Adapted Paddle Launch Vehicle

Final Report

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June 4, 2010
ABSTRACT
The Adapted Paddling Launch Vehicle project proposal is a document that outlines our problem and goals we are trying to achieve with the product. As well as give design requirements, specifications, responsibilities table, and timeline for the project.
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INTRODUCTION

Physical exercise is an important part of maintaining a healthy, active lifestyle. It is especially important for people with physical disabilities to have the opportunity to exercise no matter what disability they face. Here at Cal Poly, the kinesiology department has created an adapted exercise program that provides different means of exercise for people in the community. One such activity in the program is the adapted paddle program, which allows community members with varying forms of paralysis to participate in an organized kayaking trip at Morro Bay. This activity provides a fun way to exercise as well as a sense of freedom in the open water that may not be obtained with some of the physical restrictions experienced on land.

Our project is to construct a vehicle that will allow the kayak launch process to be safe and more efficient than the current means to help the kayakers enter and exit the water. This vehicle must assist the kayaker as they transfer from their wheelchair into the kayak, safely lower them and the kayak into the water from a boat ramp, and safely bring them back up the ramp from the water when they are done kayaking. To accomplish this, we have established five goals for this project. The first goal is to make our device accessible to a wide range of users. Our users have a wide range of disabilities and we hope to make it usable by the majority of them. The second goal is to help the person with the disability transfer from their wheelchair to kayak comfortably. If the person cannot enter the kayak easily, this may discourage them from going any further with the program. The third goal is to transport two kayakers, the person with the disability and the volunteer that shares the kayak, plus the kayak itself, from the top of a boat ramp, down to the water, and back up safely. The fourth goal is to make the vehicle easily transportable. The vehicle is of no use if the user cannot transport it with all the other equipment to the launch site. The fifth and final goal is to make sure the device is low maintenance. We want to ensure that the device does not fail easily and that any parts needed for minor repairs are easily accessible.

Figure 1. Kayakers enjoying the serenity of Morro Bay
BACKGROUND

The original method to assist kayakers with disabilities down the ramp is to physically pick them up and place them in the water as seen in Figure 1. This task takes at least four people and causes safety concerns for the kayaker.

![Figure 2. The original method of launching the kayak](image)

The method that is currently used to assist kayakers down the ramp is to physically pick them up and place the kayak on a hand cart to roll them down to the water, as presented in Figure 2. Although this current method is less physically demanding it still takes five to six people to steady the kayak.

![Figure 3. The current method of launching the kayak](image)
The current processes for entering and exiting the water are as follows:

**Entrance into water:**
1. Set kayak on ground
2. Position wheelchair near side of kayak
3. At least 2 assistants lift person with disabilities from each side while another assistant guides legs
4. All lower person into kayak
5. Adapted materials added for comfort
6. 6 assistants lift kayak and user while 1 assistant positions hand cart under kayaker
7. All support kayak while it rolls down boat ramp
8. Once kayak is in water, 1 assistant climbs into kayak
9. Both paddle out into the bay

![Figure 5. Assistants carrying kayak down boat ramp](image)

**Exiting the water:**
1. Kayak floats up to boat ramp
2. One assistant holds kayak while assistive rider jumps out
3. 6 assistants lift kayak while hand cart is placed under kayaker
4. Kayak is pushed up ramp
5. Kayak placed on flat ground
6. Kayaker lifted out of kayak and placed in wheelchair

![Figure 4. Boat Ramp in Morro Bay](image)
Another method involves the use of a small cart. The kayak is placed on top of the cart and is lowered into the water. This can be seen in Figure 3. This cart provides no assistance in transferring the kayaker from the wheelchair to the kayak.

![Figure 6. A picture of a simple kayak launcher](image)

Our background research has not yielded any patents for carts similar to the one in Figure 2. However the products we did find included a hydraulic boat lift that lifts the boat completely out of the water, and an in-water kayak stabilizer. The lift is permanently attached to the boat dock, which allows the user to get into the boat from the dock and then lowered into the water safely. The problem with this product is that it still does not help the user from getting in to and out of the kayak, has a very high cost, and is permanently attached to the boat dock; which makes it impractical solution for our problem. This product can be found in Appendices under product [1].

The other product we found requires that the kayak already be in the water. This product keeps the kayak from flipping over by using two long floats, one on each side of the kayak, which still does not solve the problems of getting in to and out of the kayak or getting the kayak into the water safely with the passenger already in the kayak. This product can be found in the Appendices under product [2].

There are many different kayak carrier designs out there, as seen in Figure 4. However this product, like the previous one, fails to meet one of our requirements: The kayak carriers are not meant to carry kayaks with riders already in them; they are only meant for pulling the kayak down to the water and back. For more information on this product please refer to the Appendices under product [3].
More research was done to find a product that could help the person with disabilities from their wheelchair to the kayak. The first was a slide bench, as seen in Figure 5. This product relies too heavily on the person’s ability to stabilize themselves and therefore would not be suitable for our application. Also, the slide bench relies on the person’s wheelchair to be the same height as the kayak once the kayak is on the cart. For more information on this product please refer to the Appendices under product [4].
OBJECTIVES

The objectives for the project are listed below. For the project to be successful, each of these objectives must be accomplished:

1. The transfer of the kayaker from their wheelchair to the kayak with little or no assistance from the volunteers.

2. The transportation of the kayaker, volunteer, and kayak down the boat ramp to the water and back.

3. The correct length and width dimensions of the structure to support a variety of different sized kayaks.

4. The ability to easily transport the device to and from the place of use.
**SPECIFICATIONS**

Below is the table of project specifications. It defines the requirements of specific parameters and quantifies the importance of each. Each requirement must be satisfied in order to deliver a safe and successful product. Verification that our design will meet these requirements is included in the testing section of this report.

**Table 1: Specifications**

<table>
<thead>
<tr>
<th>Spec Number</th>
<th>Parameter Description</th>
<th>Requirement or Target</th>
<th>Risk</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Structure Weight</td>
<td>&lt; 100 lb.</td>
<td>M</td>
<td>A, I</td>
</tr>
<tr>
<td>2</td>
<td>Capacity Weight</td>
<td>&gt; 600 lb.</td>
<td>H</td>
<td>A, T</td>
</tr>
<tr>
<td>3</td>
<td>Height Range</td>
<td>14 in</td>
<td>H</td>
<td>A, I, T</td>
</tr>
<tr>
<td>4</td>
<td>Length</td>
<td>8 ft</td>
<td>L</td>
<td>I, A</td>
</tr>
<tr>
<td>5</td>
<td>Width</td>
<td>~ 3 ft.</td>
<td>L</td>
<td>I, A</td>
</tr>
<tr>
<td>6</td>
<td>Ease of Entry</td>
<td>User Satisfaction</td>
<td>H</td>
<td>U, A</td>
</tr>
<tr>
<td>7</td>
<td>Ease of Launch</td>
<td>User Satisfaction</td>
<td>H</td>
<td>U, A</td>
</tr>
<tr>
<td>8</td>
<td>Ease of Retrieval</td>
<td>User Satisfaction</td>
<td>H</td>
<td>U, A</td>
</tr>
<tr>
<td>9</td>
<td>Ease of Transportation</td>
<td>User Satisfaction</td>
<td>H</td>
<td>U, A</td>
</tr>
<tr>
<td>10</td>
<td>Safety</td>
<td>No Injury</td>
<td>H</td>
<td>I, T</td>
</tr>
<tr>
<td>11</td>
<td>Comfort</td>
<td>User Satisfaction</td>
<td>M</td>
<td>U</td>
</tr>
<tr>
<td>12</td>
<td>Durability/Life</td>
<td>~ 2 years</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>Rust Proof/ Water Proof</td>
<td>No Corrosion</td>
<td>H</td>
<td>A, T</td>
</tr>
<tr>
<td>14</td>
<td>Cleaning</td>
<td>Hose down</td>
<td>L</td>
<td>I</td>
</tr>
<tr>
<td>15</td>
<td>Brakes</td>
<td>Lockable</td>
<td>H</td>
<td>A, T</td>
</tr>
</tbody>
</table>

Risk Key: Low Risk (L), Medium Risk (M), High Risk (H)
Compliance Key: Analysis (A), Test (T), Inspection (I), User (U)
METHOD OF APPROACH

We have developed our solution via somewhat traditional design processes. First we performed background research in the areas of existing kayak launching mechanisms and current adapted kayak launching methods. We also observed the Cal Poly adapted paddle launch program in Morro Bay, noting the needs of each participant and discussing design issues with the volunteers. With the information gathered from this experience, we felt we had enough background to begin designing a kayak launch vehicle.

Our next step was to brainstorm and produce as many ideas on paper as possible. Then we selected the strongest few ideas and performed some basic analysis on them (i.e. statics, stresses, etc.). We also discussed specific details about each design pertaining to its strength and various aspects of its functionality. The key features we discussed included various forms of adapted entry into/exit from a kayak, maneuverability of device, safety features, and reliability/ease of maintenance. Using the results from the analysis and discussion, as well as our best judgments based on our engineering expertise, we selected the final design for the project and began refining the design to ensure that all the customer needs are safely and completely satisfied.

Once we selected a specific final design, we performed detailed analysis on all facets of the design, from its structure to its mobility and assistive features. We created detailed drawings of the design and provided specifications and a bill of materials. Once the final design has met sponsor approval, we will begin ordering parts and material and start fabrication. Once fabrication of the prototype is complete, testing will begin. We will rely heavily on the input from other kayakers with disabilities during this testing phase. After testing the product we will use the test data to make any modifications possible to maximize the success of the product and ensure the satisfaction of both the sponsor and the users.
DESIGN DEVELOPMENT

We decided to split the project into three main components: the frame, the lifting mechanism and assistive features, and the launch assistance mechanism. We developed concepts for each component and compared them using decision matrices. The criteria in our decision matrices are weighted on a five-point scale: The most important requirements are given a higher point value than other requirements. Then each concept is given a “grade” based on how well it satisfies each requirement, which is multiplied by the importance. The weighted grades are totaled, and the concept with the highest score is the one that best satisfies the most important requirements.

Frame

For the frame we decided to create concepts separately for both the bottom portion of the frame and a top portion of the frame. The bottom portion of the frame will support the wheels and the top portion of the frame will hold the kayak. In between these two structures will be the lifting mechanism that will raise and lower the top frame, which in retrospect will raise and lower the kayak. Some of the major criteria for the frame are ground clearance and rigidity.

Bottom Frame

The first concept that we considered was a rectangular frame which we called Concept A, and can be seen in Figure 7. This concept is very rigid and strong; however the concept had a huge problem with ground clearance. Since the kayak needs to be as low as possible to assist the person entering the kayak, the wheels on this frame design would have to be small. With small wheels there is a possibility that the side rails would bottom out when then vehicle is going from a flat surface to descending down the boat ramp.

Figure 9. Concept A
The second concept which we called concept B can be found in Figure 8. In this concept, we considered having a bend in the axle to lower the mounting point for the lifting mechanism while maintaining a larger wheel size. We also wanted to decrease the amount of material that would have to be used; therefore we designed for only one frame rail that runs down the middle. Although this idea would cut cost and weight, it has the same fatal flaw as with the rectangular frame: Ground clearance. The rigidity was also questionable because without having two frame rails the wheel axle could twist, resulting in the vehicle not driving straight.

![Figure 10. Concept B](image)

The third concept, concept C, can be found in Figure 9. This concept combines the best ideas of the previous two concepts. It not only has a curved axle to allow the lifting mechanism to be as low as possible, but also uses two parallel frame rails that are attached at the high point in the axle. This allows the vehicle to have the necessary ground clearance.

![Figure 11. Concept C](image)
Below is a decision matrix for the bottom frame. According to the decision matrix the best concept is concept C.

Table 2. Bottom Frame Decision Matrix

<table>
<thead>
<tr>
<th>Bottom Frame</th>
<th>Importance</th>
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<th>B</th>
<th>C</th>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td>rigid</td>
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<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>low part count</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>overall life</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>frame stability</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
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<tr>
<td>ground clearance</td>
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<td>waterproof</td>
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<td>5</td>
<td>5</td>
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<td>transportable</td>
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<td>5</td>
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<td>lifting mechanism clearance</td>
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<td>5</td>
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</tr>
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<td>ease of use</td>
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<tr>
<td>low maintenance</td>
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</table>
We also decided that the frame rails should be detachable. This would improve the ease of transportation since the vehicle could be quickly disassembled and reassembled. The rails would slide into a sleeve and be secured in place with a pin. A sketch of this concept can be found in Figure 10.

Figure 12. Detachable Side Rails
**Top Frame**

We developed four concepts for the top frame. Each concept has its own pros and cons. The first concept (a) had two “U” shaped supports at either end of the structure. After some consideration we determined that this concept would start to damage the bottom of the kayaks due to the unpadded “U” supports. Of course this is unacceptable, so we came up with our second concept.

![Figure 13. Concept A](image)

The second concept (b) is similar to the first concept but incorporates two soft straps to cushion the kayak as it rests on the supports. This concept presents a new problem: The overall weight is centered in the middle of the structure where there are no supports.

![Figure 14. Concept B](image)
The third concept (c) is similar to the first two concepts but incorporated two long, thin poles that span the entire length of the structure. These poles run from either end of the U supports. Along the length of the poles we placed straps to create a cradle, which solves the problem of supporting the middle of the kayak. However it presents another new problem of having too many parts.

Figure 15. Concept C

The fourth concept (d) is similar to design (b), but shorter in length. This concept solves the three main problems that we previously encountered. The two U supports are now centered under the cockpit of the kayak, where most of the weight is concentrated. The supports also have the soft straps on them to prevent damage to the kayak. By making the structure smaller we were able to eliminate the many straps that cradled the kayak without eliminating the support, thereby reducing the part count.

Figure 16. Concept D
The following is a decision matrix that we constructed to help us decide which concept would work best for our application. This method suggests that our fourth concept (d) is best suited for our project.

**Table 3. Top Frame Decision Matrix**

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Importance</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
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<td>hold load with safety factor</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>rigid</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
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<td>stabilize kayak</td>
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<td>1</td>
<td>4</td>
<td>3</td>
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<tr>
<td>no damage to kayak</td>
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<td>1</td>
<td>4</td>
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<tr>
<td>add-ons</td>
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<td>3</td>
<td>4</td>
<td>3</td>
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<tr>
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<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>ease to assemble/ disassemble</td>
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<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
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<td>5</td>
<td>5</td>
</tr>
<tr>
<td>aesthetics</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>cost</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>231</td>
<td>243</td>
<td>248</td>
<td>268</td>
</tr>
</tbody>
</table>
Lifting Mechanism and Other Assistive Features

The lifting mechanism is the primary assistive feature. From research and interviews we have concluded that having the kayak as low to the ground as possible would be highly beneficial to help people with a range of disabilities get into and out of the kayak. There are two main concepts for the lifting mechanism: A scissor-type jack system, and an adjustable strap system. Sketches of the lifting mechanisms are presented in Figures 15 and 16.

Figure 17. Scissor Jack lifting mechanism.

Figure 18. Adjustable strap lifting mechanism.
Other assistive features in addition to the lifting mechanism will be required to aid kayakers with disabilities in getting into and out of the kayak. So far we will be using a slide bench and hand rails that are either detachable or foldable, so that they can be used only when needed and stay out of the way otherwise. Figure 17 depicts our concepts for some other assistive features.

![Illustration of other assistive features.](image)

The main advantage of the scissor jack is that, in its fully lowered position, it has a much shorter profile than other jacks. This means the kayak can be lowered to very close to ground level. The main drawback of the jack is that it is slightly more complex than the strap system, but it is also more durable over a long time period. The strap system is advantageous in that it is a simpler design, but it has more drawbacks than the jack system. To raise and lower a kayak and keep it level, both sides of each strap would have to be adjusted simultaneously. Also, it is simply not as strong as a lifting mechanism. Our decision matrix for the lifting mechanism, presented in Table 4, indicates that the scissor jack system would be the better choice, which agrees with our engineering intuition.
Table 4. Weighted decision matrix for lifting mechanism.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Importance</th>
<th>Scissor Jack</th>
<th>Adjustable Straps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum height</td>
<td>As low as possible</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Maximum height</td>
<td>As high as possible</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Height adjustment</td>
<td>Be able to level kayak with water</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Lift Front/Rear</td>
<td>Independently</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Strength</td>
<td>Be able to raise/lower with or without load</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Ease of use</td>
<td>Must be easy to operate from outside the kayak</td>
<td>4</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Cost</td>
<td>As low cost as possible</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Waterproof</td>
<td>Must be waterproof</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Must be easily maintained or replaced</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Transportability</td>
<td>Must be transportable</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Life</td>
<td>Must last as long as frame</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Safety</td>
<td>Must be safe</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Attachment</td>
<td>Connects top frame to bottom frame</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Must look good</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Assistance</td>
<td>Must help kayaker into/out of kayak</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

Weighted Total: 314  249
Since we will be using many other assistive features, a decision matrix was not required to eliminate options. Instead, a list of requirements that each assistive feature must fulfill is presented in Table 5.

**Table 5. Requirements for other assistive features.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Importance</th>
<th>Compliance</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Height adjustment</strong></td>
<td>Adjustable height to appropriately match height of kayak</td>
<td>5</td>
<td>A,T</td>
<td>A,T</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td>Be able to hold weight of kayaker</td>
<td>5</td>
<td>A,T</td>
<td>A,T</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>As low cost as possible</td>
<td>4</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td><strong>Waterproof</strong></td>
<td>Must be waterproof</td>
<td>5</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>Must be easily maintained or replaced</td>
<td>5</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td><strong>Transportability</strong></td>
<td>Must be transportable</td>
<td>5</td>
<td>A,T</td>
<td>A,T</td>
</tr>
<tr>
<td><strong>Life</strong></td>
<td>Must last as long as frame and lift mechanism</td>
<td>5</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Must be safe</td>
<td>5</td>
<td>A,T</td>
<td>A,T</td>
</tr>
<tr>
<td><strong>Attachment</strong></td>
<td>Detachable from frame or independent</td>
<td>3</td>
<td>A,T</td>
<td>A,T</td>
</tr>
<tr>
<td><strong>Aesthetics</strong></td>
<td>Must look good</td>
<td>1</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td><strong>Assistance</strong></td>
<td>Must help kayaker into/out of kayak</td>
<td>5</td>
<td>A,T</td>
<td>A,T</td>
</tr>
</tbody>
</table>
Boat Ramp Launch Mechanism:

The third component of the overall project design is the mechanism that transports the vehicle up and down the boat ramp. This is divided into two separate devices that function simultaneously to ensure successful travel of the kayaker. The first of these devices is the rigging set-up that will pull the vehicle up the boat ramp. Our goal for this portion of the design is to ensure that the kayaker and kayak safely ride up the boat ramp with minimal assistance from others, as well as allow for future automated motor-driven designs to be implemented into our structure. Since automation is not currently within the scope of this project, we have agreed that this initial design should include some sort of cable or rope attached to the end of the frame of the vehicle. This cable will be wound by a winch device that is capable of pulling the load up the entire distance of the boat ramp. Two ideas for the winch device are shown in the figures below.

The winch in Figure 18 is a hand winch that requires force applied to the handle by an assistant. The winch in Figure 19 includes an electric motor that will reel in the cable with no necessary human input. In order to choose the best device for our design, a comparison of pros and cons of each are compiled in the decision matrix shown below. Also included in the matrix is a column called “just rope”. We wanted to compare mechanical devices to the idea that the cable could be attached directly to the back of a truck, which could pull the kayak out of the water and up the boat ramp.
Table 6. Weighted decision matrix for rigging device.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance</th>
<th>Hand Winch</th>
<th>Electric Winch</th>
<th>Just Rope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Safety</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Maintenance</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Transportable</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Waterproof</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Life</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pull Load Up Ramp</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>78</strong></td>
<td><strong>80</strong></td>
<td><strong>76</strong></td>
<td></td>
</tr>
</tbody>
</table>

According to the decision matrix, all ideas seem fairly close in total value with the electric winch having the greatest result. After further consideration, we have decided to wait to choose which device will be most suitable for our project. We would like to use the electric winch because it will be able to pull the kayak up the ramp with no human effort, but the cost may be too great for the budget of our project. The hand winch is more within our budget, but it does cause safety concerns in that it requires physical human input. If we choose to utilize a hand winch in our design, we will select a gear ratio that will allow minimum user input so that they do not suffer physical strains from a difficult winching device.

The second aspect of our design for the launching mechanism is the braking system for the vehicle. Our goal for this design is to provide the user with brakes that will keep the vehicle moving down the ramp at a comfortable pace during the launch, stop the vehicle at any point on the ramp if the user deems it necessary, and allow for steering of the vehicle so that the kayak enters the water perpendicular to the shoreline. The brakes must also be waterproof because they may have to be totally submerged in water at some point during the launch or retrieval of the kayak. The brakes that we think will best fulfill these requirements are disc brakes like those found on a bicycle. They can be purchased at prices within our target budget and they can be easily incorporated on the axle of our vehicle. An initial illustration is shown in the next figure. Two brakes would be installed on each side of the rear axle. The brake pads would be on a disc attached to the axle and not directly mounted on the wheels as shown. The user could then
control each brake independently which will allow for steering down the ramp towards the water. The only negative aspect of this chosen design is that since the brakes will get wet, once the vehicle leaves the water they must be “pumped” a few times to rid the pads of excess water that would potentially inhibit the brakes from functioning properly.

Figure 22. Disk Brake Illustration
First Chosen Design Concept

- Lower rigid frame that allows for ground clearance while providing means to support the lifting mechanism (Concept C – pg 10)
- A scissor-lift device mounted to each axle that provides independent movement of each end of the kayak so that the user can choose the most comfortable kayak position during entry of the kayak and vehicle (pg 18)
- A rigid top frame that holds the load of the kayak and the user (Concept D – pg 16)
- A cable and winch system that allows travel down the boat ramp for launching and provides the forces necessary to pull the kayak and kayaker up the boat ramp upon exiting the water (pg 23)
- A disc brake system mounted on the rear axle of the vehicle that allows the kayaker to control the direction of the vehicle during the launch and provides immediate braking to address safety concerns that may arise (pg 25)

However, after reviewing our first chosen design concept with our peers, advisor, and sponsors, we felt that this concept was lacking in certain areas. We could not find a scissor jack that was waterproof and corrosion-resistant. Also, having soft straps could cause the kayak and rider(s) to swing back and forth slightly, which could be unsafe. Finally, this concept did not emphasize the assistive lifting mechanism as much as desired. After meeting with our sponsors, it was concluded that a two-stage process would satisfy the requirements much better. Therefore a new concept was developed to address these issues. The new concept led us to our final design.
Final Design Concept

Our final design consists of two parts: A launch vehicle to carry the kayak and a separate lift mechanism to assist the person with disabilities into and out of the kayak.

Launch Vehicle

The launch vehicle has a rigid frame as seen in Figure 23. It consists of two main rails that support the riders and kayak. These two main rails are detachable with use of locking pins to allow for easy transportation of the vehicle to the launch site. The rear axle will be mounted to the rails and have a handlebar attached to it to allow for steering. A Delrin flanged bushing will be used as a bearing for the steering mechanism to reduce wear and make steering feel smoother. Delrin bushings will also be used as bearings for the wheels so they roll with much less resistance. Delrin is a high-strength, low-friction plastic that is lightweight and non-corrosive, making it ideal for our needs. The handlebar is equipped with a dead man’s brake for speed control down the incline of the boat ramp and can be used as an emergency brake. A dead man’s brake works like a traditional brake, except the lever must be released rather than pulled to engage the brake. The brake we will use is a bicycle disc brake that is reconfigured to work backwards, so when the brake lever is released the brake is engaged. With this feature, the cart will automatically stop if the person steering loses their grip on the handle bars. The rigid frame allows for ropes to be attached to the vehicle to help pull the loaded cart out of the water and up the boat ramp.

Figure 23. Launch vehicle
Components and Materials

The bill of materials needed to fabricate the vehicle was found by using common sizes and parts that are readily available from vendors. The launch vehicle will be made from 6061-T6 aluminum. The reason for using 6061-T6 aluminum is its non-corrosive properties and high strength-to-weight ratio. For a list of 6061-T6 properties please see reference [7].

The wheels for the launch vehicle are shown in Figure 24. The wheels will have a safety factor of at least two. We have estimated a cost for all four wheels which can be found in the cost of goods table.

Figure 24. Vehicle wheels

The specific brakes on the vehicle have not been selected, but a disc brake similar to the one found in Figure 25 will be used. We have estimated a cost for the two disc brakes that will be needed for the vehicle. This cost can be found in the cost of goods table.

Figure 25. Hydraulic Disc brake
Bill of Materials
The material needed for this build is as follows:

- Vehicle wheels – 4
- 2 x 2 x 0.25 Square aluminum tubing – 56 feet
- 2.5 x 2.5 x 0.25 Square aluminum tubing – 8 feet
- 2 x 2 Solid Square Shaft – 1 foot
- 1 x 0.25 Round aluminum tubing – 8 feet
- Brake System – 2 brakes

Table 7. Cost analysis of launch vehicle

<table>
<thead>
<tr>
<th>Vehicle Cost</th>
<th>part</th>
<th>cost per unit $</th>
<th># of units</th>
<th>Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x2x0.25 Square Al Tubing</td>
<td>11.30/ft</td>
<td>28 ft</td>
<td>316.4</td>
<td></td>
</tr>
<tr>
<td>2.5x2.5x0.25 Square Al Tubing</td>
<td>14.00/ft</td>
<td>16 ft</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>1x0.25 Round Al Tubing</td>
<td>5.38/ft</td>
<td>4 ft</td>
<td>21.52</td>
<td></td>
</tr>
<tr>
<td>2x2 Square Al Solid Stock</td>
<td>26/ft</td>
<td>2 ft</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>wheels</td>
<td>75/wheel</td>
<td>4</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>brakes</td>
<td>50/wheel</td>
<td>2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Delrin Bushings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Shipping</td>
<td>15% total cost</td>
<td>152.088</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Cost</td>
<td>1166.008</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis

The analysis for the launch vehicle was performed using the same techniques. First we used statics to find reaction forces in the critical members of both the launch vehicle and lifting mechanism. Then we compared the maximum bending stress to the allowable stress and found the required dimensions. We checked the deflections using these dimensions and found that it was too large, so we recalculated the area moments of inertia using larger dimensions. Once deflection was minimized, fatigue and static safety factors were calculated with the new dimensions. Hand calculations and resulting safety factors can be found in the following Appendix: Vehicle Calculations.
Lifting Mechanism

The lifting mechanism will allow safe transportation of the kayaker from their wheelchair into the kayak. Initially we designed our own lifting mechanism for this process, but after further research of existing lifting mechanisms and a detailed cost analysis of our device versus these patient lifts, we determined that our design may not be the most cost effective choice for this portion of our project. Information about our design and existing lifts are detailed below.

Our Design

A preliminary drawing of our lifting mechanism is shown in Figure 26. The concept is that the kayaker would remove a hand rail from their wheelchair while a volunteer removes one from the lifting chair. The height of the lifting chair would be adjusted to the specific height of the wheelchair so that the kayaker is able to slide from one chair to the other. The hand rail on the lifting chair is then reinstalled and other features like a seatbelt are then secured so the kayaker is safely and comfortably situated in the lifting mechanism. The lifting mechanism is then pushed by a volunteer to the kayak and launch vehicle. The height of the lifting chair is adjusted so that it rests on the kayak, directly behind the cockpit. The kayaker can then slide down into the kayak, with the help of an assistant if necessary.

As stated before, the lifting mechanism is height-adjustable, ranging from the lowest wheelchair heights to the height of our kayak once it is placed onto the launch vehicle. To achieve this, we have chosen a marine jack, shown in Figure 27. The lifting mechanism also includes safety features such as hand rails, a back rest, and a safety harness to help support the person with disabilities during the transfer. The outward orientation of the frame rails at the base of the lifting mechanism will allow the mechanism to straddle the wheelchair’s wheel for easy user transfer. Caster wheels are used on the lifting mechanism to allow for easy maneuvering. The two rear caster wheels have locking features for added safety and stability during loading. The lifting mechanism also has a feature that locks it to the launch vehicle to maintain stability while the kayaker transfers from the lifting mechanism to the kayak.

Figure 26. Preliminary design of lifting mechanism
**Bill of Materials**

The material needed for this build is as follows:

- 4 - 3” Caster wheels (Load Capacity - 155 lbs per wheel)
- 16 ft - 2 x 2 x 0.25 Square aluminum tubing
- 6 ft - 2.5 x 2.5 x 0.25 Square aluminum tubing
- 1 - Chair
- 1 - Stainless steel, zinc-coated marine jack (14” height range, load capacity - 2500 lbs)

![Figure 27. Fulton heavy duty marine jack](image)

![Figure 28. Locking caster wheels](image)

**Analysis**

The mathematical analysis for our lifting mechanism is included in Appendix _. We anticipate that our structure is most likely to fail in the aluminum beams that directly support the chair for the kayaker. We modeled this part of the structure as a simply supported cantilever beam with a point load towards the end. With beams of 2.5 x 2.5 x 0.25 square aluminum tubing, we determined that our structure would have a safety factor of about 5 and a maximum deflection of 0.225 inches. We agree that this is sufficient to ensure the safety of the kayakers. A large safety factor was required for reassurance that the mechanism is safe. The marine jack used is made to lift large loads with large torques applied to it. We are using small loads with small torques so the safety factor is very high.
**Researched Patient Lift – Invacare 9805**

The Invacare 9805 Patient Lift is shown in Figure 30. As opposed to our lifting mechanism design that utilizes a cantilever beam setup with an adaptable chair, the Invacare lift uses a crane-like system, lifting the kayaker directly out of their wheelchair and suspending them over the kayak and into the cockpit. The kayaker is supported by a specialized harness, shown in Figure 29. Refer to Appendix _ for product features and specifications of the patient lift and harness. Some features and specifications of the Invacare lift are listed as follows:

- Stainless steel structure
- Hydraulic lift
- Easy Assembly / Disassembly
- Light weight / easily transportable
- Adjustable base for wheelchair access
- 20” – 64” adjustable height range
- 450 lb load capacity
- 5” Caster wheels

![Figure 29. Generic lift harness](image)

![Figure 30. Invacare 9805 patient lift](image)
Cost Analysis Comparison

As stated before, we compared the cost of producing our design to the cost of purchasing an Invacare lift and harness. These costs are illustrated in the tables below. As seen in the tables, the cost of the Invacare lift is significantly less than that of our design. It would also reduce the time commitment necessary to build this part of our design. Therefore, we are going to purchase the Invacare lift in order to safely and successfully transfer the kayakers from their wheelchairs into the kayaks.

Table 8. Cost analysis for designed lifting mechanism

<table>
<thead>
<tr>
<th>Lifting Mechanism Cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>part</td>
<td>cost per unit $</td>
</tr>
<tr>
<td>Caster Wheels</td>
<td>4.50/wheel</td>
</tr>
<tr>
<td>Marine Jack</td>
<td>85.00/jack</td>
</tr>
<tr>
<td>2x2x0.25 Square Al Tubing</td>
<td>11.30/ft</td>
</tr>
<tr>
<td>2.5x2.5x0.25 Square Al Tubing</td>
<td>14.00/ft</td>
</tr>
<tr>
<td>Bench</td>
<td>60/seat</td>
</tr>
<tr>
<td>Total Shipping</td>
<td>15% total cost</td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Cost analysis of Invacare lift and harnesses

<table>
<thead>
<tr>
<th>Invacare Patient Lift</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>part</td>
<td>cost per unit $</td>
</tr>
<tr>
<td>Lift</td>
<td>350/lift</td>
</tr>
<tr>
<td>Sling</td>
<td>20/sling</td>
</tr>
<tr>
<td>Total Shipping</td>
<td>FREE</td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
</tr>
</tbody>
</table>
The NEW Kayak Launch Process

With the use of our launch vehicle and the Invacare lift, we have designed a new process for the Cal Poly Adapted Paddle program that is efficient while maintaining the safety of the participants. This new process for launching the kayak down the boat ramp and retrieving it from the water is explained as follows:

1. Kayak is secured to launch vehicle and brakes are checked
2. Assistant helps kayaker secure lifting harness
3. Assistant attaches harness to Invacare lift
4. Assistant pumps hydraulic lift so that kayaker is suspended
5. Assistant pushes Invacare lift and kayaker to kayak and launch vehicle
6. Assistant pumps hydraulic lift, lowering kayaker into the kayak cockpit
7. Harness is detached from lift and Invacare lift is rolled away
8. Padding is added to kayak to provide comfort for kayaker
9. Assistant climbs into rear cockpit of kayak
10. Another assistant holds onto handle of vehicle and deactivates braking system
11. Assistant pushes vehicle + kayak + kayakers down boat ramp to water
12. Exiting water is the same process in reverse

Safety

Safety played a major role in our design process due to the fact that we were dealing directly with human users. Careful considerations were made to keep users as safe as possible while operating our apparatus. As previously stated our design was broken into two parts which consist of the launch vehicle and lifting mechanism. Each part has its own safety considerations.

The launch vehicle was designed with two goals in mind: transportability and strength. Having detachable rails solved the transportability problem but posed a new safety concern. The vehicle could fall apart if not properly assembled. To solve this safety issue the assistants will be trained on the proper method of assembling and checking the vehicle. The joints where the rails will connect with one another will be labeled to show assistants that a pin must be placed in that area. The pins will remain connected to the rails to avoid them being misplaced. Before operation, a final walkthrough will be necessary to ensure that all pins have been inserted.

The Invacare patient lift is guaranteed not to fail under loads less than 450 lbs according to the manufacturer. There is, however, some assembly required, which could potentially affect the overall stability of the structure if not assembled correctly. There is also a potential for safety issues if the harnesses for the kayakers are not secured correctly. As with our launch vehicle, we will provide training documents so that the volunteers will know how to properly assemble and check the device and harness.
Vendor List

The following table has a list of parts and the vendors they will be obtained from.

Table 10. Vendor list

<table>
<thead>
<tr>
<th>Part</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caster Wheels</td>
<td>Northern Tools and Equipment</td>
</tr>
<tr>
<td>Vehicle Wheels</td>
<td>Skyway Wheels</td>
</tr>
<tr>
<td>2x2x0.25 Square Al tubing</td>
<td>Metals Depot</td>
</tr>
<tr>
<td>2.5x2.5x0.25 Square Al tubing</td>
<td>Metals Depot</td>
</tr>
<tr>
<td>2x2 Solid Square Al tubing</td>
<td>Metals Depot</td>
</tr>
<tr>
<td>1x0.25 Round Al tubing</td>
<td>Metals Depot</td>
</tr>
<tr>
<td>Brake System</td>
<td>Local bike shop</td>
</tr>
<tr>
<td>Delrin Bushings</td>
<td>Plasticbushingdesign.com</td>
</tr>
</tbody>
</table>

Maintenance and Repair

One of our design goals is to keep both mechanisms low maintenance. The Invacare patient lift has warranties for parts like the hydraulic pump, and most parts like the caster wheels are easily replaceable. As for our launch vehicle, we hope to ensure low maintenance by designing a simple vehicle with a low part count. The material for both devices is water and rust proof. Both vehicles must be rinsed after each use to keep them clean and in working order. This can be done with water and a garden hose, no cleaners required.

To allow for easier repair of our launch vehicle if a component wears over time, all parts must be easily replaced. We are designing with standard, common parts so repair issues should be minimal. Some parts that may need to be eventually replaced are as follows:

- Pins - These can be misplaced even with the wire attached to them. Replacements can be found at hardware stores.
- Delrin bushings - The steering and wheel bushings will eventually wear out. Replacements can be ordered from the website listed in the above table.
- Brakes - The brakes will eventually wear out so replacements will be needed to continue safe operation. Replacements can be found at cycle shops.
- Rail padding - After many cycles of loading and unloading kayaks on the launch vehicle, the padding can wear off. A good example of this is the padding on boat trailers. Replacements can be found at department stores.
Build Plan

We will be utilizing all possible resources that Cal Poly has available for the fabrication of our launch vehicle and lifting mechanism, namely the machine shops and shop technicians. We have used computer-aided design (CAD) to make fully dimensioned engineering drawings that will be used as references for the actual machining and welding processes.

Most of the fabrication will be performed by us: We will be cutting, drilling, and assembling most of the parts for launch vehicle. However the expertise of the machine shop technicians will be required for some of the welds, as welding thin aluminum requires considerable expertise. We want to be able to guarantee the safety and durability of our final product, so out-sourcing the more advanced fabrication to expert machinists is really the only option. We opted to weld some permanent connections rather than bolt them because it will significantly reduce the part count and cost, increase the safety, and provide equal strength. Also the welded sections will be easily repairable or replaceable should any damage be sustained.

The welding will be done first, for the most part. This is typically the first step of fabrication because welding causes distortion of the welded material due to the very high temperatures the material experiences. Therefore, welding is done first so that after parts are machined, they still fit correctly. We will have to cut some of our aluminum tubing to length in order to perform all the required welding. After the welding is complete, we will drill the holes for the pin connections and assemble the rest of the structures. Next we will tap the axle holes and mount the wheels and brakes. Finally, we will run brake cable to the launch vehicle handle and finish installation of the rear axle (the one that turns the cart). After fabrication and assembly is complete, we will begin testing our product.
Ethical Considerations

The most apparent ethical issue that we faced with our design involves the safety of the kayakers using the launch vehicle and the volunteers that assist them. As previously stated, during the design process, we took careful consideration of the safety features we thought were necessary to ensure that all users had a fun and safe experience. The dead-man’s brake, for example, was implemented to prevent the vehicle from traveling at high speeds down the boat ramp. Also, the safety factors in our structural analysis are all at least at a value of five to guarantee that the vehicle will not collapse under the load of the kayak and kayaker.

When designing the structure, we wanted to create something extra rigid in order to maintain the high safety factors. However, one specification of the project is that the vehicle could be easily disassembled in order to transport it between Cal Poly and the boat ramp where the vehicle is launched. This presented two issues: the disassembly / assembly could compromise rigidity and inaccurate assembly of the vehicle by the program volunteers could directly affect the safety of the kayakers. After further analysis, we determined that the first issue would not be a problem with our design and that the vehicle would still maintain its strength despite removable connections. The second issue presented an ethical problem. We had to decide if it is acceptable to place the safety of the kayakers in the hands of the volunteers. Ideally we wanted to construct a vehicle that did not require assembly by a volunteer so that incorrect assembly issues could be avoided. However, there did not seem to be a way to transport the large vehicle without the ability to take it apart. After further considerations, we agreed that as long as the paddle launch program implemented training to teach volunteers the proper assembly of the vehicle, it would be acceptable to construct a product that can be taken apart for transportation purposes. To assist this training, we have composed an assembly section that is included later in this report.

Design Verification Plan

The following tables summarize the specifications that require testing in order to ensure that the vehicles are safe and functioning as designed. There is a specification checklist for both the launch vehicle and lifting mechanism. These test procedures will be more detailed as the building phase of the project progresses. Each specification must meet the corresponding requirements. Note that the test procedures that are listed as “User Survey” refer to a questionnaire that we will compose before the testing phase of this project begins. These surveys will allow us to better understand any concerns that the kayakers and assistants may have during the launch process so that we can make the necessary adjustments to our structures to improve user satisfaction and safety.
Table 11. Launch vehicle specification checklist

<table>
<thead>
<tr>
<th>Specification Number</th>
<th>Parameter</th>
<th>Requirement</th>
<th>Test Procedure</th>
<th>Verification Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Safety</td>
<td>Very Safe</td>
<td>Trial Runs of Process / User Survey</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>Aesthetics</td>
<td>Aesthetically Pleasing</td>
<td>User Survey</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Ease of Use</td>
<td>Easy for User / Assistants</td>
<td>User Survey</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>Transportable</td>
<td>Attach to Kayak Rack</td>
<td>Verify On-Site</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Corrosion Resistant</td>
<td>Waterproof Materials</td>
<td>Assess Components after Several Trial Runs</td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>Weight Capacity</td>
<td>600 lbs</td>
<td>Trial Run with 600 lb Load</td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>Kayak Stability</td>
<td>No &quot;Rocking&quot; Movement</td>
<td>Verify On-Site</td>
<td>X</td>
</tr>
<tr>
<td>8</td>
<td>Kayak Damage</td>
<td>None</td>
<td>Assess Kayak after Trial Run</td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>Assembly / Disassembly</td>
<td>Easy / Fast</td>
<td>Record Assistant Time / Survey</td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>Weight</td>
<td>&lt; 100 lbs</td>
<td>Weigh Structure</td>
<td>X</td>
</tr>
<tr>
<td>11</td>
<td>Comfort</td>
<td>User Satisfaction</td>
<td>User Survey</td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td>Cleaning</td>
<td>Easy</td>
<td>Rinse with Hose</td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>Braking System</td>
<td>No Failure</td>
<td>Test On-Site</td>
<td>X</td>
</tr>
<tr>
<td>Specification Number</td>
<td>Parameter</td>
<td>Requirement</td>
<td>Test Procedure</td>
<td>Verification Checklist</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------</td>
<td>----------------------------</td>
<td>-----------------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Safety</td>
<td>Very Safe</td>
<td>Trial Runs of Process / User Survey</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>Aesthetics</td>
<td>Aesthetically Pleasing</td>
<td>User Survey</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Ease of Use</td>
<td>Easy for User / Assistants</td>
<td>User Survey</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>Assembly / Disassembly</td>
<td>Easy / Fast</td>
<td>Record Assistant Time / Survey</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Transportable</td>
<td>Attach to Kayak Rack</td>
<td>Verify On-Site</td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>Corrosion Resistant</td>
<td>Waterproof Materials</td>
<td>Assess Components after Several Trial Runs</td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>Weight Capacity</td>
<td>300 lbs</td>
<td>Trial Run with 300 lb Load</td>
<td>X</td>
</tr>
<tr>
<td>8</td>
<td>Height Range</td>
<td>14 in</td>
<td>Adjust Height from Minimum to Maximum</td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>Comfort</td>
<td>User Satisfaction</td>
<td>User Survey</td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>Cleaning</td>
<td>Easy</td>
<td>Rinse with Hose</td>
<td>X</td>
</tr>
<tr>
<td>11</td>
<td>Brakes</td>
<td>No Failure</td>
<td>Test On-Site</td>
<td>X</td>
</tr>
</tbody>
</table>
ROLES AND RESPONSIBILITIES

In order to ensure that our project progresses efficiently, we have dispersed several responsibilities between all team members. These are shown below. As we get further into the design process and even begin to build our prototype, the roles will change and expand to include other areas of responsibility, like material gathering, welding, etc. These roles have not yet been delegated.

Everyone:

- Compose required technical documents
- Model the chosen concepts with CAD
- Participate in background research including patent searches, surveys of potential users, and observation of the adaptive kayak program on campus

Shannon Crilly:

- Lead contact between project team and sponsor
- In charge of schedule organization and updates
- Lead designer for launching mechanism – the component that will lower and raise the kayak down and up the boat ramp

Erik Granstrom:

- Lead designer for User accessibility – the devices that will allow for easy entry and exit of the kayak

Duane Menton:

- Designer of device structure and co-lead in stress analysis

Matthew Resendez:

- Designer of device structure and co-lead in stress analysis
The roles and responsibilities have also been put in table 2 which can be found below for quick and easy access.

Table 13: Roles and Responsibilities

<table>
<thead>
<tr>
<th>Role</th>
<th>Duane Menton</th>
<th>Erik Granstrom</th>
<th>Shannon Crilly</th>
<th>Matthew Resendez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compose Technical Documents</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CAD Models</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Background Research</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lead Contact</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Launching Mechanism for Pulling and Lower Vehicle into Water</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Entry and Exit Assisting Device</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Design of Structure</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Stress Analysis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Timeline Summary:
In the Gantt chart found in the Appendix, you will find a detailed schedule of our tasks. These tasks are milestones that we wish to accomplish as we progress through our project. These dates and times to completion are rough estimates and have been changed as needed throughout the project.
Final Design

The final completed design is shown in the picture below. The computer modeled drawings of the vehicle are included in the appendix.

With this design, the center rails attach to the front axle which is fixed and also to a collar on the rear axle which swivels so you can steer the vehicle. Two rails come off the rear axle at 45 degree angles to provide a hand rail to push and pull. Hydraulic brakes are mounted on stainless steel rotors which are secured to the rear tires to provide braking down the boat ramp. The brakes were modified to operate in reverse as a “Dead Man’s Brake”. A strap secures the kayak to two carpet-covered rails. The carpet provides extra friction between the rails and the kayak when the vehicle gets wet and prevents the kayak from slipping off. Delrin bushings were used between the axles and the wheel hubs due to their low maintenance, low cost, high strength and corrosion resistance that is not present with many low cost bearings. Delrin does not require grease or oil because it is a self lubricating material. Therefore there is no need to constantly apply grease. Since this vehicle is being submerged in salt water, a material was required that would not rust and leave grease in the water.

In order to transport the kayaker to and from their wheelchair and the kayak vehicle with little physical strain on the program volunteers, the Invacare lift was purchased. It is shown in the picture on the following page.
Build Procedure

The first step of building was cutting the extruded aluminum to length and prepping the edges for welding. Once preparations were complete, welding was performed by Eli Knight, a master welder and welding teacher at Cuesta College. Since the aluminum was so thick, it had to be preheated to 700 °F at the weld locations to achieve satisfactory weld penetration. The results were outstanding, as expected. The next step was to drill all the holes to mount axles, wheels, brakes, and pin connections. This was performed using hand drills and a drill press to ensure hole alignment. In order to get the rails of the launch vehicle to fit smoothly into their slots we had to mill the outer surface off. This reduced the size enough that they would slide on and off easily but still fit securely. We also had to tap our axle mounts so an axle could be threaded in. Next, Delrin bushings were machined to fit into the steering mechanism and wheel hubs and the launch vehicle was mocked up to see how everything fit together. Once everything was fit together, we could assemble and tune the brake system. We mounted a handle bar and brake bar, then attached springs to the brake bar. The brake bar was also connected to the levers of our Avid Code 5 disk brake kits such that the release of the brake bar would engage the brakes. The brake rotors and calipers were mounted and the brake system was tuned to optimize braking power and minimize misalignment of the rotors. Finally, the launch vehicle was cleaned thoroughly and painted. Painting the vehicle protects it from the harsh, corrosive environment of the ocean, and
improves aesthetic appeal. Once paint was dry, a layer of waterproof exterior carpet was attached to the rails that the kayaks sit on to ensure no damage was done to the kayak bottoms. After painting, final assembly was completed and testing was performed. The following figures offer a visual timeline of the build procedure.

Figure 31. Left: Welding handle bar mounts to steering axle.

Figure 32. Left: Drilling an axle mount on the drill press. Right: Tapping an axle mount.
Figure 33. Left: Drilling pin connection hole. Right: Checking pin hole for proper fitment.

Figure 34. Mock up of launch vehicle before application of paint and carpet.
Figure 35. The completed launch vehicle.

Figure 36. Close-ups of dead man brake system and calipers/rotors.
Vehicle Assembly and Disassembly

The following is a list of steps to assemble and disassemble the launch vehicle. Pictures of the parts can be found after the maintenance section.

Assembly

1. Go over the check list in the maintenance section before assembly.
2. Attach steel cables to the brake levers by pulling down on the brake lever and sliding the eye-loop over the lever. This should engage the brakes, if brakes are not engaged look to vehicle maintenance section.
3. Match the direction of the long rails by using the color coding on the steering axle and the long rails (carpet must be facing upwards).
4. Attach long rails to the steering axle first, by using the connect pins and lining up the pin holes by sliding the long rails into the appropriate shelves.
5. Attach long rails to non-steering axle by way of the connecting pins and lining up the pin holes by sliding the long rails into the appropriate shelves, NOTE: the non-steering axle should have the pin wiring attachment point towards the middle of the vehicle.
6. Double check all pin connections.
7. Double check brake power by pushing vehicle with brakes engaged. The wheels should not roll, if they do look to maintenance section.

Disassembly

1. Remove long rails from non-steering axle by pulling out the pin connections and sliding the rails out.
2. Remove long rails from steering axle by pulling out the pin connections and sliding the rails out.
3. Replace all pin connections into the proper hole without the long rails to avoid losing or damaging the pins.
4. Remove steel cables from brake levers by pulling down the brake lever and sliding the eye-loops off of the levers.
5. Review the “before storing” procedure found in the maintenance section before storing the vehicle.

Lift Assembly and Disassembly

See user manual in the appendix under assembly and disassembly section.
**Vehicle Maintenance**

The following is a list of thing to do before and after the vehicle storage. Pictures of the parts can be found after the maintenance section.

**Before Storing**

- Rinse off entire vehicle with water to avoid a buildup of salt.
- Make sure brakes are disengaged by removing steel cable off both brake levers.
- Reattach connection pins without the two long rails inserted into the axles, so not to lose or damage them.
- Disconnect handle bar assembly for easier storage (Not Required):
  - Remove brake levers by unscrewing bolts on back side of the handle bar assembly.
  - Removed zip ties by cutting them off.
  - Remove pins on handle bar assembly and replace them in the hole provided on the axle.
  - Store brake levers with screws together so not to be loss by rethreading the screws back into the brake levers.

**After Storage**

- Check that none of the connecting pins are lost, replace if needed.
- Check attachment of brake calipers by giving a firm shake to the I-shaped mounting brackets, no moment should be present:
  - If movement is present replace screws for safety reasons.
  - Also check mounting bolts for calipers.
- Check wheel clearance by giving each wheel a firm shake:
  - Each wheel should have minimal movement, less than an eighth of an inch in each direction.
  - If more or less movement is detected then tighten or loosen wheel by holding the inside nut with an open end wrench and turning the bolt with another open end wrench to the desired tightness.
- Check that wheel nut, found between the wheel and the axle, is torque tightly against the axle shelves to insure that wheel does not spin off during usage.
- Check that round handle bar is securely attached to the handle bar assembly, tighten nuts if necessary.
- Check to make sure springs are securely positioned on the braking bar and the handle bar rails.
- Check screws on the carpet, if missing replace.
• Check all Delrin bushings, both in the wheels and steering mechanism. If cracked or worn out then replace.
• Check mounting bolt for steering arm, make sure both nuts are tightened lightly to the bottom of the steering axle for desired steering action, also be sure to tighten second nut firmly to the first nut to lock in place.
• Check all other screws, bolts, and nuts. If loose then tighten securely.
• If handle bar assembly was stored separate from axle:
  o First place handle bar assembly back into the axle by using the pin connections.
  o Reattach the brake level with the long bolts provided.
  o Zip tie the brake line out of the way along the handle bar assembly.

**Brake malfunction**
• Look to the brake lever adjustment in the user manual on the brakes found in the appendix.
  o Adjust brake lever stiffness to achieve desired braking action.
• If this does work replace steel cables for desired braking action.
• If brake will still not work look to the user manual for the brakes to diagnose and fix the problem.

**Lift Maintenance**

See user manual for proper storage techniques and maintenance found in the appendix. All necessary pictures for parts can also be found in this user manual.

*Figure 37: Picture of parts found near the handle bar.*
Mounting calipers bolts
Caliper mounting bracket
Wheel nut

Figure 38: Picture of parts found near wheel.

Wheel bolt

Figure 39: Picture of parts found near wheel.
Figure 40: Picture of parts found on the steering axle.

Figure 41: Partial picture of long rails.

Figure 42: Picture of non-steering axle.
Vehicle Testing

For the initial testing of our design, we assembled the vehicle on flat ground and placed a kayak along its main rails. We then added passengers in the kayak to ensure that the structure could hold the required weight. One team member then pushed and steered the vehicle on the flat ground while the kayak remained loaded. After we verified that the vehicle could hold the load and be easily steered on flat ground, we took the vehicle to the Morro Bay boat ramp to test it in use. At the boat ramp, we loaded the vehicle with a kayak and two passengers. We then went through the launching process, using only two people to steer the vehicle down the boat ramp and into the water. After determining that the vehicle successfully and safely transported the passengers into the water, we repeated the process.

During the second test run, we simulated a situation where the assistants steering the vehicle let go while the vehicle was on the boat ramp. This would verify that the braking system was functioning as intended. As expected, the vehicle and the kayak stopped immediately on the boat ramp, preventing the passengers from accelerating into the water at unsafe speeds.

After verifying that the vehicle functioned properly, our last test was to distribute a survey amongst the kayakers and volunteers of the paddle program the following weekend. The results are included in the following table. Note that the scores listed are an average taken from all of the surveys, with 5 being the best score and 1 being the worst.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Program Kayakers</strong></td>
<td></td>
</tr>
<tr>
<td>Do you feel comfortable riding in the vehicle?</td>
<td>5</td>
</tr>
<tr>
<td>Is the patient lift comfortable?</td>
<td>5</td>
</tr>
<tr>
<td>Is the harness/lift less invasive than being lifted by the volunteers?</td>
<td>4</td>
</tr>
<tr>
<td>Do you feel safe when being transported down the boat ramp?</td>
<td>5</td>
</tr>
<tr>
<td><strong>Program Volunteers</strong></td>
<td></td>
</tr>
<tr>
<td>Is the steering comfortable?</td>
<td>3</td>
</tr>
<tr>
<td>Are the brakes easy to activate / inactivate?</td>
<td>4</td>
</tr>
<tr>
<td>Overall, is the vehicle easier than carrying the kayak down the boat ramp?</td>
<td>5</td>
</tr>
<tr>
<td>Is it easy to secure the rider in the patient lift harness?</td>
<td>4.5</td>
</tr>
<tr>
<td>Is the patient lift easy to use / straightforward?</td>
<td>4.5</td>
</tr>
</tbody>
</table>
As shown in the table, the kayakers were comfortable using our vehicle. The volunteers also agreed that the vehicle was a much easier solution to get the kayaks in the water than carrying them down the boat ramp. They did have mixed responses regarding the steering of the vehicle, which was the lowest score on the survey. Despite this result, the kayakers felt safe and the volunteers learned the steering as they had more practice. Overall, the survey proves that the implementation of the launch vehicle into the paddle program was a success.
APPENDICES

PRODUCT [1]

Below is a description of the kayak docking device along with some pictures. For more information about this see Reference [2].

*EZ Dock now provides a stable and durable system for boarding and exiting kayaks. Designed to be especially valuable for seniors or anyone that could benefit in assistance for launching or recovering from kayak or canoe activities the system provides a dry and safe platform.*

*The EZ Launch™ - Kayak and Canoe system is modular and can be configured to match any dock configuration you require. Since it is designed to withstand extreme weather conditions, the dock can remain in the water year round since ice has no affect on the dock structure, it simply “pops” to the top as an ice cube tray since it only requires 1.5” of water to float.*

*For Handicapped Access EZ Dock provides another EZ Launch model containing a hydraulic lift that is solar powered (see first video clip). This lift is designed to extend kayak and canoe access for special need users and it is simply another docking station that can be installed as a stand alone system or integrated with the standard EZ Launch - Kayak & Canoe.*

*See the EZ Dock [Kayak Rack](#) as well, another exciting accessory which allows you to store up to four kayaks on one rack and the dock system can support any number of kayaks.*
PRODUCT [2]

Below is the first page of the patent. It also contains a picture of the device. For more information on this product see Reference [3].
PRODUCT [3]

Below is a description of the kayak docking device along with some pictures. For more information about this see Reference [4].

WHEELEEZ Canoe/Kayak Tote Features:
- Heavy duty aluminum frame, completely marine grade anodized
- Sturdy double legged kick stand for easy one person loading
- Large detachable wheels with balloon tires
- Collapsible for easy in-boat storage
- Includes two 4m (13') tie-down straps
- Optional seat cover converts it to a camp stool

Tote Specifications: (For assembled tote)
- Tote Weight: 4.5kg (10 lbs)
- Crossbar to ground: 38cm (15")
- Width at axle: 90cm (35.5")
- Frame size folded, less wheels: 90x35x10cm (35.5"x13.5"x4")
- Anodized, heavy duty aluminum frame
- Maximum tote capacity: 80kg (176lbs)
- Roleez Balloon Wheels: 30x18cm (11.8x7")
- Inflate tire to maximum 0.27 Bar (4 psi)
- Use low pressure gauge for proper tire inflation
- Keep all parts freshwater rinsed and dry for storage and transport

IMPORTANT: ROLL AT WALKING SPEED ONLY!
DO NOT TOW WITH MOTORIZED VEHICLES!

Loading Technique:
- Assemble tote, extend kick-stand
- Place boat on tote with mid point of hull slightly aft of cross bar
- Strap boat to tote as pictured: one strap per cross bar
- Remember to retract kick-stand before rolling

Parts List:
1. Pre-assembled, anodized aluminum frame unit
2. Wheel assemblies
3. Quick clip pins
PRODUCT [4]

Below is a description of the kayak docking device along with some pictures. For more information about this see Reference [5].

BeasyTrans

The BeasyTrans is a portable transfer system that is designed to transfer an individual from a wheelchair to an automobile, bed, commode, or shower bench, etc. A safe seat supports the user's weight as the transfer occurs. The friction is borne by the system, not the user's skin. The circular seat rotates 360 degrees to easily turn the user to the exact angle for comfortable placement. With frictionless, sliding transfer technology, the BeasyTrans allows even the smallest caregiver to transfer patients weighing up to 400 lbs. using a smooth lateral glide. The secret is the way the seat moves smoothly across the base. Since there is no lifting involved, it helps to reduce back and brachial plexus type injuries.

The BeasyTrans system is available in three forms. The original BeasyTrans transfer board is 40" long. The BeasyTrans II is more compact, used for smaller areas and is 27 1/2" long. The BeasyGlyder is designed for transferring an individual from a wheelchair when an arm or wheel are obstacles.

BeasyTrans Features:
- Eliminates Lifting
- Increases Mobility
- Dignifies Transfers
- Reduces Back Injuries
- 40 inch and 27.5 inch Lengths
- Provides Frictionless Sliding Transfers

BeasyTrans Specifications:
- Length: BeasyTrans 40" / Beasy II 27.5"
- Width: Both systems 12" diameter seat
- Thickness: Both systems - 1" base, 1/2" seat
- Weight: BeasyTrans - 6.5 lbs. / Beasy II - 4.5 lbs

BeasyGlyder Features:
- Goes Around Wheelchair Arm
- More Time-Saving
- Increased Mobility
- No More Lifting
- Frictionless
- Portable
- Reduces Brachial Plexus Type Injuries
- Supports up to 400 lbs.
- Facilitates Caregivers
- Natural Transfer Motions

BeasyGlyder Specifications:
- Length: 32"
- Width: 10" Diameter seat & base
- Thickness: 5/8" Base, 3/8" Seat
- Weight: 4.75 lbs.
PRODUCT [5]
Below is a description of the kayak docking device along with some pictures. For more information about this see Reference [6].

Invacare Hydraulic Lift - Painted

Model No. 9805P

Features
Easy disassembly for transport and set-up.
20" to 64" range allows patient to be lifted from the floor.
Locking casters option available.
Economical with a 450 lb. weight capacity.

Description
The Invacare 9805P painted hydraulic lift was created to make transfer situations safe and affordable for everyone involved. And with its slim design, the hydraulic lift is versatile enough to use for any and all patient moves.
The features of the 9805P include a padded swivel bar and push handle, a 450-pound weight capacity, durable steel construction and 360 degrees patient rotation without side-to-side sway. Lightweight construction and easy disassembly allow quick transport and setup.

Specifications
Base Width: Open: 42.25" Closed: 22"
Base Length: 46.75"
Caster Options: Front: 5" Rear: 5"
Overall Height: Maximum @ sling hookup: 64" Minimum @ sling hookup: 20"
Base height: 6.5" (clearance)
Product Weight: 68 lbs.
Product Weight Capacity: 450 lbs.
Warranty: 3 Years
Bench Calculations

Sizing of Bench

Stresses:

\[ F = \frac{F}{2} \]

\[ R = \frac{F}{2} \]

\[ M = \frac{F}{2} \]

\[ M = \left( \frac{F}{2} \right) \cdot \text{in} \cdot \text{lb} \]

Bending:

\[ \sigma = \frac{M c}{I} \]

\[ c = \frac{b}{2} \]

\[ I = \frac{b^4}{12} \]

\[ S = \frac{M I}{c} \]

\[ S = \frac{G M}{h^2} \]

\[ h = \frac{G (4000)}{9000/9} \]

\[ h = \frac{G (4000)}{9000/9} \]

\[ h = 1.216 \text{ in} \]

For hollow shaft:

\[ \frac{h^4}{12} = \frac{h^4}{12} - \left( \frac{h-20}{12} \right)^4 \]

Let \( t = 0.25 \)

\[ h = 1.2599 \text{ in} \]

Required size for static strength

USE: \( h = 2 \text{ in} \)

Check deflection:

\[ I = \frac{h^4}{12} - \left( \frac{h-20}{12} \right)^4 \]

\[ h = 2 \text{ in} \]

\[ t = 0.25 \text{ in} \]

\[ V_{max} = \frac{F (32)}{6 (10.4968)(0.9135)} \]

\[ V_{max} = -0.222 \text{ in} \]
FATIGUE:

\[ S_{e'} = 0.5 S_{ot} \]
\[ = 27.5 \text{ ksi} \]

\[ K_a = 0.5^b \quad c \quad \text{ASSUME: machined} \quad a = 2.70 \]
\[ b = -0.265 \]
\[ K_a = 0.9846 \]

\[ K_b = 0.879 \]
\[ d_e = 0.808 \]
\[ = 1.114 \]

\[ K_w = 0.835 \]

\[ K_c = 1 \quad \text{Bending} \]

\[ K_d = 1 \quad \text{Temp. Factor} \]

\[ K_e = 0.702 \quad \text{99.97% Reliability} \]

\[ K_f = 1 \quad \text{misc. Factor} \]

\[ K_g = 1 \quad \text{Assume no stress concentrations} \]

\[ S_e = K_a K_b K_c K_d K_e K_f K_g S_{e'} \]
\[ = 9846(0.835)(0.702)(27.5) \text{ ksi} \]

\[ S_e = 12.97 \text{ ksi} \]

\[ \sigma_{max} = \frac{M E}{I} \]
\[ = \frac{4000(1)}{.9115} \]
\[ = 4389 \text{ psi} \]

\[ \sigma_{min} = -\sigma_{max} \]
\[ = -4389 \text{ psi} \]

\[ S_a = \frac{\sigma_{min} + \sigma_{max}}{2} \]
\[ = 2195 \text{ psi} \]

CHECK \[ n' = \frac{M c}{I} \]
\[ M_c = 4.59 \]

\[ n_s = \frac{S_{y}}{M E} = \frac{4000(0.115)}{4000(1)} \]
\[ n_s = 9.12 \]
Vehicle Calculations

Sizing of Cart Rails

$M_{max} = 3153 \text{ in} \cdot \text{lb}$

$S_{max} = \frac{M_{max} \cdot c}{t} \Rightarrow h = \left( \frac{6 \cdot M}{27 \cdot a} \right)^{1/3}$

$h = 1.121 \text{ in} \quad \leftarrow \text{solid}$

$h = 1.152 \text{ in} \quad \leftarrow \text{hollow}$

Check DEFL. For 2" x 2" x 1/4" t
Sizing of Cart Rails

ME 42B

Ferrite:

$$F_{ferrite} = \frac{250(21+8C) + 100(48)}{48}$$

$$F_{ferrite} = 657 \text{ lb}$$

$$R_{cut} = 3285 \text{ lb}$$

$$Y_{max} = \frac{R_{c}^{3}}{4BEI}$$

$$= \frac{3285(96)^{3}}{48(10400\times 9.115)^{3}}$$

$$Y_{max} = 0.64 \text{ in}$$

Fatigue:

$$\sigma_{max} = \frac{Mc}{I}$$

$$\sigma_{max} = \frac{3153(1)}{0.9115}$$

$$\sigma_{max} = 3459 \text{ psi}$$

$$\sigma_{a} = \sigma_{a} = \frac{1}{2} \sigma_{max}$$

$$\sigma_{a} = 1729.5 \text{ psi}$$

$$n_{F} = \frac{1}{\sigma_{a} / \sigma_{e} - 5000 \text{ psi}}$$

$$n_{F} = 5.83$$

$$n_{y} = \frac{M_{c}}{I} \Rightarrow n_{y} = \frac{51}{M_{c}}$$

$$= \frac{40000(9.115)}{3153(1)}$$

$$n_{y} = 11.56$$
Invacare Hydraulic Lift User Manual

Refer to the Invacare website for the user manual and all troubleshooting needs:


Bike Brakes User Manual

Refer to the Avid website for the Code 5 user manual:

REFERENCES


http://www.ezdockusa.com/contentpage2.cfm?page=kayak-docking-station


http://www.beachcartsusa.com/canoekayaktoteframe.htm

http://www.lifewithease.com/beasytrans.html


http://www.matweb.com/search/DataSheet.aspx?MatGUID=1b8c06d0ca7c456694c7777d9e10be5b&ckck=1


http://www.norterntool.com/webapp/wcs/stores/servlet/product_6970_200155574_200155574
Note: Cut each member at 22.5 degrees
Note: All cuts at 45 degrees
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<th>LEC SEC:</th>
<th>NEXT ASSY: Launch Vehicle</th>
<th>SIGNATURE:</th>
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