# Chapter 3
# ARIZONA STATE UNIVERSITY


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# ARCHERY ASSISTING PROSTHESIS FOR BELOW-ELBOW AMPUTEES

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## INTRODUCTION

An archery device was designed to aid a person with a below-elbow amputation. It will help the person grasp the bow in a comfortable and safe manner. The design is very adaptable to different situations, such as archery competitions, archery hunting, and target practice. The prosthetic was made primarily of aluminum and fiberglass to minimize weight.

## SUMMARY OF IMPACT

An essential aspect of a patient's rehabilitation after an injury is resuming recreational activities, as well as returning to work and family roles. When the injury involves amputation of a limb, a return to the patient's recreational activities can speed mental healing, improve self-image, and restore functionality in every-day events.

In the present case the patient was unable to continue practicing archery due pain caused by prosthetic devices. The patient's residual limb terminated approximately 8 cm below the elbow. This meant that the load bearing soft tissue area was reduced, and thus the forces caused the patient a great deal of pain. The new prosthesis was designed to eliminate this pain.

## TECHNICAL DESCRIPTION

The design requirements of the archery prosthesis can be broken into two main categories: patient requirements, and usage requirements.

***Patient Requirements:***

1. Capable of being used on a below elbow amputee with a residual skeletal forearm between 4-15 cm in length.
2. Device weight less than 1.5 times that of estimated original limb weight.
3. Comfortable under all possible loading conditions that the user may experience.
4. Safe for use in all situations.
5. Non-allergenic, biocompatible, and ergonomic during use.
6. Size and form similar to that of the user's anatomical counterpart.

***Usage Requirements:***

1. Capable of handling draw weights between 50 and 90 pounds (corresponding to the compressive strength of prosthetic).
2. Able to withstand tensile forces of 8 pounds and a torque of 10 foot-pounds.
3. Adjustable prosthetic angles and lengths for optimal bow positioning.
4. Bow able to disconnect from the prosthesis in a reasonable amount of time (maximum time of 15 sec).
5. All components suitable for outdoor use (all weather conditions)

After considering several designs it was decided that the best way to attach the prosthesis to the residual arm was to have the patient flex his elbow during use. This allowed the forces previously placed on the soft tissues of the residual limb to be redistributed to the elbow and the posterior surface of the ulna. Pain occurring with other available prostheses was eliminated. Since the patient had a very short residual limb, it did not interfere with the operation of the bow.

The portion of the prosthetic encompassing the arm was manufactured by taking a cast of the user's arm while was flexed at 90°. The cast was made from 20 cm above the elbow to 12 cm below the elbow. It was then used to produce a mold in which the user placed his arm. The mold was made of graphite/fiberglass/Kevlar laminate, an industry standard for prosthetic and orthotic applications. This material works very well, in terms of providing a stable base for the prosthesis and being biocompatible under long-term usage. A small piece of strap, 5R1, was rigidly attached to the distal end of the molded prosthesis using fiberglass. It can be tightened to better secure the prosthetic to the arm.

One of the major components of the prosthetic is the mechanism that holds the bow. An IceRoss Lock Mechanism is used. It consists of a plastic body and a ridged pin. The pin was mounted and attached to the bow by a bracket. When the pin is inserted into the body, a one-way gear rotates with the ridges of the pin and holds it securely in place. The pin can be released by pressing a large push button on the side of the IceRoss Lock Mechanism. Pressing this button releases the pin by pushing the gear into the body and out of alignment with the pin. The button is spring loaded, and thus the gear slides back into place once the button is released. The pin itself is 1 cm in diameter and performed with a large safety factor under testing. It held the required 8-pound tensile force. The body of the lock mechanism supported all of the compressive forces, relieving the pin from this duty. The pin withstood the required 10 foot-pounds of torque. An additional pin of 3/8″ diameter, called the counter pin, protrudes from the mounting bracket. The purpose of this pin is to prevent any rotation around the axis of the pins.

A 30 mm O.D. aluminum tube with a pyramid pivot joint on each end was used to attach the 5R1 to the IceRoss Lock Mechanism. The pyramid pivot joints allowed the user to adjust the angle of the bow from 0° to 10°, up to 5° more than the average angle used. The joints were attached to both the 5R1 and the locking mechanism by four 5-32 machine screws. The length of the archery prosthetic could be adjusted by changing the length of the aluminum tube.

Figure 3.1. Archery Device Being Tested by Designer.

The final archery prosthetic weighs 4.5 pounds. It was tested extensively by the designer, using many different drawing techniques and loading conditions (see Figure 3.1). It was deemed to be functional, safe, and comfortable. Testing also revealed that removal and attachment of the bow using the lock mechanism took approximately 4 sec., which was well under the 15 sec. requirement.

The final cost of the archery prosthesis was approximately $300.

# MEDICATION MANAGEMENT SYSTEM: AN AUTOMATIC PILL DISPENSER FOR PERSONS WITH MENTAL ILLNESS

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## INTRODUCTION

The purpose of this project was to design a medication management system for an individual with mental illness who has difficulty keeping track of her medication regimen. The individual takes multiple medications, each of which need to be taken at fixed dosages and prescribed intervals. However, due to the symptomatology of the disability, judgment and motivation are diminished and thus the ability to comply with the medication regimen is adversely affected.

## SUMMARY OF IMPACT

The client is an adult with schizophrenia, a disease of the brain that can be largely treated with medication. If untreated, it may interfere with activities of daily living. It is vitally important that individuals follow their medication regimen in order to control this disorder.

## TECHNICAL DESCRIPTION

This device dispenses medication up to three times a day at predetermined times. When medicine is dispensed, there is a voice-recorded message that says, "Jane Doe, it is time to take your medication". After this voice message, a buzzer sounds for up to ten minutes. This buzzer is intended to command the patient's attention to the degree that she is compelled to go to the device, shut it off, and remove the medication.

The device operates on an electrical timer (120 volts AC). The timer includes a transformer that regulates the output to 24 V AC. The timer is programmable and operates three separate channels in sequential order.

The program is set to meet the individual's medication regimen and has three on/off times per day.

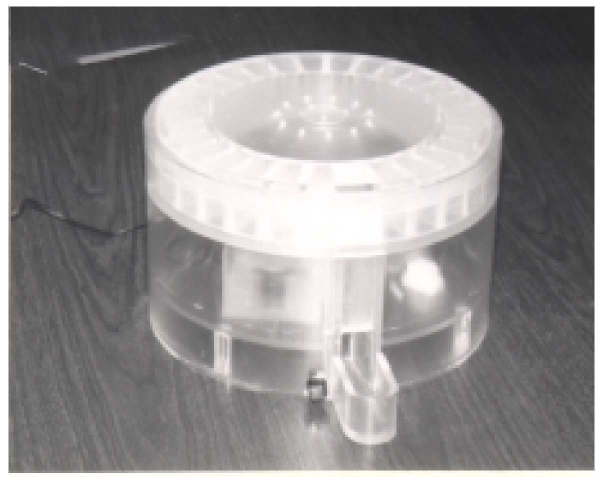

Figure 3-2. Medication Management System Prototype.

When the timer turns on, it starts powering channel 1. The output of this channel goes into a circuit that runs a motor for one minute. This motor is geared down to run at a speed of 0.034 RPM. The motor rotates a pill carousel, which revolves to an open slot that serves as a chute for the medicine to fall down into a pill-receiving tray.

After channel 1 turns off and channel 2 turns on. The output of this channel powers a circuit that contains the voice IC playback system. After one minute channel 2 turns off and channel 3 turns on. The output of channel 3 powers a circuit that contains the buzzer. This buzzer will sound for ten minutes or until it is manually turned off by a switch. Each circuit is described in more detail below:

**Circuit One:** This circuit controls the motor. The timer's 24V AC output is rectified and passed through a filter to obtain a DC current. Next, the voltage, regulated to output 12 V DC, powers the motor.

**Circuit Two**: This circuit controls the voice IC playback. The output of channel 2 is rectified and filtered in the same manner as channel 1. However, the voltage is regulated down to 6 V DC for the voice IC. When powered, the IC plays the message, "*Jane Doe, it's time to take your medication.*"

**Circuit Three**: This circuit controls the buzzer. The output of channel 3, like channel 2, is rectified, filtered and regulated down to 6 V DC. This powers the buzzer.

All of the circuit components, the motor, and the timer are housed within one unit. The system casing is cylindrical, with the pill-tray carousal on the top. The system is locked together by a hex screw, which requires a special screwdriver to remove. The patient's case manager will keep this screwdriver. The manager will refill the pill-tray once a week and make programming changes as needed.

The final cost of the system is approximately $570. Figure 3.3 shows the prototype.

**Future Work**

Several limitations that existed in the prototyping stage will not exist when product is taken to full stage production. For example, the prototype fabrication was limited to Plexiglas and PVC. In mass production, an acrylic (Acrylonitrile Butadiene Styrene (ABS)) will be used. ABS is lighter, more durable, and less expensive than Plexiglas. The manufacturing process will be thermoforming or vacuum forming. Molds will need to be made for this process but costs will be offset by reduced production time and use of less expensive materials.

Some components will be replaced with new components in mass production. For example, the electric timer will be replaced with a microprocessor chip. Additionally, the spur gear, custom made by Apache Gear, will be replaced by a stock gear made by Boston Gear, which will significantly reduce the cost.

All of the system's components will be 20 to 30 percent less expensive when purchased in bulk quantity. A preliminary analysis indicates that the product will cost approximately $260 per unit in mass production.

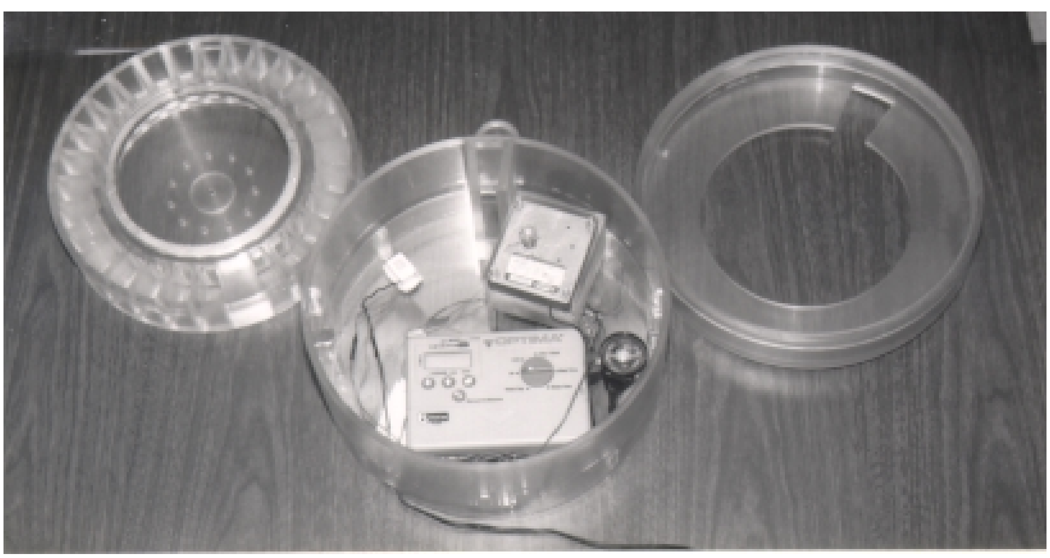

Figure 3.3. Disassembled View of Prototype.

# DUAL PURPOSE BABY SEAT

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*Client: Katherine Turner*
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## INTRODUCTION

The purpose of this project was to design a baby car seat that could also be used as a stroller. The seat has four wheels, attached to a supporting shaft, which can be folded away by simply pulling a spring-loaded pin and rotating the wheel mechanism into the folded position when it is being used as a car seat. The handle for the stroller is designed such that it does not interfere with the device when it is being used as a car seat. The design provides the child with the necessary safety when it is being used in both car seat and stroller modes.

## SUMMARY OF IMPACT

Babies may become upset and/or uncomfortable when they are placed in and lifted out of car seats or strollers. The dual function design of this device eliminates the need to transport the baby between car seat and stroller. When used as a stroller, the wheels are simply extended from the folded position to the engaged position.

## TECHNICAL DESCRIPTION

A car seat was bought and modified so that it could be used as both a stroller and a car seat. A 3/8″ steel rod was passed through both the front and rear of the car seat. This rod acted both as a support and a pivot point for the wheels and their supporting shaft. (See Figure 3.4) The supporting shaft was made from 3/4″ OD steel rod. Rollerblade wheels were used for all four wheels. The front wheels were attached to the supporting rod such that they were free to rotate in any direction, while the direction of the rear wheels was fixed. This allows the user to turn the stroller in any direction with ease.

The supporting shaft is locked in place by two rectangular pieces of steel (see Figure 3.5), one on each side of the shaft. These rectangular pieces, ½ by ½ inches and approximately 2 inches in length. They are welded to a steel plate that is bolted to the car seat.

Figure 3.4. Side View of Stroller with Wheels in the Folded Position.

All four wheels use the same locking system. Supporting shafts are released by simply pulling a spring-loaded pin. The supporting shafts must each be rotated approximately 130° to fold up the wheel structure. At this point the supporting shafts snap into a clip, which locks them in the folded position. The rods supporting the wheels were painted both for aesthetic purposes and to prevent rusting.

The handle is made of T6061 aluminum because it both lightweight and malleable. A 1″ wide piece of aluminum was bent into a U shape and riveted to the rear of the baby seat. When the wheels are extended into place, the handle is slightly above the waist level of the caregiver, for ease of reach. The handle is positioned so that it will not interfere with the device in its car seat mode.

Modifications to the original car seat do not interfere with the integrity of the structure. The stroller was tested extensively to ensure that it was stable and structurally sound before it was presented to the client.

The total cost of the dual-purpose baby seat is $360. This includes $52 for the car seat, $50 for the roller-blade wheels and bearings, $180 for labor, and $80 for other miscellaneous parts.

Figure 3.5. Dual Function Design Being Used as a Stroller.

# LAUNDRY CART TO AID A PERSON WITH A NEUROMOTOR DISORDER

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## INTRODUCTION

A laundry cart has been designed for a person with a neurological disorder affecting the motor system. The laundry cart includes a handle, a base, a supporting bar, brakes, one brake lever, and a laundry basket (See Figure 3.6). The supporting bar is used to distribute the weight of the basket and its contents throughout the base. The bar is also used to hold the laundry basket in place. The braking system has been modified so that only one lever is needed to break both of the wheels. The laundry basket can be detached for easy storage.

## SUMMARY OF IMPACT

A variety of neurological disorders can limit a person's agility, strength, and movement. At times persons with neurological disorders are able to carry on normal activities. In other instances, easy tasks, such as taking the laundry down the stairs, may be a hardship. Therefore, a modified laundry cart has been designed to allow a person to transport laundry up and down the stairs with ease. Brakes have been added to give the user increased control. The brake system enables the user to simply pull on one lever to stop both wheels, freeing one hand to hold on to a railing. An extended application of this design is to use the laundry cart to transport groceries and other bulky items to and from a multi-level building. The design is compact so that it can be stored in the trunk of a car.

## TECHNICAL DESCRIPTION

The design requirements of the laundry cart were:

1. The design must be lightweight (not to exceed 7 pounds).

2. It must not be bulky or hard to handle.

3. It must be stable so the user is not thrown off balance.

Figure 3.6. Laundry Cart in Use by Client.

4. It should be easy to use.

5. The operator must have one hand free to balance herself going down the stairs.

6. The width of the bottom portion of the basket cannot exceed 11″. (This is to ensure the device can be placed on a step without toppling over).

7. The wheels must be large enough to go up a 90-degree grade.

8. The overall design must not look abnormal or out of place. It should match the existing decor and look like a normal laundry hamper.

The laundry cart has two main components, the frame, and the laundry basket. The frame and handle bar are made of aluminum rod which has been cut and modified. The base of the laundry cart is constructed of 1″ × 1/16″ × 1″ aluminum angle. The metal was cut, bent, and welded to the desired shape. A supporting bar (15.25″ × .5″ × 1″) is used to distribute the weight of the basket and its contents between the bar and base. Four rectangular pieces of aluminum metal are used to attach the shaft and breaks. The two wheels, with a diameter of 8″, are attached to the rear of the base. Shim RSX brake sets have been modified so that only one lever is needed to brake both wheels.

Figure 3.7 shows the cart being used by the client. She found that the cart was easy to maneuver and very lightweight. She did not have a problem rolling the cart up and down the stairs.

The final cost of the laundry cart was approximately $192.

Figure 3.7. Disassembled View of Laundry Cart

# POWERED TABLE FOR A WHEELCHAIR

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## INTRODUCTION

The purpose of this project was to design a powered table for an electric wheelchair. This table is folded and unfolded by an electric motor so that it can be used by persons with quadriplegia. The table, which is attached to an aluminum frame, folds to the side of the wheelchair when it is not being used. A 12-Volt permanent DC magnet gearmotor drives a gearbelt that in turn rotates the table into position. The table can be operated manually by simply releasing a pin that uncouples the table from the motor.

## SUMMARY OF IMPACT

Wheelchair accessories play a very important role in helping persons with physical disabilities. A very important accessory is the table. Unfortunately, most of the tables on the market today are manually operated and cannot be used by persons with quadriplegia. Thus there is a need for a table that is not operated manually. This powered table design may be used for many activities, such as eating and writing. The design makes the table easy to use and the user can operate it without aid from other persons. Depending on user preference, this table can be attached to either the right or the left side of the wheelchair with little modification. It is ideal for persons with quadriplegia, but any person in a wheelchair may use it.

## TECHNICAL DESCRIPTION

The powered table consists of a PVC tabletop that is mounted on a frame made of T6061 aluminum. The table is driven by a 12 V permanent DC magnet gearmotor. This motor is mounted to the bottom of the aluminum frame. The entire frame is mounted to the right side of the wheelchair via 5 U-bolts.

A permanent DC magnet gearmotor is used because it has an internal locking mechanism that keeps the drive shaft locked in place when the motor is not powered. The motor is connected directly to the wheelchair's 12 V battery. The user engages the motor with a DPDT (Double Pole Double Throw) toggle switch. The toggle switch can be mounted at any position convenient to the user. The motor is bidirectional so that the table can be moved both to and from the usable position. The motor operates at 6 RPM and is capable of 50 in-lb of torque. The motor is coupled to the table by a 2L583 synchronizing gearbelt. The drive pulley and the driven pulley attached to the table both have the same diameter and thus the gear ratio is 1:1. When the motor is engaged the table rotates from the vertical position at the side of the chair to the horizontal position above the persons lap. In other words the table rotates 270°, taking 7.5 sec.

Figure 3-8. Powered Table for a Wheelchair.

The table is also designed so that it can be operated manually. Under normal circumstances the axle to which the table is attached is fixed to the pulley. By pushing in a pin, the axle can be released from the pulley, allowing the user to fold and unfold the table manually. The pin is spring-loaded. Once it is released the axle re-locks to the pulley. (See Figure 3-8)

The total cost of the project was $189. The major expense was the 12 V motor at $90. The pulleys were $14 each and the aluminum was $13. The cost of $189 does not include machining or labor.

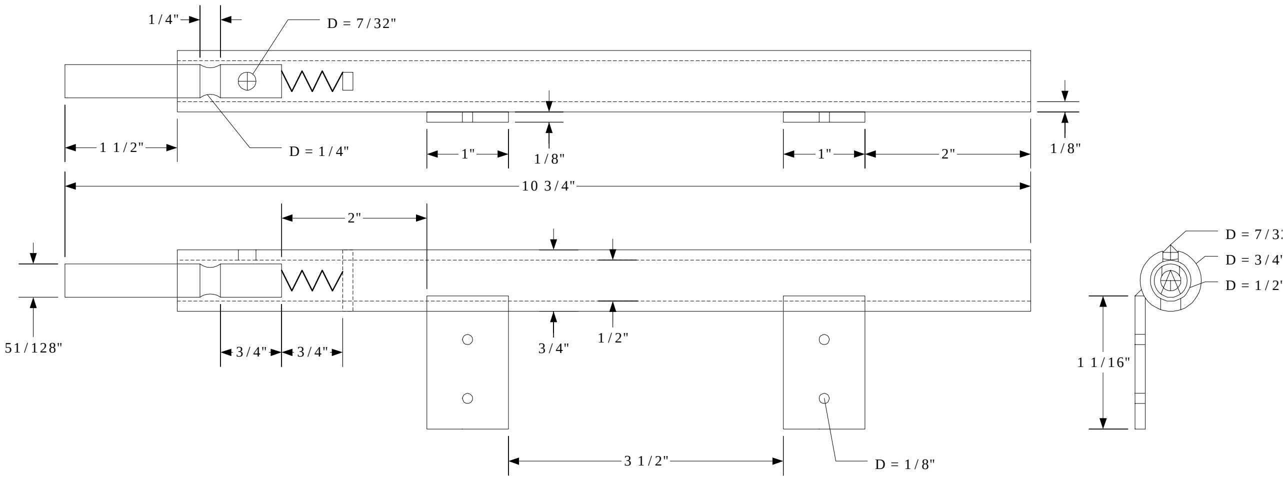


Figure 3.9. Rotating Axle and Locking Mechanism.

# STAND-ASSIST COMMODE

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*Client Coordinators: Greenfields Retirement Community*
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## INTRODUCTION

The Stand-Assist Commode is a device to facilitate sitting and standing for elderly people. When raising a person, the device first lifts the toilet seat vertically; then, the seat rotates and assists the individual in standing. The process is reversed to help a person sit. The device has handrails, which are raised and lowered with the seat so that the individual can help steady him or herself.

The device operates through the use of hydraulic cylinders, connected to the water supply at the rear of the toilet. The user controls the system by simply adjusting a needle valve. The device includes a frame and a mount for the toilet seat. It is designed such that it can be used on any conventional toilet bowl without having to make large modifications.

## SUMMARY OF IMPACT

A common problem that occurs as people get older is the onset of arthritis. This disease limits a person from doing everyday activities such as standing and sitting. Although this device was designed to help a specific individual with arthritis sit and stand independently, it could be used to help anyone with a weakened lower body.

## TECHNICAL DESCRIPTION

The Stand-Assist Commode uses hydraulics to assist a person to the standing and/or sitting position. The front cylinders have a stroke length of 10 inches and the rear cylinders have a stroke length of 14 inches. Both cylinders have a bore diameter of 2 inches. The rear stroke length is longer because the seat must be rotated forward so that the individual is urged to stand.

The water supply for the cylinders is obtained by tapping into the preexisting water supply lines at the back of the toilet. Use of water pressure in the existing lines to actuate the cylinders obviated the need for a hydraulic pump. The water flows to the cylinders through 1/4 inch polyethylene tubing. The tubing is connected to the various components such as the cylinders, the valves, and the water supply with brass compression fittings. A disadvantage to this system is that the toilet cannot be flushed at the same time that the cylinders are working, since they both use the same water supply. After using the toilet, the user must first raise himself and then flush.

The user controls the system through the use of a manual 5-port, 3-position detented valve. The first position allows water to flow into the bottom of the cylinders and out of the top, thus raising the cylinders. The second position stops all water flow and thus locks the cylinders in position. The third position allows water to flow into the top of the cylinders and out of the bottom, thus lowering the cylinders. The valve is extremely easy to use and can be mounted to any position convenient for the user.

The Stand-Assist Commode consists of a U shaped base that sits on the floor. This base is placed around the bottom of the toilet. The front cylinders are mounted to this base at an angle of approximately 46°. The rear cylinders are attached to a structure that is mounted to the base. The tops of all four cylinders are attached to a seat plate, which is machined from stainless steel. The user's toilet seat attaches directly to the seat plate.

The total cost of this project is approximately $700. The hydraulic cylinders, which were purchased for $550, constitute the greatest portion of the expense.

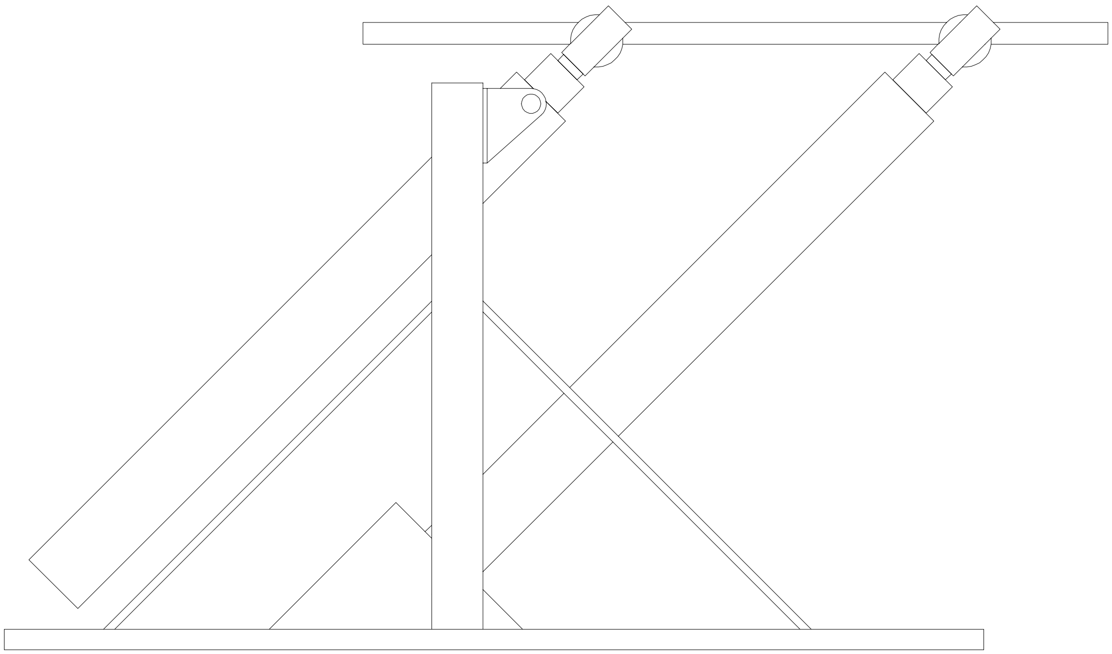

Figure 3.10. The Stand-Assist Commode (Sitting Position).

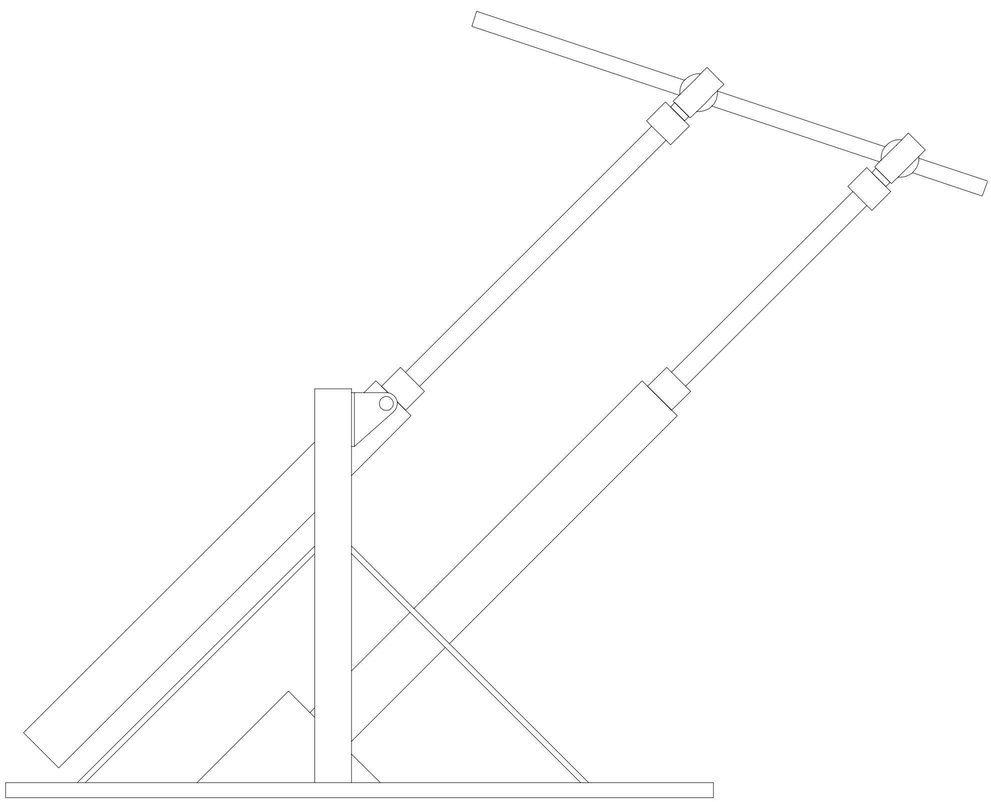

Figure 3.11. The Stand-Assist Commode (Standing Position).

# THE SUN-SEEKER: A SOLAR PANEL SYSTEM FOR RECHARGING WHEELCHAIR BATTERY APPLIANCES

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## INTRODUCTION

The Sun-Seeker, a solar panel system, has been designed to recharge batteries for people who use electric wheelchairs. The system is universal in design for all wheelchairs. It is portable and can be disassembled for transport. The Sun-Seeker consists of two solar panels (12 volts each) and a manual tracking system. Each solar panel is square and is covered with a styrene top for protection. The solar panels are supported by a suspension system that consists of four aluminum bars. This overhead system (the solar panels and suspension system) pivots about its center of mass. It is affixed to an aluminum shaft attached to the wheelchair. The solar panels are rotated by using a manual actuator. The panels are free to rotate 360° clockwise and counterclockwise.

Human factors engineering was applied advantageously in the design of the actuator. When the actuator is pushed, spring plungers embedded in the actuator provide a stimulus (about 2.3 lbs), which is close to the force of pushing. This tangible feedback is reinforced by a clicking noise that signals movement of the overhead system.

## SUMMARY OF IMPACT

The purpose of the Sun-Seeker is to recharge the batteries of electric wheelchairs. This gives the user greater freedom to partake in normal activities without recharging batteries. This device is lightweight and fits on most electric wheelchairs. The solar panels are relatively inexpensive and are affordable for most wheelchair users.

## TECHNICAL DESCRIPTION

The Sun-Seeker is a universal design. It can be mounted on a wheelchair, clamped onto a table, or fixed on a roof to charge a 12 volt or 24 volt battery.

Figure 3.12. Picture of Sunseeker Being Used by Client.

The Sun-Seeker consists of two solar panels (12 volts each) and a manual tracking system. Each solar panel is rectangular in shape and has dimensions of 19.3 in. long by 17.3 in. wide, or a total area of 4.74 ft$^2$. Each solar panel is covered with styrene concealment to protect the solar cells from damage. The solar panels are connected in a series yielding an output of 24 volts and 1.67 Amps. The solar panels are 12% efficient in converting sun energy into electrical energy. They produce 40 watts. The total weight of the solar panels and the suspension system is approximately 12 lbs.

The solar panels are mounted by an aluminum suspension system that consists of four aluminum bars. Each bar has a diameter of 0.500 in. and is bolted to the solar panels. The suspension system is connected to a supporting aluminum shaft by a joint around which the whole system pivots. The supporting shaft is 34.00 in. long with a 0.750 in. outer diameter and a 0.500 in. inner diameter. The lower end of shaft is coupled to a manual aluminum actuator that is capable of rotating the overhead system 360° clockwise and counterclockwise.

The actuator is an S-shaped object with two tubes protruding from its ends. The upper tube is coupled to the support shaft and has dimensions of $1.150 \pm 0.002$ in. O.D., $0.750 \pm 0.002$ in. I.D., and a length of 1.250 in. The lower tube, about which the overhead system rotates, is coupled to a clamp and has dimensions of $1.500 \pm 0.002$ in. O.D., $0.700 \pm 0.002$ in. I.D., and a length of 1.500 in.

Embedded in the walls of the lower tube are four stainless steel spring plungers. They are attached in a criss-cross shape. Each spring plunger has body length of 5/8 in., nose length of 3/32 in., and nose diameter of 0.07 in. The intent of the plungers was to provide a stimulus that approximates the force of pushing. When the actuator is pushed, the spring plungers provide the change in pressure (about 2.3 lbs) required to move the shaft. The user is provided tangible feedback via a clicking noise that is made when the overhead system is moved.

A clamp was attached to the bottom of the supporting shaft so that the whole system could be mounted to a wheelchair. The clamp consists of three components: a coupler to the actuator, a U-shaped body, and a tightening screw. The coupler is an aluminum bar of 0.700 in. diameter and 1.500 in. long. The U-shaped body has a wall thickness of 0.375 in. and is 2.910 in. long. A 1/4″-20 screw was used.

A 4-amp voltage regulator was used to control the voltage of the solar panels. That is, charging of the batteries is controlled by shunting the photovoltaic array when the battery is fully charged. The controller has a built-in temperature compensation sensor that assures the batteries are properly charged regardless of the thermal environment. Both the solar panels and the voltage regulator were purchased from ETA Engineering Inc., located in Scottsdale, Arizona.

Figure 3.13. Rear View of Sunseeker, Showing Method of Attachment to Wheelchair.

Tests of the Sun-Seeker were conducted by having the designer push the actuator when the entire system was fixed on a desk. Hand force was sufficient to initiate movement of the system.

The total cost of the project was $760.

# MOBILITY VEHICLE FOR A CHILD WITH CEREBRAL PALSY

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## INTRODUCTION

A child's electric toy car was redesigned so that a young girl with cerebral palsy could use it. The car is powered by a 12 V electric motor. The child initiates acceleration by pushing a button once and stops it by pushing the button a second time. The car's mechanical steering was converted to electrical steering by directly connecting a 12 V reversible electrical motor to the steering column. The steering, like the acceleration, can be controlled by simply pushing buttons. A seat was custom made for the client and installed in the vehicle. A shoulder harness and a lap belt were installed both to safely secure the child and to help her sit up straight.

## SUMMARY OF IMPACT

Children with cerebral palsy are often confined to wheelchairs that limit their interaction with the environment and their development of independence. A child's sit-in car was modified so that a child with cerebral palsy could use it without assistance from anyone. The car provides the child with a sense of independence that she would not have otherwise, and does not make the child feel self-conscious in front of other children. Additionally, it enables the child to be stimulated in novel ways, and will help develop the child's upper body strength and coordination skills. The restraining belts in the car were designed such that they would help the child sit upright, while requiring some therapeutic effort from the child. The design requires the child to control the car through a series of buttons.

## TECHNICAL DESCRIPTION

Modification of the existing vehicle involved redesigning three main components: (1) the steering mechanism, (2) the seat and restraining mechanism, and (3) the accelerator and brake pedals.

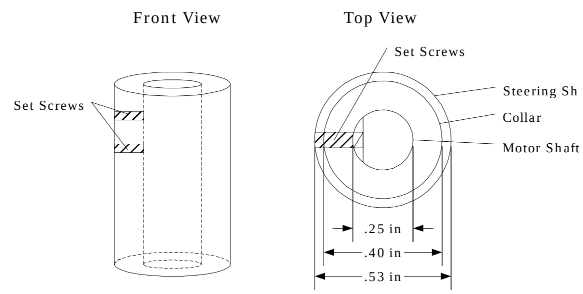


Figure 3.14. Collar for Attachment of Motor to Steering Shaft.

The mechanical steering wheel was replaced by a system that could be operated by simply engaging one button for a right turn and another button for a left turn. The steering wheel was removed and a 12 V DC reversible motor was coupled directly to the steering shaft using a 3-inch-long collar). Two setscrews were used to ensure that the collar would not move. (See Figure 3.14).

The motor was geared down to 5 RPM so that the child could properly control the steering. The motor is capable of producing 1440 in-oz of static torque, which is more than enough to rotate the steering shaft under normal operating conditions. A circuit was designed to allow forward and reverse rotation of the motor. When the child pushes a button on the left, a single pole double throw (SPDT) switch moves from its NC position to its NO position, causing the motor to rotate counterclockwise. When the right button is pushed the SPDT switch moves from its NC position to its NO position and a double pole double throw (DPDT) switch moves to the NO position causing the motor to rotate clockwise. (See Figure 3.15)

A seat was custom-made and installed in the car to help the child with proper support. The seat is held in place with Velcro straps and can be easily removed to use for other purposes. A shoulder harness and a lap belt were installed both to safely secure the child and to help her sit up straight. These straps were designed to aid the child while not allowing her to become totally dependent on the straps.

The vehicle is rear wheel driven. A 12 V motor, left unchanged, is attached to the axle of both wheels. The maximum speed of the car is 3 miles per hour. The foot pedal that had originally been used to engage the system was replaced with a push button. The button was designed so that when pushed once the car would accelerate, and when pushed a second time the car would stop. The button requires very little pressure to engage, which is important for a child with cerebral palsy. A tabletop was made and placed in the car. The accelerator button, as well as the right and left turn buttons, can be placed at any position on the tabletop convenient for the child. Velcro is used to secure the buttons to the tabletop.

The total cost to modify this vehicle was $396.19. The 12 V DC reversible motor was purchased for $127.29 and the push buttons for $146.00. Other miscellaneous parts comprised the rest of the $396.19. It should be noted that the original vehicle, which was supplied by the family, was worth about $500.00.

No pictures of the final project are included because the parents did not feel comfortable having pictures taken.

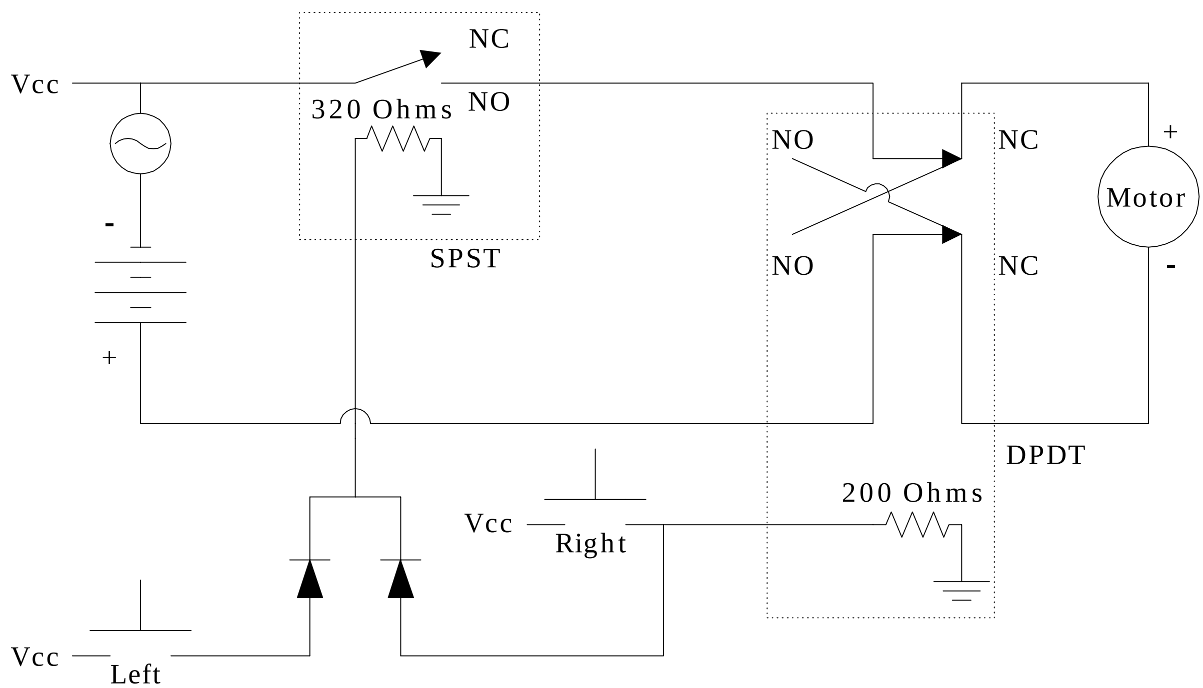


Figure 3.15. Steering Circuitry

# OFF-ROAD WHEELCHAIR FOR MULTIPLE TERRAIN CONDITIONS

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## INTRODUCTION

An off-road wheelchair was designed for use on multiple types of terrain. The frame of the wheelchair consists of an oval shaped aluminum tube that is approximately 3 feet in length. This aluminum tube is used as a base for the seat, the front axle, and the suspension system. The wheelchair has three wheels, two in the front and one in the rear. Twenty-six inch mountain bike wheels are used in the front. These wheels are attached to the front axle at an angle, both to help improve the stability of the chair, and to help the user grasp the propulsion handles with ease. A sixteen-inch wheel is used in the rear. This wheel is attached to the frame by way of an elastomer suspension system that is free to rotate as the rear wheel turns. The suspension system was fabricated by inserting a stainless steel axle through the elastomers. When the rear wheel strikes an obstacle the elastomers are compressed between an aluminum plate and a bolt, thus alleviating some shock for the user. The fork of the rear wheel is attached to the bottom of the suspension system using conventional bicycle steering bearings. The bicycle is propelled by two handles, each of which is attached to the outside of a front wheel by means of a bicycle free wheel. Braking is accomplished by pressing a pair of pads on the handles against the front wheel rims. Quick release pins allow the bike to be easily dissembled. The seat, front wheels, and front axle are detachable.

## SUMMARY OF IMPACT

Many persons with paralysis of the legs are highly active. Some perform activities that would be difficult even for people with no disabilities. The design of an off-road recreational wheelchair allows persons with lower-body paralysis to push their recreational limits to much higher levels than current wheelchair designs permit. The overall design of this wheelchair allows the user to enjoy the excitement of off-road activities with fewer limitations. The lightweight design of the wheelchair in combination with the specialized arrangement of its parts allows the user to perform difficult maneuvers over rough terrain by using their hands and by moving their center of weight. The chair is designed such that is able to withstand a great deal of force during downhill-style riding over rough terrain.

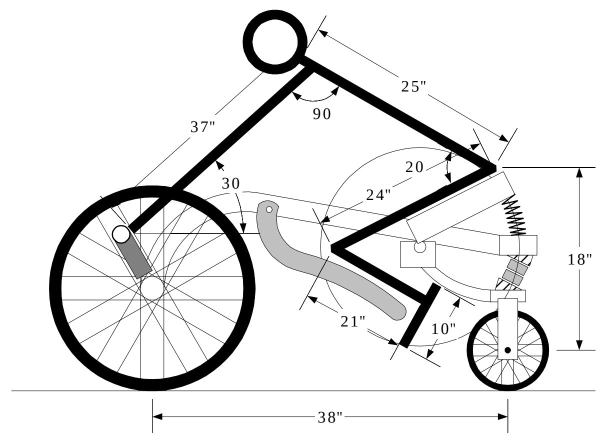


Figure 3.16. Schematic of Off-Road Wheelchair, with Dimensions

More than just an aid for an individual with a disability, the wheelchair is also a recreational vehicle. Thus the aesthetics are based on the latest designs in recreational equipment. Although the wheelchair was made for a particular client, an effort was made to manufacture the chair from easy-to-find common parts so that the price would be affordable for any potential users.

## TECHNICAL DESCRIPTION

The wheelchair was designed with a particular client in mind, but during the design process average human dimensions were considered to make the design more universal. The requirements for the design were:

1) Forces from curbs of height or depth of up to 15 cm at speeds of up to 20 mph should not damage the wheelchair;

2) While moving at low speeds the user should be able to maneuver through passages that have a width of only 3 ft; 3) The user should be able to easily climb over obstacles with sectional semicircular profile of radius up to 1 ft; 4) The wheelchair should be portable.

The single tube frame was designed to be compact and lightweight. Aluminum tubing was used throughout the design. Lower density advanced material, like graphite composites, could be used in future designs. All of the tubing used in the design are standard sizes (e.g. 0.5″, 1″, and 4″) and are easy to purchase. The design used an oval shaped main tube with a major axis of approximately 5″ and a minor axis of approximately 3″. This was simply made by compressing a 4″ circular tube into the proper shape. The suspension, seat, rear wheel and front wheels were all attached to this oval shaped tube (Figure 3.17). The additional insertion and welding on the mainframe tube were strategically located at points that increased the overall strength of the frame.

The braking system for the current design is brake pads attached on the propulsion handles. The hands of the user can also be used as maneuvering brakes. He/she would have to wear special gloves for high speed maneuvering. Future improvements could include disc brakes, or an in-the-hub braking system on the front and/or rear wheels. The current design didn't include this option because of an effort to minimize both weight and price.

The propulsion of the wheelchair is achieved by the use of two variable size handles, which are attached to the wheels through two single speed conventional free wheels. The free wheels are used to push the

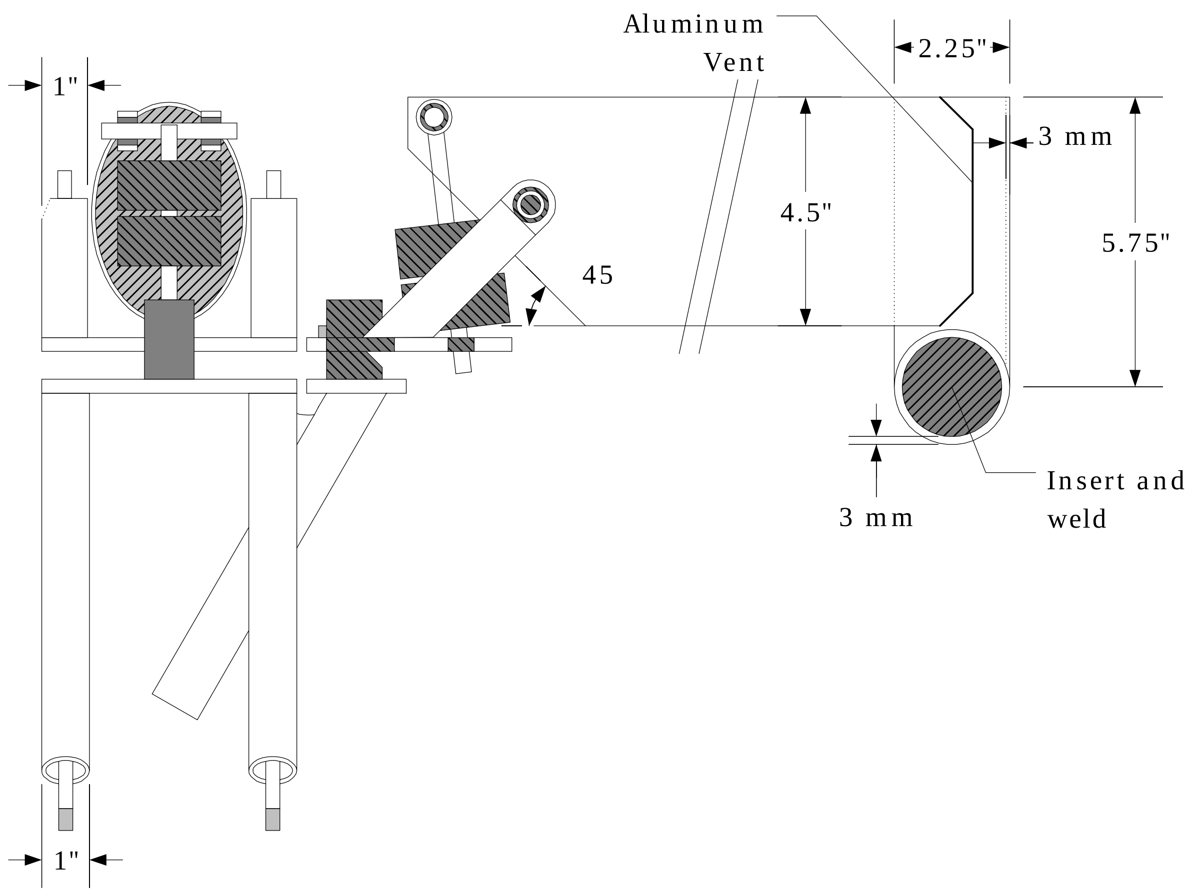


Figure 3.17. Rear View and Side View of the Main Frame and Attachments.

Figure 3.18. User Propelling Wheelchair.

wheels forward with repetitive rotations of the handles. (See Figure 3.18).

The steering of the wheelchair is achieved by applying varying braking forces on each wheel, as is done on a conventional wheelchair. Other methods for steering were considered:

1) Allow the front wheels to rotate by rotating their axle and including bearings;

2) Attach cables which will steer the rear wheel. The cables would run from the rear wheel's top fork plate to the handles in such a way that steering would be achieved from motion not used for propulsion.

The seat is constructed of two pieces: 1) the rear backrest cushion, and 2) the lower cushion. The cushions are connected to each other with a 90-degree bend polymer plate. The plate can be replaced in the future by a suspended joint for better support. The seat is attached on the mainframe tube with quick release pins. In the future suspension could also be added between the lower cushion and the frame.

Figure 3.19. The Transfer from Traditional Wheelchair to Off-Road Wheelchair.

The wheelchair was designed for an individual who was selected according to the following criteria: 1) weight of the user, 2) Familiarity with different multiple types of wheelchairs, 3) Upper body strength, and 4) Interest in recreational activities.

During the final testing by the client the following were listed as the major advantages of the Off-Road Wheelchair:

1) The sitting position allows more freedom of movement and reaching objects laying in the front of the wheelchair is easier;

2) The center of weight is low for a more stable ride;

3) The sitting arrangement of the user is such that he/she can achieve better stability by shifting his/her weight during fast motion and turning;

4) The user can employ the handles to propel himself over a curb with out any risk of falling due to the 26" high impact wheels in the front;

5) The frame design creates a high-strength low-weight (less than 25 lb) setup.

6) The frame design uses conventional aluminum 6061-T6 tubing, which is inexpensive and easy to find, in contrast to bend or variable thickness tubing;

7) The positioning of the front wheels allows the user clearance for transferring from another chair to this wheelchair. (See Figure 3.19);

8) Vibrations perpendicular to the spinal cord are reduced, minimizing the risk of spasms and pain for the user, due to the use of elastomer suspensions and placement of the user such that he/she is not sitting over the large wheel axles;

9) It is easy to change the overall width of the wheelchair for home use and for off-road use where the stability requirements are altered;

10) The user can perform high-strength curb climbing at a high speed;

11) The wheelchair folds into a small package once the various quick release parts have been removed (26"x33"x15");

12) The wheelchair is stable when used on a sloped pavement where standard wheelchair designs tend to move sideways.

The design's disadvantages reported by the user included:

1) The rear rotating wheel tends to obstruct motion over very steep obstacles like steps;

2) The slope of the seat should be adjustable to the needs of the user;

3) The brake's ergonomics should be improved so that they can be used simultaneously during maneuvering and propelling.

The client had described many problems that he had with his previous wheelchair. Most of the problems seemed to occur when he was traveling outdoors. Specifically, he mentioned the problems that he had with the small casters used on traditional wheelchairs. He concluded that the newly designed off-road wheelchair alleviated many of his problems. He emphasized the important psychological aspects of using a wheelchair that is designed as a recreational vehicle and not just an aid for a disabled person.

The final cost of the wheelchair was approximately $750.

Figure 3.20. Side View of User on Off-Road Wheelchair.