawanda Limband Brace, Inc., (Bob Catipovic, a certified prosthetist and orthotist) the use of the principle of a lever arm to hold the head up was evolved. The force due to the weight of the head is transposed to the stomach, by using the shoulder as a pivot.

The choice of material is critical. A high strength plastic offered the following advantages: high strength-to-weight ratio, expanded design possibilities, ease of manufacturing, and relatively low cost. Foam padding was used on the sections in contact with the skin for added comfort.

Forming the orthosis directly from a plaster mold of the patient provided an excellent fit. Further, the brace could then be placed directly on the skin and be covered by clothing. The only portion of the orthosis that can be seen is the section supporting the chin and the section along the neck. Polypropylene was the co-polymer plastic that was used for the orthosis. It has a closed cell nature, therefore the orthosis can be easily cleaned.

The design process of the orthosis was experimental. The preliminary prototype was made out of plaster. Adjustments and revisions were made before the orthosis was formed from plastic. Making the changes to the plaster model helped reduce the cost.

The preliminary plaster model showed a weak region in the back and also the need for an opening in order to pull the orthosis over the head. This weak region can be eliminated by inserting carbon fillers in the plastic or by choosing a stronger plastic. The carbon fillers are thin strips of carbon that are

molded into the areas where added strength is needed.

The design of the orthosis was further modified before the plastic model was made since the patient only needs support from under the chin and not around it. Therefore, the chin support was altered to a shelf-like support. The same plaster mold, however, was used to form the orthosis from Polypropylene.

Additionally, the section supporting the chin was cut so that the orthosis could be pulled over the head. A thin foam padding with Velcro strips was used as a fastener to hold the two sides of the orthosis together. A belt was also made of Velcro riveted to each side of the orthosis and secured to the front.

The plaster orthosis was shown at ECMC's Rehabilitation Center to Dr. Pendergast (Physiologist), Caroline Teter (Occupational Therapist), and Dr. Didi Fischer (Physiologist). The general consensus was that the orthosis was quite unique and apparently feasible.

The orthosis was then made from plastic and was shown to Dr. Chutkow (Neurologist), Anna Wilson's doctor. He has written a prescription for us to make an orthosis for Jessie.

The prescription orthosis that is being made for the patient will be reinforced with carbon strips. Also, a carbon reinforced polyester will be used for another orthosis to determine which has sufficient strength. An opening provided in the back of the orthosis will also be tested to possibly eliminate the need for the aperture in the chin support.

Total project cost was about \$525.

# Assistive Ski Device: Stand-Up Ski Sled

*Designer: Corie Dzubak, Kee Wee and Todd Avery*  
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## INTRODUCTION

This assistive device allows a user with disabilities to ski while standing upright on a platform that is attached to skis.

Carol Susan Johnson, age 12 years, was born with Cri-du-Chat Syndrome, an anomaly of the fifth chromosome that results in mental retardation, muscular weakness, poor balance, and lack of coordination. Carol Susan ambulates independently but encounters difficulty maintaining her balance when she is out-of-doors during the winter months due to the snow and slippery conditions. Last winter she was encouraged to attempt to use cross-country skis but her physical limitations precluded her success. Therefore, it was agreed that an assistive ski device would be designed to provide Carol Susan with the opportunity to participate in outdoor winter activities, given her physical and cognitive abilities.

It was requested by her parents that this ski device allow Carol Susan to stand, rather than being seated, thereby using her ability to maintain an upright position. It was determined that Carol Susan would need some type of vertical support, and so a standard walker was used for this purpose. As Carol Susan's previous experience with skis and poles demonstrated that she was neither able to coordinate her movements nor those of the ski equipment, it was decided that the ski device would be designed in such a manner that the user would not be responsible for controlling direction or speed.

## SUMMARY OF IMPACT

This "stand-up ski sled" enables the user to engage in an out-of-door winter activity by providing her with the support and stability that she requires in order to "ski." As she remains standing on a platform using a walker for support, the need has been alleviated for her to control either direction or speed. This device can be used at her home, in her neighborhood, at the playground, or at a ski area. She can now join family, friends, classmates, or other skiers in the enjoyment of outdoor winter recreation.

## TECHNICAL DESCRIPTION

The skis are a 130 cm, foam core downhill model manufactured by Elan. The walker a standard Invacare adjustable height, aluminum walker with an original base size of 19" x 16" with anodized aluminum horizontal supports. The platform is 1/2 inch Lexan (Polycarbonate). The bindings are plastic open boot-style (removed from a snowboard). Miscellaneous items used were aluminum-base telescoping tubing, push pins, screws and steel mountings.

The adjustable-height walker is attached to the Lexan platform, as are the bindings. The aluminum base telescoping tubing controls the discrete angle adjustments of the skis by the use of push pins. With the rear tubing at a maximum distance and the front tubing at a minimum distance, the maximum snowplow angle is obtained.

Total project cost was about \$590.

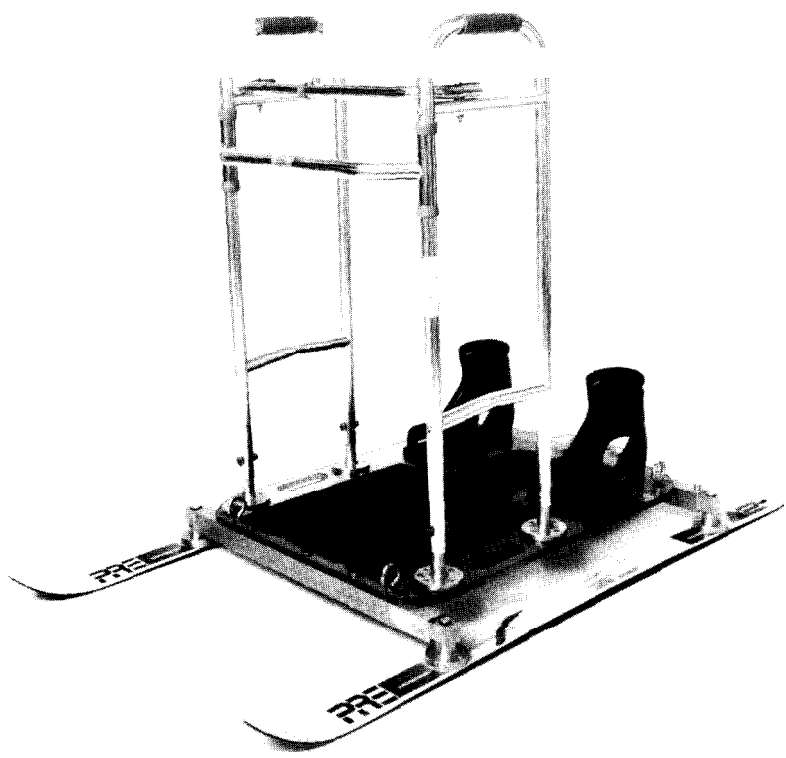


Fig. 9.5. Assistive Ski Device.

# Wheelchair Tie-Down Mechanism System: Securely Fastens a Wheelchair in a Van

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## INTRODUCTION

The objective of this project was to design and build an assistive device to be used to hold a wheelchair in a van. The need for improvement over existing devices was due to: the difficulty of the disabled person to use it without help, it is not safe enough, and obtrusive mounts attached onto the wheelchair interfere with regular wheelchair activities.

## SUMMARY OF IMPACT

As described, an assistive device was successfully built that holds a wheelchair in a van. This device offers an improvement over existing devices in the marketplace. It is much less difficult for the disabled person to use without assistance, it's safer, and unobtrusively mounts onto the wheelchair without interfering with regular wheelchair activities.



Fig. 9.6. Close-up of Wheelchair Tie-Down Mechanism.

## TECHNICAL DESCRIPTION

Existing designs require metal mounts fixed onto the wheelchair that hold two beams onto which **an** electric lock unit operates and securely fastens the wheelchair in place. These brackets are mounted in such a way that in case of **an** accident the impact may cause the fasteners to break and therefore defeat the purpose of the lock mechanism which itself is very safe. The metal brackets are bulky and certainly not aesthetically pleasing. Moreover they interfere with everyday maneuvering of the wheelchair. As an alternative design, the electric lock mechanism has been mounted on two 3 x 5 angle irons. The lock is now submerged into the van floor and consequently, a portion of the moving platform was removed.

A new design for the brackets was also needed since the lock has been moved.

The alternative design for the positioning of the lock unit allowed easier mobility of the user in the **van**. The **new** brackets offer many advantages:

**Strength and safety** - The brackets are mounted onto a solid frame member of the wheelchair and the shape of the brackets gives them their strength.

**Hassle-free installation** - They are easy to install without any tools or adjustments and they **can** be removed conveniently and thus allow anyone to fold the chair.

**Non-obtrusive** - Their dimensions and their positioning permit the wheelchair to be maneuvered over curbs or up **any** stairs without interference.

**Aesthetically pleasing** - The brackets are slim and hardly noticeable.

The **main** part of the brackets consists of square tubing. They are shaped so that they can slide into position on to the wheelchair's frame. Two pins on **each** bracket lock them in place. Three plates, which are welded onto each of the brackets, support the two beams. The brackets, as well as the 3 x 5 angle iron,s are coated with a black finish for **protection** against rust and for aesthetic reasons.

After trying this alternative design, the user was quite satisfied and felt more secure than before. The

new system allowed him to get into locking position in the first or second try, which represented for him an important saving of time. His wife was also pleased when she realized how easy it was for her to remove the brackets from the wheelchair. This permitted her to install them quickly on another (similar) wheelchair when maintenance was needed on the user's wheelchair.

The total cost was about \$25.



Fig. 9.7. Wheelchair with Tie-Down Mechanism.

# Mag-Hold Walker: A Custom-Built Cerebral Palsy Walker

*Designers: Daniel J. Snyder, Ronald Scheffler, Daniel Shea  
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## INTRODUCTION

The goal of this project was to improve a walker for a boy with Cerebral palsy. The walker is important for Matthew Stem for exercise and to prevent his muscles from atrophying and for internal organ development.

## SUMMARY OF IMPACT

One of Matthew's problems with his old walker is that it does not support his upper body. He needs someone to hold him, otherwise, he leans to one side and loses his balance. The balance ring that is currently on the walker does not fulfill his needs. Another problem with the old walker is that he has a tendency to move sideways when he wants to move forward. A further difficulty is that his feet tend to "scissor" together or his feet get ahead of his trunk. There was also a need to have some kind of armrest installed with hand grips. Finally, a seat was needed.

## TECHNICAL DESCRIPTION

First, we decided to remove pieces from the existing walker that would not help Matthew walk. The balance ring, brakes and handlebars were thus removed.

To support his body, we thought of installing a cam-actuated magnet that could be turned on and off with a switch.

A belt, made at the University's upholstery shop, was constructed and a low-carbon steel plate was attached to the belt with rivets to be put around Matthew's body. A secondary strap was installed on the belt that runs between Matthew's legs so that he could not twist in the belt. The magnet was attached to the walker frame with a clamp. The magnet is attached to a piece of angle iron that is attached to a short piece of 7/8" steel pipe that goes on the upper cross-member. The pipe can tilt on the

cross-member to allow for different tilt angles of Matthew's body. Matthew's physical therapist, Mark Costello, recommended a forward tilt angle of about 15 degrees.

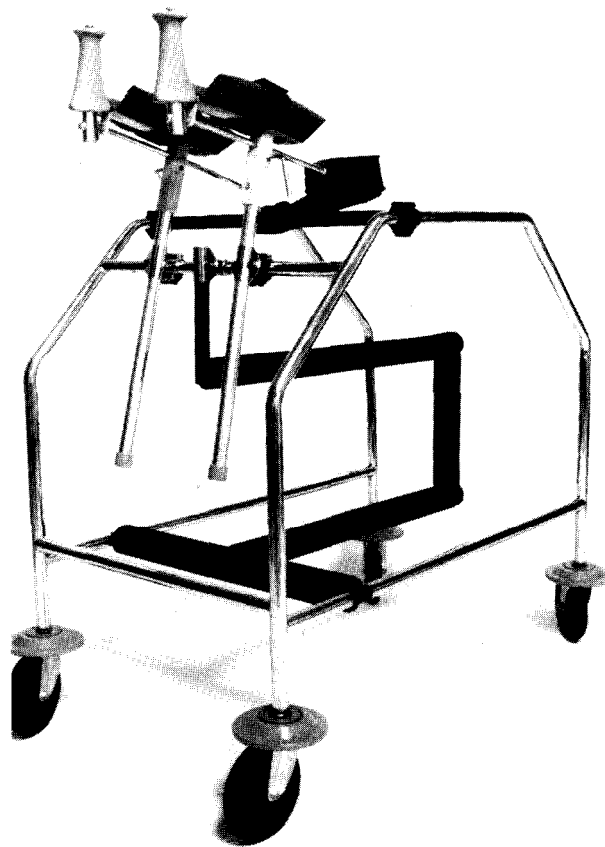


Fig. 9.8. A Custom-built Cerebral Palsy Walker.

To increase Matthew's mobility we decided to increase the wheel size so that the walker could roll smoother and more easily over cracks in the floor or over carpet. To prevent Matthew from rolling sideways we put non-swivel wheels in the rear and swivel wheels in the front for turning. A factor that contributed to the sideways motion was a lack of upper-body support. The magnet and belt would also help to rectify the sideways motion problem. To prevent Matthew from getting stuck against a wall we had decided to use bumpers made of wheels above all four comers so that he could "roll off" from a wall.

Commercially available armrests were used with hand grips that can be adjusted in the side-to-side direction, and also be adjusted in the forward direction away from his body. These armrests also have Velcro straps so that arms can be strapped to the armrest. Further, the armrests can be adjusted for different height and angle variations for potential other users and to perfectly fit Matthew's needs now and later.

To prevent Matthew's feet from "scissoring" and to prevent his feet from getting too far ahead of his body, a U-bar attachment was used. The top part of the U-bar (if the U was placed on its side) is attached to the clip for handlebars that were removed

when the modifications were started. The bottom part of the U-bar is attached to a cross member that is welded 10 inches in front of his leg to limit his stride. Both the U-bar and cross member are made of 7/8" steel pipe from Service Steel in Buffalo. The main purpose of the U-bar is to keep his feet apart so that they do not "scissor" together, preventing him from walking. The top edge of the U-bar is 21 inches away from the floor and Matthew's inseam is 25 inches. This space allowed for padding and when his legs are separated slightly the inseam will also decrease slightly.

The U-bar separates his feet and limits his stride and is well padded along with the cross member so that Matthew does not bruise himself.

The team has accomplished all of its goals in trying to make the best possible walker for Matthew Stein. We have solved the problems of his feet getting ahead of his body, maintaining his balance and preventing his feet from "scissoring." We have also given him comfortable armrests and for a smoother ride we decided on larger wheels. The next step is to see when Matthew can start walking on his own. Meanwhile, he will get his necessary exercise and his internal organs will develop better.

Total project cost was about \$250.

# Automated Window Control Device: Bedside Controlled Motor Drive

*Designers: Michael D. Giesler, Ruma K. Amin, Neal Brandl*

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## INTRODUCTION

The project goal consisted of the development of a mechanism to assist handicapped individuals in remotely opening and closing household windows.

## SUMMARY OF IMPACT

We designed and installed a full-scale working prototype window opening device in the home of Allen Johnson of Gowanda, New York. Allen suffers from Cerebral Palsy and has very limited motor

skills. Nevertheless, he is very alert and displays a high mental capacity, but his physical abilities are so few that he is wheelchair-bound and cannot speak. We have incorporated a foot switch that is attached to the wall near Allen's bed for simple opening and closing operation. For Allen to ho something for himself, such as opening and closing his bedroom window, is a great accomplishment. The window is a link to the outside world and this device creates a sense of control and independence in Allen's life.



Fig. 9.9. Automated Window Control Device.



## TECHNICAL DESCRIPTION

Our device included the replacement of manual cranking power with a D.C. electric motor. The significant considerations were the drive train, the motor size, the motor mount, and the control circuit.

For durability and space considerations, we decided to use a pair of 2 inch diameter, 90 degree mounted, 1:1 ratio miter gears for our drive train.

The motor was selected for its ability to create enough torque within a certain range of rpm necessary to crank the window under various conditions, including weather hazards, plus an addi-

tional margin of safety. Normal modes of operating would require approximately 60 rpm at a maximum of 30 in-lbs of torque.

Once our mechanical layout with our motor selection, gear mesh, and mounting was complete we needed to design a control circuit. First, we converted our incoming A.C. power from the wall plug into D.C. using a rectifier. We used two SPDT momentary switches mounted beneath a kick pad to operate the window in the open and closed directions.

Total project cost was about \$232.

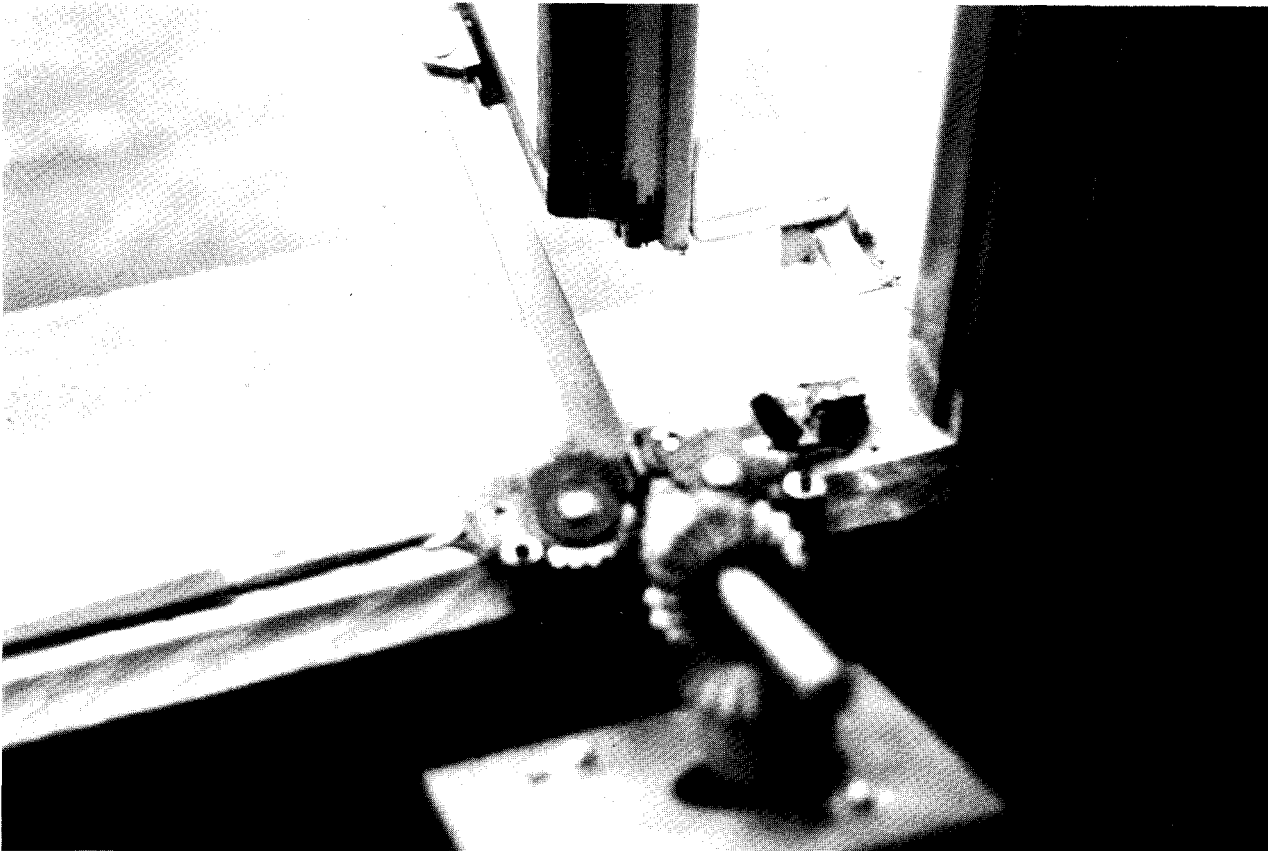


Fig. 9.10. Close-up of Automated Window Control Device.

