Final Report
Multi-Terrain Wheelchair

By
Peter George
Robert Knapp
Fryderyk Karnas

Team 2

Client Contact:
Brenda and Sean Stenglein
34 East Howey Road
Ashford, CT 06278
Phone: 860-429-1059
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Abstract

There are quite a few wheelchairs on the market that claim to be able to traverse multiple kinds of terrain. However, the modifications of such wheelchairs make them very large, bulky, and heavy. Another problem with wheelchairs of this type is that they are most likely electric, making them very limited in their mobility.

The members of Team 2, with the aid of an NSF grant, intend to design and build a manual wheelchair that is small and effective, yet modified in such a way that the device can traverse regular terrain, as well as ice, sand, and snow. Such a wheelchair will be unlike anything on the market today, yet will be effective and reliable.

This device will aid children like Sean Stenglein, a child with cerebral palsy, by helping them to enjoy the outdoors during days that he would be unable to go outside.

1 Introduction

1.1 Background

Cerebral palsy is a disorder that can be caused by lack of oxygen to the brain at birth, which can affect the functioning of the cerebrum, a part of the brain that controls motor functions and coordination. Individuals that suffer from cerebral palsy can suffer from a wide range of effects, which can make diagnosis and treatment specific to the patient rather difficult.

One very special individual is Sean Stenglein. He is a 10 years old boy and struggles with motor operations due to his disorder. This includes loss of control in his legs which causes him not to be able to stand on his own or walk on his own. Along with not being able to control his legs, Sean has trouble controlling other parts of his body as well, including his arms and mouth, making it difficult for him to pick things up and talk.

Sean has the mental and emotional power and capability to do any activity that someone without his condition can do. He wants to participate with others and share his knowledge and skills. However, his condition limits him in his ability to physically move and accomplish the goals he wants to achieve. Sean’s condition is one of cerebral palsy only, with no other complications. His mind, ability to learn and think, and mentally accomplish tasks is better than average. His bones and muscles perform as they should. The only complication, due to Cerebral Palsy, is his ability to control his motor functions, or his appendage movement. Sean feels the need to participate, and his participation is vital to his growth, both physical and mental.

Because of Sean’s disability, he finds it hard to coordinate his movements, such as walking and communication. An easy answer to his problem would be to put him in an electric wheelchair for the rest of his life. However, this would hinder his physical development because, over time, his muscles and bones would become so weak to
the point that he would have limited use of them. As sharp and ambitious as Sean’s mind is, he deserves to walk and participate in the same activities that others do.

Sean has a speech therapist trying to help him to be able to talk. He is capable of talking when his body is under control and his muscles are relaxed. However, sometimes when Sean gets excited and tries to talk he cannot control just the muscles around his mouth and moves his whole body instead.

Sean also has a physical therapist, Steve Moran, who is vital to any progress Sean makes toward gaining control of his body. Mr. Moran knows all of Sean’s current capabilities which include the ranges of motion of all parts of his body. It is very important that Sean exercises so that he does not lose muscle mass. If Sean were kept in a wheelchair for his whole life he would never be able to walk, but exercise brings hope.

Sean is 52 inches tall and weighs roughly 55 pounds. As a result, Sean has a rather lightweight build that makes him easily prone to injury. Safety precautions must be taken when designing a device for Sean’s usage.

1.2 Project Purpose

Regular wheelchairs work very well on flat, relatively smooth terrain such as pavement or tile. However, the problem comes when a handicapped person in the wheelchair has to be mobile during the winter when there is ice or snow on the ground outside. The person also cannot go on the beach because the wheelchair would sink in the sand when he tries to propel himself. The goal of this project is to design a wheelchair device such that a handicapped person, such as Sean Stenglein, can be mobile on sand, ice, and snow and participate in activities with his family and friends.

1.3 Previous Work

1.3.1 Previous NSF Designs

There was an “All Terrain Wheelchair” completed by the University of Toledo in Ohio in the year 2005. This project had a third wheel that came out in front of the wheelchair frame to give the wheelchair more stability. This design was essentially a tricycle mixed with a regular wheelchair design. The front wheel would help stabilize the two rear wheels, but would not give any aid in steering or propulsion. Although and interesting approach, the members of Team 2 will not be using anything from this design.

In 1994, the University of Hawaii designed a wheelchair with wheel adapters and casters so that the wheelchair can go on sand. This design took an existing wheelchair and modified the wheels so that the device could traverse sand. The members of
Team 2 will take the wide wheel idea from this design and incorporate it into their present design. However, design will be modified to fit Sean’s wants and needs.

In 2000, The University of New York in Buffalo designed a wheelchair accessory platform that the wheelchair strapped on to and could be propelled to give the rider more options to conquer different kinds of terrain. This was a rather interesting idea but made the entire wheelchair device very top heavy, so it was at risk of falling over. The members of Team 2 will not be using anything from this design.

1.3.2 Products on Market

There are a few manual off-road wheelchairs on the market today (like the Lasher Sport, Lic BT-Trail being one of them), but the far majority of them are electric. Since the motor adds a considerable amount of weight to the device, we believe it would be a better option to go with a manual wheelchair. However, there are none on the market that have a satisfactory design. A picture of the Lasher Sport can be found in Figure 1.

![Figure 1: Lasher Sport Trail Wheelchair](image)

Another off-road wheelchair is the Landeez All-Terrain Misc Sport Wheelchair. A photograph of this device can be found in Figure 2.
1.3.3 Previous Patents

An all terrain wheelchair was patented (US Patent 5427398) to convert an existing wheelchair into an all terrain vehicle by Steven L. Weybrecht on October 29, 1993. The design is unlike the design proposed because it doesn’t have tread-like belts that go over the front and back wheels, increasing the surface area in contact with the ground. A picture of Weybrecht’s design can be found in Figure 3.
1.4 Project Map

Using designs and devices previously engineered, the members of Team 2 have explored various design ideas and concepts. They took features from all various designs and create an optimal design that is specific to Sean’s needs and requests. This design will be broken down into subunits that will allow for easier understanding and analysis of each part of the design.

Other criteria will be discussed and reviewed, such as realistic constraints (both engineering and otherwise), safety issues, impact of this design on the engineering community, and any new material acquired. Towards the end of this document, a rough timeline will be presented, as well as each member’s contributions to the project.

2 Project Design

After looking and researching different designs for a Multi-Terrain Wheelchair, the members of Team 2 came up with three very different designs. With each of these designs having its strengths and drawbacks, the members of Team 2 had to combine them and take from the combination an optimal design.

2.0 Tentative Alternate Designs

2.0.1 Alternate Design 1

The Multi-Terrain Wheelchair will start with the modification of an existing wheelchair frame. The front axle where the front wheels attach will have to be extended so that the front and back wheels are in side alignment. All four wheels will be modified so that the treads can interlock with wheels so that there is no tread-wheel slip. This will maximize the efficiency and power output by the subject to the wheels and treads. A side view drawing of the design can be found in Figure 4.
Short skis will be attached to the wheelchair’s frame via a manual jack that will be located on the back of the chair. The purpose of this jack is to raise or lower the frame, and wheels/treads, relative to the skis. This will adjust the amount of force on the wheels, making it easy to control how much grip and weight the treads actually have on the ground. The wheelchair will also be coated with an anti-corrosion treatment to allow for a longer life and more rigorous usage.

A front view of the design can be found in Figure 5.

![Figure 5: Alternative Design 1 (Front-View)](image)

The wheelchair will be self-propelled like a normal manual wheelchair. A propulsion wheel will be added on the outside of each of the back wheels which will allow the subject to control his speed and direction. The propulsion wheel will be pushed like a propulsion wheel on a regular manual wheelchair, and the device will steer much like a tank, by having one tread stop and the other tread rotate around it.

This method of propulsion and steering is a major drawback to this type of design, however. Although the wheelchair can easily traverse sand, snow, and ice, the amount of mechanical output that is required to move such a device is massive. A tank can output a lot of mechanical energy due to its massive and powerful motors. However, when the motors are removed, the energy and force required to move treads along any kind of terrain is fairly large. It is believed that this is a very creative design; however, not entirely practical because a person will most likely not be able to put out as much energy and force as is needed to propel and steer such a device.

2.0.2 Alternate Design 2

The goal of this design is to make the multi-terrain wheelchair as user friendly as possible. Its purpose is to offer the user the ability to manually adjust the wheelchair with minor mechanical knowledge so that it is suitable for a given terrain. In addition, the user is able to attach and detach a previously owned seat which is known to offer the proper support for exceptional comfort. This design is based on the fact that the customer would like the multi-terrain wheelchair to also function as a sled when desired if possible. The frame consists of stainless steel bars, which are not only light-weight but also durable ensuring years of proud ownership. Figure 6 shows the top-view of the steel frame.
Bars 1 and 4 will function as the attachments to either large wheels or skies. Bars 1-4 will all be telescopic allowing for the modification of the width of the multi-terrain wheelchair in order to complement the width of the user owned seat. They will also give the ability to decrease the width in order to make the wheelchair easier to transport. Bars 7 and 8 are the handle bars of the wheelchair.

Figure 7 shows the side view of the multi-terrain wheelchair frame with wheel connections connected.

Bar 9 is also telescopic giving the user the ability to raise or lower the handle-bars in order to allow individuals of varying heights to push the wheelchair with ease and comfort. Bar 10 is used to attach either large wheels or skies to the back of the wheelchair. Bar 11 is actually a caster which holds the front wheel giving it the ability of a 360 degree turn. It can detach from bar 6, and a new bar can be connected to allow the attachment of front skies. In other words, the user will be able to have a 4-wheel multi-terrain wheelchair ideal for sandy or rocky terrains, a hybrid wheelchair with two front skies and two back wheels ideal for level snowy conditions, or a full ski wheelchair which in reality will function more like a sled than a wheelchair.

When the user wants to convert the multi-terrain wheelchair to a sled, telescopic bars 5 and 6 can be extended forward and bars 1-4 can be extended outward for
increased stability. This sled design is currently being evaluated, in order to decide whether additional side safety sleds will be required to prevent the sled from flipping.

Figure 8 shows the front view of the multi-terrain wheelchair in 4 wheel mode.

As can be seen in the figure, when the back wheels are attached, the grip rings are located on the inside of the tires due to the width of the back tires. The wheels will be made of some sort of soft plastic to enable easy transport through tough terrains as well as absorb shock. Three tire variations are currently being investigated: tread-less, thick triangular treads, and thin triangular treads. Figure 9 shows the side view of the multi-terrain wheelchair in 4-wheel mode in order to give a perspective of the proposed size of the tires.
2.0.3 Alternate Design 3

This design of the multi-terrain wheelchair is a device which can better help Sean propel himself in snow and sand. The way it will help is because he can use his legs to propel himself instead of his arms. This device has pedals for Sean to use just like a bicycle. The pedals will power the back wheels which will be larger in size than bicycle wheels to help the wheelchair gain traction. To control the device Sean will use handlebars which will turn the front wheels left and right. The good thing about having Sean use his feet to propel the device is that the leg muscles are much stronger than the arm muscles. In addition, Sean rides a tricycle at home so he is used to the pedaling motion. This is relevant because in order to increase the traction of the device the wheels need to be larger. Larger wheels will need a larger force to propel them which can be given by Sean’s legs. Also since Sean will be using this device in snowy and icy conditions the device should not move very fast, which means a gear ratio can be implemented to lessen the force needed by the pedals to propel the wheels. Having Sean use his feet can be useful in safety precautions also. A brake can be made for Sean to use with his feet, such as pedaling backwards which is used on many bicycles. As well as having a foot brake Sean can have a hand brake which will give him two ways of controlling the device to a stop.

Another good feature about this design is that it can be pushed like a wheelchair from behind. The pedals can be disconnected for this purpose. Having many options for the user can lead to a good device since the user can use whatever option works best for him at the time.

The basic design will be an ordinary wheelchair which will be modified to be useful for Sean. The rest of the frame will be made of stainless steel which will prevent rust in the snow and at the beach. The chain used will be a normal bicycle chain.
Figure 10: Alternate Design 3 (Top View)

Figure 11: Alternate Design 3 (Side View)
2.1 Optimal Design

2.1.1 Objective

The Multi-Terrain Wheelchair based on a manual wheelchair frame, but modified in such a way that it can traverse multiple kinds of terrain, including sand, ice, and snow. The client, Sean Stenglein, has requested to have a wheelchair device that his family can take to the beach in the summer and take outside in the snow during winter. Through research, it has become apparent that there are not many such devices on the market today.

A major problem, however, with this design is the subject cannot propel himself at all. The design of the Multi-Terrain Wheelchair will be modified to allow for self-propulsion. The method of doing this will be discussed below.

The wheelchair will also have some of the following added features that most wheelchairs on the market do not have:
- Removable wheels for easy transport and storage.
- An umbrella holder.
- A water bottle holder.
- Tentatively, a snowball throwing device so Sean can participate in snowball fights with his friends during the winter.
- Telescopic foot holders that adjust as Sean grows so he is always comfortable.

A three dimensional drawing of the Multi-Terrain Wheelchair can be found in Figure 12 below.

![Figure 12: 3D Drawing of the Multi-Terrain Wheelchair](image)
2.1.2 Subunits

2.1.2.1 Steel Frame

The design of the Multi-Terrain Wheelchair is relatively complex. Figure 13 shows a three dimensional drawing of the device’s frame.

![Figure 13: 3D Drawing of Frame of the Multi-Terrain Wheelchair](image)

The frame will be made of stainless steel that is relatively inexpensive when compared to other possible materials. Stainless steel is also very strong and does not rust or tarnish with increased use or age.

The frame will be welded together for the most part for maximum support. The only exceptions would be the foot supports that would extend and adjust telescopically.

Starting from the top, there will be handles welded to the frame to allow someone to assist in the motion of the subject. They will be able to manually push or move the wheelchair without the aid of subject. This will allow for complete control of the wheelchair and the subject by whomever is watching over the situation.

2.1.2.2 Seat

Moving down the frame, a “makeshift seat” will be permanently attached to the frame of the wheelchair. This seat will not be the main seat used with the wheelchair, but will serve as a temporary backup in the event that the user does not have the main seat with them. This “makeshift seat” will satisfy all of Sean’s needs in terms of the angle his hips have to be at and the ability to secure him in the seat. It will only be used for short distances or time periods for which the user does not have access to the main comfortable seat. This “makeshift seat” will have a seatbelt that will go around Sean’s waist to stabilize his hips and keep him in the wheelchair.
The client currently has a working car seat that will be able to be attached to the steel frame of the wheelchair. This will act as the main seat that will be used with the device. Currently, the car seat that is being used is a Tumble Forms Carrie Seat. A photograph of this seat can be found in Figure 14.

![Carrie Seat](image_url)

Figure 14: Carrie Seat

The seat that the client has does not look exactly like the one pictured above. The seat owned by the client has more padding and less of a plastic frame than the one pictured, but the basic design is the same.

The Carrie Seat will act as a more comfortable option for Sean to sit in when he uses the wheelchair. The seat is already equipped with seatbelts and a strapping mechanism that can be used to attach it to the frame of the Multi-Terrain Wheelchair. The Carrie Seat also provides the therapeutic positioning, comfort, and stability that Sean needs in a seat that he will be using extensively. Also, the group has decided to use the seat that the client already has in order to reduce the budget of this project.

2.1.2.3 Foot Supports

The foot supports will be below the Carrie Seat and the “makeshift seat” and in front of the front wheels like a normal manual wheelchair. They will be attached horizontally to the stainless steel frame and extend below the level of the seat.

The foot supports will be welded to a steel tube that will be able to extend forward or contract backward telescopically. These telescopic components will be locked in place by a screw and whole mechanism. The outer tube will have a manual screw perpendicular to it that will be able to screw completely through one side of both the inner and outer tube. To make it adjustable, and still have a locking ability, there will be holes about every inch along the smaller, thinner pipe. The holes that the screw will go through will be roughly a ¼ inch in diameter. Figure 15 diagrams this locking capability.
Figure 15: Screw Locking Mechanism for Telescopic Parts

The foot supports will allow for Sean’s feet to be stabilized and secure. They will be similar to the shoe supports on the Standing Gardener design. The telescopic feature will allow the wheelchair to grow as Sean becomes larger in order to have an increased lifespan and usage.

2.1.2.4 Wheels

The main feature of this device will be the all terrain wheels that will be larger than the wheels on a regular wheelchair. The wheels on the Multi-Terrain Wheelchair will be wider and will have snow treads that will be able to traverse terrain in snow, ice, and sand. The wheels will act as a balloon, increasing the wheels’ surface area that is in contact with ground. At the same time, it will have just enough surface area to maximize the ease of moving the wheelchair. The amount of surface area in contact with the ground is a delicate balance between ease of moving the device and the need for traction while still staying above the sand or snow as to not sink down in it. As traction is increased, the ease of movement is decreased and it would take more energy and strength to propel the device.

The members of Team 2 feel that the dimensions of the wheel should be to maximize both of the aspects of traction and mobility with as little hindering of movement as possible. Because of this maximization of the criteria for the wheels, the members of Team 2 have designed the back wheels of the Multi-Terrain Wheelchair according to the specifications listed in Table 1.

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<thead>
<tr>
<th>Wheel Dimension Type</th>
<th>Dimension Measurement</th>
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<tr>
<td>Outer Radius</td>
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<tr>
<td>Wheel Width</td>
<td>9 inches</td>
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Table 1: Dimensions of Back Wheels
The “Outer Radius” column is the distance from the center of the wheel to the outer most part of the rubber. The “Wheel Width” column is how wide the wheel is at its widest point.

Table 2 has the dimensions of the front wheels:

<table>
<thead>
<tr>
<th>Wheel Dimension Type</th>
<th>Dimension Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Radius</td>
<td>6 inches</td>
</tr>
<tr>
<td>Wheel Width</td>
<td>7 inches</td>
</tr>
</tbody>
</table>

Table 2: Dimensions of Front Wheels

The front wheels will be on swivel casters so they can rotate around in a complete circle relative to the frame of the wheelchair. This will allow for maximum steering capabilities for the device. The back wheels will be high enough to come up to Sean’s sides. The radius of the rear wheels on an average manual wheelchair is about 12 inches, so the members of Team 2 thought this would be a reasonable value for the radius of the Multi-Terrain Wheelchair.

As far as steering and propulsion of the Multi-Terrain Wheelchair goes, it will have a stainless steel hand-grip wheel. However, unlike a normal manual wheelchair, the gripping wheel will not be on the outside of the wheel. Instead, it will be placed on the inside of the wheel, between the wheelchair frame and the rear wheel itself. The reason for this feature is because the rear wheels are so wide; Sean would not be able to generate enough mechanical power to move them. Sean’s arms work best if they are against his elbows as close to his abdomen as possible and his elbows are bent at a 90 degree angle. For this reason, it would be best to place the gripping bar as close to him as it can get in order to maximize the amount of power he can generate in propelling and steering himself.

The wheelchair wheels Team 2 will be using have been quoted at fifty dollars for two, and have been tested to be appropriate for both winter and summer conditions, including sand, snow, and ice.

A three dimensional diagram of the wheel can be found in Figure 16:
2.1.2.6 Other Features

- The Multi-Terrain Wheelchair will have removable front and rear wheels to make transportation of the wheelchair easier. The Stenglein family must be able to fit this device into their Yukon XL Truck when they go to the beach during the summer or go sledding in the winter. This feature will allow for easier storage of the wheelchair when it is not being used.
- The entire width of the wheelchair will be less than 32 inches, in order to fit through most door frames.
- The Wheelchair will have an umbrella holder on the rear of the frame behind the seat. The umbrella holder will consist of a hollow steel tube that will fit most beach umbrellas with a stopper at the end to keep the umbrella from sliding all of the way through. This will protect Sean from the rain, should the weather suddenly change while Sean is using it. Mostly, however, the umbrella will protect Sean from the sun while at the beach so he doesn’t get burned while exploring in his wheelchair.
- A water bottle holder on the arm rest because Sean commonly gets thirsty with physical activity.
- Tentatively, the Multi-Terrain Wheelchair will have a spring loaded snowball thrower on one of the arm rests. This will allow Sean to participate in snowball fights and snow games with his friends and family during the winter. This feature will be removable so that during the summer months when it is not needed.

2.2 Prototype

As the building process commenced, the members of Team 2 realized that building a wheelchair from scratch is a very complicated process. Wheelchair design is an intricate science within itself. As a result, they decided to purchase an already manufactured and working wheelchair and modify it so that it would be able to go on sand, snow, and ice. The design suddenly went from building a wheelchair from
scratch to acquiring wheels from Wheeleez® and modifying them to be able to be attached to the wheelchair.

2.2.1 Front Wheels

The first step was to make front feet to attach the front wheel casters. This was done by creating a plate that could be bolted on to the front wheel caster. This can be seen in Figure 17, below.

![Figure 17: Front wheel plate.](image1)

A foot bar was then welded onto the front wheel plate that would be attached to the original front wheel hole in the wheelchair via a large metal pin. These pins can be seen in Figure 18, and the completed foot can be seen in Figure 19.

![Figure 18: Front wheel large pin.](image2) ![Figure 19: Completed front wheel foot.](image3)

The large pins pictured in Figure 18 were welded on to the foot bar from the end with the smaller radius. The rest of the pin was then inserted into the hollow cylinder where the old front wheels of the wheelchair were attached. Two holes were drilled in the large pins pictured in Figure 18 so a cotter pin could be inserted in order to lock the front wheels in a fixed position relative to the wheelchair.
The purpose of the cotter pin for the front wheels is to provide the wheelchair with two different configurations of motion. The first configuration is to have the front foot bars perpendicular to the front of the wheelchair frame, thus coming out straight forward in front of the wheelchair. This would be known as the Zero Degree position. The purpose of this position is to make the wheelchair more mobile when the client is not sitting in it. With this configuration, the wheelchair can be folded up much more ease and be stored or transported in a smaller space. This configuration is not recommended for traversing terrain with the client seated in the wheelchair.

The second configuration is known as the Angled position. In this front wheel position, both of the front wheels are angled outward at roughly a 70 degree angle from the Zero Degree position. This provides a wider base for the weight to be spread out and distributed. While in this wheel configuration, the wheelchair is much less likely to tip over while being propelled and has a much more solid foundation than the Zero Degree position.

These two wheel configurations were designed and implemented into the wheelchair to give it much more versatility and mobility while riding and transporting it.

In addition both of the wheel positions, the front wheels can also spin a full 360 degrees because of the ball bearings in the black casters. The completed front wheels can be seen in Figure 20, below.

![Figure 20: Testing of front wheels.](image-url)
2.2.2 Rear Wheels

The attachment of the rear wheels was approached very similarly with regard to the front wheels. The first step was to make two long axels that would attach each of the rear wheels to the frame individually. The axel can be found in Figure 21, below. It was impractical to make the rear wheels rotate about a common axel because the presence of the axel would hinder the folding of the wheelchair. In order to keep the folding ability to make the wheelchair more manageable during transportation, each of the rear wheels would have to be mounted separately.

Two foot bars were made that would attach the axel to the frame wheel, much like the foot bars machined for the front wheels. Four custom threaded bolts (two for each wheel) were made on the lathe to attach the foot bar to the frame. These can be pictured in Figure 22, below.

Since the majority of the axel was a uniform radius (except for one end where it was to be welded into the foot bar), the rear wheel could slide back and forth along the axel. This posed a problem because the wheel would hit and rub against the foot bar, creating friction and decreasing the life of both the wheel and foot bar. As well as this problem, the current design made it very difficult to push the wheelchair due to this friction created.

The solution was to create a bushing, or spacer, to go between the wheel and foot bar in order to create just enough space for the wheel to rotate and spin freely. The completed rear wheel attachment setup can be found in Figure 23.
2.2.3 Straps and Supports

The next step was to make sure the Tumble Forms Carrie Seat fit into the wheelchair. The placement of the seat was successful. The straps that are attached to the seat wrap around the rear and bottom of the wheelchair frame to provide stability. The almost completed wheelchair can be seen in Figure 24.
Figure 24: Wheelchair with seat.

Sean’s knees and feet still had to be stabilized, while the Carrie Seat’s seatbelt stabilized his hips. This was done by making straps that would be attached to the leg rests and foot rests. This can be pictured in Figure 25, below.

Figure 25: Leg and Foot straps.

The leg straps will stabilize the client’s knees and lower legs while the foot straps, which are inserted through the foot supports, will support the client’s feet.

2.2.4 Design Side Note

Throughout the design process, the members of Team 2 ran into some minor problems. Although most of them could be solved with a simple idea, one major problem did present itself. The original optimal design called for rear wheels to have a
12 inch radius. However, the largest wheels Team 2 could find had an 8.25 inch radius. Therefore, in order to put push rims on the wheels, the push rims could have a radius no larger than 8.25 inches or else the wheelchair would not be able to move because the push rim would be below the ground. It would take a lot of strength to generate enough power and torque to move these smaller rear wheels with the proposed propulsion method. Such an obstacle presents a problem, especially when the ground is uneven or a rough terrain.

One possible solution was to modify the wheels in such a way to make the Multi-Terrain Wheelchair entirely a push wheelchair with no method of self-propulsion. The members of Team 2 discussed this option with the Stenglein family, and they agreed that it would most likely be the best option. As a result, the Multi-Terrain Wheelchair is entirely a push wheelchair and is designed to traverse rough terrain.

3 Realistic Constraints

The main realistic constraint that affects this project is economic. There are devices on the market that do similar things as the ones in this project, but they cost upwards of multiple thousands of dollars. Likewise, some are not covered by insurance, so families have to pay full price for these items. The main goal of this project is to design a device that is affordable and functional.

Comfort is very important to the design of the Multi-Terrain Wheelchair. If Sean isn’t comfortable in them he won’t want to use them. Sean will be using these devices for extended periods of time and if he is uncomfortable this could cause him to be sore.

The last major constraint would be environmental. The Multi-Terrain Wheelchair must be able to endure elemental extremes of hot, cold, and weather changes as these devices will be used outside during weather extremes. It will be made of materials that will not be compromised under environmental extremes, and be able to remain working after years of use.

The strength of the aluminum bars as part of the frame will take care of most of the engineering constraints on the Multi-Terrain Wheelchair. The device will under very few stresses, apart from the ones caused by Sean’s weight and the weight of the device itself. It is for this reason that properly assembling and welding is important in order to minimize the internal stresses in the device.

4 Issues of Safety

Mechanical safety is another major factor to consider when designing and building this device. Sean’s health and safety must come first and foremost with the design of these devices. There can be no sharp edges on this the wheelchair that
anything could get caught or cut on. The wheel casters for the front wheels will be as nearly frictionless as possible to allow for maximum mobility so the wheelchair doesn’t get stuck when he is trying to turn or move it.

In terms of structural safety, the material strength of the aluminum should take care of any internal stresses that the device frame may be under.

The wheels will be wide enough to provide a strong base in the Angled Position as to not have the wheelchair tip over. The speed of the wheelchair can be controlled with the manual brakes, and the propulsion wheel rim on the rear wheels. The wheels will be made to be able to theoretically traverse all kinds of terrain.

Traversing sand shouldn’t be a problem because of the width of the wheels to spread out the weight across the ground so the wheelchair doesn’t sink. The same principle would be for traversing ice, but the problem comes with a lack of friction leading to a lack of control of the wheelchair. To solve this problem, the wheels will have treads deep enough to provide enough friction. If this solution doesn’t work, chains will be provided to attach around the wheels to give the wheels more friction than they would have otherwise.

5 Impact of Engineering Solutions

The design of this device does not have any global effect on the community of Engineers. This device is simply for Sean to make his life and the lives of his friends and family more fun and enjoyable. It is Sean’s never ending goal to jump, run, play, and participate like other children. His mind is sharp, but he has a motor control disability that limits him in his physical ability. It is therefore the mission of Team 2 to aid in the quality of life of Sean and to give him options in doing various tasks that he would not normally have.

The design of the Multi-Terrain Wheelchair is not meant to be patented and sold on a grand scale, but rather to improve the quality of life of a Sean. Through using Engineering principles and knowledge, the goal of this project is to solve the problems designing a wheelchair might present and aid in the life of Sean Stenglein.

6 Life-Long Learning

Many new techniques have been acquired as a result of this design project. Traits and skills such as leadership, organization, and timeliness have been honed and sharpened. The members of Team 2 have become more organized and have learned to plan ahead and categorize the importance of issues that need addressing, and can address them in a timely manner. However, these skills can always be expanded and made more efficient.
It is not only planning and social traits that have been learned from the design of this project. Knowledge of engineering computer programs such as Microsoft Visio, Microsoft Project, and Autodesk Inventor have also been gained in the design of this device. These are vital tools in the world of engineering when designing or analyzing a structure or system.

The surface of self betterment has just been scratched and there is always room for improvement and gaining knowledge. It is the day one thinks he knows all that is the day one stops learning. Such a day would be a poor day, because to hinder the gain of knowledge is to hinder growth.

### 7 Budget

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<tr>
<td>Cushion Poly Foam 6 x 50 x 60 inches</td>
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### 8 Team Member Contributions

#### 8.1 Robert Knapp (Bioinstrumentation Track)

Mr. Knapp took on the challenge of Team 2’s alternate project, the Standing Gardener, for the most part. He did most of the report writing for this portion of the project throughout the course of the semester. Unfortunately, neither of these projects contains circuitry or instrumentation analysis, but Mr. Knapp was able to use his expertise in Biomedical Engineering none the less and aid the design of both the Standing Gardener and the Multi-Terrain Wheelchair.
8.2 Fryderyk Karnas (Biomaterials Track)

Mr. Karnas took it upon himself to learn the workings of Autodesk Inventor, and provided the members of Team 2 with all of the three dimensional modeling drawings seen in this report (and in report of Team 2’s alternate project, the Standing Gardener).

Mr. Karnas also used his expertise in the classes he has taken in materials engineering as part of his track to research the materials that the members of Team 2 will use to build both projects. It will be up to him to maximize the material properties for each of the design, while choosing the right materials and staying within the group budget. Initially, the group was over the requested budget by a reasonable amount, and Mr. Karnas has been able to find material manufacturers to cut costs, while maintaining efficiency and material strength.

8.3 Peter George (Solid Biomechanics Track)

Mr. George has taken upon himself to do most of the report writing for the Multi-Terrain Wheelchair throughout the course of the semester. Mr. George mirrors Mr. Knapp such that their duties were very similar, but each working on his respective project. It was up to Mr. George to provide a structurally sound design for both devices Team 2 is designing, in order to minimize internal forces and stresses of both devices while they are being subjected to the applied loads of Sean’s weight. Safety is a very important factor in the design of a device for someone who is handicapped, and it is the duty of all of the members of Team 2 to maximize the safety and effectiveness of each design.

8.4 Team Collaboration

The task that lied ahead of Team 2 at the beginning of the semester was a grand one, and could not be completed by any member alone. Through collaboration and working together, the members of Team 2 have come up with a sound design that they plan to build and prototype. Mr. George and Mr. Knapp did not do all of the writing of the reports. In fact, the majority of the brainstorming of ideas and concepts was done by all members of Team 2 and nothing was written until each member had his time to input their questions, ideas, or concerns. In addition, each member learned to use Microsoft Visio, as well as maintain the team website.

As far as the actual construction and fabrication of the Multi-Terrain Wheelchair went, the members of Team 2 worked together quite well in solving engineering problems. Each member took an equal load in honing skills in machining, whether it was on the miller or welder. When confronted with a problem, the team members worked out possible solutions and didn’t stop discussing the issue until a common consensus was reached.

9 Conclusion

By keeping in contact with Sean and his family, a good understanding of Sean’s abilities was obtained. An understanding of what options and features will maximize his comfort and production was gained. Not only do the members of Team 2 want Sean’s experience to be more enjoyable but they want his parents’ to be also.
Since the design of the Multi-Terrain Wheelchair is not on the current market, the outcome should be a positive one. The materials that are being used to build both devices are relatively inexpensive, when compared to what products are already on the market that will accomplish similar tasks; the cost of these designs is a fraction.

The key criterion of this project is that Sean is safe and is supported while accomplishing the things he needs to complete. These devices will allow Sean to grow, both physically and mentally, in ways that he would be unable to otherwise. This wheelchair will give Sean mobility in during the winter and summer months in a way that he wouldn’t have otherwise.

10 References

- Carrie Seat Website: http://www.southwestmedical.com/Pediatric_Products/Car_Seats/Carrie_Seat_-_Junior_Size/1577p0

11 Acknowledgements

The members of Team 2 would like to thank the National Science Foundation for its grant that is funding this project.

Dr. John Enderle and Mr. David Price would also like to be thanked for giving their time and expertise in aiding the development of this project.

12 Appendix

12.1 Updated Technical Specifications

**Physical:**
- 304 Stainless Steel

**Mechanical:**
- Size: 36x28x42 inches (LxWxH)
- Weight: 45 pounds (lbs.)

**Electrical:**
- N/A

**Software:**
- N/A

**Environmental:**
- Storage and Use: -10 - 110°F
Safety: Smooth edges to prevent injury, and manual hand brakes for stopping and lowering device. All terrain tires will be used in conjunction with possible chains needed for traction on ice.

Maintenance: Drying and lubrication of moving parts.