Safety Instructions

Please use your Powerchair often and have fun. But, with all things, observing a few rules will ensure safe maneuvering. So please...

(1) Do not drive the Powerchair without reading this instruction manual.
(2) Do not use the joystick in an erratic manner when going up or down an incline.
(3) Do not carry passengers or exceed the maximum user weight (Table 2).
(4) Do not use on the road.
(5) Do not sit on the Powerchair when in a vehicle.
(6) Always stop fully before changing forward or reverse direction.
(7) Always engage a slow speed when going down gradients (move the joystick slowly towards center position to reduce the speed).
(8) Always use the safety belt (Fig.13).
(9) Always keep the feet on the footrest while driving.
(10) Always make sure the batteries are fully charged before setting out on a long trip.
(11) Avoid exposure to rain, snow, ice, salt or standing water whenever possible. Maintain and store in a clean and dry condition.
(12) Avoid sudden stops and starts.
(13) Always have chain guard attached.
(14) Always make sure someone has the remote killswitch in hand.
(15) Limit usage in the rain to emergencies only.
(16) Do not operate in the dark.
(17) Routinely make sure all the bolts are secured and aren’t loosening.
(18) Avoid touching electrical components when the power chair is powered on.
Parts & Accessories

Figure 1 - Front Tire

Figure 2 - Rear Tire
Figure 3 – Footrest

Figure 4 – Battery / Battery Charger
Figure 5 – Motor

Figure 6 – Frame
Figure 7 – Seat

Figure 8 - Joystick
Figure 9 – Shocks

Figure 10 – Armrests
Figure 11 – Headrest
Figure 12 – Chain

Figure 13 - Component Box
Figure 14 – Chain Guards
Power Chair Features

- Sturdy-wide frame
- Seat Release for easier transport
- Fully adjustable headrest
- Four Independent Motors
- Four-wheel independent suspension
- Removable Footrest
- Safety Harness and Two-point buckle for safety
- Chain-Driven
- Removable Seat (for transport)
- Removable Seatback (for client growth)
- Independent Suspension
- Remote Kill switch Integration
- Adjustable Armrests
- Rugged Tires
- Bright Blue color for good visibility
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Introduction

This Powerchair is the ultimate combination of style, comfort, safety. The rugged tires provide a safe and comfortable ride. This manual contains important information regarding the safe use of the Powerchair. Please read it carefully before using the Powerchair and make sure you understand all the instructions.

Figure 15 - Upper Diagram Side view of Powerchair
Figure 16 - Lower Diagram Side view of Powerchair
Figure 17 - Front view of Powerchair
**Preparation for Use**

The Powerchair has many features designed to give the user maximum comfort. Adjustments can be made to the following parts of the Powerchair:

(1) Armrests can be set at different lengths in or outward.

(2) Arms can be adjusted in height.

(3) Headrest can be adjusted in height or angle.

(4) The seat can be easily exchanged if user is uncomfortable or outgrows current seat provided.

Adjustments should be carried out by a provider/attendant while the user is seated in the Powerchair with the Powerchair turned off.

NOTE: Before using the Powerchair for the first time, be sure the batteries have been connected. Charge the Powerchair for at least 6-8 hours prior to first time use.

NOTE! Maximum efficiency can only be achieved with sufficient battery power and adequate run-up distance.
Adjustment Procedures

![Armrest Adjustment Diagram](image)

Figure 18 - Arm rest Adjustment (Horizontal)

The armrest allow for slight adjustment inwards or outwards from the seat of the wheelchair by removing the indicated screws in (Figure 18) and moving the armrest to the desired position and then securing it again with the screws.
The armrest also can be adjusted in terms of height in the indicated positions in Figure (19). Removing the two screws and then placing them in the desired position and securing them.
The headrest is fully adjustable in terms of height and depth. Loosen the adjustment screws in the back of the headrest and then set to the desired position and then secure them.
Disassembly & Assembly Instructions

This Power chair has the ability to be disassembled to make transport of the Power chair easier.

Chair Release

This power wheel chair features a quick release mechanism of the seat to make transport or storage of the power wheel chair easier. Both left and right sides of the power wheel chair have a seat frame attachment to keep the seat secure. (Figure 20) To move the seat, first remove both of these screws on the left and right sides of the wheelchair seat frame attachment. Once they are removed, push down the quick release bar in the front of the wheel chair and left the front of the chair. Tilt chair back and lift out of the side chair holders.
**Attaching Chair**

To attach chair, position chair onto the right and left side holders with the chair tilted back. Once in position the chair should be resting on the front release bar. Push down on the release bar and the mechanism should lock. Test to see if the chair is secure in the front. Put the two screws in the side holders of the chair.

**Harness and Two-point buckle**

For added safety the operator of the wheelchair should be firmly secured in the wheelchair with the harness and two-point buckle. Adjust each to provide a comfortable but firm fit.
A kill switch is also installed to cut power to the Power chair in the event of an emergency. The remote for the kill switch works up to 250 feet away.
Figure 24 - 3built Kill switch system

Footrest

Attachment Screws

Figure 25 - Footrest and Attachment screws
The footrest can be easily removed to make transport easy by removing the two attachment screws.

**Battery & Battery Charging**

![Battery & Charger connection](image1)

One end of the charger is connected to an Outlet. The other end is connected to the battery connector. Make sure that the battery connections are matched up correct, so that the pins match the corresponding hole. Once properly connected status LED lights should start to show up to indicate that it is charging.

![LED status display on battery](image2)
The battery features an LED light display to show the user the status of the battery. This Battery is 36 V so a maximum of 12 red LEDs will light up when the battery is full charged. After the charger is removed from the battery the LEDs may still be on or blinking, however, this is normal and you can use the battery right away.

**Battery Storage**

If the battery will not be used for more than a month, please charge the battery before storing it. The voltage should be checked at least once a month to insure that it is functioning properly. If the voltage is lower than its nominal voltage of 38.4 V, then please charge it.

**Battery Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage:</td>
<td>36 Volts</td>
</tr>
<tr>
<td>Capacity:</td>
<td>15 Amp Hours</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>8.9 x 4.1 x 5.9 inches (225 x 105 x 150 mm)</td>
</tr>
<tr>
<td>Weight:</td>
<td>12.3 lbs (5.6 kg)</td>
</tr>
<tr>
<td>Charging Voltage:</td>
<td>45 – 46 Volts</td>
</tr>
<tr>
<td>Rated Discharging Amperage:</td>
<td>15 Amps</td>
</tr>
<tr>
<td>Max Continuous Discharging Amperage:</td>
<td>30 Amps</td>
</tr>
<tr>
<td>Maximum Discharging Current:</td>
<td>60 Amps</td>
</tr>
<tr>
<td>Discharging Cut-off Protection:</td>
<td>40 Amps</td>
</tr>
<tr>
<td>Lifecycle of the whole pack:</td>
<td>&gt; 85% capacity after 1000 cycles</td>
</tr>
<tr>
<td>Charger:</td>
<td>2.5 Amp</td>
</tr>
</tbody>
</table>
Operation Instructions

Once all adjustments are made to the Power chair, the user is ready to begin use.
The joystick works in 8 positions: forward, back, left, right, forward-right, forward-left, back-right, and back-left. Push the joystick in the direction you want to go. The further you push it, the faster the speed will be. Releasing the joystick will automatically stop the Power chair.

**Getting Ready to Drive**

Step 1  Move the power switch located in the rear component box to the ON position. An LED located on the microcontroller should indicate that the power is on. Wait a couple of minutes for the DCDC converter to charge to provide current flow to the motors.
Figure 16 - Microcontroller Power Off
Figure 17 - Microcontroller Power On

Step 2 Push the joystick to control the speed and direction of the Power chair

NOTE! Choose an area with plenty of space to drive the Power chair. Start with slightly pushing the joystick until you are familiar with the controls. In a short time you will be in total control and can then increase the speed.
Maintenance

**Tools Needed**

- Phillips Screwdriver
- Flathead Screwdriver
- Pliers
- Hex Keys
- Ratchet

A monthly inspection should be performed to make sure all nuts and bolts are still tight. If any loose nuts and bolts they should be tightened immediately before use.

**Cleaning and Disinfection**

Use a damp cloth and mild, non-abrasive cleaner to clean the plastic and metal parts of the power chair. Avoid using products that may scratch the surface of the power chair.

WARNING! Never hose off your power chair or place it in direct contact with water.

**Chains**

- The chain should be lubricated and cleaned especially after extended use.
- The chain should also be checked periodically to make sure that it is secure and functioning properly.

**Chassis**

- Periodically check to make sure all nuts and bolts associated with the chassis are secure and not loose.
- Clean the chassis as needed to prevent dirt build up and rust

**Motors**

- Maintenance of the motors should be left to a professional if a problem were to arise.
- Remove an excess dirty caused from the chain.
**Tires**

- The tire pressure should be checked periodically for optimal Power chair performance.
- The front tires are PR1MO DUROTRAP with a max load of 200 kg at 250kPa (35 Psi).
- The back tires are PR1MO Powertrax with a max load of 200 kg at a max of 55 Psi.
- Also, check to make sure both front and rear wheels are secured to the wheel chair, if not, tighten the screw located within the wheel hub.
- Check for tire wear and if the thread is too worn, then they should be replaced.

![Figure 18 - PR1MTRAP Tire (Front)](image1)

![Figure 19 - PR1MO Powertrax Tire (Rear)](image2)

**Batteries**

- Fully discharge the battery before charging to ensure optimal performance of Power chair.
- Always ensure that the switch is in “off” position when not in use. Under no circumstances should you cross active leads, either when the switch is on or by removing the electrical tape on the switch.
Component Box

✓ Make sure component box is not taking in any water
✓ Clean inside box if necessary
✓ Make sure the component box is secured to the chassis
✓ Unnecessary component box movement can damage the electronics

Seat Belt and Safety Harness

✓ Make sure they are properly secured
✓ If harness is loose, tighten on the back of the seat

**Suspension**
✓ If shocks are not stiff enough, tighten the nut located on the top of each shock absorber

**Chassis**
✓ Clean regularly
✓ Check to make sure welds have not become loose
✓ In the event a weld is loose, do not use the power chair until it is professionally fixed to prevent injury

**Wires**
✓ All wires should be contained or covered. Check to make sure that there are no exposed wires. Make sure power is off if an exposed wire is found before touching any wire the wire. Someone with experience should re-tire any wire that may become loose.

**Seat Back**

A special feature of this Power chair is the ability to change the seat back of the Power chair if the user were to outgrow the current one provided. The seat back has four holes that attach it to the frame and four holes that attach the harness. (See Figures 36 & 37). A larger seat back that originally came with the chair can be used if Nathan grows enough.
Figure 22 - Left side of Seat Back
Figure 23 - Right Side of Seat Back

Figure 24 - Seat Back
Paint

If paint needs to be reapplied, the original color is blue.
Technical Description

Specifications

<table>
<thead>
<tr>
<th>ITEM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length (with Tires)</td>
<td>48 inches</td>
</tr>
<tr>
<td>Overall Width (with Tires)</td>
<td>33 inches</td>
</tr>
<tr>
<td>Overall Height (with Tires)</td>
<td>50 inches</td>
</tr>
<tr>
<td>Overall Length (without Tires &amp; Seat)</td>
<td>33 inches</td>
</tr>
<tr>
<td>Overall Width (without Tires &amp; Seat)</td>
<td>25 inches</td>
</tr>
<tr>
<td>Overall Height (without Tires &amp; Seat)</td>
<td>18.5 inches</td>
</tr>
<tr>
<td>Seat Dimensions (L X W X H)</td>
<td>20.5 inches X 20 inches X 29.5 inches</td>
</tr>
<tr>
<td>Battery Capacity</td>
<td>15 Amp Hours</td>
</tr>
<tr>
<td>Suggested Max User Weight</td>
<td>Around 100 lbs</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>About 5 mph (Walking speed)</td>
</tr>
</tbody>
</table>

Treaded front and rear tires for improved traction and operation on rough terrain

The power chair has tires with larger treads suited for off road. The larger tires will allow for smaller obstacles and better traction through grass and dirt. The front and rear tires are attached to the four lever arms of the power chair with the aid of key and screw to lock them in place. They are rotated by a chain and gear system.

Joystick control

The joystick works in eight directions, which distributes the power differently to the wheels. The top speed of the power chair is walking speed as a safety precaution. Sudden changes in direction should be avoided.
Schematic 1: Above is circuit design and below is the PCB design.

Chair manual portability
If batteries were to die or a malfunction occurred, the chair can be moved manually with slight resistance from the chains.

**Seat belt and harness**

While using the power chair safety is the number one concern. The seat belt and harness should be worn by the user at all times during operation. Both secure the user to the chair and prevent unwanted user movement during operation.

In the appendix, a section from the final report will give more detailed information about the parts.

**Troubleshooting**

**The chair won’t move**

- Check to make sure the power switch is in the ON position.
- Check to see if power light on the microcontroller is lit.
- Ensure the battery is charged
- Make sure the motors and the microcontroller have a wired connection
- Check to see if the kill switch is active.
- Ensure that the battery is putting out more than 20V by checking the +Vin and –Vin terminals of the 24V DCDC converter. If the voltage is less than 20V, charge the battery.
• Check that the 12V DCDC converter is putting out 12V. If no output is detected, turn the chair off, wait a minute, and turn the chair on. Wait five minutes before attempting to use the chair.
Seat belt and/or harness are uncomfortable

- Loosen the straps on the seat belt and/or harness for a better fitting

The armrests are not tall enough

- Adjust the height by removing the screws on the side of the armrest and then secure them

The chains are not moving smoothly

- Lubricate the chains

The wheels seem loose

- Check to see that the center screw is tight

The tire seems to be flat
• Elevate and securely support chair so that the wheel is off the ground
• Loosen the center screw and slide wheel off
• Check air pressure by unscrewing air cap and testing with a bicycle pump.
• If pressure is low, add pressure using bicycle pump.
• If a slow leak is suspected, pour soapy water around the wheel. Check for bubbles in the soapy water.
• Fix and/or replace the wheel

How should I store my power chair and its battery?

• Charge batteries at least once per week if it is not being used regularly
• If stored for an extended time, fully charge battery and disconnect it
• A cold or frozen battery should be warmed for several days prior to recharging

How can I safely transport the power chair?

• The seat can be easily removed (see instructions above) and the footplate can be removed
• For easy transport and maintenance the pins on the lever arms may be removed with a rubber mallet, and the shock absorbers detached from the frame. Inside the motor wire tubing the connectors to the motors may be disconnected, and the entire lever arm removed from the chair.
• If you have disconnected the motor leads, please take the time to ensure that all are properly +/- for the chair to move in the right direction.

The kill switch is not working?

• You are using the remote out of range
• Check the batteries in the remote

Appendix – From final report

1.1. Prototypes

The prototype is based off of the optimal design that was discussed earlier. However, this section will go much more in depth of the various parts.
1.1.1. Mechanical

The mechanical section will discuss a majority of the physical aspects of the power chair.

Lower Frame Fabrication

To start the mechanical fabrication, the base frame had to be made. The frame was made up of 2”x2” square aluminum tube. This required cutting the aluminum stock into two pieces that were 30” long and three pieces that were 21” long. In figure 20, below, the two horizontal pieces on the top are 30”, and the three pieces placed vertically were 21”. With this setup, this gives the base frame a length of 30” and a width of 25”. This makes the power chair design large, with plenty of space to place various components that will be needed. It is important to note that these pieces were cut at about a quarter inch larger and then milled down on both sides to the proper size. This ensured that the edges would be smooth.

![Figure 20: Lower Frame. 30”x25”](image)

Lower Frame Modifications

Once the lower frame pieces were cut and welded together, as seen in figure 20, modifications were done to make provisions for attaching other components. It is important to note that the middle piece was not attached due to modification that took place in a later meeting with the client where it was originally planned that the piece would be support the rear portion of the seat. However, this was not put in, and another system was devised to secure the rear portion of the seat, which will be discussed later.

The seat base had to be attached in the front and rear. For the front, the purchased seat frame allowed provisions for a latching system. As long as there was a circular rod, the frame could detach from the frame simply by pushing on the latch. The optimal rod diameter was 7/16”. Two 2”x2”
aluminum square tubes were cut to two inches each. Holes a little larger than 7/16” were made in the center to allow the rod to go through on both sides of the tube aluminum to act as the support. These aluminum square tubes were welded onto the frame, so they would stay in place. Figure 21 shows the system.

![Figure 21: Seat frame attachment at the front](image)

After a meeting with the client, it was realized that the seat needed tilt further back than the team had planned. Therefore, the middle piece of the lower frame was removed to allow the seat to rest lower. The seat frame had two protrusions on the side of the seat, which rested well on the sides of the lower frame. Two pieces of aluminum at about 1.5”x1”x.5” were cut and milled. They were welded onto the frame at angle of 20º, relative to the frame. Once welded, the seat was placed onto the frame. Then, a quarter inch hole was drilled on both sides to allow it be screwed and bolted. This would allow for a relatively easy way to remove the seat when needed. In summary, the front latch would have to be depressed and the two bolts at the rear would have to be removed to remove the seat. This process is quick and easy.

![Figure 22: Seat frame attachment at the rear, on the left side.](image)

The last modification made to the lower frame was in regards to making the holes for attaching the plexiglass box. Holes were made one inch and four inches from the rear on both sides of the frame,
in the center. These holes were to be quarter inch in diameter and would correspond to the holes made in the plexiglass box. The holes were made all the way through the tubing, so the holes would be present on both sides of the tubing. This would allow a screw to be put in from the top, and a bolt could be used on the bottom for securing the box. The plexiglass fabrication will be discussed later on.

![Figure 23: Holes for plexiglass box attachment](image)

**Lever Arm Fabrication**

The next parts fabricated were the four lever arms. These arms would be mounted on the aforementioned lower frame via lever arm mounts, which will be discussed later. The ideal length was determined to be 18”. Similar to before, these pieces were cut from stock aluminum and milled down to make sure the length was accurate.

**Lever Arm Modifications**

There were two major modifications to make on the bearing arms. Once modification involved making holes and pockets for the bearings. The other modification that was needed was to make provisions for a motor mount, where the motor mounting plate would bolt onto.

Bearing holes needed to be made in two locations on each lever arm, each on the opposite ends of the lever arm. The upper part of the lever arm utilized the Spyraflo bearing that allowed for a .5” axle to go through it, while the lower part of the lever arm utilized a Spyraflo bearing that allowed for a .75” axle to go through. Regardless of the axle diameter, both bearings had the same size footprint, so the holes and pockets made for either bearing were exactly the same.
Figure 25 shows the scaled drawing of the locations of the holes for the bearings. The bearing was placed on the graph paper, and the holes were marked. The centers were found from this sketch by measuring the center from the top left corner. The coordinates were entered into the milling center and the holes were drilled with drill bit of the respective radius. For the center hole, a pocket program was made to create the hole, since there was not a drill bit large enough to make this hole. A 9/16” end mill was used to create the pocket with a radius of .825”. Please note that in figure 25, the center hole shown was smaller than the actual hole that was made. All of these holes were done on all four lever arms, on both sides. Therefore, this procedure had to be repeated eight times. It is important to note that a practice run was done first to ensure the coordinates were accurate.

<table>
<thead>
<tr>
<th>Holes</th>
<th>X-coordinate in inches</th>
<th>Y-coordinate in inches</th>
<th>Radius in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>.375</td>
<td>-.4375</td>
<td>.375</td>
</tr>
<tr>
<td>Center</td>
<td>1.46875</td>
<td>-1</td>
<td>.825</td>
</tr>
<tr>
<td>Bottom</td>
<td>2.5625</td>
<td>-1.625</td>
<td>.375</td>
</tr>
</tbody>
</table>

The following is the code used on the milling machine to create the center hole:

```
X center        1.4688 abs
Y center        -1.000 abs
Radius          .8250
                CCW
Tool Offset Left
Fin cut 0.000
Feed rate       3.0
```
With calculations in regards to chain length to the wheel sprocket, four holes were made on the lever arms that would correspond to the motor mounts, which will be discussed in the next section. The holes were made at the following coordinates, with respect to the upper corner of the lever arm.

**Table 2: Coordinates for motor mount holes on lever arm**

<table>
<thead>
<tr>
<th>Holes</th>
<th>X-coordinate in inches</th>
<th>Y-coordinate in inches</th>
<th>Radius in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.875</td>
<td>-.5</td>
<td>.25</td>
</tr>
<tr>
<td>2</td>
<td>8.275</td>
<td>-.5</td>
<td>.25</td>
</tr>
<tr>
<td>3</td>
<td>6.875</td>
<td>-1.5</td>
<td>.25</td>
</tr>
<tr>
<td>4</td>
<td>8.275</td>
<td>-1.5</td>
<td>.25</td>
</tr>
</tbody>
</table>

**Motor Mounts**

Four motor mounts were fabricated. The first step that was done was to make the holes that lined up with the four holes on the lever arm. Each mount measured 5” by 2.8125”. The holes were made with respect to the top, left corner, in figure 26. The hole coordinates are as follows:

**Table 3: Coordinates for motor mount holes, attaching to lever arm**

<table>
<thead>
<tr>
<th>Holes</th>
<th>X-coordinate in inches</th>
<th>Y-coordinate in inches</th>
<th>Radius in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.5</td>
<td>-.75</td>
<td>.25</td>
</tr>
<tr>
<td>B</td>
<td>.5</td>
<td>-2.15</td>
<td>.25</td>
</tr>
<tr>
<td>C</td>
<td>1.5</td>
<td>-2.15</td>
<td>.25</td>
</tr>
<tr>
<td>D</td>
<td>1.5</td>
<td>-.75</td>
<td>.25</td>
</tr>
</tbody>
</table>
Next, the actual holes for mounting the motors were made below where the previous holes were made. Holes 1, 2, and 3 used a drill bit that allowed provision for 10x32 machine screws. A pocket was also made to allow for the motor gear to protrude. The diameter of the hole was one inch. The coordinates of the holes are as follows, noting that the coordinates are with respect to the ‘O’ at the bottom right of figure 26:

<table>
<thead>
<tr>
<th>Holes</th>
<th>X-coordinate in inches</th>
<th>Y-coordinate in inches</th>
<th>Radius in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.9375</td>
<td>-.75</td>
<td>10x32 drill bit</td>
</tr>
<tr>
<td>2</td>
<td>1.9375</td>
<td>-2.16</td>
<td>10x32 drill bit</td>
</tr>
<tr>
<td>3</td>
<td>0.6875</td>
<td>1.375</td>
<td>10x32 drill bit</td>
</tr>
<tr>
<td>Center</td>
<td>1.5</td>
<td>-1.5</td>
<td>.5</td>
</tr>
</tbody>
</table>

Lastly, with respect to the ‘O’ on the lower, right corner, 3 inches were milled, going left in figure 26. About half of the motor mount was milled off to make it thinner, allowing for more clearance for the chain to rotate around the protruding motor sprocket. This made the width of this portion about .25”.
The finished mount can be seen in figure 27, noting that the milled off portion is mounted so it is facing the outside of the power chair.

![Figure 27: Motor mount. View from under the power chair.](image)

**Lever Arm Mounts**

In total, eight lever arm mounts were fabricated. The pieces were 3.25”x1.5”. A hole with a .5” diameter was drilled through, with the center being .5” from the bottom. At the top, one inch was placed on the lower frame to allow for the piece to be welded on to the frame. The mounts were placed, so the center of the piece was 8.5” away from the closest edge of the power chair frame. Figure 28 shows the placement of the lever arm.
Upper Spring Mounts

In total, eight upper spring mounts were fabricated. The pieces were 2.25”x1.5”. A hole with a 5/16” diameter was drilled through, with the center being .5” from the bottom. Also, the aluminum stock that was originally .5” thick was milled entirely, so it would be only .25” thick. At the top, one inch was placed on the lower frame to allow for the piece to be welded on to the frame. The mounts were placed, so the front edge lined up exactly with the closest edge of the power chair frame. A one inch spacer was placed in between the mounts, on the center of the frame, to allow for proper placement for welding. Figure 29 shows the mounting location and fabricated piece.
Lower Spring Mounts

The lower spring mounts were created by cutting aluminum stock that was .25” thick to 1.5” by 1”. It was cut and milled for proper size. A 5/16” hole was made in the center of the piece at the coordinate (-.75, -.5), relative to the top, right corner in figure 30. Eight pieces like this were made. Then, pairs were assigned to which arm they would go to. Either the front, right, or front, left, etc. This was important because the top most corner was cut off at a 45º angle to allow for better rotation of the shock. Then, a one inch spacer was placed in between the pair of mounts, dead center, on the top of the lever. The pieces were then welded in place.
Footrest mount

For mounting the footrest, an aluminum piece of dimensions 8”x1”x.5” (LxWxD) was used. From the width, 1/16” was milled off. The depth was cut in half to .25” by milling, as well, for the 7.5”. About .5” in length was kept at .5” in diameter, so it would lock into the foot plate. Making these alterations allowed for the piece to fit in the slot in the foot plate. Lastly, two holes were made from the top to allow for mounting on to the frame. The coordinates were (.5, -.5) and (.5, -1.5), with respect to either the top left or right corner that was milled. The drill bit used was a .25” in radius. Once mounted onto the foot plate, the aluminum piece was held in place and the holes were marked with a hole punch. Then a drill was used to drill all the way through the square aluminum tube to the other side. This allowed a system to be made, where the fabricated aluminum piece could be bolted onto the lower frame.
Lever Arm Axles

The lever arm axels hold the lever arms in place. They were created from half-inch diameter aluminum round stock and lathed to the proper length. Both ends of the rods were threaded by hand using a half-inch/13 threading die.

Wheel Axles

The wheel axels started as .65-inch round aluminum stock. The stock was cut and lathed to a length of 5.25 inches. This stock was then lathed down to a diameter of .53 for two inches on one side. The smaller diameter would allow the stock to fit into the wheels purchased at NEAT marketplace. The bearings purchased for the lever arms have an inner diameter of .65 inches, so the rest of the bearing was left at its original length. Once the diameters were properly lathed .25” holes were drilled on either end of the axels. Threading was then placed into the holes to allow screws with washers to secure the wheels and sprockets in place on the axels. 0.25”-wide slots were milled into both ends of the axels. These slots are for the mounting of keys from the sprockets and wheels and allow the motors to drive the wheels.

Gears and Chains

The motor required a chain size #25. This naming scheme indicates a pitch size of a quarter inch, meaning that each link was a quarter inch away from the next one. It was determined that the chain length had to be two feet long to fit around the wheel sprocket and motor sprocket. The amount of teeth on the motor was nine. The amount of teeth on the wheel sprocket was 30. This allowed for a 30:9 gear ratio. The ratio was determined mathematically to limit the speed of the chair to walking speed when the motors run at the decided highest voltage. Only one link from each chain had to be removed with a chain breaker to provide proper tension.
Armrest

Figure 32: Chain mounted to motor and sprocket.
The armrests were designed to be height adjustable. Two pieces of aluminum that had the dimensions 16”x1”x.5” (LxWxD) were cut and milled as necessary. From the top, one inch down in the center, quarter inch holes were drilled. Five more holes were made, each an inch lower than the previous one. The holes were also threaded. Another piece of aluminum was prepared to have the holes line up with the piece fabricated before. Rectangular tube aluminum that had the outer dimensions of 16”x1.5”x1” was prepared so two piece were available. This top piece would ideally slide on top of the previous piece, which would be welded to the frame, the holes made in the pieces would line up with the other piece, so both can be screwed and welded. The six holes were made in the same manner as before; however, the first hole was made 3 inches down from the top instead of only one inch. This piece was designed to rest on the lever arm at the lowest setting. The thinner piece would be welded with two inches on the lower frame. Figure XX shows the first piece (lower) and the second piece (upper
Piece). The lower pieces were welded on to the lower frame, 5.25” from the front of the power chair. Two inches of the piece would be welded onto the frame.

Next, pieces were fabricated that would be welded onto the upper tube aluminum. Two pieces from the rectangle tube aluminum stock was cut into 3 inch pieces. In the center of the piece, from the top, holes were made at .5”, 1.25”, 2”, and 2.75” down with a quarter inch drill bit. The same procedure was done to four pieces of aluminum with the dimensions 4”x1”x.5” (LxWxD). The coordinates for the holes can be seen in the following table. The following diagram shows the scaled drawing.

<table>
<thead>
<tr>
<th>Holes</th>
<th>X-coordinate in inches</th>
<th>Y-coordinate in inches</th>
<th>Diameter in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.5 (.75 for tube)</td>
<td>-.5</td>
<td>.25</td>
</tr>
<tr>
<td>2</td>
<td>.5 (.75 for tube)</td>
<td>-1.25</td>
<td>.25”</td>
</tr>
<tr>
<td>3</td>
<td>.5 (.75 for tube)</td>
<td>-2</td>
<td>.25</td>
</tr>
<tr>
<td>4</td>
<td>.5 (.75 for tube)</td>
<td>-2.75</td>
<td>.25</td>
</tr>
</tbody>
</table>

Once all the pieces were fabricated, further welding was done. First, bottom of the 4” piece was welded to the top of the larger rectangular tube aluminum, at 90ºC. This was done to another piece, as well. Then, two 10.5” rectangle tube aluminum was cut and milled to size. Then, the two other 4” piece was welded 90º to the large piece, as well. The three inch tube aluminum was welded onto the 10.5” tube aluminum, as shown below. Velcro was placed on the horizontal surface to attach padding. At the end of the armrest, black containers were bolted on by drilling two quarter inch holes and making sure they lined up with the four inch piece. The left container houses the joystick, while the right container can store belongings. Figure XX shows the final assembly.
Headrest Mount

On the back of the rear seat rest, four screw holes were found to allow for mounting a headrest. Since the headrest being used did not attach readily to the seat, fabrication needed to be done to allow attachment. The holes on the seat were mapped out to see the distances relative to each other. On a piece of square tube aluminum with the following dimensions: 5.5”x2”x2” (LxWxD). Holes were made according at the coordinates listed in the table, with respect to the top, left corner.

<table>
<thead>
<tr>
<th>Holes</th>
<th>X-coordinate in inches</th>
<th>Y-coordinate in inches</th>
<th>Diameter in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.75</td>
<td>-.5</td>
<td>.25</td>
</tr>
<tr>
<td>2</td>
<td>3.75</td>
<td>-.5</td>
<td>.25</td>
</tr>
<tr>
<td>3</td>
<td>1.75</td>
<td>-1.5</td>
<td>.25</td>
</tr>
<tr>
<td>4</td>
<td>3.75</td>
<td>-1.5</td>
<td>.25</td>
</tr>
</tbody>
</table>

Next, the hole for allowing the headrest rod to go through needed to be made. The square rod was a little larger than .25”x.25”. Using the smallest end mill available, a square of a little larger than this was milled out on both sides of the square tube, in the center of the mount, with respect to the sides. Figure XX shows the final fabricated piece.
Plexiglass Box

The plexiglass was made to ensure that all the electrical components fit inside and would be kept from getting wet. Also, a custom box would make the box seem like it actually fit in with the design of the power chair. There were two thicknesses in plexiglass available. One was .25” thick, and another one was of unknown thickness since it was donated. It was thinner. From the thicker plexiglass, three pieces of dimensions 30”x8” were cut. Two pieces with the dimensions 7.6”x7.6” were cut. Lastly, from the thinner plexiglass, a 30”x10” piece was cut. This would be the lid, which would be attached by hinge system. The pieces were glued together. The large thick piece served as the base, while the other large pieces were glued on top of it, on the long edges. The squares were glued in between the two large pieces to form the box. The base piece had holes with a diameter of a quarter inch drilled through to line up exactly with the ones already drilled on the lower frame. This would allow the box to be secured to the frame. The following image shows the complete box.
Seat Modifications

The original seat purchased from N.E.A.T. Marketplace had a large rear seat support. The team desired to use a tighter and more supportive back support for Nathan. Therefore, the original rear seat support was removed, and replaced with a smaller one. The switch was simply because the mounting brackets lined up exactly with the screw holes found in the new rear support.
Mounting Springs

Once all the lever arms were put in place and the spring mounts welded on, the springs could be attached. The springs had built in bearings that allowed for a 5/16” screw. Two 2” screws were used for each spring, for the attaching to the upper and lower mounts. They springs were then bolted into place.

Wheels

With the keys placed in each wheel, the wheels were put into the wheel axle. Once on, the axle was put through the wheel axles. Once through, the sprocket with the key was put in to stabilize the axle. For full stabilization, a .25” x20 screw that was .5” in length with a one inch was washer was screwed on to each side of the axle to conceal the axle and limit movement. This process was done for all four wheels. Figure XX shows the mounted wheel.

Harnesses

The seat came with a two-point buckle; however, it would be ideal to have a four-point harness for further constrain when needed. There were many screw locations on the rear of the seat. The four point harness screwed in easily at the various points on the rear. The following image shows both harnesses.
Chain Guards

For further safety, it was necessary to guard the chains from any objects that may have come in the way. Chain guards were fabricated from four aluminum sheet metal, sized at 12 by 11 inches. Using a clamping device, 90 degree corners were made, so it could attach to the lever arm. Off of the lever arm, a raised bump was made to accommodate the height of the sprocket. From here, it bent down again to actually cover the chains. The following figure shows the final product.
Figure 41: Chain Guard.