ANTARCTIC CYCLE
ME 1501-1502

Technical Design Report

Antarctic Cycle
Project #F00/S01

Final Report

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This report outlines the development of the Antarctic cycle. The original objective of the project was to finish building and test a 2000 Northeastern University Capstone Design Project, the Tundra Tiger Trike. The Tundra Tiger Trike is a recumbent style tricycle that was designed for travel in Antarctica. In the fall of 2000, we conducted tests on it that simulated the terrain that it would be subjected to in Antarctica. This testing revealed that the initial design of the Tundra Tiger Trike would be unsuccessful. A decision was needed whether to go with a redesign of the Tundra Tiger Trike or go with a completely new design. Since concepts of a redesign could be simulated by quick modifications to the Tundra Tiger Trike, several concepts were quickly tested. The tests proved the existing cycle would not meet the needs of our sponsor. Ineffective steering, poor weight distribution, and extensive frame rework due to failures pushed the team towards developing a new design. The new design, known as the Hybrid Tricycle, was developed based on the knowledge gained from testing of the Tundra Tiger Trike. The concept is similar to a tricycle, with one front tire and two rear tires. It mates the drive assembly of an all-terrain vehicle to a bike allowing for greater stability, better weight distribution, and easy operation. By using standard components, we cut costs dramatically while maintaining a wide variety of flexibility and completing the project on time. We believe that this hybrid concept will meet the needs of the Antarctic researchers'.
Need for the Project
The cycle is desired by researchers in Antarctica to travel between their base camp and observation station, a distance of approximately one kilometer.

Antarctica has two fairly distinct seasons, the summer and winter. The summer season is sunny, and relatively warm – though temperatures rarely exceed −18 degrees Celsius. During the summer season the path between the base camp and observation station is negotiable due to frequent travel. Thus, researchers are able to use standard means of transportation such as mountain bikes.

Winter in Antarctica is characterized as dark, windy, and extremely cold with temperatures ranging between −40 and −100 degrees Celsius. Due to a lack of traffic, the path becomes covered with loose snow and mountain bikes get stuck. As a result, the researchers are frequently forced to walk between base camp and the observation station. The researchers desire a human-powered vehicle to travel in both the summer and winter in order to avoid walking.

Project Objective and Requirements
Design Objectives
The cycle must be capable of traveling in both the summer and winter seasons in Antarctica. The terrain in the summer resembles packed beach sand while the winter resembles loose beach sand. Therefore the design objective is to develop a cycle that is capable of traveling in both packed and loose beach sand while also being able to endure the extremely cold temperatures.

The cycle must also be designed such that the rider can operate it in their heavy clothing. Therefore the cycle must be ease to get into to and require no fine motor skills to operate.

Design Requirements
The cycle must be shippable to Antarctica in the cargo hold of a Lockheed C-130.

Design Concepts Considered
We considered modifying the Tundra Tiger Trike or designing a new cycle. Testing of the Tundra Tiger Trike revealed that it would be unsuccessful in Antarctica. This was mainly due its immobility in loose sand. As stated in the design objectives, the Antarctic terrain in the winter season resembles loose beach sand. A combination of its weight distribution and narrow tires caused the Tundra Tiger Trike to sink in the loose sand and become immobile. We considered modifying the Tundra Tiger Trike to increase its tire width and improve the weight distribution, but these modifications required extensive rework of the cycle.

A successful design had to limit the amount of pressure exerted on the sand to limit sinking. Based on the extensive rework and cost that would be associated with modifying the Tundra Tiger Trike, new designs were considered. The key goal of these new designs was to lower the amount of pressure exerted by the cycle drive tires on the sand. A design consisting of two wide rear drive tires and one narrow front tire for steering was developed. The wide rear
drive tires limit the amount that the cycle sinks into the sand while the narrow front tire allows for enough grip to enable steering. These conclusions were reached by our testing of the vehicle's mobility on the beach sand.

**Recommended Design**

The Hybrid Tricycle combines ATV and bike components to deliver two wide drive tires and one narrow front tire for steering. We decided that the use of two wide rear tires for driving the cycle and one narrow front tire for steering was optimal. This configuration was provided if we used the drive assembly of an all-terrain vehicle (ATV) in combination with standard bike components. This design, known as the Hybrid Tricycle, uses a youth model Polaris® Scrambler drive assembly in combination with a Ladies Schwinn® touring bike. We designed an Adapter Assembly to unite the two technologies.

A Polaris® Scrambler drive assembly provides a small, rugged, and easily mounted drive. The Polaris® Scrambler drive assembly was chosen for its rugged design, relatively small size and weight in comparison to adult model ATV drive assemblies, and the manner in which it mounts to the frame. Although designed for a youth model ATV, the Scrambler's drive assembly is extremely rugged for the manner in which we use it. Our cycle's weight with rider is less than that of the design weight the assembly supports on the Scrambler with a youth rider and will be subjected to far less severe loading. It easily mounts to the frame with just four bolts.

A Ladies' Schwinn® touring bike allows easier mounting for the rider and is made of 7071 aluminum. By using a standard bike frame we saved money and development time. The Ladies Schwinn® touring bike was chosen for several reasons. First a ladies style bike allows for easier entry by the rider by lowering the height of the top tube. This will make it easier for the heavily clothed riders in Antarctica to get on the cycle. Next the bike is made of 7071 aluminum, which has excellent mechanical properties at the low temperatures. The final reason for selecting the bike frame was cost. Our initial intent for the Hybrid Tricycle was to make our own custom aluminum frame. However, the benefits of designing a custom frame were dwarfed compared to the drawbacks. The one benefit of a custom frame would be our control over the design of it. The drawbacks were primarily cost and time. The cost of welding alone for a custom aluminum frame would have been higher than the entire cost of the Schwinn® bike. That does not even take into account the cost of material and labor. Time was also a key drawback. A custom frame would have required much longer to have produced and that would have limited our ability to test the cycle prior to completion of the project in late May 2001.

The Adapter Assembly is made of 6061 aluminum and it mates the ATV and bike components. After selecting the ATV and bike components, our design efforts focused on the development of the Adapter Assembly. Constructed out of 6061 aluminum, the Adapter Assembly mates the Carrier from the ATV drive to the rear tire dropout of the bike frame. It also contains a third sprocket that routes the chain from the bike sprocket to the ATV sprocket. The Adapter Assembly was constructed out of 6061 aluminum because of its excellent mechanical properties at low temperatures and its high level of availability. It is held together with zinc coated steel hardware consisting of a nut, lock washer, and bolt at each connection point. The nut and bolt are used to hold each component together so that once the cycle is in Antarctica and the different thermal contraction rates of the steel and aluminum have caused the cycle components to become loose, they will simply need tightening. Zinc coated hardware is used to delay the effects of galvanic corrosion resulting from the use of dissimilar metals.
Financial Issues

The Hybrid Tricycle costs approximately one third the cost of the Tundra Tiger Trike. Since the Tundra Tiger Trike had already consumed approximately $3,000, our design intent was to minimize the cost of developing a workable solution. The cost of the Hybrid Tricycle is approximately one third of that spent of the Tundra Tiger Trike.

Recommended Improvements

The Hybrid Tricycle could use multiple gears and fenders covering the rear tires. We were unable to provide multiple gears in the design of the Hybrid Tricycle. This was because we wanted the cycle to be durable and rugged for the Antarctic environment and the addition of a derailleur lowered the durability of the cycle by adding components that were likely to experience problems with the extremely cold temperatures.

The cycle would also benefit from the addition of fenders covering the rear tires. Fenders would serve as further protection for the rider from the moving parts of the cycle.
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“We the team members,

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Hereby assign our copyright of this report and of the corresponding Executive Summary to the Mechanical, Industrial and Manufacturing Engineering (MIME) Department of Northeastern University.” We also hereby agree that the video of our Oral Presentations is the full property of the MIME Department.

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We would like to thank the faculty and staff of the MIME department for the knowledge, support, and faith you have demonstrated in the last nine months.

We would like to thank Eric Dilg at The Bikeway Source in Bedford, MA for the immense resources he provided to us.

Finally we would like to thank our fellow students for providing professional grade competition.
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1. INTRODUCTION

The objective of the design group is to develop a human-powered vehicle for the Center for Astrophysical Research in Antarctica (CARA). CARA was formed in 1991 to establish an observatory at the South Pole and to pursue a set of astrophysics research projects, which exploit the unique advantages of the high Antarctic site (CARA, 1999). The researchers desire a vehicle that is capable of traveling between base camp and the observatory, a distance of one kilometer. Figure 1 shows the path between the CARA buildings and the observatory.

Figure 1- Footpath between the CARA buildings and the observatory

The group contacted two CARA researchers, Randy Lansberg and John Kovac out of the University of Chicago, and gained an understanding of the Antarctic environment and the expected use of the vehicle. Although Antarctica is covered with snow and ice, it is really a desert environment. The monthly precipitation averages less than 4 millimeters a month. The snow, which has been there for years, has been worn down and now resembles sand particles. The rough edges and branches of each snowflake have eroded away, leaving just a smooth, round surface. This erosion, combined with the extreme cold temperatures, means the snow never melts or compresses. Instead, the snow displaces like loose, dry sand.

Antarctica has two fairly distinct seasons, the summer and winter. The summer season is sunny, and relatively warm – though temperatures rarely exceed −18 degrees Celsius. During the summer season the path is negotiable due to the warmer temperatures. Thus, researchers are able to use standard means of transportation to get from place to place. Trucks, snowmobiles, and even standard mountain bicycles work during these summer months. A human-powered vehicle is desired due to the high price of gasoline in Antarctica. Lansberg and Kovac stated that the price of gasoline in Antarctica is approximately $11.00 per gallon.

Winter in Antarctica is characterized as dark, windy, and extremely cold with temperatures ranging between −40 and −100 degrees Celsius. Due to the wind and a lack of traffic, the paths become covered with loose snow during this season. Small snow drifts form, with a hard crust on top and loose snow inside. Most forms of transportation don’t work because they freeze up from the extreme cold or break through the crust of the snowdrifts and get stuck in the snow.
In addition, the researchers must wear extreme cold weather gear to protect themselves from the cold. Figure 2 shows some of the researchers in their extreme cold weather gear.

![Researchers in extreme cold weather gear](image)

**Figure 2 – CARA Researchers in their extreme cold weather gear**

Extreme cold weather gear consists of many layers. The first layer consists of a T-shirt and long pants. An insulated working trouser and fleece jacket are then put on. Plastic boots are worn to protect the feet and keep them dry. Down overboots are used to keep the feet warm. The hands are covered with three thin layers of finger gloves and full down mitts. For the head, a fleece Balaclava is worn. A Balaclava is a full head covering with just the eyes, nose, and mouth cut out. In the winter, self-contained breathing apparatuses, like those used for fire safety, are worn to further protect the face. These consist of a plastic mask (with breathing holes) that fits over the nose and mouth and under the Balaclava. A down parka is the final layer for the torso of the body. A radio and optional headlamp finish off the ensemble.

This clothing inhibits the researchers' fine motor skills, leaving them with only basic body movement, and little dexterity. The design goal of the Antarctic cycle is to provide these researchers with a human powered cycle to travel from station to station in the harsh Antarctic winter.

Currently there are two proposed solutions to the problem. One solution has been proposed by the Art Institute of Pittsburgh, but has been unsuccessful to date. A student design group at Northeastern University proposed a second solution in June of 2000. Unfortunately, the Northeastern team was unable to finish a workable cycle. The project, named the Tundra Tiger Trike, was then handed over to this group for completion.
2. STATE OF THE ART REVIEW

The cycle project was started less than one year ago, at which time an extensive patent and literature search was conducted. The previous Northeastern University design team determined that “The conventional bike is constantly undergoing changes and innovations. However, limited advancement has been made in the field of snow bikes or their components. Even more neglected is the area of arctic bikes.” A search of the Delphion Intellectual Property Network yielded an incredible 7084 patents on a search for bicycles, 38 of which pertained to recumbent bicycles. There were no patents found for Arctic or Antarctic bicycles. There was only one patent for an “ice bicycle” in 1971. The patent pertains to a device that straps around a standard tire. It is important to note that not only is this patent out of date, but also the technology is of no use to the Antarctic cycle design team. This tends to confirm the statement by the previous team that there is no current patent that applies to an Antarctic cycle design.

The literature search conducted by the previous Northeastern team found only one Antarctic bicycle design by the aforementioned Art Institute of Pittsburgh named the Ice Prowler. The Ice Prowler is a two-wheeled design that uses heavily modified bicycle frame and golf cart tires. The initial Ice Prowler design was sent to Antarctica during the summer season of 1999/2000. The researchers rejected the Ice Prowler because it was too slow as a result of poor gearing. In addition, the researchers found that the cycle was unstable at low speeds due to its two-wheeled design. Our team has been in contact with the Art Institute, and a redesign of their existing cycle is currently underway. There is currently no working solution to the Antarctic cycle design problem.
3. REQUIREMENTS AND SPECIFICATIONS

3.1 Requirements
There are several requirements for a bike designed to operate in an Antarctic climate.

3.1.1 Safety
The most important requirement is safety. Since medical assistance in Antarctica is limited, it is of utmost importance that the user does not get injured while operating the cycle. Any breakage resulting in an accident could have catastrophic consequences; even simple things, like improper user positioning in the extreme cold, can cause frostbite.

3.1.2 Stability
To prevent loss of control, good steering and braking systems are important to the vehicle. It must be easy to control for the user who is wearing several layers of protective clothing.

3.1.3 Usability
The vehicle must be able to travel a distance of 1 kilometer in Antarctica without inducing a cardiovascular workout. It should also be fun to ride.

3.1.4 Reliability
The environment requires the use of materials and lubricants that are capable of successfully operating at temperatures averaging -50 degrees Celsius. As a result, most natural lubricants will not work, nor will most plastics withstand the extreme cold. In addition, the low temperatures cause some metals, such as steel, to become brittle. It is important to account for these factors in designing a reliable vehicle.

3.1.5 Cost
The initial Northeastern University design team spent over three thousand dollars in developing the Tundra Tiger Trike (Ulinks 2001). A similar budget has been allotted for this project.

3.1.6 Manufacturability
Due to time constraints, any custom components will be designed such that they can be manufactured at Northeastern University.
3.2 Specifications
There are few hard numbers that the cycle has to conform to. Randy indicated that there is little possibility that the team will hit weight or size limitations, as the cargo hold on the LC 130 that will deliver the cycle is 6 feet wide and can lift considerable weight. The group will shoot for a weight of 80 lbs and a size of approximately 4 feet wide by 6 feet long. These dimensions are around the approximate girth of the existing cycle.

3.2.1 Size
The only size constraint imposed on the design is that it must be capable of being shipped to Antarctica in the cargo hold of a Lockheed C130 cargo jet.

3.2.2 Weight
The weight of the vehicle should be thirty-five kilograms or less. This will allow the researchers to turn the vehicle around on the path.
4. TESTING OF TUNDRA TIGER TRIKE

4.1 Fixing the Tundra Tiger Trike

The first task of our design team was to complete the previous build of the Tundra Tiger Trike. Figure 3 demonstrates the areas that were addressed before the Tundra Tiger Trike would work.

1) New slots were machined in the steering member to mount the wheels as the previous wheel mounts sheared off.

2) The chain was lengthened and the bottom bracket assembly was modified and moved farther away from the seat. This allows for more clearance between the pedals and the steering member.

3) A new steel steerer tube from a mountain bike fork was installed to fix two major problems. First it raised the steering member out of the path of the pedals so the bike could be pedaled with the heel of the foot. Secondly it replaced the initial aluminum steerer tube that failed causing the cycle collapse, and the rider to crash to the ground.

4) The rear tire was repaired so that it held air.
4.2 Faults Found During Testing
With slight modifications, a workable cycle was finished and taken for a test ride at Revere Beach in Revere, Massachusetts.
The test was a qualitative measure of the cycle’s performance and stability on both compact and loose fine-grain sand. The
testing demonstrated several of the cycle’s flaws.

4.2.1 Inability of the Cycle to Move in the Loose Sand
While the cycle performed adequately in the compact sand close to the water, it became impossible to pedal in the loose dry
sand on the upper part of the beach. The ineffectiveness of the cycle was due to the drive tire digging into the sand rather than
propelling the cycle forward, eventually leading to complete immobility. It was also apparent that gearing would not fix the
problem.

4.2.2 Pedal Interference with Cross-member
The initial design of the Tundra Tiger Trike was such that the steering cross-member obstructed the path of the pedals. Our
design modification made the cycle operable; however, the modification still limited the rider’s full range of motion. Unlike
pedaling a standard bicycle, which uses the ball of the foot, the modified Tundra Tiger Trike must be pedaled with the rider’s
heel. This interference also limited the cycle’s turning ability.

4.2.3 Poor Stability
Due to the nature of the steering, the cycle was unstable while both stationary and in motion. The steering is set up such that
any shift in the rider’s weight causes the wheels to turn. For example, if the rider shifted heavily to the right, the wheels
would turn to the right until they came in contact with the seat.

4.2.4 Brake Lever Location
As seen in figure 3, the brake lever on the Tundra Tiger Trike is located on the side of the seat making it difficult to activate
while in motion. Not only is the brake hard to locate, but the rider’s hand must also come off the steering handle in order to
operate it. This can cause the rider to lose control of the cycle.

4.2.5 Length of the Drive Line
The distance from the crank to the rear cog is 1.3 meters. This length causes the chain to stretch and torque under load
resulting in frequent chain skips. In addition, the long chain runs next to the rider’s leg and creates a hazard to the user. The
researchers’ extreme cold weather gear could easily be caught up in it.

While there are several problems with the design of the Tundra Tiger Trike, the foremost problem is the inability of the cycle
to move in the loose sand. According to Landsberg and Kovac, the Antarctic snow is best simulated by loose sand. Failure in
the loose sand indicates that the cycle will be inoperable in Antarctica. Our efforts then focused towards understanding the
characteristics of loose sand.

4.2.6 Size/Adjustability of Cycle
The seat on the Tundra Tiger Trike is not adjustable. The only method of adjusting the cycle requires unbolting parts of the
 driveline and swapping chains. This is not a practical means of adjusting the cycle between riders. In addition, the cycle is
improperly sized for the average user and a 2-meter tall person cannot ride comfortably on the Trike.
5. SAND TEST

The test of the Tundra Tiger Trike demonstrated that the team must reduce the amount that the cycle sinks in the loose sand due to both static and dynamic loading. While the dynamic aspect is difficult to model, the team sought to understand the static characteristics of loose sand. Attempts at finding the relevant information through print and electronic media were unsuccessful, so the group conducted its own experiment.

The experiment involved the following materials:

- Bag of fine, screened sand
- 0.305 meter (12 inch) x 0.356 meter (14 inch) x 0.152 meter (6 inch) plastic tub
- Ø 0.051 meter (2 inch) x 0.083 meter (3.25 inch) rigid cylinder
- Assorted weights totaling 18.1 kilograms (40 pounds)
- Photocopy of a ruler

It was conducted in the manner described below:

1. The plastic tub was filled with the sand to approximately half the volume of the tub.

2. A photocopy of the ruler was taken and then adhered to the side of the cylinder so that the depth of the cylinder in the sand could be determined from the visibility of the ruler.

3. The surface of the sand was leveled using a straight edge, and the cylinder was gently placed on top of the sand in the center of the tub.

4. Incremental amounts of weight were then added to the top of the cylinder and the corresponding depth of the cylinder was recorded.

Steps 3 and 4 were repeated numerous times until a certain level of confidence in the test results was obtained. The pressure the cylinder exerted on the sand at each load increment was then calculated and plotted versus the depth of the cylinder in the sand. Figure 4 below shows this plot.
As can be seen from Figure 4, the slope of the curve begins to increase dramatically as the pressure approaches 34 to 41 kilopascals (5 to 6 pounds per square inch). The calculated pressure exerted by the Tundra Tiger Trike’s drive tire while carrying a rider is also plotted in Figure 4. According to Figure 4, the calculated rear tire pressure from the Tundra Tiger Trike of approximately 55 kilopascals (8 pounds per square inch) corresponds to a sand depth of nearly 13 millimeters (0.5 inch) due to its static weight. This value appears consistent with the observations obtained during the testing of the Tundra Tiger Trike at Revere Beach.

The experiment demonstrates that the amount of static pressure exerted on the sand can be reduced. There are two methods of accomplishing this, the contact area of the drive tire(s) can be increased and/or the weight distribution can be modified to shift the weight away from the drive tire(s).
6. DESIGN CONCEPTS

Sand testing produced two methods of limiting the amount of static pressure exerted on the sand. The contact area of the drive tire(s) can be increased and/or the weight distribution can be modified to shift the weight away from the drive tire(s). The concepts found in Table 1 were then developed with these methods in mind.

Table 1 - Design matrix of the proposed concepts

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Weighted Total: -4 7 33 12 4

Legend
Concept I: Current design, (new tire mounts, clearance of pedals, chain guard)
Concept II: Recumbent w/ brake steering, (solid cross member, chain guard)
Concept III: Recumbent w/ rack and pinion steering, (solid cross member, chain guard)
Concept IV: Tricycle <2R|1F>, (direct drive|braking)
Concept V: Quadcycle <2R|2F>, (rack and pinion steering, positraction)
Concept VI: Quadcycle <2R|2F>, (head set steering, positraction)

Weight Scale

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low priority</td>
</tr>
<tr>
<td>0</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>10</td>
<td>High priority</td>
</tr>
<tr>
<td>10</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Scoring System

1 Good
0 Satisfactory
-1 Poor
6.1 Redesign Tundra Tiger Trike (Recumbent Tricycle)
To increase the stability of the Tundra Tiger Trike, this concept involved fixing the cross member to the frame. Two different steering methods were considered to accommodate the fixed cross member.

- **Rack and Pinion Steering** – Similar to automotive steering, it involves a steering shaft that has a small gear at its bottom that meshes with a toothed bar connected to the steering linkage that controls two front wheels. This method of correcting the cycle was eliminated due to its complexity.

- **Brake Steering** – This method involved steering by brakes individually mounted on the front wheels. Preliminary testing proved this method to be unsuccessful.

Both of these designs require a new frame - not only to accommodate a moving seat and a new steering mechanism, but also to mount a wider rear tire to attain the proper weight distribution. This redesign would be costly and time consuming.

6.2 Quad Cycle
In an attempt to satisfy the stability requirement of the vehicle, a quad cycle concept was considered. Steering would be accomplished through either rack and pinion or by the use of a headset. While this four-wheel concept provides many beneficial attributes, it was not pursued due to its complexity.

6.3 Hybrid Tricycle
Unlike the recumbent Tundra Tiger Trike, this concept has two rear drive tires and one front tire for steering. Analysis based on a design matrix, which can be found in Table 1, yielded this concept as the most desirable.
7. HYBRID TRICYCLE

The nine-month time line of the project does not allow for a complex custom design. The aluminum frame of the Tundra Tiger Trike must be redesigned and rebuilt to accommodate a moving seat for a taller rider, a wider rear tire, and a new steering mechanism. While some of these modifications can be produced with ease, complex custom steering mechanisms and bearing sets will pose a much larger problem when it comes to completing the design on time. In addition, the added parts and pivot points of a rack and pinion type steering system are undesirable. The team is also uneasy about building on a cycle that has proved to be unreliable. During the initial testing, several components on the Tundra Tiger Trike failed including the wheel mounts, derailleur, and the steering bars.

7.1 Hybrid Tricycle Concept

Based on the above reasons, the team has decided to abandon a redesign of the Tundra Tiger Trike and go with the hybrid tricycle concept (see Figure 5). The hybrid tricycle concept involves using two wide rear tires to drive the cycle and one narrower front tire for steering. To accomplish this, the concept utilizes existing all terrain vehicle (ATV) and mountain bike technology. It allows for the use of standard parts such as wheels, hubs, axles, and frame. These standard components reduce the overall cost of the bike while allowing for a large number of options to choose from. In addition, the hybrid tricycle concept allows for a schedule that the design team believes it can meet.

Figure 5 - The Hybrid Tricycle concept.

7.1.1 ATV Components
The hybrid tricycle concept relies on the selection of a rear drive assembly. The drive assembly needed to provide several qualities in order to be successful.

- Easy to mount
- Wide selection of adaptable components (hubs, tires, wheels)
- Rugged
- Chain driven
Both ATV and go-cart drive assemblies delivered these qualities. The go-cart rear assemblies were difficult to mount, requiring the addition of a rear beam perpendicular to the frame to hold the axle at both ends. The go-cart parts are inexpensive; however the savings are offset by additional weight, frame modifications, and bearing sets required by the design.

ATV drive assemblies easily mount through the use of a carrier bearing set (see Figure 6). They offer a wide selection of adaptable components such as hubs, tires, and wheels. The ATV drive assembly is rugged having been designed to withstand both the transmission of high power and heavy weight loading. It delivers these qualities along with being chain driven. For these reasons the selection of a rear drive assembly for the hybrid tricycle focused on ATV technology.

7.1.2 Mountain Bike Components
The cycling industry has proven that it is capable of providing strong, durable components at low cost, and the Antarctic cycle design team wishes to take advantage of this fact. The front of the hybrid tricycle will use standard mountain bike components such as wheel, tire, fork, headset, and handlebar assembly. In addition, the drive will be made primarily of mountain bike components, including bottom-bracket, crank set, chain, pedals, and rear cog. The team believes that mountain components are well suited to the task due to their long life and proven success rate. In the event that a part does fail, the components are inexpensive and available from a wide variety of manufacturers.

7.1.3 Frame Selection
The frame is a major component of the hybrid tricycle. Two options were explored, designing a custom frame or using a standard mountain bike frame.

7.1.3a Custom Frame
Initially the team was going to design a custom frame capable of uniting the mountain bike components with the rear ATV drive assembly. The team began by designing a frame based on an 18-inch women's bike frame. Material selection for the frame came from finite element analysis based on von-mises' stress, and maximum deflection. In the end, 1.75 square inch square 6061 aluminum tubing was selected for the custom frame.

7.1.3b Standard Mountain Bike Frame
After further consideration, the team discovered that an entire aluminum 18-inch women's bicycle costs around $375 with decent components. In addition, the 18-inch bicycle could be had immediately. For comparison purposes, the team researched the cost of the previous Tiger Tundra Trike frame, which was quoted at 1000 dollars (Ulinski). The Tundra Tiger Trike also took a much longer time for design, quote, and delivery. Based on these facts, the team decided to purchase an 18-inch women's Schwinn Searcher GSX 7005 series aluminum bicycle for $375 dollars.

The decision to use a standard mountain bike frame as opposed to a custom frame saved the group a substantial amount of time and money. However, the use of a standard mountain bike frame required the design of a custom assembly to mate the bicycle frame to the ATV drive assembly.
7.1.4 Adapter Assembly
The team elected to mount the ATV drive assembly to the frame by designing a 6061 aluminum adapter assembly. The adapter assembly mounts to the frame dropouts where the rear wheel normally sits and centers the axle about the frame. The bottom half of the adapter assembly bolts on to the existing holes in the axle carrier assembly (see Figure 5). Additional clamps will help secure the adapter assembly to the frame.

Due to the hybrid design, the ATV tires measure 18 inches in diameter versus the 27-inch diameter of the front bicycle tire. The adapter assembly accounts for this offset in order to keep the cycle level. However this large drop causes the chain to interfere with the frame, so the adapter assembly will need to include a device to relocate and tension the chain so that it is no longer a problem.

Figure 6 - The Adapter Assembly mounted to the ATV drive assembly.

7.1.5 Drive-line
The drive-line of the cycle is another point where the two technologies collide. The design requires that the ATV axle be driven from a mountain bike crank. This means an ATV cog must be mated to a mountain bike crank, or a bicycle cog must be mounted to the ATV axle. Many different size cogs are available for mountain bikes; however, there is usually only one size rear cog available per ATV line. Using an ATV drive-line will drastically reduce the number of gearing options. In addition, two ATV cogs and an ATV chain are much heavier than two mountain bike cogs and a mountain bike chain. The ATV parts are designed to handle multiple horsepower, and while this does provide a better factor of safety, mountain bike components are also designed to handle more power than a human can provide and are more than adequate. Due to these factors the team has decided that the best method is to use a mountain bike cog and drive-line.

7.2 Hybrid Tricycle Testing
After completion, the hybrid tricycle and the Tiger Tundra Trike were taken to Revere Beach for a second test session. While the Tiger Tundra Trike quickly dug into the sand and became immobile, the Hybrid tricycle floated on the sand as intended and could be ridden for long distances. Though the design was successful, the team wanted to compare the actual results to the sand experiment to see if the experiment was accurate. The experiment showed that the Tiger Tundra Trike rear tire would sink into the sand test 0.5 inches, however the beach test demonstrated that the actual rear tire sinks into the sand by approximately 1.5 inches nearly 3 times higher than the experiment predicted. Since the team used this experiment to select a new tire width for the hybrid tricycle, the hybrid tricycles rear tires sank farther in the sand than expected as well. While the
team was shooting for a final sinking depth of 0.15-0.2 inches, the actual rear tires on the hybrid tricycle sank in the sand by 0.5 inches again nearly 3 times higher than anticipated. The team reasoned that the experimental error is most likely due to the cylindrical cross section of the actual tires vs. the rectangular cross section that was used in the sand test experiment.

While the results were off, the team was successful in limiting the static sinking on dry sand. The tires on the hybrid tricycle are sufficiently wide enough to prevent the dynamic problems encountered on the Tiger Tundra Trike. The team documented how well the Hybrid Tricycle works on dry fine grain sand. The test also demonstrated that the initial gearing was too low, and the rider had to pedal very fast to exceed a walking pace. The hybrid tricycle performed so well on dry sand that the gear ratio was increased by approximately a third without adversely affecting performance. Overall the Revere Beach testing showed that the hybrid tricycle is ready for further testing in Antarctica.

7.3 Hybrid Tricycle Shortcomings

While the hybrid tricycle has many positive aspects, there are areas of concern that the group recognizes and is addressing.

7.3.1 Ergonomics

CARA researchers Randy Landsberg and John Kovac indicated that the positioning of the rider’s hands on the Tundra Tiger Trike, which located them by the side of their body, would aid in eliminating frostbite. The hybrid tricycle is unable to deliver such a design. The geometry of the hybrid tricycle was chosen to keep the hands as close to the body as possible in a standard riding position.

Similarly, the researchers indicated that the wide seat used on the Tundra Tiger Trike would minimize the amount of compression that their clothing endures. A high amount of compression affects the insulating ability of their extreme cold weather gear by breaking the thermal barrier provided by air pockets inside the gear. In effect, it creates ‘cold spots’ in their protective clothing. While there are several extra-wide saddles available for standard bicycles, none will provide the same surface area as the seat found on the Tundra Tiger Trike, and there is currently no way we can test how this will affect the rider.

7.3.2 Speed / Cardiovascular Concerns

Walking in snow or sand can be a cardiovascular workout in itself. In addition to the medium, the high altitude and lower air density of Antarctica place higher demands on the cardiovascular system than at sea level away from the poles. The initial design intent was to deliver a multiple speed cycle that would aid in minimizing these factors, but time and reliability concerns have not allowed for the development of a gearing system that we feel confident will function in Antarctica.
8. ANALYSIS

The hybrid tricycle design does not require many theoretical calculations; however, there are several areas of the cycle where analysis and calculations are necessary in order to assure that the design will function. These areas include material selection, drive assembly and tire selection, adapter assembly design, force calculation, gearing, and cost.

8.1 Materials
Aluminum is best known for three properties, it is lightweight, corrosion resistant, and it lacks a ductile – brittle transition. These properties drove our decision to use aluminum wherever possible. In addition it has excellent low temperature properties, aluminum alloys are used for structural parts operating at temperatures as low as –269 degrees Celsius. As the temperature is reduced, the strength of aluminum alloys increases because the ductility increases. This can be seen in Tables 2 and 3, which show tensile properties in relation to temperature for the two grades of aluminum used in the cycle’s design, 6061 and 7005.

Table 2 – Tensile Properties of 6061 Aluminum

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>MPa</td>
<td>MPa</td>
</tr>
<tr>
<td>-80</td>
<td>338</td>
<td>290</td>
</tr>
<tr>
<td>-28</td>
<td>324</td>
<td>283</td>
</tr>
</tbody>
</table>

Table 3 – Tensile Properties of 7005 Aluminum

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>MPa</td>
<td>MPa</td>
</tr>
<tr>
<td>-80</td>
<td>441</td>
<td>379</td>
</tr>
<tr>
<td>-28</td>
<td>421</td>
<td>359</td>
</tr>
</tbody>
</table>

The tables show how the strength of the aluminum alloys increase as the operating temperature is reduced. The two temperatures in the tables are roughly the temperatures the cycle will be operating in.

Due to time and cost, the group had little choice in material selection for many of the cycle’s standard components. For example, many of the ATV components are only manufactured of steel. Attempts at obtaining engineering information on the standard components used on the cycle were also often unsuccessful. The ATV components are manufactured in Japan and the United States representatives were unable to provide any relevant information concerning specific material composition or engineering drawings.

8.1.1 Ductile – Brittle Transition
Ductile-to-brittle transition is a characteristic of certain alloys that lose their ability to deform elastically as temperature approaches a specified range. Steel and other alloys that are either body centered cubic (BCC) or hexagonal close packed...
(HCP) exhibit this trait. Aluminum has a face centered cubic (FCC) crystalline structure and does not exhibit this transition from ductile to brittle. This allows aluminum to maintain its ductility at extremely cold temperatures.

Steel, which is used for all the ATV and some of the bicycle components, was chosen because it is the only material option available for these components. The team feels confident that the steel being used on the hybrid tricycle will perform as desired, as snowmobiles, traditional mountain bicycles, and other automotive vehicles are all in service there.

### 8.1.2 Thermal Expansion

The other problem with using dissimilar metals is thermal expansion. As the temperature changes, the aluminum and steel expand and contract at different rates. This creates thermal stresses in the components, which must be addressed during the design stage.

Thermal stresses are calculated using the following equation.

\[ \delta_p = \alpha \Delta TL \]  

Where \( \alpha \) is the linear coefficient of thermal expansion, \( \Delta T \) is the change in temperature, \( L \) is the original length, and \( \delta_p \) is the change in length of the member. The coefficient of thermal expansion for structural steel and 6061 aluminum are 12 \((10^{-6})/°C\) and 24 \((10^{-6})/°C\) respectively. This means that aluminum will contract twice as much per unit length as steel when experiencing the same temperature variation. In order to combat this difference in thermal expansion, all bolts and fasteners must be preloaded.

### 8.1.3 Galvanic Corrosion

A potential problem with the material selections made for the cycle is galvanic corrosion. Galvanic corrosion occurs at the contact point of two metals or alloys with different electrode potentials. There are several places on the cycle where aluminum components mate with steel components. An example of this mating of dissimilar metals is where the carrier mates with the adapter assembly. To prevent galvanic corrosion, all fasteners used on the cycle are zinc plated. The zinc plating corrodes more readily than either the steel or aluminum. This causes the zinc to dissolve, protecting the other metals until no more zinc remains.

### 8.2 Drive Assembly Selection

As discussed in the final concept section, the rear components from the ATV were designed to handle a gross vehicle weight greater than 400 pounds. In addition, the components are designed to withstand 4.5-35 horsepower, and severe loading conditions, such as impacts caused by jumping. The target design weight of the cycle, with 250 lb operator, is 330 lbs, and humans are not capable of providing much more than 1 horsepower. This means that the ATV components are over-designed. The group considers them more safe than excessive. The mountain bike components are also designed to withstand the forces that a human can develop, and are strong enough not to warrant custom designed parts. Cold weather considerations will play...
a large part in exact component selection. Because it is brittle at low temperatures, plastic in the components must be minimized or eliminated.

In addition, the Polaris® parts are low in cost. Other ATV axle assemblies from alternate manufacturers such as Honda® were examined, however the design team determined that these assemblies contained features that could not be used, and added unnecessary cost and weight. This left the team to strongly consider the Polaris® parts as the best off-the-shelf solution.

8.3 Tire Selection
The results obtained from the Static Loading Capacity of Dry Sand Experiment showed that the static pressure exerted by the tires on the sand was a key design criterion. Directly related to the static pressure exerted by the tires is the weight distribution of the cycle. The weight needs to be distributed such that the pressure of the drive tire(s) is low enough to minimize the static displacement of the sand, while also allowing adequate displacement of the sand by the steering tire(s) to avoid “plowing”.

8.3.1 Drive Tire(s)
Figure 4 illustrates the approximate depth that a tire will sink into the sand under a certain static pressure. After a static pressure of approximately 5 pounds per square inch, the effect of static pressure on tire depth in the sand dramatically increases. The addition of dynamic loads induced by the drive tire(s) adds to the problem. Therefore the design criterion is to select a drive tire(s) configuration that provides a pressure level of 2 to 4 pounds per square inch.

![Diagram of tire pressure calculation]

**Figure 7 – Methodology used in calculating cycle pressure on sand**

The hybrid trike design utilizes two youth ATV tires for driving. Following Figure 7, each of these tires has a width of approximately 8 inches combining to give a total drive-pressure bearing width of nearly 16 inches. In comparison to the
Tundra Tiger Trike drive pressure-bearing width of 2.5 inches, the hybrid trike delivers six times greater drive pressure-bearing width. Figure 4 shows that for an equivalent load and contact length, this six-fold increase in width lowers the pressure exerted on the sand by a sixth. The youth ATV tires are heavier than the mountain bike tire used on the Tundra Tiger Trike and they have a smaller diameter, which will lower the value of the contact length. Based on these factors, the pressure exerted will not be as good as one sixth of that induced by the Tundra Tiger Trike, but it will be significantly less.

**8.3.2 Steering Tire(s)**

Since the front tire is not powered, it does not suffer the dynamic loading problems, and will not dig in to the sand. However, the front tire is still subject to sinking by static pressure, and this must be analyzed in order to prevent problems. Friction caused by the front tire sinking must remain adequate to turn, yet not cause too much drag. From the previous test of the Tundra Tiger Trike, the team feels that the steering tire(s) should have a static pressure in the range of 5 to 6 pounds per square inch.

The main problem with the existing design is the width of the rear tire. The team discovered that an optimal design requires 8-inch wide tires. The hybrid design focuses most of the weight of the cycle on the rear two ATV wheels where weight can be easily distributed through wide tires. The back ATV assembly is from a small, lightweight Polaris® four-wheeler. The Polaris® rear end was chosen because of its simplicity.

**8.4 Adapter Assembly Design**

The Adapter Assembly combines the mountain bike frame to the ATV drive assembly. It is composed of the following custom parts:

- Frame Mount Block (quantity: 1)
- Base Plate (quantity: 1)
- Spacer (quantity: 2)
- Arch (quantity: 2)

Through the use of a mountain bike skew, the Frame Mount Block connects the Adapter Assembly to the rear dropouts of the Schwinn frame. (Note: The rear dropouts are the slots located in the rear of the frame where the back tire mounts on standard bicycles.) The Frame Mount Block is bolted to the Base Plate which keeps the Spacers and Arches separated so that they straddle the carrier of the Polaris® ATV drive assembly. Bolts are then used to lock the carrier to the Arches.

Each custom part in the Adapter Assembly is made of 6061 aluminum. This material was chosen based on its availability and favorable mechanical properties that were previously mentioned in the Materials section of this chapter. Zinc coated hardware is used to bolt the assembly together.
Figure 8: The Adapter Assembly consists of the Frame Mount Block, Base Plate, Spacers, and Arches.

Beam theory analysis was used to determine the thickness of the Base Plate. The Base Plate was modeled as a cantilever beam fully fixed at one end and subjected to a 150-pound transverse load at the other end. The flexural formula was used to obtain the appropriate height. A factor of safety equal to 1.5 was used in the analysis. Equation 2 shows that the cross-section of the plate had to be designed such that the combination of the moment of inertia divided by the distance from the neutral axis to the surface was equal to 0.09 cubic inches. Equation 2 was then solved for the plate thickness (h) resulting in Equation 3. Setting the plate width (b) to 8 inches yielded a minimum theoretical plate thickness (h) of 0.26 inches.
Figure 9 – Methodology used in calculating the required plate thickness for the Adapter Assembly

A finite element analysis was later conducted on the base plate using ALGOR. The analysis modeled the base plate with plate elements under a 300-pound static load. Figure 10 shows a contour map of the displacement, while Figure 11 shows a contour map of the von mises stress.
As Figure 10 shows, the maximum displacement is only a few thousandths of an inch. Figure 11 reveals that the peak stress is well below the yield strength of 6061 aluminum.
8.5 Power Calculation

The ability of a human operator to power the hybrid tricycle is an important design consideration. The following road load power equation was used to determine the power required to operate a standard bike along with the power required for the Hybrid Tricycle.

\[ P_{\text{rolling resistance}} = c_R M_v g \cos \alpha S_v \]  
\[ (4) \]

\[ P_{\text{aerodynamic resistance}} = \frac{1}{2} \rho_{\text{air}} C_D A S_v^3 \]  
\[ (5) \]

\[ P_{\text{total}} = c_R M_v g \cos \alpha S_v + \frac{1}{2} \rho_{\text{air}} C_D A S_v^3 \]  
\[ (6) \]

**Power vs Speed**

![Graph showing power vs speed for a standard bike and Hybrid Tricycle](image)

*Figure 12 – Power requirement versus speed for the Hybrid Tricycle and a standard bike*

Figure 10 shows a plot of the power required versus speed for both a standard bike and the Hybrid Tricycle. At the desired top speed of 6.2 mph you can see that the difference in power required between the bike and Hybrid Tricycle
is minimal. This 12% difference in power verified what our testing had demonstrated, that our bike is nearly as easy to pedal as a standard bicycle.

8.6 Gearing
One of the requirements of the bike is a velocity of 10 miles per hour. To achieve this, the cycle must be properly geared. The gearing calculation uses a cadence of 80 revolutions per minute — this is a comfortable pedaling speed for most non-cyclists. The gear ratio necessary to operate the hybrid cycle at 10 miles per hour for this cadence was found in Table 4 to be 2.33:1.

Table 4 - Ratio Calculation

<table>
<thead>
<tr>
<th>Hybrid Tricycle</th>
<th>Standard Mountain Bike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheel Diameter</td>
<td>18 in</td>
</tr>
<tr>
<td>Wheel Circumference</td>
<td>4.7 ft</td>
</tr>
<tr>
<td>Cadence</td>
<td>80 rpm</td>
</tr>
<tr>
<td>Velocity</td>
<td>10 mph</td>
</tr>
<tr>
<td>Back Wheels</td>
<td>186.7 rpm</td>
</tr>
<tr>
<td>Ratio</td>
<td>2.33</td>
</tr>
<tr>
<td>Wheel Diameter</td>
<td>26 in</td>
</tr>
<tr>
<td>Wheel Circumference</td>
<td>6.8 ft</td>
</tr>
<tr>
<td>Cadence</td>
<td>80 rpm</td>
</tr>
<tr>
<td>Velocity</td>
<td>10 mph</td>
</tr>
<tr>
<td>Back Wheels</td>
<td>129.3 rpm</td>
</tr>
<tr>
<td>Ratio</td>
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</table>

8.7 Cost
The previous version on the Tundra Tiger Trike cost $3005 (Ulinski, 2001). While the budget for this project is similar, the team has tried in every possible way to keep expenditures down.

8.7.1 Redesign Tundra Tiger Trike (Recumbent Tricycle)
The initial purpose of the project was to modify the existing Tundra Tiger Trike to make the design functional. However, testing demonstrated that the existing design would need extensive rework to perform adequately in the Antarctic environment. This rework included a new custom steering mechanism, a new drive wheel and tire, a new seat mount, and a new frame. Though the team and sponsor hoped the redesign would not be costly, the group estimated the cost of these changes to cost an additional $2445 as seen in Table 5.
### Table 5 – Cost Estimate of Redesigning Tundra Tiger Trike

#### ATV/Motorcycle

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Axle</td>
<td>$70</td>
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<tr>
<td>Sprocket</td>
<td>$85</td>
</tr>
<tr>
<td>Bearings (x2)</td>
<td>$60</td>
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<tr>
<td>Wheel</td>
<td>$65</td>
</tr>
<tr>
<td>Tire</td>
<td>$75</td>
</tr>
<tr>
<td>Custom hub</td>
<td>$100</td>
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<tr>
<td>Hardware</td>
<td>$55</td>
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<tr>
<td><strong>sum-&gt;</strong></td>
<td>$510</td>
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#### Driveline Redesign (2 sections to shorten chain)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Chain (x2)</td>
<td>$70</td>
</tr>
<tr>
<td>Additional Bottom Bracket</td>
<td>$35</td>
</tr>
<tr>
<td>Additional Sprockets (x2)</td>
<td>$50</td>
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<tr>
<td><strong>sum-&gt;</strong></td>
<td>$155</td>
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#### Steering (Rack and Pinion)

<table>
<thead>
<tr>
<th>Item</th>
<th>Each</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Swing Axle Pivot Bushes, Acetal (4)</td>
<td>$24</td>
<td>$96</td>
</tr>
<tr>
<td>Front Swing Axle Pivot Pins with nuts &amp; washers (2)</td>
<td>$21</td>
<td>$42</td>
</tr>
<tr>
<td>Front Stub Axle, left &amp; right, welded &amp; drilled, with uprights &amp; steering arms (2)</td>
<td>$70</td>
<td>$140</td>
</tr>
<tr>
<td>Front Stub Axle Bushes, Acetal (4)</td>
<td>$18</td>
<td>$72</td>
</tr>
<tr>
<td>Front Stub Axle Bolts, 12mm. Includes, washers &amp; nyloc nuts(2)</td>
<td>$15</td>
<td>$30</td>
</tr>
<tr>
<td>Front Swing Axle Arms, right &amp; left. Fully welded &amp; drilled(2)</td>
<td>$75</td>
<td>$150</td>
</tr>
<tr>
<td><strong>sum-&gt;</strong></td>
<td></td>
<td>$530</td>
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#### Total Projected Cost

<table>
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<tr>
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<th>Cost</th>
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<tr>
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<tr>
<td>Estimated at ~125%</td>
<td>$3,056</td>
</tr>
<tr>
<td>Estimated at ~80%</td>
<td>$1,956</td>
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#### Frame (material & assembly)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame (material &amp; assembly)</td>
<td>$1,000</td>
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#### Seat

<table>
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<tr>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Removal of current seat</td>
<td>$50</td>
</tr>
<tr>
<td>Adjustable Mechanism</td>
<td>$200</td>
</tr>
<tr>
<td>New Welding</td>
<td>$40</td>
</tr>
<tr>
<td><strong>sum-&gt;</strong></td>
<td>$250</td>
</tr>
</tbody>
</table>
8.7.2 Hybrid Tricycle

For comparison purposes the team did a cost estimate for the hybrid tricycle design. As seen in Table 6, this estimate assumed that the team would build a new frame similar in cost to the Tundra Tiger Trike. The initial cost estimate for the Hybrid Tricycle came to $1802, a savings of $650 over the redesign of the Tundra Tiger Trike. When the team decided to purchase a bicycle, the estimate dropped by another $500 dollars. This savings is due to a lower frame cost and the fact that the complete bicycle already includes several of the needed components. Overall the Hybrid Tricycle will save approximately $1150 dollars over a redesign of the Tundra Tiger Trike, reinforcing the team's decision to start from scratch.

Table 6- Cost Analysis of Hybrid Tricycle

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost Custom Frame</th>
<th>Cost Purchased Frame</th>
<th>Cost Custom Frame Estimated at -125%</th>
<th>Cost Purchased Frame Estimated at -125%</th>
<th>Cost Custom Frame Estimated at -80%</th>
<th>Cost Purchased Frame Estimated at -80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rim</td>
<td>$50</td>
<td>$35</td>
<td>$50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fork</td>
<td>$100</td>
<td>$30</td>
<td>$30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seat</td>
<td>$40</td>
<td>$26 incl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seat post</td>
<td>$80</td>
<td>$44 incl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crank set</td>
<td>$60</td>
<td>$30 incl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chain</td>
<td>$40</td>
<td>$20 incl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom Bracket</td>
<td>$50</td>
<td>$16 incl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapter</td>
<td>n/a</td>
<td>n/a</td>
<td>$200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sum --&gt;</td>
<td>$933</td>
<td>$355</td>
<td>$340</td>
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</tr>
</tbody>
</table>

Frame

Estimate: $1,000

Total Projected Cost

Custom Frame

Estimated: $1,802

Estimated at 125%: $2,252

Estimated at 80%: $1,441

Purchased Frame

Estimated: $1,250

Estimated at 125%: $1,563

Estimated at 80%: $1,000
9. CONCLUSION

Currently there is no human-powered vehicle that can be used by Antarctic researchers to travel one kilometer during the Antarctic winters. The Art Institute of Pittsburgh designed a bicycle that was tested in Antarctica. Their bike did not perform the task as intended, and they are currently working on a redesign. Local testing of Northeastern University’s Tundra Tiger Trike has indicated that its initial design will not work in Antarctica as well. There is still a need to solve the Antarctic cycle design problem.

The group has developed a new concept that it feels will perform better than a redesign of the Tundra Tiger Trike. The new concept, known as the hybrid tricycle, presents some risk over a redesign of the existing Tundra Tiger Trike, yet it uses simple, proven cycle geometry and off-the-shelf parts rather than custom built components. This is an advantage over the existing cycle from manufacturability, cost, and design standpoints. While the team recognizes the design’s drawbacks, all preliminary calculations and tests indicate that the hybrid concept will have the highest chance of working in Antarctica. The team believes the design is workable in all aspects, and that the cycle is ready for testing in Antarctica.
REFERENCES


http://www.delphion.com/

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“Bike Nashbar” November 15, 2000

http://www.nashbar.com/

“Cambria Bikes” November 15, 2000

http://www.cambriabike.com/

“Polaris Industries” November 25, 2000

http://www.polarisindustries.com/

“ATV Source” November 25, 2000

http://www.atvsourcse.com/


APPENDICES

Appendix A: Mechanical Drawings for Adapter Assembly

Arch
Frame Mount Block
Spacer
Appendix B: Bill of Materials for Hybrid Tricycle

### Bicycle Components

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schwinn Searcher GSX Complete Bicycle</td>
<td>1</td>
</tr>
<tr>
<td>Rim</td>
<td>1</td>
</tr>
<tr>
<td>2.35 x 26 Tire</td>
<td>1</td>
</tr>
<tr>
<td>2-3 x 26 Tube</td>
<td>1</td>
</tr>
<tr>
<td>Spokes</td>
<td>36</td>
</tr>
<tr>
<td>36 Hole Hub</td>
<td>1</td>
</tr>
<tr>
<td>Front Fork for Wide Tire</td>
<td>1</td>
</tr>
<tr>
<td>New Full Length Chain</td>
<td>1</td>
</tr>
<tr>
<td>Riser Handle Bars</td>
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### ATV Components

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
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<tbody>
<tr>
<td>Axle</td>
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</tr>
<tr>
<td>Axle Bolt</td>
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</tr>
<tr>
<td>Axle Washer</td>
<td>2</td>
</tr>
<tr>
<td>Axle Pin</td>
<td>2</td>
</tr>
<tr>
<td>Hub</td>
<td>2</td>
</tr>
<tr>
<td>Hub Bolts</td>
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</tr>
<tr>
<td>Wheel</td>
<td>2</td>
</tr>
<tr>
<td>8&quot; ATV Tire</td>
<td>2</td>
</tr>
<tr>
<td>Sprocket Holder</td>
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</tr>
<tr>
<td>Carrier</td>
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</tr>
<tr>
<td>Bearing Spacer</td>
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</tr>
<tr>
<td>ATV Bearings</td>
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</tr>
<tr>
<td>Short Spacer</td>
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<tr>
<td>Brake Side Spacer</td>
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<tr>
<td>Sprocket Side Spacer</td>
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</tr>
<tr>
<td>M12-1.25 x 1.5</td>
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</tr>
<tr>
<td>M12 Flat Washer</td>
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</tr>
<tr>
<td>M12 Lock Washer</td>
<td>4</td>
</tr>
<tr>
<td>0.5x5 UNC Hex Head Bolt</td>
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</tr>
<tr>
<td>0.5 UNC Nut</td>
<td>4</td>
</tr>
<tr>
<td>0.5 UNC Washer</td>
<td>4</td>
</tr>
<tr>
<td>0.5 UNC Lock-Washer</td>
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</tr>
</tbody>
</table>

### Raw Material

<table>
<thead>
<tr>
<th>Item</th>
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</thead>
<tbody>
<tr>
<td>2&quot;x1.5&quot;x8&quot; 6061 Block</td>
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</tr>
<tr>
<td>5&quot;x8&quot;x1.5&quot; 6061 Block</td>
<td>2</td>
</tr>
<tr>
<td>8&quot;X9&quot;X1/2&quot; 6061 Plate</td>
<td>1</td>
</tr>
</tbody>
</table>