Elk Ridge Ski Area: Poma Lift Stick

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Document

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1.0 Introduction

The Elk Ridge Ski and Outdoor Recreation Area, located in Williams, AZ is in need of a new Poma lift stick that accommodates both skiers and snowboards equally. Our clients, Tammy Fountain and Jim Gratton, have requested that a senior capstone team from NAU help develop a new design to make the lift equally accessible for skiers and snowboarders.

The current Poma lift stick design consists of a straight pole attached to a spring mechanism which clamps onto the lift cable when removed from the pole storage area. The end of the pole is curved slightly to ensure ease of boarding and dismount. It also has a small round disc to support the riders' weight while being transported up the lift line. This is convenient for skiers whose feet are separated, but very inconvenient for snowboarders whose feet are both strapped down together.

Based on our initial conversations with our clients, the following needs statement was developed:

> "The current Poma lift stick does not accommodate skiers and snowboarders with equal support and comfort."

From this need statement and further discussion with our client, it was determined that there were several objectives for this project. Some of these are: accommodating a wide variety of people, maintaining contact with the ground while providing obstacle clearance, and allowing riders to board and dismount the lift quickly. These objectives led to the development of the following set of design requirements.

- The cost to manufacture the new device must cost less than the price of a new Poma lift stick purchased from Poma.
- It must take less than thirty seconds to board or dismount the lift.
- The new device must have an attachment configuration that has the exact same size and dimensions as the current attachment configuration.
- There can be zero millimeters between the bottom of a rider's ski or snowboard and the packed snow.

- The new devices must be able to vary in height by 0.5 meters to traverse obstacles under the snow (rocks, branches, etc.).
- There must be 1.5 meters of head clearance measured vertical from where a rider's weight is carried.
- The device must be able to hold a 180 kg person without deforming more than 5 mm.
- The material must have a life of at least 40 years under all loads and weather environments.

2.0 Final Design

The final design of this project consists of three different design areas. The first is the pole design which is the main structure of this project. It defines the shape and function of this design. The second portion is the plate design which provides the extra support and comfort that makes using this design practical and enjoyable for riders. The final portion of the design is the inner pole assembly which is maintained from the old Poma lift system.

2.1 Pole Design

The finalized design of the new Poma stick consists of a ninety-six inch straight bar followed by a 120o angle bend. There is then a twenty inch straight portion followed by a 90o bend. The final portion consists of a twenty inch straight portion with another 90o bend at the end. This configuration creates a long straight segment that attaches to the lift line with a flattened out "U" shaped portion at the end which allows both skiers and snowboarders to ride the lift comfortably. Skiers ride with their mid to lower back resting on the "U" portion while snowboarders ride with their mid side or hip resting on the "U". There will also be a handle affixed to the straight portion of the pole to allow riders to hold on for greater stability. The handle will be affixed approximately two feet above the "U" portion of the lift to provide a comfortable location. The exact dimensions of the new pole can be seen in Figure 1 below.

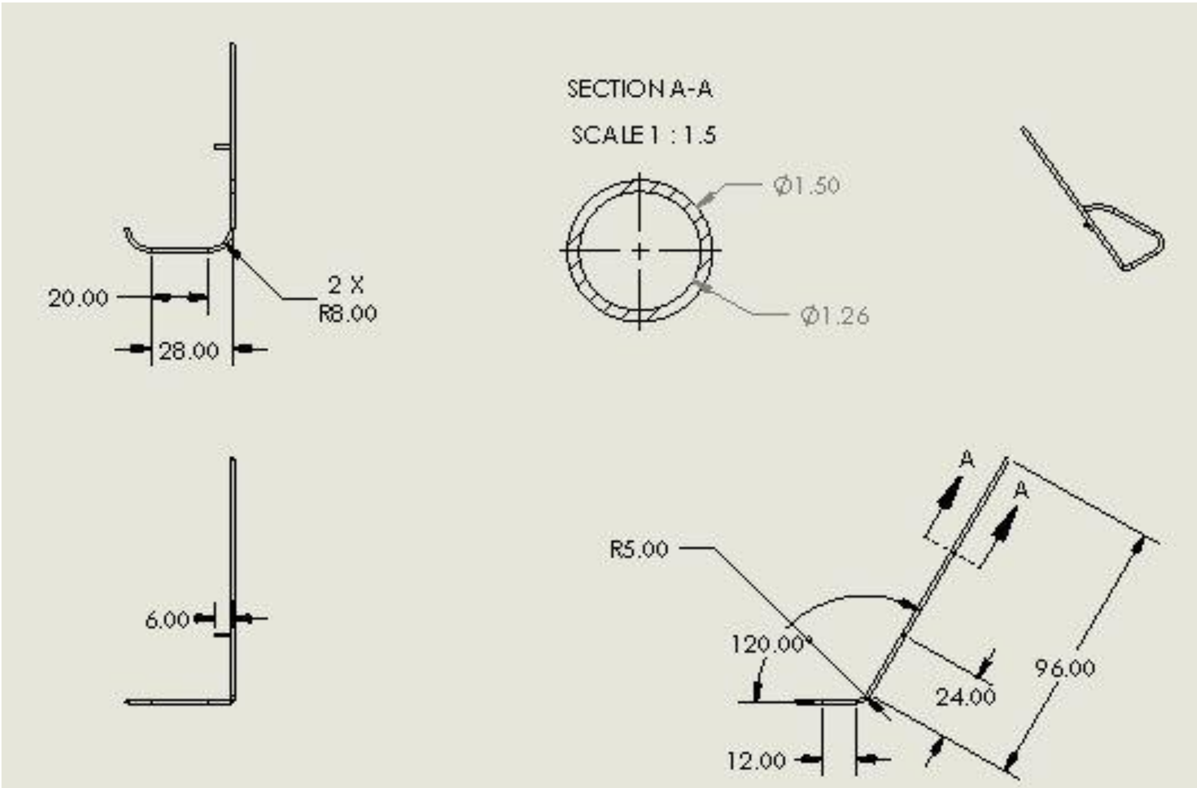

Figure 1: Pole Design

2.2 Support Seat Design

To provide extra comfort and support, a support seat is affixed to the flat area of the "U" portion shown above. This seat consists of a steel sheet metal rectangular plate that is one and a half feet wide and eight inches long. The steel will be as thin as possible while still providing enough structure and keeping the weight low. On top of the steel plate will be two inch thick foam padding that is covered in a weather resistant PVC vinyl covering. This covering will be attached to the steel plate using approximately twenty rivets to ensure a tight seal.

The whole support seat will then be attached to the pole design above by drilling two holes through the pole and the steel plate. Bolts will then be placed through the pole and plate and secured. Around and in between these bolts, the steel plate will be welded to the pole assembly to prevent water and ice from getting inside the pole and bolts.. When the steel plate is securely attached to the pole design, foam padding will be added for comfort and vinyl will then be attached using the rivets. A diagram of the support seat can be seen in Figure 2 below.

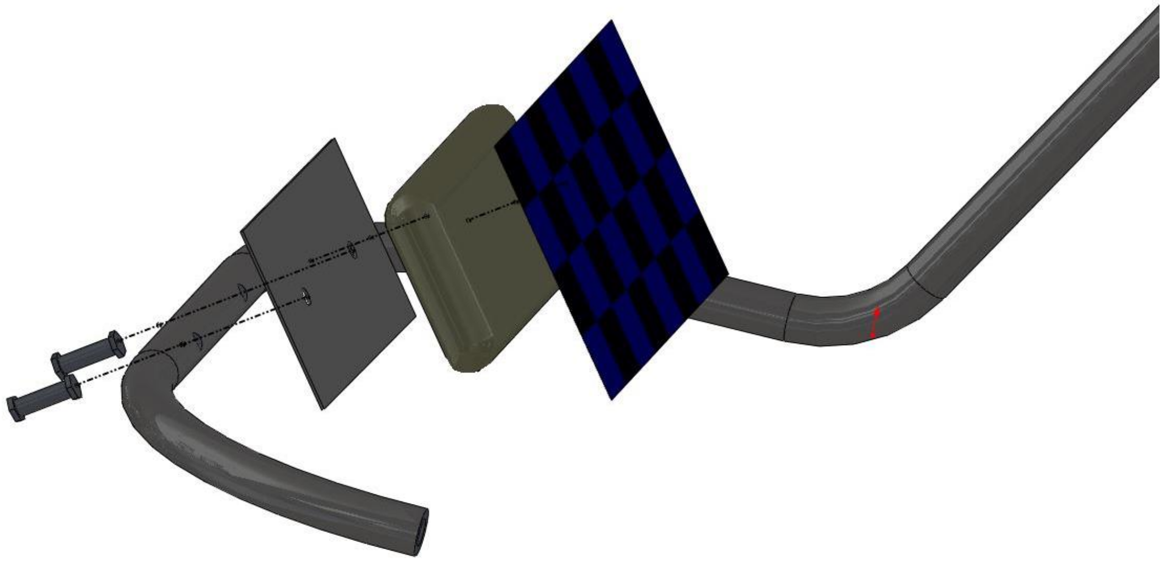

Figure 2: Support Seat Assembly

2.3 Inner Pole

To facilitate riders of different heights and changing mountain terrain, the old Poma system has an inner pole assembly that consists of the inner pole, a return spring, and a shock absorbing spring. This system has been in place for many years and has worked successfully in all weather conditions. Due to its success, it was decided to maintain this inner pole assembly. An exploded view of the assembly can be seen in Figure 3 below.

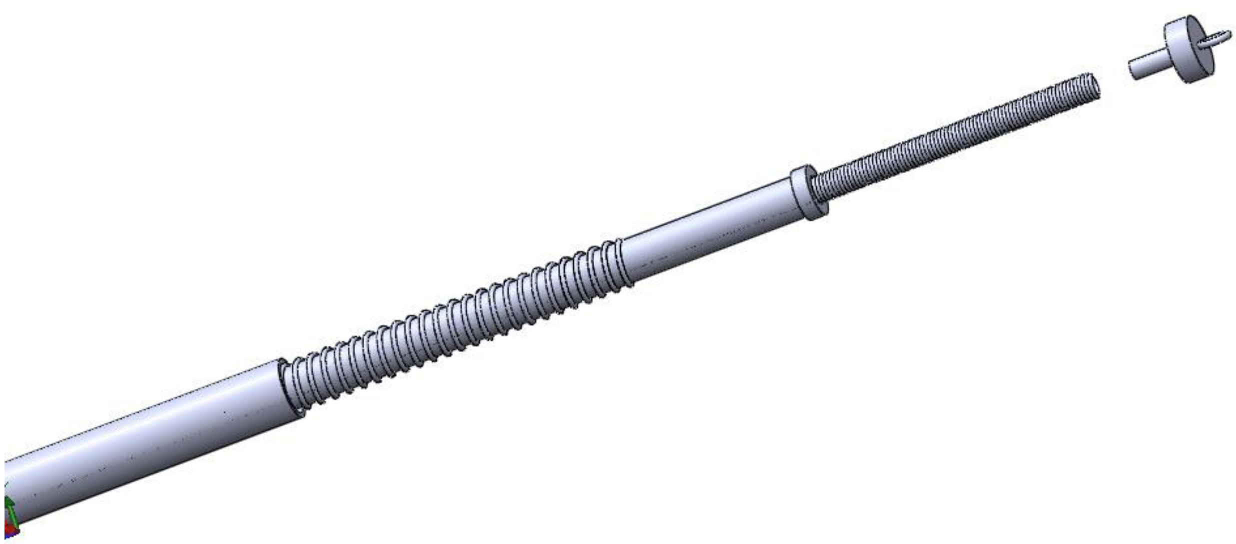

Figure 3: Inner Pole Assembly

In the figure above, there is an outer spring and an inner spring attached to the inner pole. The outer spring is the shock absorbing spring and is used to absorb large impacts applied to the lift and reduce stresses on the inner spring by preventing the pole from being easily over extended. This spring simply rests in the space between the inner and outer poles and is not attached to any part of the system. The inner spring is the return spring which helps maintain the static equilibrium of the system. It runs all the way from the top of the inner pole to the bottom of the straight portion of the outer pole assembly. When there is no weight on the pole, the return spring ensures that the Poma relaxes back to its fully unstressed state. This spring is attached by a pin to a press fit cylinder that sits at the end of the straight portion of the outer pole design. The entire inner pole spring assembly is secured by a press fit cap with a hole in it to allow the inner pole to slide in and out.

3.0 Spring Analysis

The new Poma pole design is somewhat heavier than the old design so to ensure safety, an analysis of the maintained spring system has been completed. As discussed above, there are two springs assembled inside of Poma lift stick: a return spring and a shock-absorbing spring.

3.1 Spring Characteristics

To successfully analyze the springs, the specific dimensions, and spring specifications had to be determined. This was accomplished through caliper measurements, force meter measurements, and some estimation based on reasonable assumptions.

3.1.1 Return spring

The return spring is the main spring used to recover deformation of the whole Poma lift stick system. It extends through the whole inner pole and is fixed on the top of the inner pole. This means it has the same length as the inner pole system. The characteristics for the return spring are listed in Table 1 below.

Table 1: Return Spring Characteristics

Free length H_0/(mm)	1900
Spring diameter D/(mm)	14
Wire diameter d/(mm)	2.4
Active coils Na	792
Pitch p/(mm)	2.4
Stiffness (N/mm)	0.154
Material	music wire

3.1.2 Shock-Absorbing Spring

The shock-absorbing spring is located in the gap between inner and outer poles. It is used to absorb the probable impact under extreme load applied on the lift. The characteristics of the shock-absorbing spring are listed in Table 2 below.

Table 2: Shock-Absorbing Spring Characteristics

Free length H_0/(mm)	300
Spring diameter D/(mm)	28
Wire diameter d/(mm)	3
Active coils Na	32
Pitch p/(mm)	9.375
Stiffness/(N/mm)	1.15
Material	music wire

3.2 Analysis.

To fully analyze this system, three different possible problems were considered: yielding, buckling, and fatigue.

Yielding:

Using the previous calculation that the slope of the mountain is 30°and considering that riders may lean their bodies back to get more support, the friction of a waxed ski on snow was determined to be approximately 0.01. Maximum axial load on the return spring then is 246 N (about 25 kg) with deflection of 1.6 meters before the shock-absorbing spring effect. Using the equation for stresses in springs, the max shear stress on the return spring is 640 MPa with a safety factor of two.

The likeliness of actually engaging the shock-absorbing spring is very low and it is much stronger than the return spring. Assuming sixty-five kilograms are applied to the spring, the deflection will not be greater than 5 cm. From this, the safety factor was determined to be at least larger than 10.

Stability

The return spring is always under tension and shock-absorbing spring is within the inner pole as a rod inside. Because of this setup, buckling cannot happen in inner spring system.

Fatigue

In this application, the load cycle will only effect the lift operation. For this case, the load cycles are on a significantly smaller order of magnitude than materials' life. This means that fatigue failure is very unlikely in this system.

4.0 Materials

Materials are needed for several different applications in this project. Piping must be selected and purchased to have the new pole fabricated. Materials for the support seat must be found that would survive the extreme weather conditions of a winter area. Also, several accessories are needed for proper use and assembly of the design. The team has researched various ways to obtain the needed materials from online dealers to local stores to find the most practical and cost effective purchasing option

4.1 Pole

Some of the online stores had very good deals on tubing by the foot, many required purchase in bulk. In addition, the stores that sold tubing by the foot charged large amounts for shipping and handling. Because of this it was decided that a Flagstaff vendor would be most suitable for the project’s budget. A fourteen foot section of ASTM A36 steel tubing has been purchased from Maygora’s Welding Company. The tubing has an outer diameter of 1.5’’ and a wall thickness of .120’’. It was found that A36 has a yield strength of 250 MPa. This means that the steel will have a higher factor of safety than the previously selected ASTM A56. Another added benefit is that this tubing was cheaper than many of the A56 steels considered. The inner diameter of the current Poma pole is approximately 1.3 inches or 33mm. This new tubing has an inner diameter of 1.26 inches or 32mm. It has slightly thicker walls than the tubing on the old design. This makes the new tubing slightly heavier than the old, but a stress analysis on the inner spring system shows that this will not cause any safety issues. Bending and torsion tests will be performed to ensure that the tube will indeed be safe for riders.

4.2 Seat

A piece of steel sheet metal was also purchased from Mayorga's Welding Company to use as a base plate for the support seat. The sheet is 24’’ x 28’’ and is sixteen gauge A36 steel. This piece of steel rather thin; it is only .0598 inches thick. This helps reduce the weight and it will provide sufficient structure once it is secured to the outer pole design. With a yield strength similar to the tubing, it will resist deformation for the extent of its intended use. For comfort measures, there will be at least two inches foam attached to the top of the plate. This will be standard foam that can be purchased from a local crafting store. To protect the foam from corroding quickly, PVC vinyl fabric will be used to cover the foam and the plate. This fabric currently used outdoors at Elk Ridge Ski Area and is a proven weather resistant material. This will either be purchased from an online dealer or excess fabric will be used that is already at the ski area.

4.3 Accessories

Several small accessory pieces are required to finalize this design. The handle on the outer pole will be covered with a leather bicycle handle bar cover. This allows for an easier grip by the rider as well as accommodates for the cold for riders who do not ride with gloves. The leather should be well weather resistant and this should be able to be purchased from a local convenience store or bicycle shop. The only other needed accessories are standard bolts and nuts to secure the seat and standard rivets to secure the vinyl covering to the steel plate.

5.0 Prototyping

The steel piping is currently out for fabrication at American Spring Flagstaff. The staff there will be making the major bends in the pipe to get it to the desired shape. The steel plate, foam, vinyl, rivets, and bolts are currently in the Northern Arizona University machine shop. The steel plate is being machined down to the desired dimensions and the edges are being machined to ensure that the steel does not cut the vinyl or injure any lift riders.

When the pole is fully finished, it will be moved to the NAU machine shop to have the seat assembly and handle attached. There the holes for the bolts will be drilled and the base plate of the seat will be attached. From there the foam and vinyl will be attached to the plate and the plate will be welded between and around the bolts. This will help reduce water and ice being introduced into the system which can cause cracking. After the seat is assembled, the small handle will be welded onto the outer pole.

The final step in the prototyping process is to insert the inner pole assembly into the new outer pole. However, this presents a problem because the diameters of the new piping are slightly larger than the diameters of the piping on the old Poma assembly. To be able to make the old inner pole assembly compatible with the new outer pole design, new caps have to be manufactured to secure the two together. These caps will be modeled after the current caps but with adjusted diameters to allow them to be press fit into the larger pole.

There is a top cap that will be a fairly standard pipe cap press fit into the inside of the outer pole. It will have a hole in the center that is approximately the diameter of the inner pole to allow the inner pole to slide in and out of the assembly as it adjusts to terrain and different heights of people. A diagram of the new top cap can be seen in Figure 4 below.

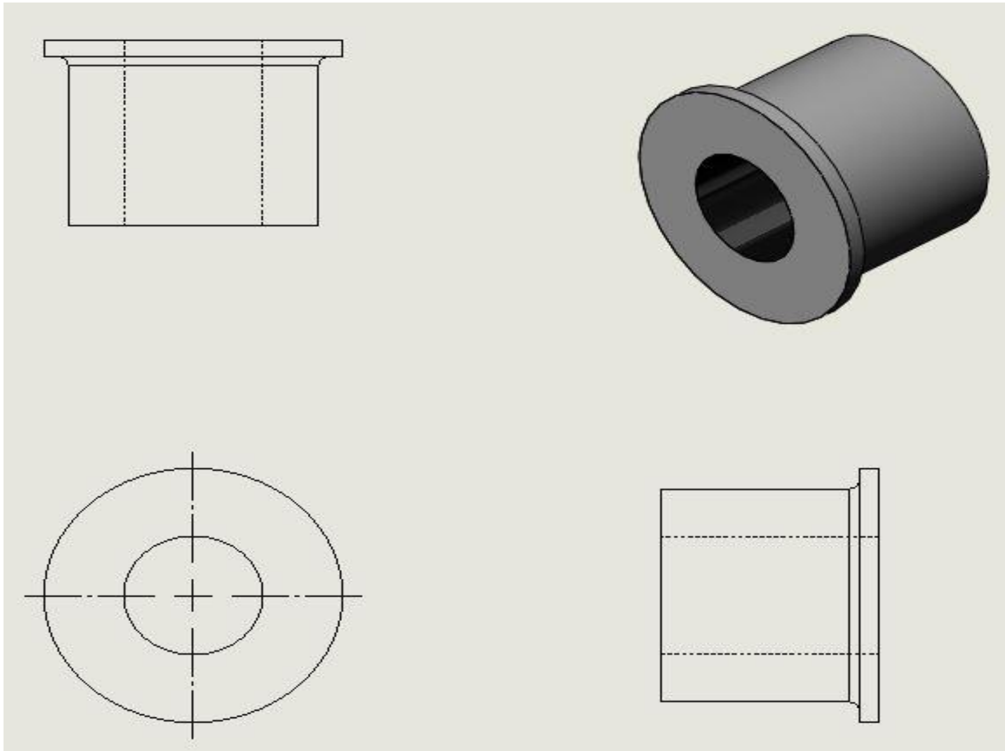

Figure 4: Top Cap Diagram

The second piece that needs to be manufactured is the lower attachment piece. It is a cylinder that is approximately the inner diameter of the outer pole. It has holes through the center that allow the lower spring to sit into the cylinder and be secured in place with a pin. There are holes through the side that allow the pin to slide through and secure the spring. There is also a ridge cut around the circumference of the cylinder to cause a raise in the material sides. This is what creates the press fit system that secures the lower attachment in place. A diagram of the lower attachment can be found in Figure 5 below.

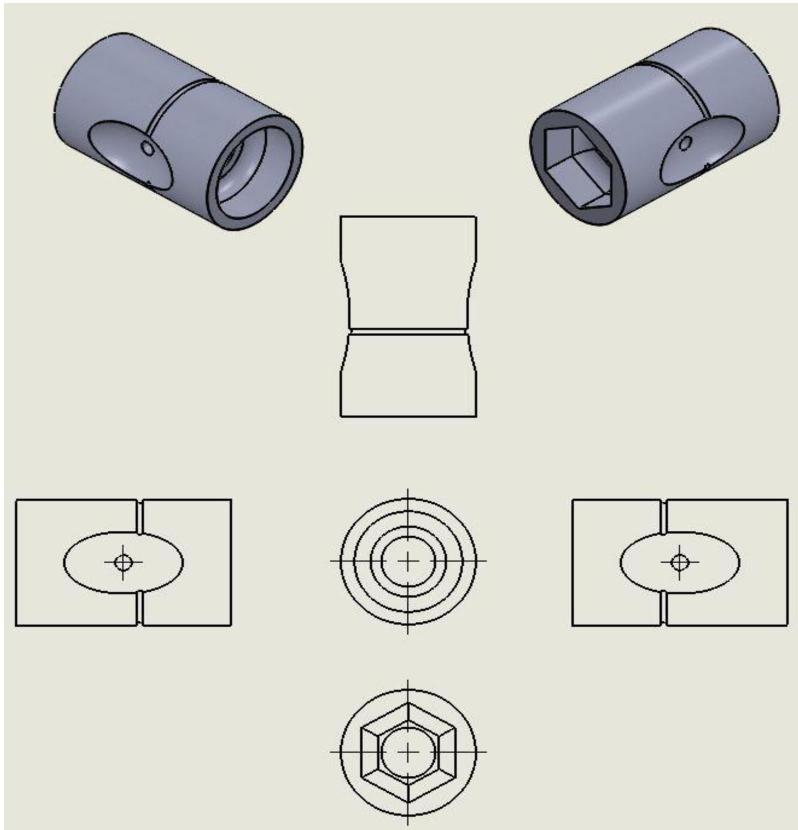

Figure 5: Lower Attachment Diagram

6.0 Budget

The monetary constraint of the project is around $200, which is the price to purchase a new Poma stick. Since the inner pole assembly is maintained in the design, the team's target budget for building the prototype is around $120. This is about half the cost of the constraint budget, but allows for the additional outer pole material that is used in the new design.

Our initial cost analysis was around $140. This cost analysis was done with Schedule 40 at a price of $7.00 per linear foot. This was the major consumption of the budget. This was still the case when the tubing was changed to A36 steel, but significantly decreases the unit price of the outer pole. A complete cost analysis is seen in Table 3.

Two components of the inner pole assembly have to be re-made in order to fit the dimensions of the tubing purchased. This added to the cost analysis. The price of these two components includes the price of raw material and the manufacturing of the piece.

Table 3: Complete Cost Analysis

Item	Unit Cost ($)	Quantity	Total ($)
1.5" steel tubing	$2.15	14	$30.10
16 gauge steel plate	$5.00	1	$5.00
Vinyl	$6.71	1	$6.71
Foam	$4.59	1	$4.59
Bolts for seat (pkg)	$6.78	1	$6.78
end caps	$4.00	2	$8.00
3/4" handle ($/ft)	$0.81	1	$0.81
handle covering	$8.00	1	$8.00
inner attachment (raw material and manufacture)	$20.00	1	$20.00
top inner cap (raw material and manufacture)	$20.00	1	$20.00
			$109.99

The cost for this prototype is just below $110.00. This is slightly below the targeted budget. The lower cost analysis allows for additional material that might be added as well as any modifications that may need to be done to the prototype after testing.

7.0 Testing

The testing of this prototype will be executed in two different stages: shop testing and on-site testing. The shop testing will provide most of the initial information on the safety and structural security of the design. The on-site testing will provide information on the feasibility of the use of this design and information about any adjustments that may need to be made.

7.1 Shop Testing

Advanced finite element modeling conducted in SolidWorks showed that the maximum design load was significantly below the material limits. In addition, a large factor of safety was determined using a conservative analysis. Based on these calculations, it was determined that minimal shop testing is needed.

The main test that needs to be completed in the machine shop is to apply a reasonable load to the prototype to make sure the fabrication doesn't significantly weaken the structure. The dimensions of the prototype limit the resolution of testing that can be done. Without large machinery, it is difficult to get an accurate estimate of the loads applied and resulting deformations. The intended method of testing is to secure the outer pole assembly using weighted blocks and standing walls. A known weight will then be applied point where the resultant force of a rider would fall. This weight will also be applied to the areas that the pole has been machined (i.e. the bends/critical points). The known weights will likely be generated by human body forces and/or large metal objects found in the shop.

The theoretical fixed point of the analysis done is the top of the outer pole assembly. However, in practice, the true fixed point of the design is the top of the inner pole and spring assembly that attaches to the lift line. To ensure that the added weight of the new design will not reduce the safety of the assembly, the upper spring assembly will also be mechanically tested.

7.2 On Site Testing

Once the shop tests are completed and no further anticipated design alterations are required, the prototype will be taken to Elk Ridge Ski area for on-site testing. The prototype will be tested on the current Poma lift system. This will be achieved by attaching the prototype to the Poma lift line and using riders of different weights and heights. The feasibility of its use for very small riders will be tested while stationary to ensure the safety of the young rider. Riders will be questioned about the comfort of the `design and its ease of use to determine if any small modifications may improve the design.

8.0 Conclusion

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Appendix A: Gantt Chart Spring 2013