CHAPTER 17
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VEHICLE CARRIER FOR A RECUMBENT TRIKE

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INTRODUCTION
The goal of this project was to design and construct a racking system that will allow the family of an individual with a disability to transport easily and safely his recumbent tricycle using a standard automobile. The client is a teenage male who has undergone numerous surgeries and chemotherapy treatments to treat a malignant tumor in the lower rear portion of his brain. These treatments have resulted in a number of medical side-effects including poor balance, which prevents him from remaining upright on a standard two-wheel bicycle. As a result, he owns and rides a recumbent tricycle. Although he has no problems riding his trike, his family does have problems transporting it as a result of its awkward geometry and weight. The family currently transports the trike using a trailer attached to the hitch of their van. They feel that the current trailer is difficult to attach to the van, awkward to load with the trike, and difficult to maneuver once it is loaded. A custom aluminum rack was designed and mounted on top of a commercial aluminum cargo carrier. This cargo carrier is mounted to a standard, two-inch hitch receiver on the client’s van. Aluminum ramps allow the trike to be rolled onto the aluminum frame. The trike is secured in place on the racking system using ratcheting nylon tie-down straps. Figure 17.1 displays the client and his mother with the client’s tricycle, testing the finished

Figure 17.1. Client (on left) Testing Trike Racking System

Figure 17.2. Vertical Hitch-Mounted Rack

Figure 17.3. Top Mounted Roof Rack
racking system.

**SUMMARY OF IMPACT**

Due to the client’s medical condition, bicycling is one of the few outdoor activities that he can participate in with his family and friends. He currently lives on a road with a high volume of traffic. As a result, his trike must be transported to local parks or bicycle trails in order for him to use it. Since his mother finds it difficult to load his trike and transport it using the family’s trailer, the client must often wait until his father returns home to use his trike. Providing a racking system that the client’s mother can attach easily and safely to her vehicle, and then load and maneuver, will allow the client to use and enjoy his trike more frequently. This will also reduce stress on the client’s mother, making the process of transporting the trike safer and less physically demanding.

**TECHNICAL DESCRIPTION**

The trike weighs roughly 60 pounds, is slightly over 6’ in length and nearly 30” wide. The only commercially available racks found were for standard two-wheel bicycles. Such racks cannot accommodate the client’s trike because of size, geometry and weight constraints. Most commercially available products make use of a top-mounted roof rack, a hitch-mounted rack, or interior storage. Because of the large physical dimensions of the trike, interior storage systems were not an option. Three design options for mounting and orienting the trike using either a hitch-mounted system or a roof-mounted system were considered.

The first design option was a hitch-mounted rack that oriented the tricycle vertically on the back of the vehicle, as shown in Figure 17.2. This design would consist of a lower frame that would connect to a standard square two-inch hitch receiver on the automobile. Mounted on top of the lower frame would be two short vertical rails and a long center rail. Wheels on the platform would allow it to slide up the detachable hinged ramps at the end of each. To load the trike onto the rack, the hinged ramps would be pivoted down, with one end resting on the ground. The front wheel would be lifted into the sliding center mount. Using the mechanical crank, the bike would be pulled into place with the two back wheels riding up the previously lowered, hinged ramps. When the bike is in position, the hinged ramps would be raised against the rear wheels to secure them in place. However, there were several apparent problems with this option. First, the front wheel of the trike would be required to lift a large portion of the tricycle’s weight, which is nearly 60 pounds. It would have to be determined if this small front wheel was capable of holding such a weight. Second, the vertical design would keep the back hatch of the vehicle from being opened as the center rail would extend above the top of the vehicle, whether it was a minivan or SUV.

The second design option was a roof-mounted design, as shown in Figure 17.3. This design would consist of a permanently mounted, commercially-available roof rack that would be mounted onto the top of the automobile. Two horizontally-mounted rails would be attached to the roof rack. At the rear of the vehicle, two detachable rails would connect to the horizontal rails and extend, on an angle, down to the ground. The tricycle would be mounted to a sliding platform by its wheels. Wheels on the platform would allow it to slide up the detachable

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Figure 17.5. House of Quality for Three Design Alternatives
rails and lock into place on the horizontal rails, on top of the automobile. Because of the weight of the tricycle, an electric winch, mounted on the horizontal rails, would be used to pull the sliding platform up the detachable rails. The roof rack option also had several problems. First, having the entire rack structure and tricycle mounted on the roof could cause significant drag and road noise as the automobile is driving. Second, the design is complicated, requiring an electric winch with a power supply, permanently-mounted components, and a sliding platform with a locking system. Further, this rack could not be easily moved from vehicle to vehicle, as the horizontal rails would be hard-mounted to the top of the vehicle.

The third and final rack orientation that the designers considered was a hitch-mounted rack with the tricycle oriented horizontally along the rear of the automobile. A sketch of such a rack system, with the tricycle in place, can be seen in Figure 17.4. This design consists of a lower frame that would connect into the standard square two-inch hitch receiver of the vehicle. On top of the lower frame would be an upper frame on which the wheels of the trike would rest and onto which the trike would be secured. A set of two removable rails would extend from the upper frame to the ground. Once these were in place, the front wheel would be lifted onto the upper frame and either set into a center rail or a sliding mount that would ride along the center of the upper frame. Either of these two options would work to keep the front wheel straight as it moved along the length of the rack. The tricycle would next be pushed such that the rear wheels would ride up the removable rails and onto the upper frame. Finally, the tricycle would be secured to the upper frame using either wheel or frame mounts.

This horizontal hitch-mounted rack did not appear to have the same drawbacks as the other two designs. It was found that the length of the tricycle (73”) was only slightly longer than the width of the smallest vehicle this rack would be used on (72”). As a result, very little drag or wind noise would be expected. Also, the height of the rack is fairly low (less than two feet from the ground). Thus, no mechanical or powered devices were thought to be needed to load the trike. Only simple ramps were
expected to be necessary. Overall, this design appeared to be simple with no readily apparent problems.

The three alternatives had to be systematically compared. Through group discussions and client input, a set of customer requirements was established and ranked in order to numerically compare the three design alternatives. The customer requirements included: ease of rack installation, ease of loading the bike on the rack, single person operation, portability between vehicles, allowance for use with additional bicycles, enabling of use of back hatch, and aesthetics.

Using these requirements and a numerical ranking system including values from 1 to 10 (10 being of highest importance, and 1 being of the lowest importance), a house of quality was established to compare the three proposed rack designs (see Figure 17.5). Each design alternative was ranked in terms of how well each met the established customer requirements. The horizontal hitch-mounted rack resulted in the highest total ranking.

After establishing the basic layout of the rack design, further specifics of the design had to be established. A major decision involved choosing the nature of the frame construction for the rack. Four options were taken into consideration. These included an entirely custom built aluminum frame, a custom built steel frame, and a custom built aluminum upper frame that could be attached on top of either a pre-existing steel hitch carrier or a pre-existing aluminum hitch carrier. These four options were compared using ideal design characteristics, including that it be lightweight, strong, stable, inexpensive, useable for multiple purposes, and corrosion resistant.

A second house of quality was created to compare the alternatives based on these design characteristics. The same method was used. The custom frames were outperformed by the two alternatives using existing cargo carriers, because the latter may be used for multiple purposes and have higher rankings for strength, stability and cost. The custom aluminum frame built on top of an existing aluminum cargo carrier resulted in the highest total ranking because of the option of using an existing steel carrier that is lightweight, corrosion resistant, and compatible in terms of materials.

It was decided that the best alternative for the tricycle rack was a horizontal hitch-mounted layout that consists of a custom aluminum frame constructed on top of an existing aluminum cargo carrier. After establishing the basic design layout and frame construction of the racking system, a conceptual design, including the determination of all components of the rack, was conducted. Draw-Tite’s Aluminum Cargo Carrier (Part No. 7501), with overall dimensions of 24” × 60” and a weight capacity of 600 pounds, was selected. The weight capacity was sufficient, as the trike weighs no more than 60 pounds and the weight of the upper aluminum frame would not exceed 20 pounds. This
cargo carrier, shown in Figure 17.6, was also selected because of its lower weight of 40 pounds as compared to a comparable steel carrier that would weigh roughly 60 pounds. The client’s family reported that 60 pounds would be the maximum weight that they could lift.

The designers then selected the aluminum angle and channel to construct the upper frame of the racking system, shown in Figure 17.7. This would be mounted on top of the aluminum cargo carrier to allow for compatibility with the carrier material and to keep the frame as light as possible. Taking into account the size and geometry of the trike, recommendations from the supplier, and stock availability, the team chose two types of aluminum stock from Tri-State Aluminum (Toledo, Ohio): channel (2.500” × 1.500” × 0.125” (6063-T52 Aluminum)) and angle (2.000” × 2.000” × 0.188” (6061-T6 Aluminum)). Figure 17.7 shows the upper frame mounted on top of the aluminum cargo carrier. The aluminum frame is mounted using the rear and front support rails. Two commercially available zinc-coated steel clevis pins and cotter pins are used to secure each support rail to the cargo carrier.

On top of the support rails are two side rails on which the two rear wheels are mounted. A center rail supports the front wheel and allows the front wheel to ride along it as the trike is loaded. All three of these rails are welded to the support rails. Two center support rails are welded between the center rail and side rails to add rigidity to the frame. Two removable ramp rails are connected to the side rails when loading the trike. These are connected using simple hooks on the ramp rails that hook to two standard 0.313” 18/8 stainless steel bolts, which span the width of the rear side rails.

To load the trike, the ramps are attached to the side rails. The center rail keeps the front wheel moving in a straight path. Once the trike is in place on the upper frame, it is mounted using several pieces of hardware. Details regarding mounting the rear portion of the trike can be seen in Figure 17.8, where two wheel tabs are welded into the side rails of the upper frame. When loading the trike, the rear wheel rides up the ramp and over the rear wheel tab. The two wheel tabs then keep the wheel from rolling in either direction. To keep the wheel from rolling up over either of the tabs, a tie-down mount is mounted directly on the cargo carrier. A tie-down strap is then attached to both the axial frame of the trike and the tie-down mounts. This applies force straight down on the frame of the trike, keeping the rear wheels from traveling vertically out of the side rail and wheel tabs. This conceptual method of securing the rear of the trike can be seen in Figure 17.9.

U-bolts and a ratcheting tie-down strap are used to secure the rear wheels. Two 18/8 stainless steel u-bolts are mounted on the cargo carrier, under the axial frame of the trike, using stainless steel locknuts. A single commercially available ratcheting tie-down strap is then placed through the two u-bolts, and each end is placed on one side of the axial frame of the trike. The strap capacity of 433 pounds was assumed to far exceed any forces it will be subjected to, while holding the 60-pound trike in place. By ratcheting the strap tight, both wheels are pulled securely down into the rear side rails and between the previously described wheel tabs.

Two standard 0.313” diameter 18/8 stainless steel eye bolts and a ratcheting strap identical to the one used on the rear of the trike were used to secure the front of the trike, as shown in Figure 17.10. The eye bolts were mounted directly to the cargo carrier. The ratcheting strap was then hooked at each end to an eye bolt and tightened around the top tube of the trike. This pulled the front wheel down into the center rail such that it could not move vertically out of the channel.
The last critical component of the design involved the selection of proper hardware to secure the cargo carrier to the automobile. To attach the cargo carrier to the vehicle’s hitch receiver, a 0.625” diameter stainless steel locking pin by Reese Heavy Duty was chosen. This pin is rated to withstand the load capacity of the cargo carrier. Also, the locking feature of this pin will keep the racking system and the trike from being stolen from the client’s vehicle. The client’s current standard bike lock will lock the trike directly to the cargo carrier. Thus, indirectly, the trike will be able to be locked to the automobile.

The rack design in combination with the trike on the back of the client’s vehicle was found to result in the taillights being obstructed at certain angles. As a result, a simple turn signal kit was mounted to the cargo carrier to supplement the vehicle’s taillights if they are obstructed by the trike. Figures 17.11 and 17.12 show photographs of the final racking system assembly mounted on a vehicle with a standard hitch receiver.

Because the Draw-Tite cargo carrier makes the critical connection between the automobile and the racking system, stress calculations were made to calculate the factor of safety against bending failure in the 2.00” x 2.00” square mild steel tube with 0.125” thick walls that connects the cargo carrier to the automobile. Using the maximum energy distortion theory of failure, a factor of safety of 9.14 was calculated.

The total cost of all parts used to build this unit was $450.

Figure 17.10. Securing of the Front Wheel

Figure 17.11. Final Trike Racking System (Rear View)

Figure 17.12. Final Trike Racking System (Top View)
INTRODUCTION
Conventional wheelchairs cannot be used to access most park facilities because it is difficult to navigate over terrains other than hard flat surfaces. An all-terrain wheelchair was designed to allow park visitors with disabilities the opportunity to explore park trails. The wheelchair was designed to allow the user to maneuver the chair on his or her own, as well as to allow for assistance if needed. The chair was adjustable to allow for the majority of park visitors with disabilities to explore the park regardless of body size. The design accounted also for the various terrains that would be encountered on the trails, including pavement, stones, sand, snow, hills and tree roots. The all-terrain wheelchair is shown in Figures 17.13 and 17.14.

SUMMARY OF IMPACT
The metropolitan park system operates 11 scenic parks and two recreational trails. The largest attractions are the various trails maintained in each park. The all-terrain wheelchair allows individuals with disabilities independently to access the trails.

TECHNICAL DESCRIPTION
Design specifications were:

1. The drive tires must have a large width, large diameter, and contain deep tread,
2. The non-drive tires should be larger than normal to allow the chair to climb over obstacles,
3. The chair should be wider and longer than a standard wheelchair to add stability,
4. The chair should be lightweight to allow ease of use and maneuverability in rough terrain,
5. The chair should have the ability to be operated independently or with assistance,
6. The chair should be adjustable to fit the 5th to 95th percentile of users, and
7. The chair should be safe for all users to operate.

Four design concepts were evaluated: a four-wheel rear-wheel-drive chair, a four-wheel front-wheel-drive chair, a three-wheel front-wheel-drive chair, and a three-wheel rear-wheel-drive chair. The four-wheel option was not selected because a fourth wheel represents an additional wheel to get caught on obstacles and would cause added weight to the chair, which would reduce its maneuverability. A front-wheel drive chair was not selected because if the steering wheel were in the rear, it would be awkward for the user to operate, especially if caught on a hidden obstacle. Also, it is easier for a user to sit above the wheels and use his or her weight to drive the chair. A three-wheel rear-wheel-drive design was chosen.
A longer frame and wider base was used in the design to give the chair greater stability, as shown in Figures 17.13 and 17.14. A standard upright wheelchair design would result in a high risk of tipping the chair while out on a park trail. Since the wheelchair of this design has a wider base and longer frame, it is more difficult to tip the wheelchair while operating it on the trails. Even though the wheelchair’s frame is larger, the overall weight of the chair was not compromised. The wheelchair’s frame was built out of high strength, corrosive-resistant 6061 aluminum. The aluminum stock is 2” x 2” and has a 1/4” wall thickness. This grade of aluminum gives the chair a strong frame, while also being lightweight. Two 26” x 2.1” mountain bike style tires with a deep tread pattern were used as the rear tires. Each of these two main drive tires is equipped with an inner push rim for independent operation. These tires will supply traction in sand, snow, gravel, and mud. A Roleez balloon style tire with casters was used as the third front tire and was mounted using a yoke, so that it is able to spin independently 360 degrees. The front tire is 7.5” wide and 12.5” in diameter, so it is easy to navigate through dense terrain.

Inner push rims on the rear tires give the user the ability to navigate independently. Push-rods made
from 1” diameter aluminum tubing with a wall thickness of 1/8” were added to the back of the chair to allow an assistant to push the rider and chair through the trails.

Given that a wide range of people will be utilizing the wheelchair, it has the ability to accommodate varying sizes. As shown in Figures 17.13 and 17.14, the front tire of the wheelchair is held on by a single aluminum arm. This was designed so the rider can easily enter and exit the wheelchair from the left side. Also, the seat is mounted on a set of tracks in order to slide forward or backward. It can be positioned where the riders feel most comfortable reaching for the rear tires to push themselves along.

Additional safety components protect the riders from injury. One feature added to the wheelchair was a safety harness for the rider. This personal constraint will prevent the rider from falling out of the wheelchair if the user encounters rough or sloped terrain. Another added component was a braking system similar to that found on a standard wheelchair. By flipping the brake lever, a braking block is locked against the rear tire to prevent the chair from rolling. The final safety feature added was a wheelie-bar in the back. This bar allows the chair to tip back slightly, but will stop the chair from completely flipping over.

I-DEASTM (Integrated Design Engineering Analysis Software) 10, a finite element analysis (FEA) software package, was used to perform the structural analysis. A three-dimensional model was constructed and used to verify that the chair would withstand impact and wear. It was determined that the maximum stress from impact is 90.8 MPa and the maximum deflection is 13 mm. Both of these were results of a frontal impact load resulting from striking a rigid wall at 15 mph. From all the calculations, the chair has a factor of safety of 3.

The total cost of all parts was $800.
Figure 17.14. All-Terrain Wheelchair
WALKER WITH REMOVABLE TRAY

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INTRODUCTION
A college student with cerebral palsy uses a Reverse K walker for mobility, as depicted in Figure 17.15. This walker is placed behind the user and is pulled rather than pushed. It also has a fold-down seat so that the user can rest, as seen in Figure 17.16. However, it is difficult to carry items around, such as a book bag or a laptop computer, without assistance. The purpose of this project was to develop a removable tray to be attached to the walker to allow the client to carry his belongings with him. The carrier was designed to keep the walker balanced, to maneuver easily through narrow doorways and hallways, and to carry several everyday items. Aluminum tubing was used to create the frame of the carrier. A pair of casters was mounted to the bottom of the carrier, as shown in Figure 17.17, to enhance mobility. The device is easily attached and detached from the walker and can be easily folded up for storage or travel, as shown in Figure 17.18. The finished product was tested to ensure it would hold up to 50 pounds.

SUMMARY OF IMPACT
This removable and collapsible tray can be used when needed to carry items, thus enhancing the client’s mobility and independence.

TECHNICAL DESCRIPTION
Design criteria include developing a removable tray that is safe, durable, collapsible, detachable, lightweight, and easy for the client to use. To make the tray detachable, it was designed using clamps that attach to the middle and top bars on the back of the walker. Attaching the tray at two different locations ensures that the unit is sturdy. Wheels
were mounted on metal poles extending from the bottom of the carrier’s tray to the ground, providing stability and mobility.

The device is made collapsible by hinges attached to the tray that allow the tray to fold up and hinges added at the top of the metal poles to allow the poles to fold down. Two additional hinges mounted to the bars that attach to the top bar of the walker make the device completely collapsible, as shown in Figure 17.18.

Aluminum T4 6061 was the material of choice because it is lighter than stainless steel. Locking devices were added to the construct, as shown in Figure 17.17, to provide additional safety and stability.

DEASTM (Integrated Design Engineering Analysis Software) 10, a finite element analysis software package, was used to perform the structural analysis. A three-dimensional model was constructed and used to calculate the stresses throughout the walker and removable tray. Using a factor of safety of 2, pipes having 1” diameter and ¼” thickness were used.

The total cost of parts was $250.
TANDEM ICE HOCKEY SLED

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Client Coordinator: Calvin Smith, Recreation Inclusion Specialist
The Ability Center of Greater Toledo & Toledo Metroparks
Supervising Professor: Mehdi Pourazady
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INTRODUCTION
Sledge or sled hockey is an adapted ice hockey sport that allows a person with limited mobility from the waist down to participate. Players use two-blade sledges that allow the puck to pass underneath them. They control the sled with two sticks approximately one meter long. On one end of the stick is a blade used to maneuver the puck; on the heel of the stick, sharp teeth are used to propel the sled forward. Some individuals with limited arm strength, such as young children or people with quadriplegia, are unable to use the standard skate sled. The purpose of this project was to design and construct an adult tandem hockey sled for two individuals, a driver and a passenger, to participate in ice skating together. No tandem hockey sled is currently available on the market. A computer model of the unit that was developed is shown in Figure 17.19 and the unit itself is shown in Figure 17.20.

SUMMARY OF IMPACT
The unit will allow a seated passenger with limited arm strength (preventing him or her from moving the sled on his or her own) to participate in sled hockey while seated on the same sled with an individual capable of propelling the sled. This is a new design concept because no tandem hockey sled is currently available on the market.

TECHNICAL DESCRIPTION
Design requirements were to develop a sled that is compact, lightweight, easy to maneuver, and has adjustable seats. The sled had also to meet the U.S. Sled Hockey Association (USSHA) standards. Two design concepts were evaluated. The first concept featured two individual sleds that could be combined to form a single tandem sled. This option was cost prohibitive. The second concept was a sled that would allow a driver and a passenger to ride in close proximity to each other, with the driver’s legs resting under and to the sides of the passenger’s seat, as shown in Figure 17.20. This sled is wider than a single sled, so that the driver’s legs do not cross the boundary of the sled’s frame, to minimize the chance of injury.

After consulting with Unique Inventions, Inc., one of the largest manufacturers of hockey sleds in North America, the following overall dimensions were determined: length of frame = 64”; width of frame = 18”; height from bottom of frame to ice = 3.5”; and the weight of the frame should not exceed 45 pounds. The frame and cross members to hold the seats and skate holders were made of tubular 6061 T6 aluminum. The seats, safety restraints, skate holders and skates were purchased from Unique Inventions, Inc.

The team used I-DEASTM (Integrated Design Engineering Analysis Software) 10, a finite element analysis software package, to perform the structural analysis. The stresses and maximum deflections were determined in the seat bracket, skate bracket and sled frame. Maximum stresses of 7980 psi, corresponding to a factor of safety of 4.4, were found to occur in the seat bracket with a concentrated load of 400 pounds in its middle.

After the frame components were fabricated, they were welded together. The seats were then fitted to the seat brackets. Seat restraints were attached to the seats. The seat brackets, skate brackets and frame were primed and painted to make the sled more aesthetically pleasing, and the seat and skate brackets were then bolted to the frame of the sled. The finished unit is shown in Figure 17.20.

The total cost of all parts was $720.
Figure 17.19. Computer model of the unit

Figure 17.20. Finished unit
AIMING DEVICE AND STAND
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INTRODUCTION
A previous senior design group designed and constructed a “bite-trigger” mechanism that allows a client with mobility impairments to shoot a rifle with help from an assistant. The client uses a wheelchair. He has the ability to move his head and shoulders, has limited movement in his right arm, and has no fine motor control of his right hand. Requiring the assistant to aim and move the rifle is cumbersome. The client desires to control the movement of the gun, aim, and fire with the least amount of help from an assistant. The purpose of this project was to develop an aiming system that allows the client to accomplish this goal. The existing “bite-trigger” mechanism was incorporated into the design. The system includes three main components: a gun holding mechanism to secure the gun in place, an aiming mechanism to move the gun, and a wheelchair mount to attach the gun holding and aiming mechanisms. A 12V motor was used to power a wheel that allows horizontal motions of the aiming mechanism. A custom-built screw drive linear actuator was used to provide the vertical motions. The aiming mechanism was controlled using a headrest interface to allow movement of the rifle using inputs from the client’s head movements. Figures 17.21 and 17.22 show a computer model and a picture of the entire assembly.

SUMMARY OF IMPACT
The system moves the rifle using inputs from the client’s head movements. The successful completion of this project has enabled this individual to aim and shoot his rifle without assistance from others.

TECHNICAL DESCRIPTION
The design was required to incorporate the following features:

1) The rifle must be securely attached to the client’s wheelchair,
2) The device must allow the client to control the movement of the rifle, aim, and fire the rifle as independently as possible,
3) It must be able to safely withstand the recoil of the rifle and prevent the rifle from moving relative to the device,
4) It must allow for an assistant to reload the rifle without removal from the device, and
5) The device must allow for the use of the existing “bite trigger” mechanism.

The design team decided that the most effective and efficient way for the client to control the movements of his rifle is to use control inputs from his head motions. The design of the system was broken into four areas: the gun holder, the aiming system, the mounting system, and the user interface.

In the design of the gun holding system, the primary focus was safety. The gun holder consists of a metal arm made of 1” aluminum channel and rubber posts that are attached to the arm. A strap is placed over the rifle between these two posts to secure the rifle to the holder arm. Also, a strap goes around the back of the rifle to prevent the recoil from causing it to fly backwards. At the back of the holder are two triangular plates, made of 0.25” thick aluminum 6061 alloy, to which the strap is attached. These plates also have a pin attachment to the aiming system.

The aiming system consists of two parts: a swing arm and a horizontal aiming frame. The swing arm is made of 1” aluminum channeling and has a pivot connection on two vertical plates (0.25” thick aluminum) that connect to the gun holder pivot point, allowing vertical aiming. A horizontal pivot
at the back of the arm connects to the horizontal aiming frame, allowing horizontal aiming. A three-wheel system at the end of the swing arm holds it firmly to the front of the horizontal frame. Two wheels are mounted under the frame, and a powered wheel is mounted above the frame. All wheels are 1 5/8" in diameter. The horizontal frame is made of 1 ¼" aluminum rods; the front end is bent into an arc, as shown in Figure 17.22, to allow the wheels to travel over it. The arc at the end was made by machining a 1 ¼” thick piece of aluminum. A 12 V motor rated at 50 in-lb of torque with a speed of 1.3 rpm was selected to allow the full range of horizontal motion to be accomplished in roughly 40 seconds. For vertical motion, a custom-built screw drive linear actuator with a pitch of 10 threads per inch was used. The motor is rated at 240 in-lb at 6 rpm, which provides 6 inches of linear travel per minute. The motion from the actuator is transmitted to the gun holder arm via a mechanical linkage.

The mounting system, depicted in Figure 17.21, consists of three parts made of steel tubing: the wheelchair arm mounts, a cross tube, and a vertical mounting post. The arm mounts connect the system to the wheelchair. The armrests on the client’s wheelchair have a vertical post and a horizontal post that are used to connect arm mounts. A half tube is placed around these posts, and they are pressed up against the wheelchair arms using the cross tube. A tubular steel frame connects the attachment points to the cross tubes that go over the client’s legs.

Mounting blocks are used to allow the system to be adjustable. Horizontal adjustments of the mounting system take place by pushing the arm posts in and out of the ends of the cross tube. The vertical post is able to slide up and down in the mounting blocks of the cross tube to provide vertical adjustment. Attached at the top of the mounting post are ½" steel rods that go through holes in the horizontal aiming frame. They are secured in place by clamping shaft collars rated at 600 lbs.

A wheelchair headrest that had been used to control a wheelchair is the user interface. It will not interfere with the bite trigger, but allows controlling of vertical and horizontal motions independently. The left and right buttons of the headrest aim the gun horizontally. When a switch in the back of the headrest is depressed, the sides of the headrest may be used to aim the gun vertically.

A circuit was developed to allow the signals from the activation of the switches to control the motors. A housing attached to the gun holder contains all of the electronic components. The headrest switches can be plugged into and unplugged from the housing, as can the 12 V battery connectors that power the electronics and motors.

The cost of material and most of the components was $600. Some components were donated.
INTRODUCTION

The client, who has no use of his legs or left arm and only limited use of his right arm and hand due to cerebral palsy, requested a camera mount that is easy to adjust and align and able to secure either a digital camera or camcorder. Figure 17.23 shows the camera stand, and Figure 17.24 shows the client demonstrating how the unit is used with a digital camera.

SUMMARY OF IMPACT

The client has a passion for photography and is hoping to start his own digital imaging business. The camera stand enables him to take still or video digital images with ease and comfort. The client tested the unit and found it efficient and convenient to use.

TECHNICAL DESCRIPTION

Design requirements included developing a camera stand that is easy to use, and easy to adjust both horizontally and vertically in order to align the pictures. The system must be easily put on and taken off of the wheelchair and should not interfere with the client’s movement. The camera stand was also required to hold either a digital camera or camcorder and rest at the client’s eye level. To make this system easy to adjust a flexible shaft design was selected. A system was developed that includes a universal camera mount, flexible heavy duty flexible tubing, and a wheelchair mounting bracket.

A tripod head from a Sony Remote Controlled Tripod (Model # VCT-D68RM) was used. This head, shown in Figure 17.25, was used because it is a standard universal camera mount and it utilizes a remote control. The universal camera mount is an industry standard and can be used with virtually any camera or camcorder. This camera mount also had a quick release function, a feature in which the client had expressed interest. The tripod head also came with a remote controlled handle that could control some of the basic camera functions. Using this handle the client can turn the camera on and off, zoom in and out and start and stop recording. This is ideal because it enables him to use the handle to align the shot, as well as to take the picture or video.
A flexible shaft can be bent, twisted and positioned in almost any orientation without requiring the client to adjust any screws or fastening mechanisms. It was thus used to hold the camera on the camera mount and tested to ensure that it was flexible enough for the client to move easily and robust enough to hold the camera in place. The client found that he was able to move it around easily. It was also found that the shaft held rigid with a one pound load but began moving slightly after the load was increased to one and a half pounds when tested at the weakest position. It was thus decided to use two of these shafts to hold the camera. The system is able to support approximately three pounds, almost twice the average load for both digital cameras and camcorders (which weigh approximately 0.8 lbs and 1.2 lbs, respectively).

The final feature of the camera stand was the wheelchair mount, which attaches the camera stand unit to the wheelchair. A lockable mounting bracket, shown in Figure 17.26, was used to allow the unit to be taken on and off easily. The mount remains fixed on the client’s wheelchair, and the camera stand can be taken on and off from the fixed wheelchair mount with a simple turn of a handle. The system will not interfere with the chair.

The system was put together by connecting the two flexible shafts to the camera mount. Each flexible shaft was then connected to a brass pipe. These two pipes were bolted to the opposite sides of an aluminum snap lock adjustable pipe. These pipes run down along the left side of the wheelchair, and the central pipe locks into the wheelchair mount, as shown in Figures 17.23 and 17.24.

The cost of all parts was $200.
EXTENSION PUSH HANDLES FOR A MANUAL WHEELCHAIR

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INTRODUCTION
The purpose of this project was to design and fabricate adjustable push handles to attach to a manual wheelchair. A person of any height can become fatigued when bending over and pushing a wheelchair for an extended period of time. The final design will be used by a woman with cerebral palsy and her attendant. An attachment, including two adjustable push handles as shown in Figure 17.27, was designed to be used with the client’s current wheelchair. Figure 17.28 shows a picture of the push handle system attached to the wheelchair. This attachment can easily adjust to any height and disconnects to ensure that the chair will still collapse for transport. A cup holder is attached to the side of the right adjustable wheelchair handle to allow for easy carrying of a beverage if desired.

SUMMARY OF IMPACT
The client owns an Invacare 9000 XT manual wheelchair, shown in Figure 17.28, that is not ergonomically-friendly to various heights of attendants. Significant effort is required to push the wheelchair. Her attendants occasionally become fatigued when bending over and pushing for an extended period of time. The chair was adapted with a set of adjustable push handles to make it easier for the attendants.

TECHNICAL DESCRIPTION
The height of the handles on the Invacare 9000 XT manual wheelchair is 38 inches from the ground. To ensure that the existing wheelchair remains unchanged, it was decided to keep its existing handles and add adjustable extension push handles. These extension handles can be removed when desired to allow the wheelchair to be folded up and stored in the trunk of a car or in other storage areas.

The push handles were attached to the wheelchair at two locations, the wheelie bar points and the existing handles, as shown in Figures 17.27 and 17.28. The wheelie bar points were identified as support points because the client does not use wheelie bars.

The height of the two extension handles was the most important factor. The handles were made adjustable to accommodate varying heights of attendants. Each extension handle has two parts: the upper part is the extension handle tube, and the lower part is the support tube. Holes were drilled in the support tubes at one-inch increments to create a total of eight holes. They were drilled on the back and on the side of the support tubes so that the handlebars of the extension handle tubes can be positioned straight back or to the side. Titanium tubes were used for the upper parts of the extension handles. Aluminum was used for the lower parts of the extension handles (the support tubes). Aluminum and titanium were used since they are strong, lightweight materials that are aesthetically pleasing. The upper and lower parts of each of the extension handles were attached together using 5/16” aluminum retaining pins with steel springs that allow for quick and easy adjustment.

Holes were drilled on the underside of the existing handles of the wheelchair and also on the underside of the wheelie bar points to attach the extension handles to the wheelchair. The support tubes were attached to the wheelie bars using 5/16” aluminum retaining pins with steel springs. Two spring clamp assemblies were fabricated to attach the support tubes to the handles of the wheelchair, as shown in Figure 17.27.
Each spring clamp assembly includes a small tube and a spring clamp. A retaining pin is inserted into the clamp assembly’s small cylindrical tube, which is inserted into one of the wheelchair handles. The spring clamp allows the support tubes of the extension handles to be clamped to the spring clamp assemblies, which are inserted into the wheelchair handles. The retaining pins are easily compressed during installation and removal of the extension handles.

A removable cup holder is attached to the left support tube.

The cost of all parts was $300.
POOL WHEELCHAIR

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INTRODUCTION
Staff members of a recreation center requested a chair with adjustability to aid in wheelchair transfer and safe operation in a swimming pool. Many of the individuals who will use the chair have limited dexterity and require simple operation so they can use the chair independently. The wheelchair will transport the user independently into the pool using an access ramp. The chair is constructed of furniture-grade 1.25-inch Polyvinyl Chloride (PVC) pipe and fittings to resist corrosion caused by water and chemicals in the pool environment. The seat is adjustable in the horizontal direction, allowing each user the ability to select the ideal distance from the rear wheels. The armrests are adjustable in the vertical direction and drop low enough to be flush with the seat. Two footrests are placed at two different heights from the floor, allowing the user to choose which one is more comfortable. Each footrest is adjustable in the horizontal direction and is fully retractable. Buoyancy problems were alleviated by replacing the standard air inner tubes of the rear wheels with solid rubber inserts. The completed chair is shown in Figures 17.29 and 17.30.

SUMMARY OF IMPACT
The pool wheelchair previously used at the recreation center lacked adjustability, which is a major problem that limits its use by diverse individuals. The newly-constructed wheelchair’s adjustability allows for safer wheelchair-to-wheelchair transfer, safer operation, and increased ergonomic comfort for all users.

TECHNICAL DESCRIPTION
The final design has a PVC pipe frame, adjustable armrests, an adjustable footrest, an adjustable seat, low buoyancy tires, and stainless steel hardware.

Furniture-grade PVC was chosen due to its high resistance to decomposition instigated by exposure to UV light. Also, PVC can be bonded together using adhesive and is lightweight while maintaining strength. The pipe measures 1.25” in diameter and has a schedule 40 wall thickness. The frame is a boxed design, with the user sitting on the top of the box. Rear wheels are attached to the bottom rear of the box, and front casters to the bottom front of the box.

Quarter-inch holes were strategically placed in the frame to allow it to quickly fill with water and reduce buoyancy in the pool. The holes and slots also allow for easy drainage to prevent mold.
buildup in the frame. Wheelie bars were added to the bottom rear of the frame to provide safety when using the ramp to get in and out of the pool.

Armrests are supported with posts that are dropped into a slide collar mechanism located on the seat platform. Holes were drilled into the slide collar on the seat platform as well as in the posts. A stainless steel pin was inserted into both sets of holes simultaneously to fix the armrest at the desired height. The other end of each armrest is attached to the post behind the seatback with a slide collar, allowing for movement. The armrests can also adjust to a level just above the seat, allowing an individual to transfer independently from a standard wheelchair to the pool wheelchair.

Two footrests were installed. Each is composed of two 90-degree elbows and three sections of pipe. The assembled design is U-shaped. The footrest was placed on the bottom of the box frame. Four slide collars were placed on the vertical members of the box frame. The sides of the U shape have two slide collars per side. These collars are bonded together, allowing for vertical adjustability and translation in and out of the chair.

The seat is a molded seat, the same in construction and appearance as the original chair. Although the seat was the same, the newly designed frame allows for adjustment. The seat was supported by two members running front to back within the box frame. The seat is attached to four slide collars that run along these members using stainless steel hardware. One of the four slide collars has a 3/8” hole drilled through it. The member this collar slides along has holes drilled every 2” along it. A stainless steel pin is driven through both sets of holes simultaneously to fix the position of the seat at

Figure 17.30 Completed Chair

a location comfortable to the user. Velcro chest straps and lap belts are integrated into the seat to aid individuals with low abdominal and upper body strength.

The 24” rear wheels are fitted with solid tires. These reduce buoyancy and thus increase safety over the previous design. Stainless steel shafts and hardware were used to attach the wheels into the shaft inserts located at the lower rear corners of the box frame. These 7/16” stainless steel shafts are of considerable strength.

The front wheels are stemmed casters. Stem inserts were placed in the bottom of the pipes that composed the front section of the box frame. The 7/16” stems from the casters were press fitted into the inserts.

The total cost of the parts used to construct the chair was about $700.