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Trials Bike Frame Concept

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Senior Design Project Report

Trials Bike Frame Concept

ME480-0704-03

April 17, 2007

By

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Project Summary

Development of a Concept Trials Frame was a mechanical engineering design project that developed a new bicycle frame that has the strength and durability to be used for *trials* bike riding. The scope of the project was placed solely on the bicycle's frame. Current frames were analyzed based on their strength, durability, stiffness, weight, and appearance. These factors were ranked for importance and became the performance targets for the new frame. Several designs that utilize elastic strain energy to increase performance were brainstormed. Following SolidWorks modeling, equivalent impact loads were calculated using several analytical methods. These loads were then applied to the solid models in Algor finite element analysis (FEA) software. The results of these analyses were used to strengthen the frame where necessary. Finally, several iterations of optimization were completed to reduce the weight of the frame. The final frame weighs 4.7lbs, has a stand over height of 227mm, and will not yield during the high impact conditions of trials riding.

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1. Introduction

At the most basic level, trials riding can be summed up as advanced bicycle handling skills (Anonymous B). Riders navigate over natural and man-made obstacles on a bicycle similar to a mountain bike. Large, knobbed tires with low pressures are used to add grip and cushion impacts. Riders often jump onto boulders and off walls, balance on narrow ledges, and maneuver around very confined corners. Basic trials maneuvers include the pedal-up (Figure 1), side hopping (Figure 2), and gaping (Figure 3). Because of these extreme conditions, trials bikes have to be very durable and impact resistant. There are 2 main styles of trials bicycles. The most common are those using 26 inch wheels, or “stock” bikes. The alternative uses 20 inch wheels. These are referred to as “mod” bikes. The stock style can be broken down into two sub-categories. The trials bikes with traditional geometry that mostly resemble mountain bikes are called “street” bikes while those with more aggressive geometry are referred to as “comp” bikes (Anonymous B). Unlike mountain bikes, comp frames usually have very high pedal height and stand over clearance. This, along with low weights, make trials bikes easy to balance on the rear wheel and jump to high obstacles. This project focused on a comp frame.



Figure 1 (Anon)



Figure 2 (Anon)



Figure 3 (Anon)

Trials can currently be described as a niche market of cycling. Based on general web searches, it appears that there is a greater following of the sport in England and other European countries. This would immediately open the market for any trials frame to an international audience. However, the sport is growing and quickly becoming popular in the United States. While trials specific frames work best, mountain and BMX bikes work equally well for someone entering the sport. It provides a way to entice young riders to the sport of cycling that doesn't include popularity-robbing spandex. This presents yet another after school activity which could possibly deter crime while providing much needed physical fitness. Too many young people are battling obesity, so anything that gets them outside moving should be encouraged. Because the sport is growing so much, there is also a demand from experienced riders for more performance enhancing bikes. This project is aimed at developing a frame that will continue to advance the sport of trials at this exciting time.

1.1 Benchmarking

To deal with the high impacts common to trials riding, frames are designed with additional cross members. The 2006 Zoo Pitbull (Figure 4) uses a design that bends the top tube into the seat tube position then adds large ribbing for additional stiffness. A similar design is used for the 2007 YaaBaa Bow (Figure 5). This frame bends the seat stays around to take the place of the seat tube and connects them to the down tube a couple of inches above the bottom bracket. Because there are two seat stays, bracing was not need as with the bent single tube of the Pitbull. Both of these designs are aimed at increasing the maximum buckling load without adding a lot of weight. Current trials frames weigh on average between 4.25 and 4.75 pounds. The lightest weight found was 3.75 pounds for the Planet X Ali Bango (Anonymous C). The wheelbase determines the size of a trials frame, not the height. Wheelbases range from 1000 to 1115 millimeters (1050-1115mm for comp frames).



Figure 4



Figure 5

Several bike designs using spring mechanisms to efficiently harness elastic strain energy to enhance a rider's performance were also discovered. The first is the flex board and compression spring SlingPower Technology (SPT) used by Slingshot Bicycles in Grand Rapids, Michigan (Figure 6). During an impact, the coil spring stores the energy while the wheelbase momentarily elongates, pivoting at the fiberglass flexboard. When the load is released, the spring pulls the wheelbase back to the initial state, giving the rider a boost of energy. During normal riding, this energy is used to propel the bike forward. If a vertical load is applied while stationary, the action of the wheelbase shortening propels the bike upward.



Figure 6 (Anonymous D)

The second elastic strain energy enhancing device found was a solid composite rear suspension mechanism (PT#6,783,142) developed by a Pennsylvania State University engineering student. The only movement of this suspension is due to the flexing of the carbon fiber elements. Similar to SPT, this suspension element returns the energy to the rider when the load is removed. FEA performed by the student shows that a vertical load will displace the rear wheel up and backward. This effectively lengthens the wheelbase for the same effect seen from the SPT. The energy release will also directly produce an upward reaction force from the rear wheel. FEA also showed that the horizontal load from chain tension while pedaling will move the rear wheel down and forward. This will directly raise the rear of the bike momentarily during a sharp pedal kick.

1.2 Design Approach

The design process started with a brainstorming session. Each team member initially developed several concepts for the performance of the frame. Once a concept was selected, the team separated again to brainstorm and sketch specific designs that would utilize the concept decided on previously. Decision matrices were used to narrow these initial concepts down to the one that would be investigated further.

Once the general architecture was determined, SolidWorks modeling was used to develop specific geometry for each component of the frame. These components were then assembled and transferred to ProEngineer's Mechanical. Using the solid mechanics mode, FEA was performed on the frame to determine which components needed to be increased and which could be reduced in size. The FEA software was also used to evaluate the fatigue resistance of the frame.

1.3 Product Concept

Current trials frames are rigid in structure. This forces the rider to only use the bicycle's mechanical advantage to make large jumps. A close look at the behaviors of both the SPT and solid member suspension revealed an opportunity for performance enhancing possibilities of a

trial bike. The vertical movement experienced when a frame is flexed can provide a boost when jumping. To that end, the project frame was designed with a specific amount of vertical flex that will store and release elastic strain energy like that of the composite insert. With this behavior, the rider will be able to use potential energy to preload the frame prior to a large jump.

1.4 Concept Explanation

The most striking comparison to the energy storing behavior of the design is a pogo stick. First patented in 1919, the pogo stick consists of a T-handle with a rubber foot connected to foot pegs with a compression spring (Anonymous E). When the rider pushes down on the foot pegs, the compression spring stores the energy. The energy is then released giving the rider a boost of height (3-6 inches). This is the same action used by a trials rider when starting a side hop or bunny hop.

In the past decade, the compression spring has been replaced in several designs by various materials. One example developed by a team at Carnegie Mellon University uses a fiber reinforced composite spring that bends like a bow. Heights of up to 20 inches are common with the Bowgo (Anonymous E). Another variation is the FlyBar which uses 12 elastic bands and claims heights up to 6 feet (Anonymous F). These show that alternative materials can store more elastic energy than traditional metal springs.

Kangaroos also use elastic strain energy to their advantage. The exterior ankle tendons of the kangaroo store a large amount of energy with each hop. This allows the animal to hop at any speed without using any extra energy (Kram, Dawson pg 1). A trials rider will often balance on the rear wheel using small hops to gain balance before a large jump. During this, the chainstays can act just as the kangaroo's tendons do, reducing the energy needed to set up the jump and increasing the height of the jump.

2. Frame Design

2.1 Design Constraints

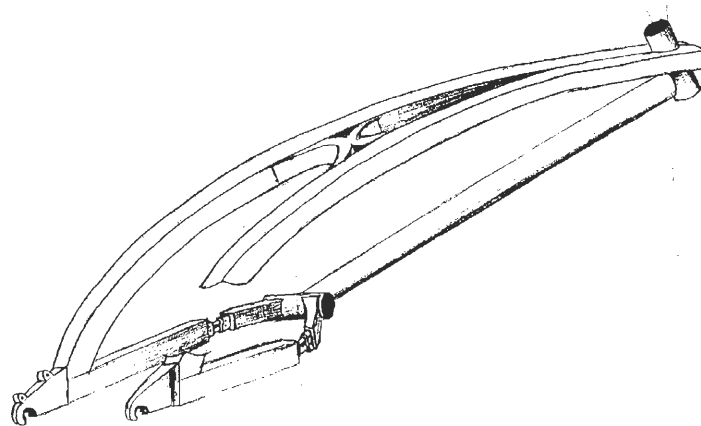
As mentioned previously, the frame was designed using stock-comp geometry. Because of this, the wheel base is 1075mm. The chainstays are 385mm in length and have clearance for a 27 by 2.5 inch tire. The head tube angle is set at 73 degrees. Based on the benchmarking, the target weight will be 4.0-4.25 pounds and the stand over height (ground to top of frame at the bottom bracket) will be 305-430mm.

When developing a frame that will enhance the performance of a rider, competition regulations must be regarded. To be allowed in international competition, the frame must comply with the regulations set forth by the Union Cycliste Internationale (UCI), the governing body of cycling. The United States cycling governing body was contacted for more specific rules and they also referred to the UCI rule book. To comply with these rules (Appendix C), trials frames must be free of sharp edges. This is to protect the health and safety of the rider from unnecessary injury during a fall. Additionally, a sudden failure during a routine landing could also injure a rider. To eliminate this risk, the frame must retain adequate impact resistance.

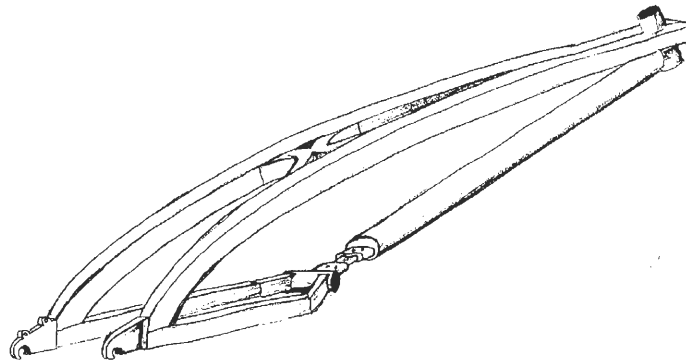
Cost was also considered. A low cost, high performance frame was the target. This increases marketability of the finalized design. Additionally, this helps increase the accessibility of the sport for younger riders, in turn promoting a healthy lifestyle as mentioned in the introduction. However, as a performance-enhancing frame, the integration of the strain energy mechanism into a low weight design took precedence over ultimate low cost. This was done with consideration to avoid patent infringement issues with product found during benchmarking.

2.2 Initial Concepts

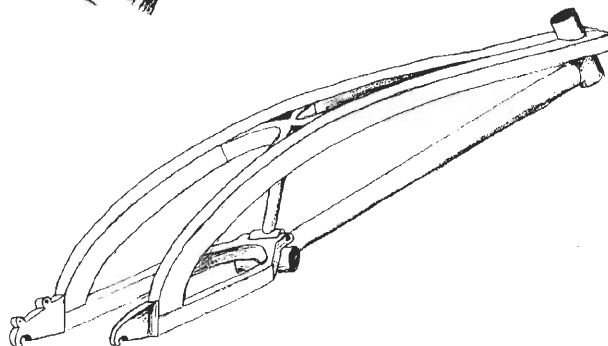
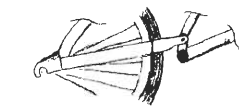
Following individual brainstorming, the design team had four initial concepts to analyze. Each design had a different mechanism and associated position which allows the frame to flex in the vertical direction. Each frame has extended arching seat stays (see Appendix A for a bicycle diagram) aimed at recreating the behavior found in kangaroos' tendons.



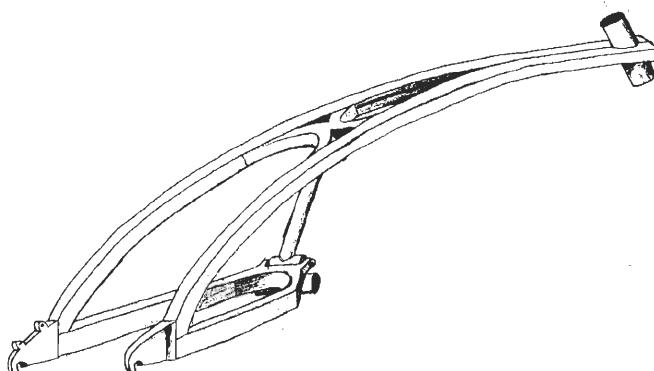
Concept 1- Dual flex boards in the chainstays



Concept 2- Single flex board in the downtube



Concept 3- Hinged chainstay-bottom bracket link



Concept 4- Hinged chainstay-bottom bracket link without down tube

After careful evaluation, concept 1 was chosen as the best design. The dual flexboard design best mimics the design seen in the composite suspension. This gives the best advantage in most trials maneuvers. The vertical deflections help increase height for pedal-ups and side-hoping. Additionally, the horizontal deflection from the chain will increase height and distance for gapping with pedal kicks. Initial FEA showed the same deflection direction on concept 1 as with the composite suspension. A completed design matrix is shown in Table 1.

	Performance Variables			
Weighting Factor	5	3	3	1
Design Feature	Rebound	Ride Quality	Aesthetics	Overall
Initial Concept 1	5	5	5	55
Initial Concept 2	5	4	5	52
Initial Concept 3	3	3	3	33
Initial Concept 4	2	3	4	31

Table 1

2.3 Material Selection

There were four main materials identified that could be used for the frame:

- Titanium
- Steel
- Aluminum
- Carbon

Weighting Factor	Performance Variables					
	4	5	3	4	5	1
Design Feature	Tensile Strength	Cost	Manufacturability	Durability	Weight	Total:
Titanium	4	2	3	5	4	75
Steel	4	5	3	5	1	75
Aluminum	3	4	4	2	4	72
Carbon Fiber	5	1	3	2	5	67

Table 2

Based on the decision matrix, titanium and steel show the most promise. Titanium would be ideal for maximum performance but steel would be better for economic reasons. Since more emphasis had consistently been placed on enhancing performance, titanium was selected over steel.

2.4 Component Development

2.4.1 Head Tube/Top Tube/Seat Stays

The original top tube is a very simple part that took advantage of the simplicity of splitting the seat stays before the arc (shown in Appendix D, Figure A-1). While this design may have been easier to manufacture, it has several significant disadvantages. To start, the seat stays are very long, far longer than required by wheel clearance. Structurally, this is not ideal, nor is it ideal for the rider, who needs a narrow frame for knee clearance while riding. Second, this design is very heavy because for the majority of its length, the top tube is actually split into two tubes, giving it much more mass without any added benefits.

This second design (shown in Appendix D, Figure A-2) discarded many of the disadvantages of the first phase discussed above. The top tube is much longer in this design, helping to create a much more efficient structure with respects to weight. It also has seat stays which taper more than previously, making the design more visibly appealing and also narrower for ease of riding. Wheel clearance continues to be overly conservative in this design as well. However, it is still not ideal in terms of overall weight.

The third iteration of the design has the basic architecture as all the following design iterations. It has a longer top tube; the head tube is angled at 17 degrees, essential to proper mounting of the fork and front tire clearance with the rest of the frame. It also features a continuously variable curve in its seat stays, helping to maximize weight savings while still maintaining structural integrity. It also includes a cross bar, which could help in obtaining a mounting position for the seat tube, which was added in this phase of the frame design.



Figure 7

The fourth design (shown in Appendix D, figure A-3) capitalizes on all the advantages of the third design phase and adds to them in order to create what is the final basic shape for the top tube. The major differences in this phase are the elongated top tube, which reduces weight, and also the much smoother transition into the seat stays, making the whole structure more of an arch shape. Wheel clearance was tested with this design and the split of the seat stays was made as gentle as possible while still providing good tire clearance.

This model of the top tube is the final iteration (Figure 8), with all of its dimensions fixed for the final design of the bike frame. The only dimension not finalized is the tube thickness which can be adjusted in Algor during optimization. New features incorporated into this design include a tapered top tube, starting with a thicker cross section at the high stress area that attaches to the top tube. It then tapers down until it connects with the seat stays, which are also smaller than in previous iterations. The head tube has also been redesigned, with a thinner cross section in the middle and only widening out at the top and the bottom where the head set will be pressed into place.

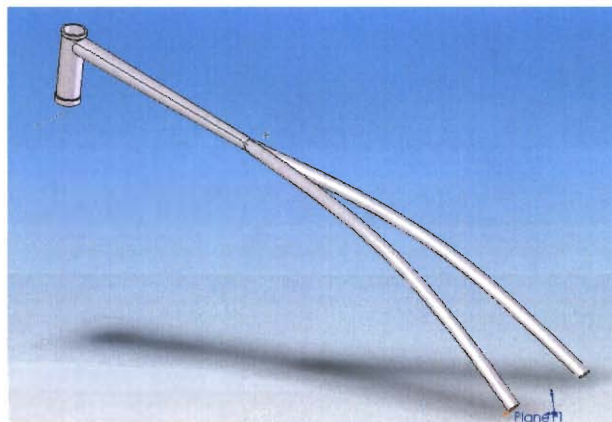


Figure 8

2.4.2 Down Tube

The down tube plays a major role in the front end stiffness of the frame. A frame that has a stiffer front end (i.e. head tube and surrounding area) responds faster to a rider's actions. Thus, a

better performing frame has a stiff head tube. To improve this, a diamond shaped down tube was chosen. This cross section better resists torsion than a normal circle. Additionally, a large height was chosen so thinner walls could be used. The initial wall thickness was 1.8mm, but this was later reduced due to FEA findings. Figure 9 shows a section view of the lower end of the down tube.

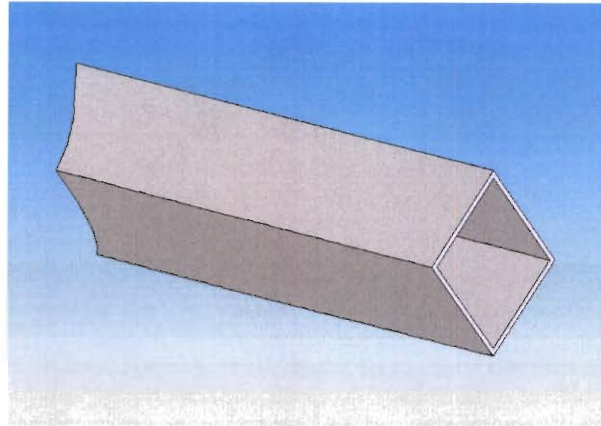


Figure 9

2.4.3 Seat Tube

Initially, there was no seat tube in the design. During the continued discussions, it was decided that some kind of a seat tube or enclosed member would be beneficial. The main reason for this decision is rider control. The design team felt that without a tube holding the middle of the frame together, the response of the frame during an upward pull would be slow. However, to allow for free flex from the seatstays, a large forward angle was given. This allowed for longer seatstays and gave the frame an aggressive look.

Another change from standard seat tubes was the dual tube concept used. Because of the long length, a single tube would have allowed for more torsional rotation in the middle of the frame. This was reduced by using a seat tube that attached to both edges of the bottom bracket and attached together to the top tube (Figure 10). The two tube concept also allows for a smaller tube diameter without reducing the strength and stiffness of the frame as a whole. The original diameters used were 25mm but this was reduced to 15mm after analysis.

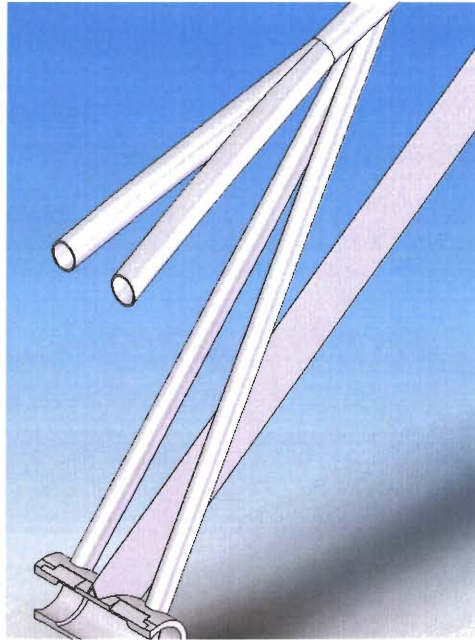


Figure 10

2.4.4 Bottom Bracket

Great attention was given to the bottom bracket area. The bottom bracket is the point that the pedal bearings are threaded into. As a result, the force from the pedals is applied directly to the area so the behavior of the bottom bracket affects the overall handling of the bike more than any other area. Care also had to be taken to ensure that the crankarms and chainrings will not interfere with the chainstay arms.

Traditional bottom bracket shells are 68 or 72mm across. There are, however, bottom brackets for 100mm shells. This oversized shell width was chosen because it will provide the additional balance that is needed in trials riding. Additionally, an oversized shell diameter was also used to increase the torsional stiffness of the bottom bracket while allowing for a lower weight. An initial design (Figure A-6) was developed with rectangular sections of material removed from the top and bottom of the area directly behind the threaded area. Sections were also removed from the sides and bottom of the arms in an attempt to reduce weight while retaining stiffness from an I-beam type configuration.

Following the assembly of the initial frame, time was spent analyzing the design in Algor to reduce weight without reducing stiffness. In addition to the rectangular cutout design, a bottom bracket was modeled that used triangular cutouts behind the threaded area (Figure 11). Both of these designs were analyzed with 17mm cutouts on the top and the bottom and with the cutouts going directly through the bottom bracket. The deflection in the x and y directions at the end of the arms were plotted vs. the weight of each configuration (Appendix B). Based on this plot, the triangular cutouts that go directly through had the lowest weight without giving up a great deal of lateral stiffness. Because the vertical deflection will be increased by the strain energy device, the stiffness in this direction was neglected.

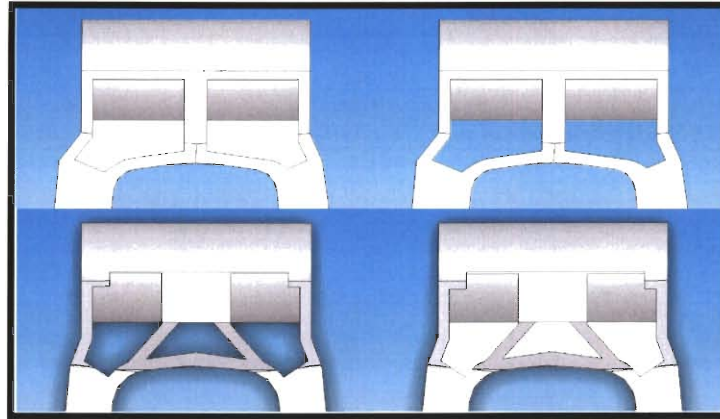


Figure 11

Once the best concept had been chosen, additional analyses and changes were completed. The first major improvements came from moving the connection points of the angular ribs toward the center 5mm. Figure 12 shows a model with exaggerated displacement of the original rib configuration. The excess movement in the crossing rib can easily be seen near the corners. Figure 13 shows how much the movement was reduced by moving the ribs inward.

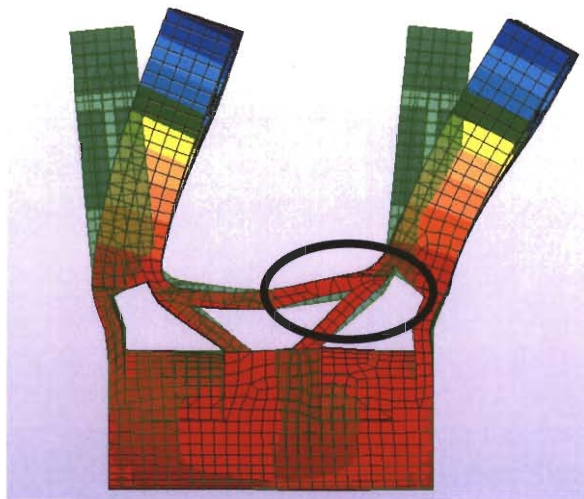


Figure 12

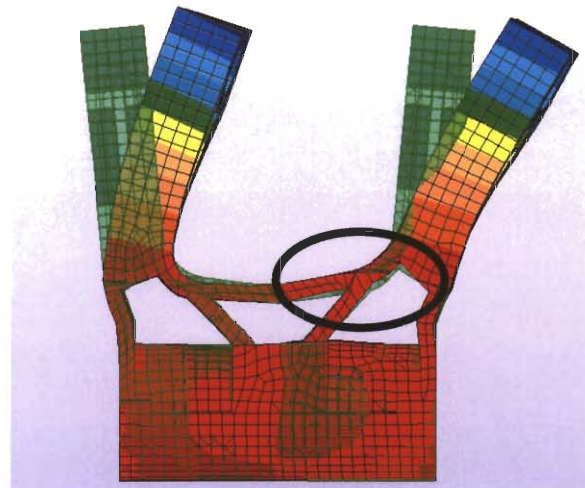


Figure 13

Other large improvements included extending the bottom cutout to the outside triangle cutouts and adding one on the top surface to create a horizontal I-beam. This also greatly reduced displacement as well as the weight. The extensions of the triangle into the chainstays were also reduced and played a large role in this increase as well. Finally, increasing the radius of the transition from the bottom bracket to the chainstays from 10 to 15mm helped increase the stiffness and reduce the maximum stress seen from a lateral load (A complete chart of changes and deflections at each point can be found in the appendix). The final bottom bracket (Figure 14) has the same amount of deflection as the original concept but with a 32% reduction in volume.

Full frame analysis revealed a hot spot around the insert clamp area. To eliminate this, the thickness of the clap was increased. This did add a little weight but was necessary for the robustness of the design.

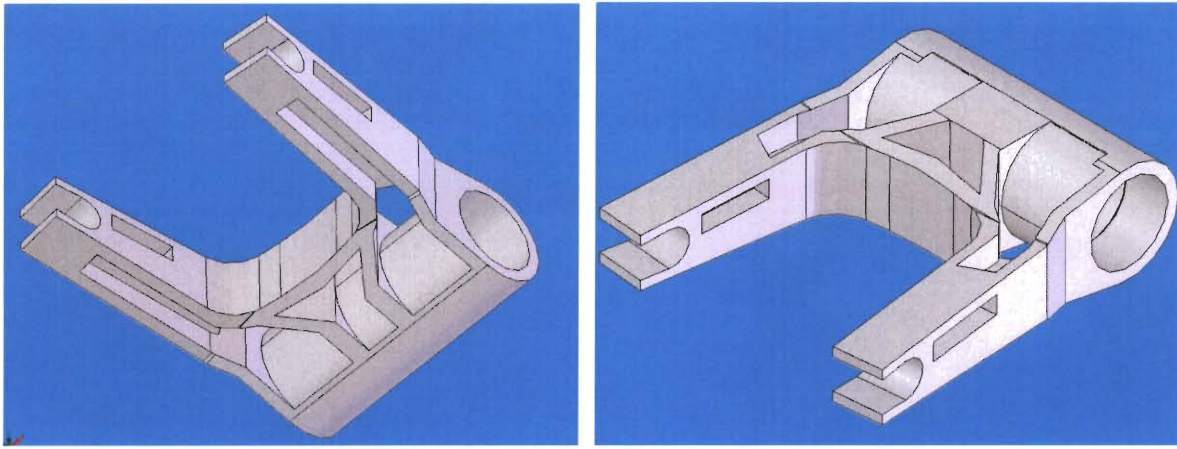


Figure 14

2.4.5 Strain Energy Component

Several concepts for the specific design of the strain energy component were considered. The four concepts for analysis that were developed include:

- SPT flexboards turned 90 degrees in each chainstay
- box chainstays cut out and wrapped in carbon fiber
- chainstays with a thin cross section for flex
- Flat- diving board type - chainstays

Based on the decision matrix (Table 2), it was determined that the composite insert would be the best solution for the strain energy component. Initially, an insert was designed that mirrored the one used by Slingshot Bicycle Company for their SPT. This new insert was needed because the width of the chainstays did not allow for the insert used for the SPT. Eventually, this was changed for the exact insert used in the SPT. This change was made to ease manufacturing difficulties. Because the SPT insert is 50mm across and the chainstays in the prototype design are 20-25mm, the insert was rotated 90 degrees.

	Performance Variables				
Weighting Factor	5	2	3	4	1
Design Feature	Spring	Cost	Manufacturability	Durability	Total
Composite Insert	4	4	5	5	63
Diving Board	5	3	4	3	55
Carbon Wrap	3	2	3	3	40
Thin Cross Section	2	5	2	1	30

Table 3

2.4.6 Chainstays

Initial design of the chainstays, which connect the rear dropouts to the bottom bracket, consisted of bending a single rectangular bar. Slots would then be removed, cutting the piece threefold, for composite insert placement. Dog bone-shaped extrusions would be machined out in order to position and pin the flexible insert. The back side, or u-shaped piece, of the chainstays would

then be aligned and welded to the bottom bracket providing ample surface area. This concept proved to be quite heavy and perhaps over-engineered.

The first improvement was to place the insert directly between the bottom bracket and the chainstays. This eliminated a weld and replaced it with the flex-feature while additionally dividing the chainstays into two separate and symmetrical parts. Another consideration coming into the picture was interference with the pedals. With the initial design, an essentially straight line was formed between the bottom bracket and the rear dropouts. This was not providing satisfactory pedal clearance. A bow, or kink, was included to keep the chainstays narrow as far aft as possible before mating with the dropouts. Additionally, the part was very heavy. Lightening holes were added which eliminated approximately half of the part's weight.

Initial loading conditions were placed on the frame which returned minimal stress related consequences. The frame and its components were still rather weighty. The next modification (similar to Figure 15) made to the chainstays involved lightening holes extruded completely through the structure. Round holes were used in order to minimize localized stress concentrations and a bridge-like arrangement was formed.

This configuration showed low stresses as well indicating excessive material. Also new for this revision was turning the composite insert on its side by 90 degrees. This would allow more flex throughout the frame and a different attachment mechanism (Figure 16). The chainstays also moved away from a solid structure and towards a hollow member. The solid housing for the composite insert is aligned and welded onto the hollow chainstays.

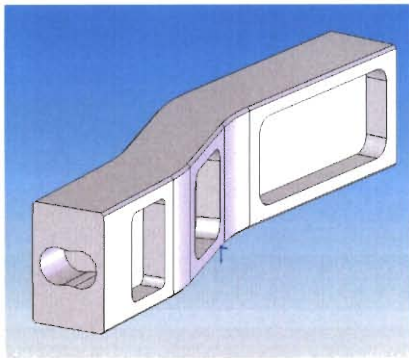


Figure 15

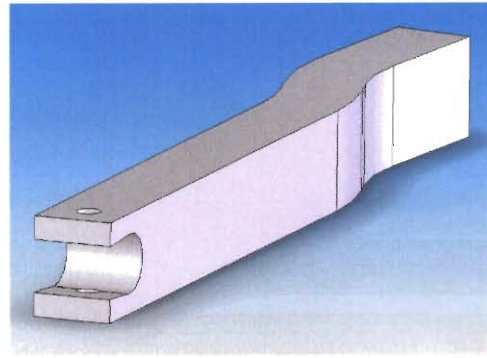


Figure 16

2.4.7 Dropouts

The major constraints on the rear dropouts, which connect the chainstays, rear axle, and seatstays, are the angle and placement of the mating chainstays' and seatstays' surfaces. The initial design (shown in Appendix D, fig. A-5) contained deep wells for the chainstays and seatstays. The seatstays were initially rectangular and later changed to a circular cross section.

After finding that the dropouts were a bit heavy and very strong, the next major change reduced the depth of these wells and attempted to consolidate the structure and overall size of the part. The rear axle was aligned with the center of the chainstays and the angle of the top surface was modified slightly to facilitate changes in the seatstays.

The final revision includes a number of changes while maintaining an appropriate amount of strength. The five to six millimeters width required for the rear axle clamp is included which allows 40% of the weight to be removed from the structure. Secondly, additional surface area is provided for the clamp on the rear axle. Third, the axle slot is positioned at a 15 degree angle to assist the clamp in reducing slippage of the wheel. Lastly, the rear wall of the structure is blended with a spline feature in order to avoid sharp stress concentrations.

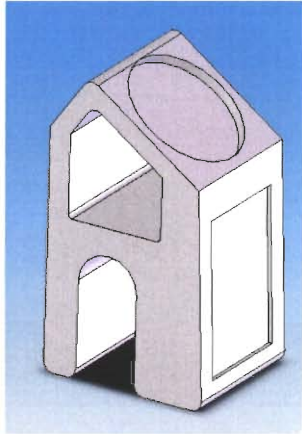


Figure 17

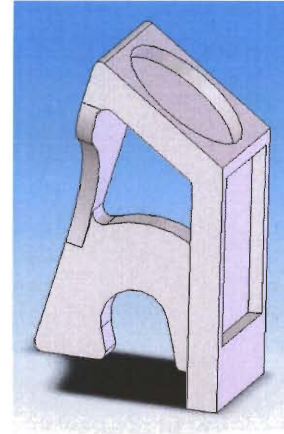


Figure 18

2.5 Completed Frame

Many attempts were made prior to completion of a satisfactory model. Complications with modeling software and assembly processes were core problems. To put the individual parts together, each one must meet the next exactly. If the distance was off by any number, however minute, the mate would not connect. To overcome this problem, specific meeting points needed to be defined so the different team members could model individually but still have the pieces fit together as if they were made as one.

The first frame that incorporated all of the final design concepts is shown in Figure 19. Several problems in need of repair were instantly obvious. The first of these problems was the weight. This frame weighed 10.4lbs which is more than two times the goal weight. This was the driving force behind the majority of the refinements at this stage. Another noticeable problem was the stand over height. The side view of the frame revealed that the top tube was much higher than desired. The measured stand over height was 382mm. This not only increased the weight, but a high top tube can impede performance in trials riding. When trying to move onto a high obstacle, the rider needs to be able to pull the bike as close to their body as possible to reach the extra height. Therefore, the top tube was lowered for future models.

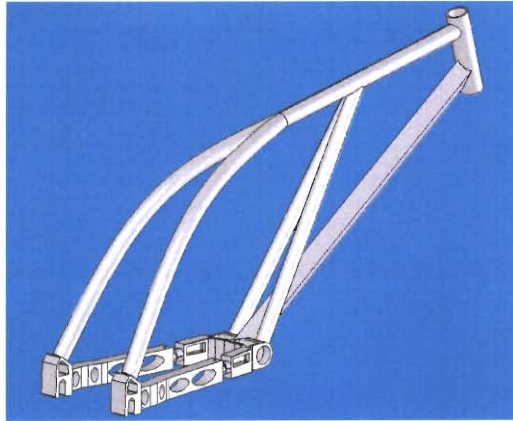


Figure 19

After making refinements to each part, a second complete model was assembled. This frame (Figure 20) had a much lower top tube and a reduced weight. The stand over height was now only 227mm. This is much lower than the target of 302mm. Additionally, the weight of the frame had been reduced to 5.4lbs. This was still above the original target of 4.25lbs but is within the range of competitive trials frames. Therefore, it was determined that this was an acceptable weight to begin finite element analysis. (For specific changes made to each component of the frame, see section 2.4)



Figure 20

3. Design Analysis

3.1 Qualitative Analysis

Prior to complex modeling, a beam model of the selected concept was constructed. FEA was conducted on this model applying arbitrary loads to the rear wheel mounts. Arbitrary values were applied as this analysis was intended only to check that the behavior of the frame was the same as the solid composite rear suspension mechanism found during benchmarking.

After analysis, the proposed trials frame concept was found to behave the same as the desired benchmark. When a vertical load (i.e. landing impact) was applied, the rear wheels moved upward and rearward (Figure 21- Yellow member). A horizontal load (i.e. drive chain tension)

moved the rear wheel down and forward (Figure 21- Red member). These results gave the design early verification that it could not only meet current benchmarks, but significantly improve the rider's performance as well.

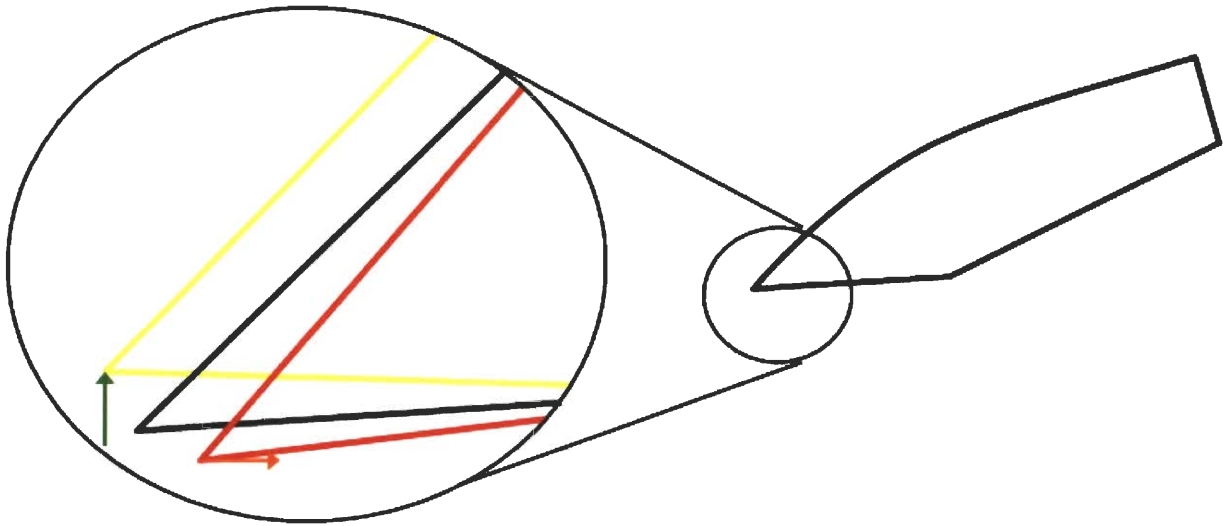


Figure 21

3.2 Force Models

Before detailed analysis of the frame could begin, knowledge was needed of the various loading conditions that will be seen during its lifetime. Initial attempts to gain load data were directed towards obtaining the actual force models used by the industry sponsor. Unfortunately, through discussions it was revealed that loads had not been previously acquired. Instead, the forces were determined through educated estimates using kinematics and energy methodology. To continue with the design process, the team investigated two possibilities of determining the loads experimentally. Eventually, various methods of mathematical calculations would be used to determine the expected loads a trials frame will be subjected to.

3.2.1 Load Cases

The first loading case that needed to be analyzed is a 2-wheel landing. This is a common landing for trials riders when dropping the bike down from smaller heights. The exact maneuver to be analyzed is a drop from a height of four feet with the bike landing simultaneously on the front and rear wheels.

The second loading case to be analyzed is a rear-wheel landing with the brake engaged. This is the most common type of landing the bike will experience. The advantage to the rider of landing on the rear wheel first is that the impact can be absorbed over a greater period of time by landing on the rear wheel first and then transferring to the front. This landing is necessary for drops of over five feet when the impact of landing on both wheels instantly would cause the rider to lose control. In the most extreme of cases, the bike and rider may be subjected to a fall of ten feet. This is height used for the analysis, and the load on the rear tire was estimated to be 70% of the total impact force. The rest of the impact force will be absorbed by the front tire once the rider transfers his or her weight forward.

3.2.2 Strain Gage Testing

The next concept explored was affixing strain gages to an actual trials frame so as to measure strain across various frame members. Frame coatings, particularly paint, would need to be removed so the gages could be soldered directly to bare metal. The gages investigated were all composed of Wheatstone Bridge configurations. The most likely configuration to be used was the half or quarter bridge. Ten to fifteen foot wires attached to the bridge arrangement would lead to a signal conditioning device and then into a data acquisition system via National Instrument's LabVIEW, programmed on a portable laptop. Limited distance maneuvers in trials riding made this option of following the rider from obstacle to obstacle seemingly feasible. After further investigation, noise factors in long wires, the susceptibility of gages falling off, and the severe time constraints of the project made this option impractical. This strain gage method could have turned out to be a design project in itself.

3.2.3 Load Cell Testing

Load cells commonly used in weighing vehicles surfaced as the next possibility for determining how much force is exerted on a frame during riding. If the bridge configuration inside the load cell was known, one could assemble a setup similar to that mentioned for the strain gages. To determine the loads, the rider would land on the scale and a peak value could be recorded. Another option was to remove the dampening component of a full suspension mountain bike. A smaller load cell could then be installed into the frame. The frame could then be ridden and the max force delivered to the rear wheel through that frame member could be determined. Unfortunately, these options failed because adequate information on the bridge setup inside of the load cell and a semi-destructible rear suspension bicycle frame were not available.

3.2.4 Mathematical Calculations

Two mathematical approaches were used to approximate the forces seen by a trial frame.

The first method used for force determination involved simple kinematics and energy equations. By choosing a height and rider weight, a model could be created to simulate impact mathematically. To compensate for the impact forces, observations were made about how much time it took for the rider to fully absorb the impact of a drop from the specified height.

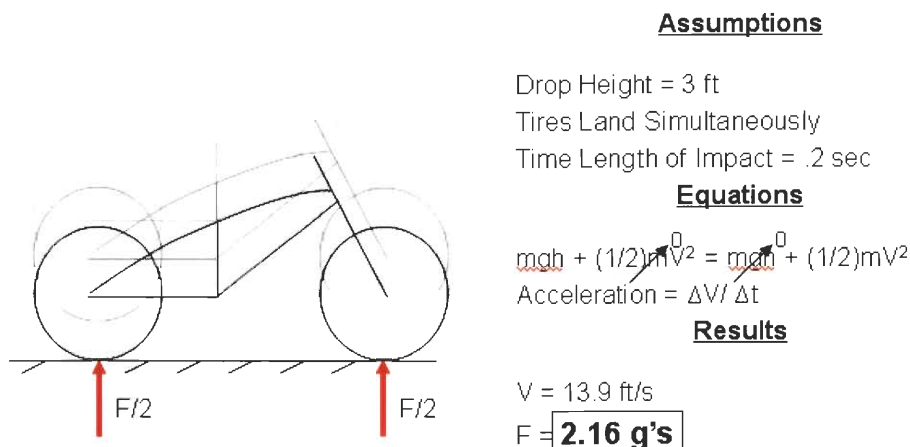
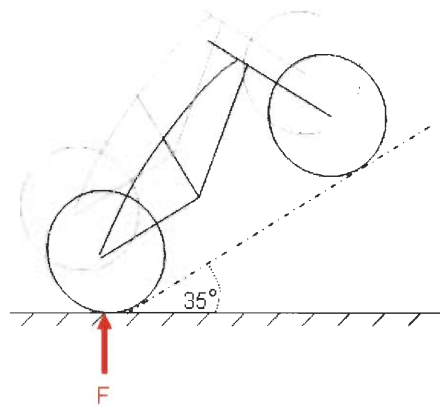


Figure 22



Assumptions

$h_1 = 3\text{m}$

$h_2 = 0\text{m}$

$\Delta t = .20\text{sec}$

Worst case ~ each tire 75% of load

Tire Dampening ~ 10%

Rider does not un-weight bicycle

Equations

$$PE_i + KE_i = PE_f + KE_f$$

$$a = (V_i - V_f) / (t_i - t_f)$$

Results

$$a = -2.93g$$

$$F = mR + ba$$

Figure 23

The second method of mathematical calculations involved the use of FEA software. In this method the bike frame was given boundary conditions according to each maneuver and subjected to a static force of the rider's weight. Analysis was run and the maximum displacement was recorded. Once the maximum static displacement was known, it was put into the following equation:

$$F_e = W(1 + \sqrt{1 + 2h/\delta_{st}})$$

Where:

F_e = Equivalent Force

W = Weight

H = Initial Height

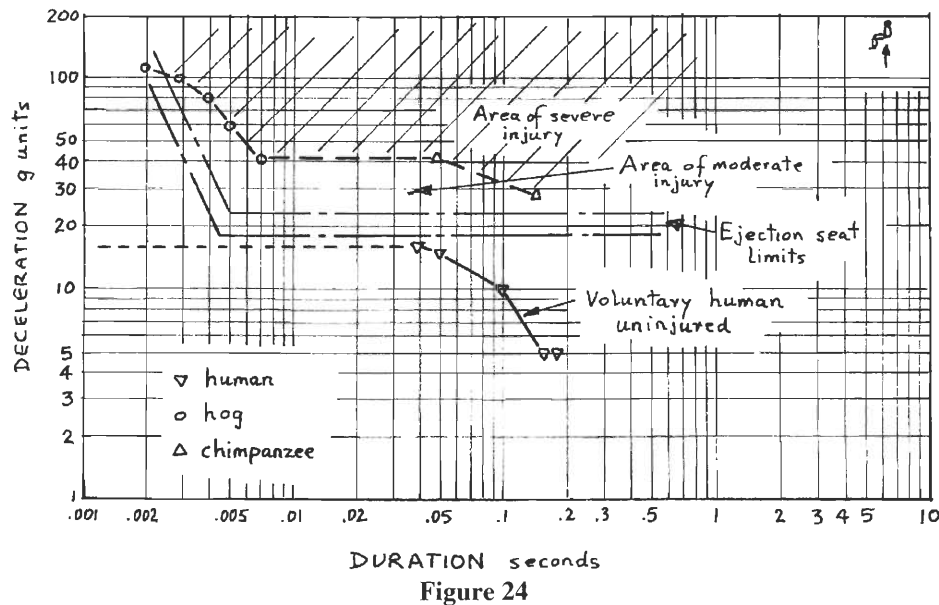
δ_{st} = Static Displacement

The static force is then replaced by the equivalent force, and using the same constraints, the model is analyzed again, this time for the impact loading. This developed loads of 155.4g and 87.1g for the 2-wheel and rear-wheel landings respectively.

It is worth noting that both of these methods have inherent flaws which make them only approximations, as the difference in loading calculations suggests. The first method is very simple and can give only an idea of the load, and is also based on measurements of the time it takes for the rider to absorb a shock, which are subject to human error. It also does not take into account the flexibility of the frame, which is a significant factor in the magnitude of the impact force. The second method is excellent for getting an impact force for a specific frame configuration. However, this method neglects several crucial factors that affect the impact forces. The most important factor not included is the rider and tires absorbing some of the shock, essentially dissipating the load over time. This results in the equivalent force being abnormally large. Because of this, the second method has an inherent safety factor built in. It is extremely difficult to define exactly how much safety factor without some kind of empirical data reference.

3.2.5 Applied Loads

Because of the large differences in the two mathematical approaches taken, more information was needed before the final loads were acceptably defined. Research was done on how many G forces an average human can withstand over a given period of time. This was important as it enabled the load to be limited to a force that the rider could take without falling off the bike or becoming severely injured. In essence, this study provided a ceiling of load values and was closely related to the loads used during the FEA.



With this information, a compromise of the two methods was reached. The average impact time for a trials landing was estimated at 0.2 seconds. Based on the human acceleration data, the maximum load a human can tolerate for this time without sustaining injuries is around 20g. To build a safety factor into the analysis, this load was increased to 35g. This load was used for both the 2-wheel and rear-wheel landing.

3.3 Finite Element Analysis

Once a frame was developed which was satisfactory in terms of weight, FEA analysis was begun to determine whether the frame would be able to withstand the loads encountered during use, both in a single instance and over time. As mentioned before, the two maneuvers the frame was designed to withstand are the 2-wheel landing and the rear-wheel landing.

The design team chose the Solidworks Computer Aided Design (CAD) package for their solid modeling due to its user-friendly nature and its compatibility with ProEngineer's Mechanica. Of any FEA software packages that were available, the team seemed to have the most experience with Mechanica. Mechanica is a P-method solver which offers various thermal and structural analyses. This provides the advantage that the program automatically optimizes the needed functions to converge to the best solution. However, the method Mechanica uses to run the analyses requires extensive active memory and an hour would commonly be necessary to complete a study. Because of these problems, alternative software which could deliver results in

a timely and efficient manner was investigated. Algor simulation software was found to support Solidworks drawings and did not require extensive active memory to finish the analysis. However, this is a H-method solver so the element mesh needed to be refined by hand to converge to the best solution. While Algor's FEA solver introduced challenges of its own, it proved to be much more appropriate for the team's intentions.

3.3.1 Two Wheel Landing

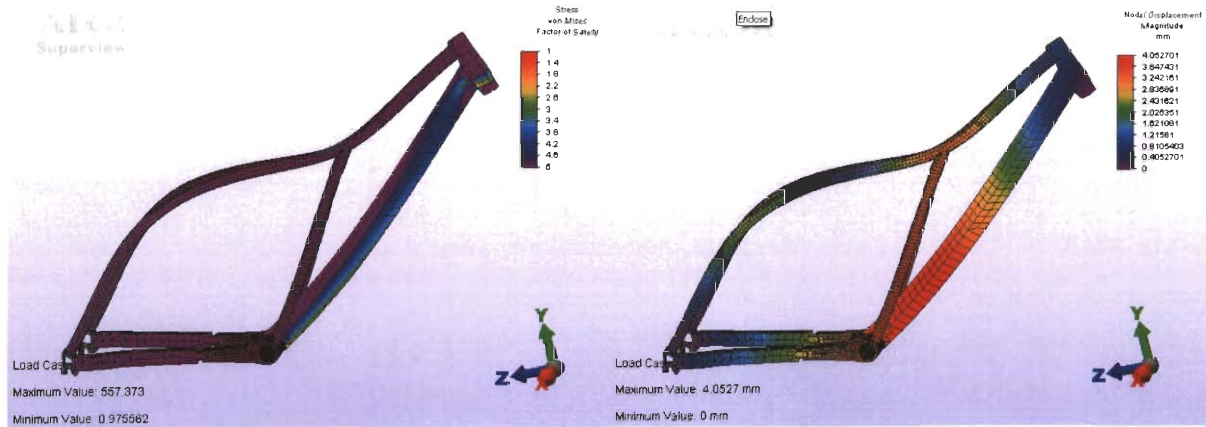
The two wheel landing is only used by a trials rider on relatively small drops or possibly in error. The highest drop a rider usually encounters when using a two wheel landing is four feet. This is the height that was used to determine the impact loading which is delved into more detail above. Once the bike frame was imported into Algor from SolidWorks it had to be constrained according to the force and boundary conditions that it would encounter in a real landing. The bottom of the head tube is pinned, which means that it will have zero displacement in the x, y, and z directions, although it is allowed to rotate freely about all axes. The rear dropouts are constrained in a similar manner. The boundary condition was applied to the surface which would contact the rear axle. It is pinned as well, to provide rotation about all axes, yet no translational motion. The force is applied downward on the bottom bracket. It is applied on the bottom inner surface of the tube where the pedal axle would sit. This simulates the rider's weight acting through the pedals upon landing (Figure 25). Based on the load cases calculated in the previous section and an approximately 215lb rider weight, the final force applied comes to 33250 N. For material constraints, all parts with the exception of the composite inserts are Titanium Alloy (6Al-4V). The composite inserts, are fiberglass bars. (For a table of material properties, see Appendix F)



Figure 25

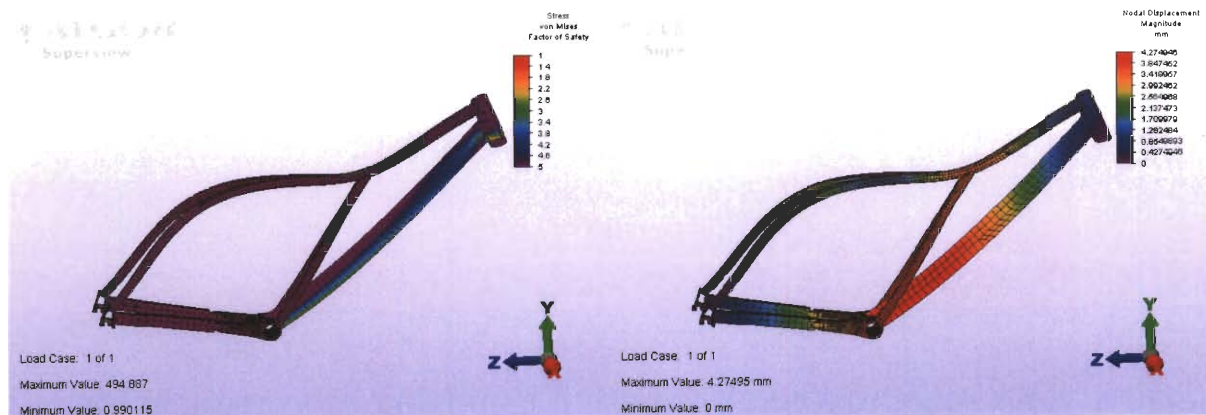
Some optimization was then completed using the two wheel landing maneuver with the following values for tube thicknesses:

Top Tube Diameter: 1.7mm
Down Tube Diameter: 1mm
Head Tube Diameter: 2mm
Seat Tube Diameter: .5mm



The results were in close proximity to those desired, and the weight was also within the target range. Several more iterations were run until this particular design was optimized to have the following tube thicknesses:

Top Tube Diameter: 1.2mm
 Down Tube Diameter: 1mm
 Head Tube Diameter: 2mm
 Seat Tube Diameter: .5mm



From the analyses, we can see that the safety factor is close to one, which is sufficient to conclude that the frame will not break when this load case is applied. This is an acceptable level due to the conservative nature of the impact force calculations. Additionally, it is known that the material strength increases as loading rate increases, minding that the above safety factor is with respect to sustained loading.

Following the rear wheel landing analysis for this same frame, it was determined that several reinforcements were necessary in order to make the bike frame safe.

3.3.2 Rear-Wheel Landing

The rear wheel landing is the most rigorous load case that the frame was designed to withstand. This is probably the most commonly used landing by the trials rider, and is employed for the

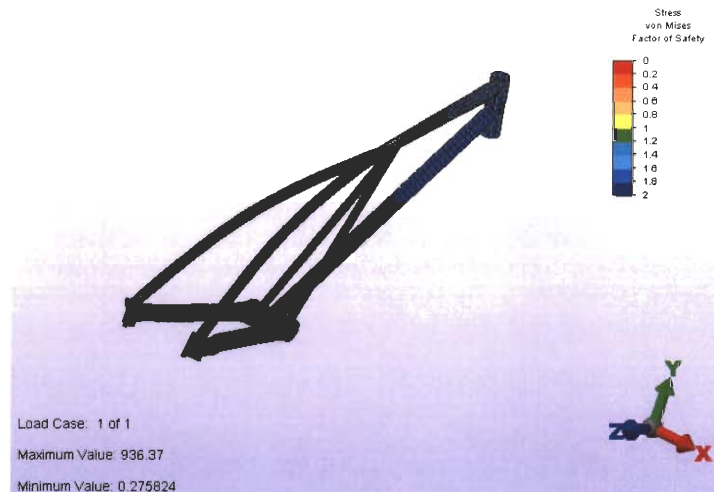
entire spectrum of drops between two feet to ten feet. For this analysis, the bike frame is only being analyzed for failure after the initial rear wheel impact. The bottom of the head tube is pinned where the front fork connects. The bottom bracket is also pinned, allowing rotation about all three axes with no translational motion (Figure 26). Finally, the impact force is applied to the point on the rear dropouts where the axles contact. Additionally, the load was applied at a fifty degree angle to the vertical because the rider always comes down on an angle when landing on the rear wheel. Upon inspection of initial rear-wheel analyses, it was discovered that the rear dropouts were moving horizontally away from the center line of the bike. This will not happen in actuality because the hub and axle of the rear wheel keep the dropouts the specified 135mm apart. To remove this unnatural movement, constraints against translation in the x direction were placed on the inside faces of both rear dropouts. As with the 2-wheel landing, the impact force was 35g for a rider of approximately 215 lb, resulting in an impact force of 33250 N.



Figure 26

While the two wheel landing was already within the tolerances desired, the frame is sub par when subjected to the rear wheel landing. The minimum safety factor is typically between .2 and .3 which is unacceptable even with the highly conservative impact force, and it could not be said with confidence that the frame would remain intact over time. Results from the original frame are as follows:

Top Tube Diameter: 1.7mm
Down Tube Diameter: 1mm
Head Tube Diameter: 2mm
Seat Tube Diameter: .5mm



Top Tube Diameter: 1.2mm
 Down Tube Diameter: 1mm
 Head Tube Diameter: 2mm
 Seat Tube Diameter: .5mm

After the stress analysis, it was determined that because the points on the frame of high stress were more or less concentrated to a couple spots. The best way to fix these problems while still keeping weight low was to add reinforcements to the affected areas. This adds a minimum amount of weight, and it is also simple to do and requires a minimum amount of time for manufacture. Figure 27 shows the reinforcements circled in red.

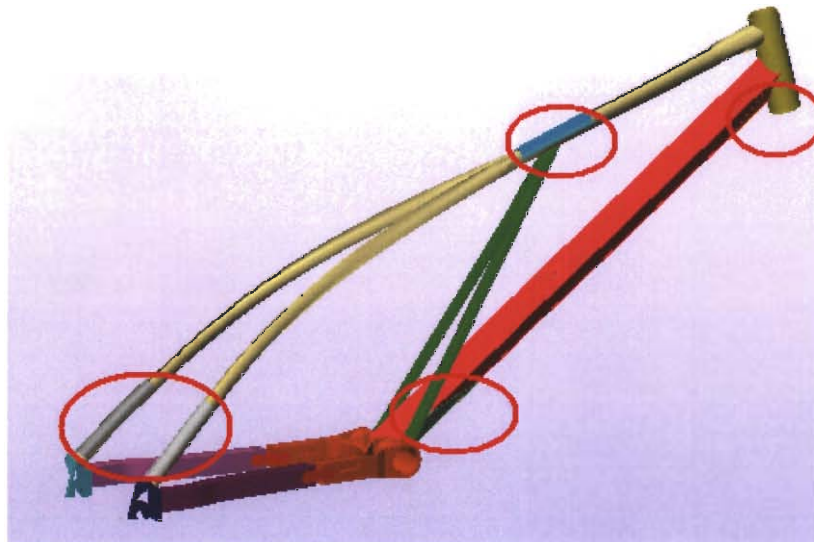


Figure 27

The downside to adding reinforcement patches is that stress concentrations were produced at gusset-edges. However, FEA analysis showed that the concentrated stress was still less than it had been without the reinforcements and furthermore affected a much smaller area. Because the two wheel landing had already met the specifications desired in terms of safety factor, it was

unnecessary to re-analyze for this maneuver when adding additional material would only make the safety factor increase.

3.3.3 Final Optimization

Once the reinforcements were added, the safety factor exceeded the intended goals for much of the frame. Once this was attained, it was then possible to reduce some weight by making tube thicknesses smaller. After much experimentation it was found that most of the tube thicknesses could be reduced without much consequence on the overall stress in the frame. After the final optimization, the tube thicknesses on the final frame design are as follows:

Seat Tube = .5 mm

Down Tube = 1.0 mm

Down Tube Gussets = .75 mm

Seat Stay Reinforcement = .75 mm

Top Tube Reinforcement = 1.5 mm

Top Tube = 1.2 mm

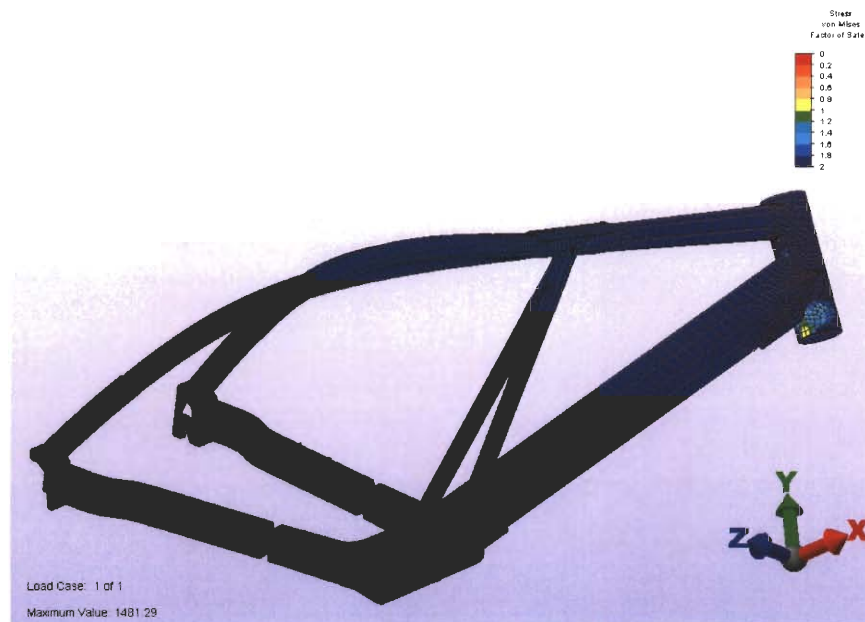


Figure 28

Figure 28 shows the 2 wheel landing following the addition of reinforcements and subsequent optimization and weight reduction. It can be seen that the frame has a safety factor of greater than one everywhere except the bottom of the head tube. This however is a product of the boundary condition at this location and does not represent the real world stress that would be seen. This area needed to be constrained for no translational movement because allowing it to move in any direction would cause the model to pinwheel, making analysis impossible. In reality this area may move slightly as the front fork increases in angle to accommodate the lengthening of the wheelbase. In this condition there would not be the extreme bending stress that is present in the diagram.

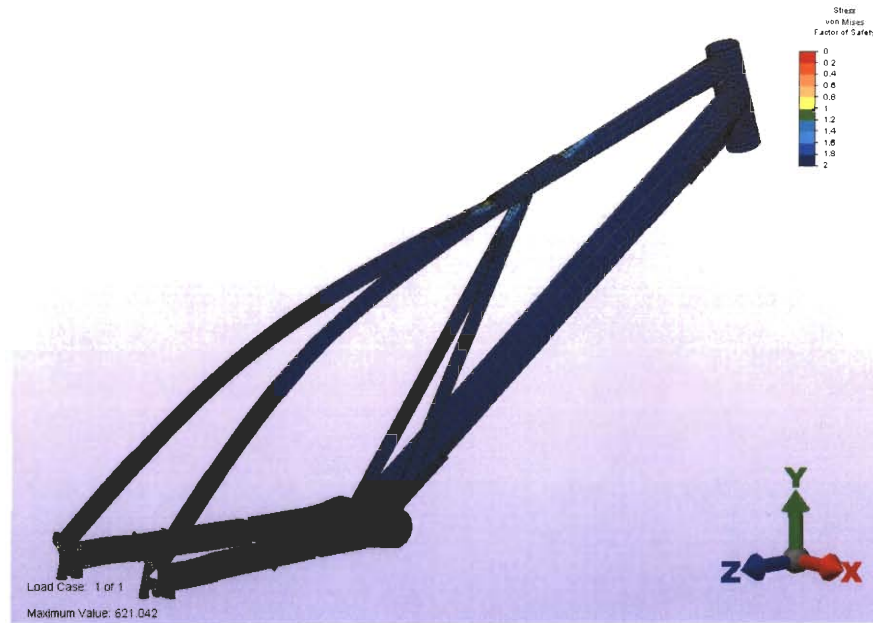
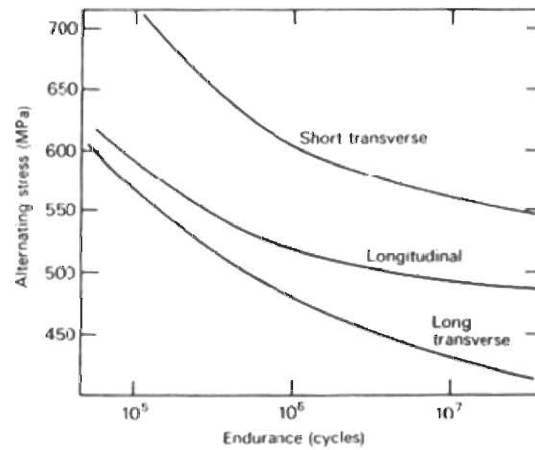


Figure 29

Figure 29 shows the results of an analysis of the final frame during the rear wheel landing maneuver. This maneuver was more affected by the reinforcements than the two wheel landing, and the stress concentrations are noticeably different. Instead of totally eradicating the stress concentrations as happened in the two wheel landing, the reinforcements instead spread the stress out while at the same time reducing it. The safety factor is consistently greater than one, however, even in the areas of high stress above the seat tube and on the rear dropouts. While it is possible that there may be some minor yielding at these points, that does not equate to failure (noticeable deformation) and it can be confidently said that the frame will not fail under this load condition. This is due to the large safety factors already built into the impact loading and the increase in material strength during an impact load.

3.3.4 Fatigue

Bike frames are also subjected to fatigue loading. The pedaling action from the rider provides the majority of this stress. To evaluate this phenomenon, an analysis was run using the same boundary conditions as the 2-wheel landing load case. However, instead of the 35g load spread over both sides of the bottom bracket, a 3g load was applied to one side of the bottom bracket. This was because when the rider is pedaling, all of his force will be on just the forward pedal. The stress limit to survive 10^6 fatigue cycles 6/4 titanium is 520MPa (Figure 30).



Rotating-cantilever fatigue (S-N) curves for three testing directions in 57 mm thick, forged and annealed Ti-6Al-4V bar.

Figure 30 (Boyer)

The results of this analysis (Figure 31) showed that the stress in the frame is much less than the limit for fatigue. There was a bit of stress concentration on the bottom of the head tube near the down tube, however this was due to boundary conditions as described in section 3.3.3.

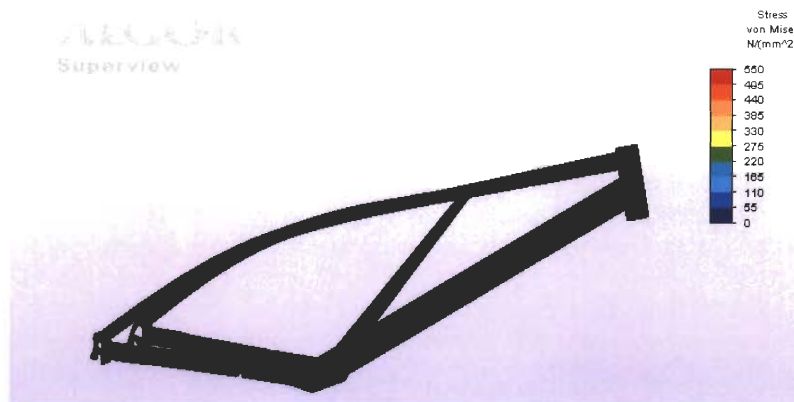


Figure 31

4 Final Design

The final design (Figure 32) had a weight of 4.7lbs. This was slightly above the target weight of 4.25lbs. However, it is still within the competitive range of weights discovered during the benchmarking process. As the previous section has shown, the frame has sufficient strength to withstand the high impact nature of trials riding. It also will absorb the fatigue stress applied by pedaling without failure through at least 106 cycles. The final stand over height is 227mm. This is much less than the 302mm set as the minimum target. Since all of these constraints have been met or exceeded, an acceptable frame has been designed.

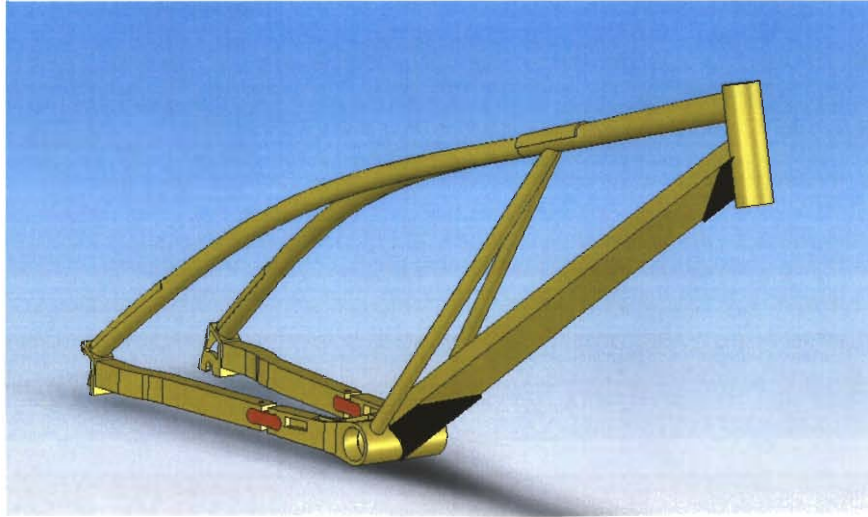


Figure 32

Bibliography

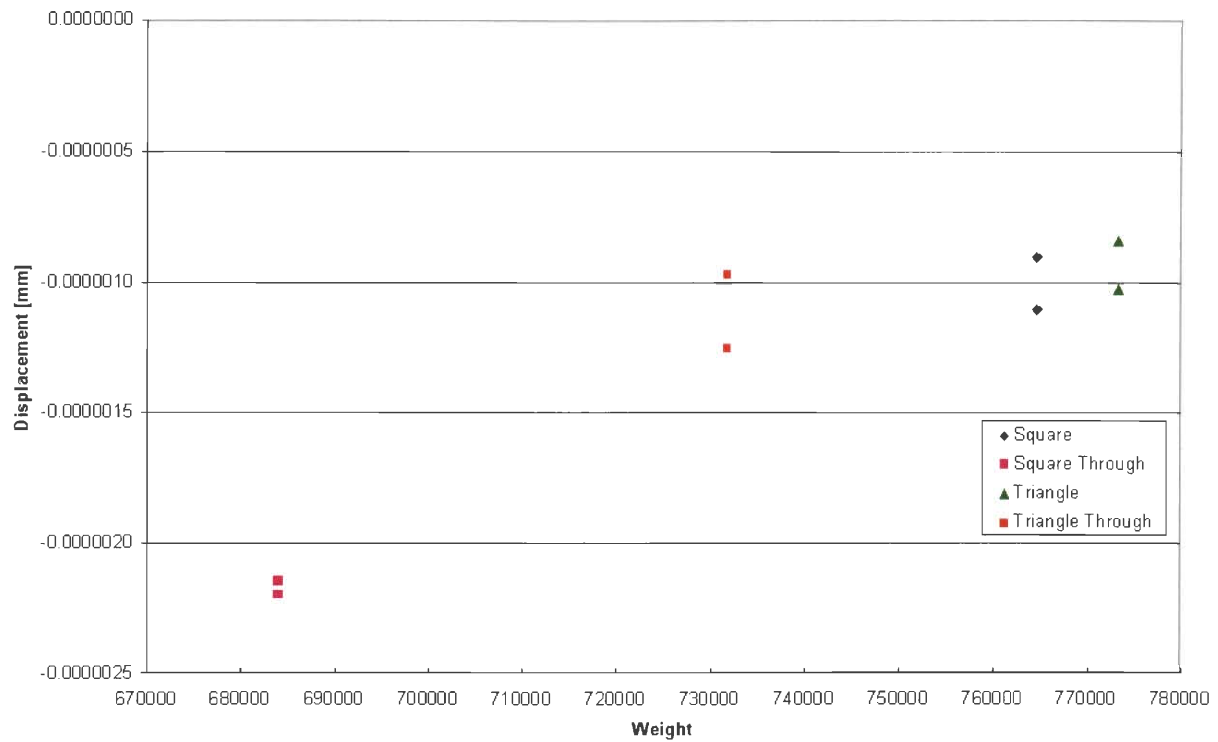
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Appendix A- Bike Diagram

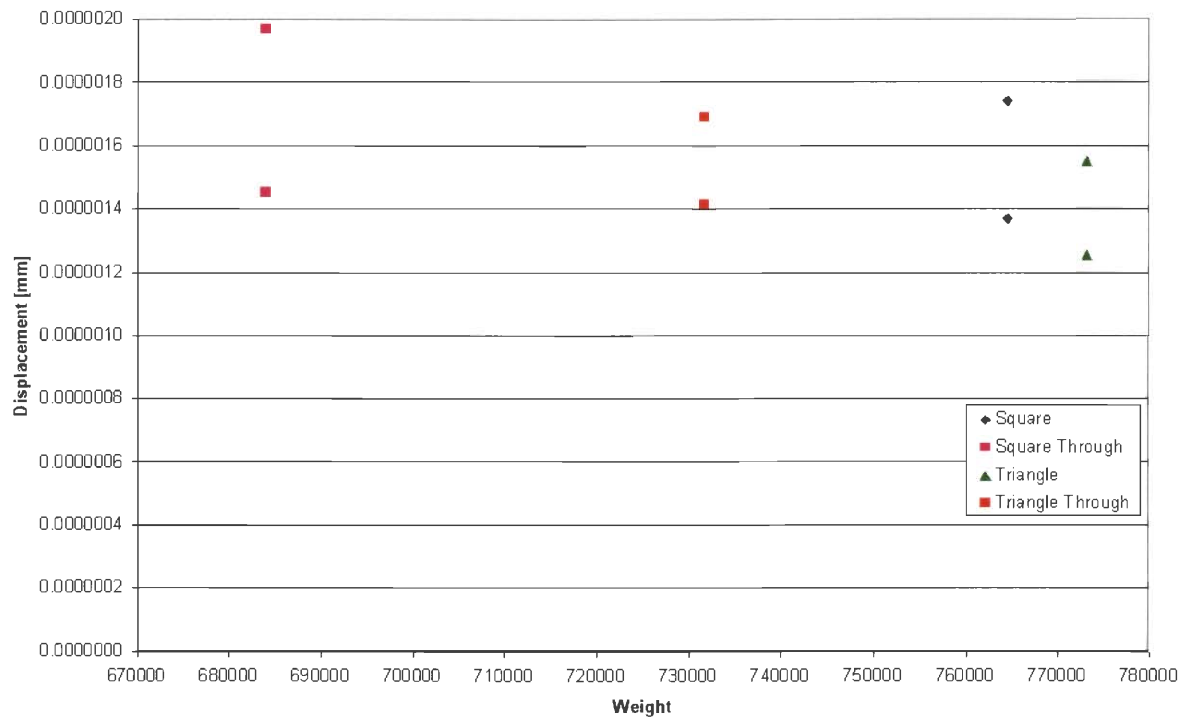


Appendix B- Bottom Bracket Design Analysis

Horizontal Stiffness Comparison



Vertical Stiffness Comparison



Revision Level	Change	Right X-Displacement	Left X-Displacement	Volume
Initial	-----	-1.2508e-006	-9.69905e-007	0.00016990
1	25mm height	-1.67407e-006	-1.30149e-006	0.00013469
2	shorter side cutout	-1.63471e-006	-1.27104e-006	0.00013566
3	4mm back brace and cross ribbing	-1.86671e-006	-1.3862e-006	0.00013034
4	5mm back brace w/4mm cross ribbing	-1.80314e-006	-1.34415e-006	0.00013247
5	5mm back brace w/4mm cross ribbing but moved rear pt 5mm inward	-1.66986e-006	-1.33138e-006	0.00013076
6	New insert cutout-new loading placement	-1.41788e-006	-1.14248e-006	0.00013650
7	Moved rib point to 10mm inward	-1.4893e-006	-1.21187e-006	0.00013521
8	Moved side cut outs back, extended bottom cut outs and added top cut out	-1.1107e-006	-8.92051e-007	0.00014932
9	Increased depth on top and bottom cut outs, moved outside corner pt of through back	-1.26122e-006	-1.02219e-006	0.00014143
10	Moved outside corner pt of through forward	-1.191e-006	-9.84048e-007	0.00014233
11	Increased rib thickness to 5mm	-1.14975e-006	-9.59044e-007	0.00014425
12	Decreased BB shell diameter to 43mm, reduced arm width to 20 mm, made end thickness 21mm	-1.39361e-006	-1.37158e-006	0.00011557

Appendix-C- UCI Regulations

Chapter **IV** EQUIPMENT

The bike in general

7.4.01 A trials bike shall have two brakes in working order (front and rear wheels).

7.4.02 The frame, the handlebars and the fork shall not be cracked.

7.4.03 Pedals and wheels shall not show too much play.

7.4.04 No pedal hooks or toe-straps shall be allowed.

7.4.05 Bikes shall not have any sharp edges that could cause injury.

7.4.06 Tyres may not be fitted with chains, ropes or other devices.

26" Bikes (Mountain bikes)

7.4.07 Normal commercially available 26" wheel mountain bikes with a minimum of working 6 gears of different size shall be permitted. (text modified on 1.01.04).

TRIALS REGULATIONS E0107

7.4.08 Only one rock-ring chain guard shall be authorized on the transmission side. No additional, lower chain guard may be fitted.

Retrieved 4/7/07 at 4:30pm from <http://www.uci.ch/imgArchive/Rules/7tri-E.pdf>

Appendix D- Component Pictures

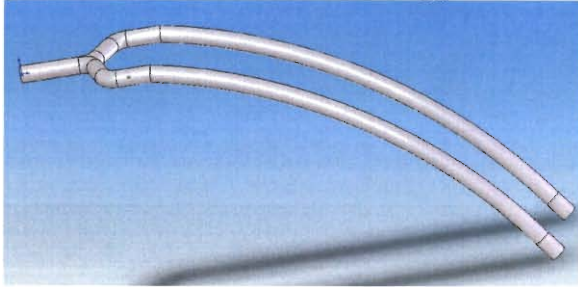


Figure A- 1

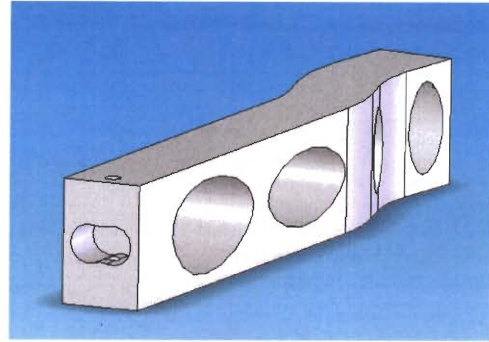


Figure A- 4



Figure A- 2

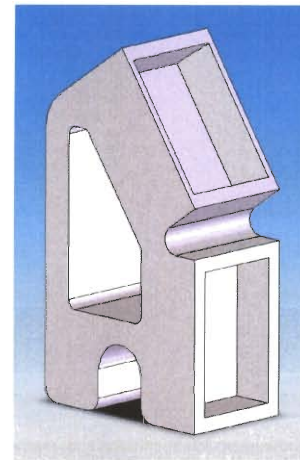


Figure A- 5

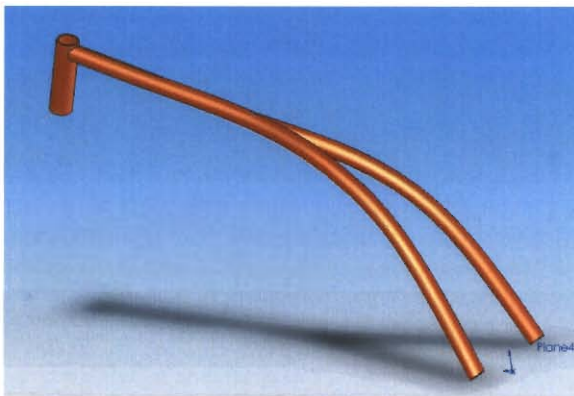


Figure A- 3

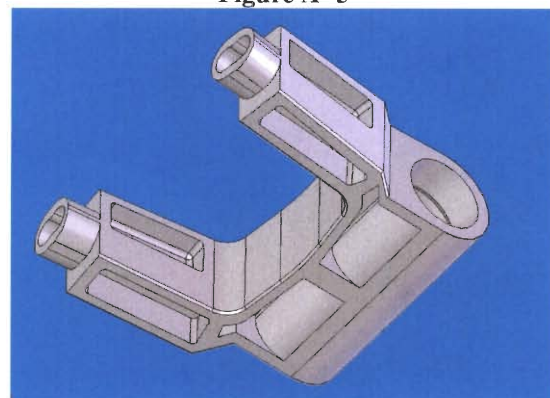
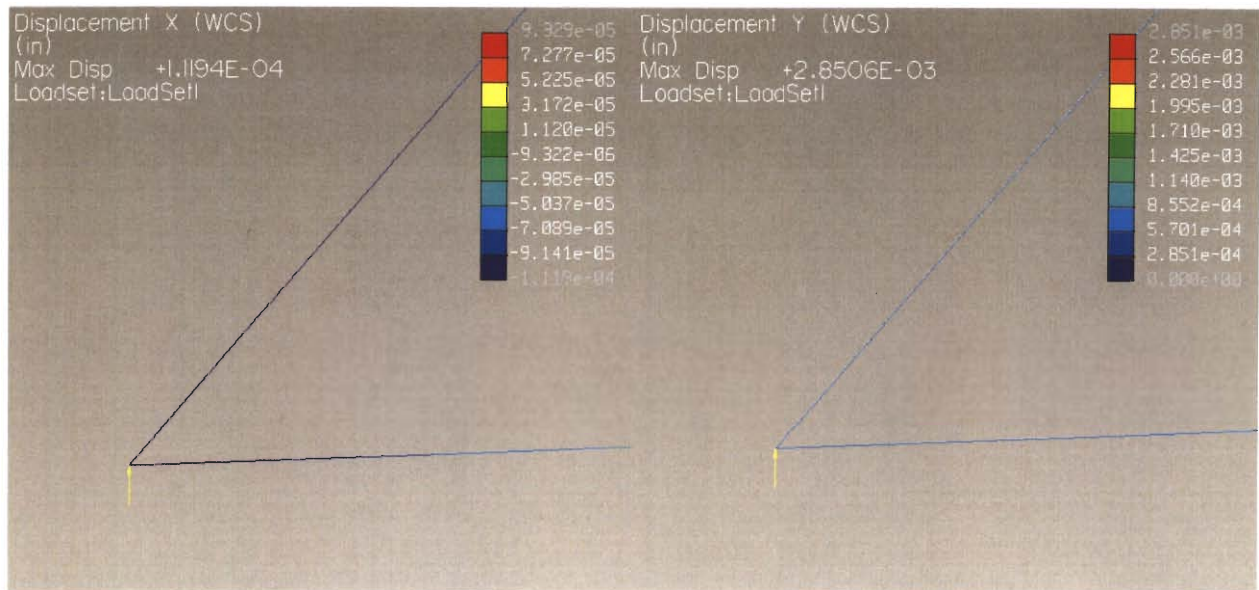


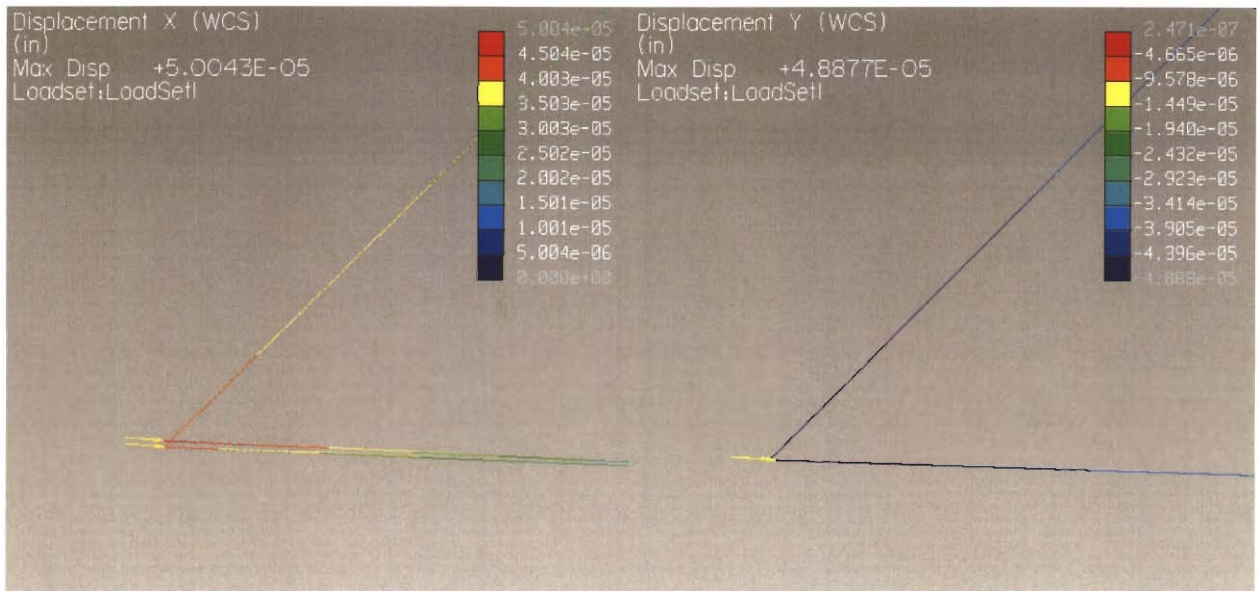
Figure A- 6

Appendix E- Quantitative Functional FE Analysis Results

- Vertical Load



- Horizontal Load



Appendix F- Material Properties

	Mass Density [kg/mm ³]	Modulus of Elasticity (E) [N/mm ²]	Poisson's Ratio (μ)	Shear Modulus of Elasticity (G) [N/mm ²]
Titanium Alloy (6Al-4V)	4.3816*10 ⁻⁹	113760	.35	42058
composite inserts (fiberglass)	1.95*10 ⁻⁹	17930	.33	2930

Anonymous G. Fiberglass Technical Data. Retrieved 4/6/07 at 1:00 from http://k-mac-plastics.net/data%20sheets/fiberglass_technical_data.htm

Appendix G – Resumes

1303 Douglas, Apt #1
Kalamazoo, MI 49007
(616) 901-4861

Home Address: 6340 Greeley NE
Rockford, MI 49341
email: david.boboltz@wmich.edu

Objective: Engineering related career in a fast paced environment where leadership and technical design skills can be used to innovatively accomplish a complex goal

Education:	
<i>9/02 – Present</i>	Western Michigan University 3.52 Grade Point Average
	Kalamazoo, MI 49008
	Bachelor of Science in Engineering – Mechanical Engineering
	Anticipated Graduation – April 2007
	Senior Design Project: Development of Prototype Trials Frame
	Fundamentals of Engineering Exam Registered for October 2007
	Tau Beta Pi
	Lee Honors College
	Dean’s List – Fall 2002–Spring 2004, Spring 2006

Work Experience:

- 12/05 – Present* **FEMA-Corporation** – Kalamazoo, MI
Scholarship Student Intern
 - Setup and performed various fatigue and prototype tests
 - Analyzed data and prepared reports
 - Assisted engineers with data analysis for product development
 - Led redesign of production fixture to reduce assembly time
 - Developed testing to determine fixture feasibility and capability
 - Inspect incoming production parts for print compliance
- 9/03 – Present* **Lee’s Fun and Adventure** – Kalamazoo, MI
Sales Associate
 - Interact with customers to determine correct product to fulfill specific requirements
 - Train new employees on cash register and store policies
 - Advise management over future merchandise purchases for stock

11/03 – 2/04	Caledonia High School – Caledonia, MI Assistant Varsity Ski Coach Instructed athletes to advance ski racing skills for competition Managed athletes at races to ensure that they remained focused and on schedule
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Extracurricular Activities:	President of WMU Cycling Club – 2004, 2005, 2006
	Director of club’s collegiate races– 2005, 2006
	Obtained \$10,000 budget for the 2006 events
	Scheduled and supervised 30 volunteers
	Coordinated with local law enforcement and obtained government permits
	Organized club meetings and travel to events
	Oversaw club finances and maintained yearly budget
	Contracted with sponsors
	Race Director – 2005 Michigan State Championship Road Race
	Coordinated with local law enforcement to provide 10 personal for road safety
	Arranged for Right-of-Way permits from government officials
	Developed registration system for over 200 athletes
Race Director – 2006 BTR Park Criterium	
Collaborated with and advised WMU Community Outreach for event	
Boy Scouts of America Eagle Scout Ranking – 1999	

Rob Harmer

1304 Greenwood Avenue ∞ Kalamazoo, MI 49006
Phone: 248.939.6873 ∞ E-mail: robbie.harmer@wmich.edu

OBJECTIVE

To obtain meaningful and challenging work experience within the intellectual property legal field.

EDUCATION

WESTERN MICHIGAN UNIVERSITY

Kalamazoo, Michigan

- ∞ Expected Graduation: April 2007
- ∞ Major: Bachelor of Science in Engineering- Aeronautical
- ∞ Minor: Business Management
- ∞ Current GPA: 3.92/4.0
- ∞ Additional Programs: Lee Honors College, Western Michigan University

WORK EXPERIENCE

FORD MOTOR COMPANY

Dearborn, Michigan

Product Development Intern

May 2005-August 2005

May 2006-August 2006

- ∞ Secured roughly \$1 million in cost saves through frame hole, laser cell, and blank optimization studies.
- ∞ Communicated supplier expectations and demanded results regarding formability and durability issues.
- ∞ Lead suspension Fastener Health Chart analysis process for a new Ford vehicle program.
- ∞ Advised Design and Release Engineers on necessary component modifications to meet requirements.
- ∞ Facilitated supplier meetings concerning part sizing, design, and load bearing applications.
- ∞ Managed preliminary part selection and sizing for new rear suspension module.
- ∞ Obtained *Green Belt Training* and learned the *Global 8D* problem solving strategy.

TRW AUTOMOTIVE

Livonia, Michigan

Engineering Co-op

April 2004-August 2004

- ∞ Administered many tests including failsafe, tire pressure monitoring, and EHCUs.
- ∞ Reduced test data and integrated summarization with automated processes.
- ∞ Designed extended failsafe manual for employees to use in stability system testing.
- ∞ Headed torque wheel acquisition process for several team's bench mark vehicles.
- ∞ Authored vehicle work requests, prepped vehicles for testing, and interacted with numerous teams to complete written goals.

FORD FLIGHT OPERATIONS

Romulus, Michigan

Airport Management Assistant

May 2003-July 2003

- ∞ Gathered knowledge of jet aircraft systems through cockpit jumpseat rides.
- ∞ Conducted routine inspections and part changes with mechanics in order to keep aircraft current.
- ∞ Reported to management regarding my inspection of union contracts and database maintenance.

INTERNATIONAL FENESTRATION COMPONENTS

Northville, Michigan

Project Leader

June 2002-August 2003

- ∞ Developed product cost estimating model for use by top financial executives.
- ∞ Analyzed and organized machinery blueprints collection so as to aide technicians.
- ∞ Created many product catalogue brochures for company portfolio.

ACTIVITIES & HONORS

Vice President: Tau Beta Pi Engineering Honor Society
National Scholars Honor Society
Golden Key National Honor Society
National Dean's List
Western Michigan University Dean's List

Keystone Leadership Society
Salvation Army
Habitat for Humanity
Society of Automotive Engineers (WMU Chapter)
Western Michigan University Academic Scholarship

Caleb J. VanderVeen

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Current Address
447 West Vine apt. E-1
Kalamazoo, MI 49001
(269) 330-6295

Permanent Address
8315 Brookwood Dr
Portage, MI 49024
(269) 327-7833

Objective Motivated student interested in gaining hands-on experience in the design or manufacturing side of the aerospace industry. Seeking full-time summer position or internship in aerospace, automotive, or related industry.

Education *Western Michigan University*, Kalamazoo, Michigan
Bachelor of Science in Aeronautical Engineering
Anticipated graduation date: December 2007

Work Experience Denso Manufacturing Michigan, Battle Creek, Michigan
Lab Technician, June 2005-September 2006

- Perform Operation and Prototype checks on HVAC and radiator units
- Perform Temperature Control and Distribution on HVAC units, along with various other testing
- Work with engineers on probable causes of problems found during testing

Western Michigan University, Kalamazoo, Michigan
Assistant Researcher, September 2006-Present

- Conduct wind tunnel tests
- Fabricate test stands

Meijer Corporation, Portage, Michigan
Utility Worker May 2001-August 2003
Cashier, August 2003-Present

- Assist in training of new employees

Pioneer Seed Corn Company, Portage, Michigan
Andy Simmons Corn Detasseling
Foreman, June 1999-August 2004

- In charge of between 8 and 12 employees
- Operate heavy farm machinery
- Responsible for performance of under-employees and other foremen and their crews
- Make decisions independently when out of contact of contractor

Activities Member of the American Institute of Aeronautics and Astronautics

- 2005 Team Member of WMU student branch of AIAA and participant in Design, Build Fly competition

Appendix H- ABET Outcomes

Assessment of Program Outcome #5 ME4800

Evaluation of program outcome “An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”

1. This project involved the design of a: *system / component / process*

Description:

See page 5 and 8

2. The **need**:

See page 6

3. The **constraints**: (Explain and justify any constraint that was relevant to the project. At least 3 constraints must be addressed)

Economic:

See page 9

Ethical:

It took a small degree of ethics to decide upon objectives up front as opposed to modifying goals after the fact. For example, it would have been quite easy to raise the target weight for the frame late in the design process.

Health & Safety:

See page 9

Manufacturability:

See Section 2.4

Others:

Technical regulations- see page 9

4. Is there a potential for a new patent in your design? Explain and compare with related patents.

4. _____ There is the potential for a patent on the location of the use of the flex boards. Pivot less chainstay designs have been patented in the past but none used fiberglass boards as the main force for this pivot. Related patents include #6,783,142 and #6,406,048. _____

Assessment of Program Outcome #12 ME 4790/ME 4800

Evaluation of program outcome “An understanding of the impact of the engineering solutions in a global, environmental and societal context”

1. Is this project useful outside of the United States? Describe why it is or is not-provide details.
See page 6
2. Does your project comply with US and/or international standards or regulations? Which standards are applicable?
See page 9
3. Is this project restricted in its application to specific markets or communities? To which markets or communities?
The frame can be sold in any market
4. If the answer to any of the following is positive, explain how and, where relevant, what were your actions to address the issues?

Design is focused on serving human needs. Design also can either negatively or positively influence quality of life. Address the impact of your project on the following areas.

Air quality?

If used for transportation, trials bikes can cut down on traffic pollution and congestion.

Water quality?

Only the production of the raw materials for the frame might affect water quality but the quantity of trials frames produced per year is low enough that there will be no major impact.

Food?

The project will have no impact on food sources or quality.

Noise level?

Other than the reduced traffic possible if used for transportation, trials frame will have no impact on noise levels

Does this project impact:

Human health?

See page 6

Wildlife?

Only the production of the raw materials for the frame might affect wildlife but the quantity of trials frames produced per year is low enough that there will be no major impact.

Vegetation?

Only the production of the raw materials for the frame might affect vegetation but the quantity of trials frames produced per year is low enough that there will be no major impact.

Does this project improve:

Human interaction?

Hopefully this project is grounds for bringing people together in support of a common interest. Friendships and lifelong memories are developed through competitive sports and a sport accelerating at this rate might turn up in the X-Games several years from now.

Well being?

See page 6

Safety?

While trials riding may present additional risk to careless riders, we'd like to think that an overwhelming offsetting percentage of individuals will be inspired to become active and promote a healthy lifestyle which counters obesity and heart disease.

Others?

Assessment of Program Outcome #9 **ME 4790/ME 4800**

Evaluation of program outcome "**A knowledge of contemporary issues**"

1. Why is this project needed now?

____ See page 6 _____

2. Describe any new technologies and recent innovations utilized to complete this project.

____ See pages 7 and 8 _____

3. If this project is done for a company—how will it expand their potential markets?
---*how will it improve satisfaction of the company's existing customers?*

____ The project was not done at the request of a company. _____

---identify the competitors for this kind of product, compare the proposed design with the company's competitors' products.

____ See pages 6 and 7 _____

5. How did you address any safety and/or legal issues pertaining to this project (e.g., OSHA, EPA, Human Factors, etc.).

____ Care was taken during the brainstorming stage so as to avoid infringing upon previous intellectual property. The SlingPower technology has been patented for a while although applying it to a trials' frame is novel. Additionally, a Slingshot representative encouraged us to utilize this product. _____

6. Are there any new standards or regulations on the horizon that could impact the development of this project?

____ None that are known. _____

7. Is there a potential for a new patent in your design? Please document related patents.

____ There is the potential for a patent on the location of the use of the flex boards. However, there is no current plan to file for a patent. Related patents include #6,783,142 and #6,406,048. _____

Assessment of Program Outcome #13 **ME 4790**

Your responses will be used in the Evaluation of program outcome "**A recognition of the need for, and ability to engage in life-long learning**"

ME 4800

Mechanical and Aeronautical Engineering Design Project

For each team member:

David Boboltz

1. List the skills you needed to execute your responsibilities on the project as outlined in ME 4790.

_____Converting dynamic loads to static loads_____

_____Model complex parts in SolidWorks_____

_____Analyses solid models in Algor FEA software_____

2. List how you gained the requisite skill, or enhanced your existing skill, to the benefit of your design team and the project.

_____Converting dynamic loads to static loads- reviewed dynamics material and learned impact force theory with the help of my teammates._____

_____Model complex parts in SolidWorks- Self taught myself most functions needed and used the knowledge of a co-worker for the more difficult parts._____

_____Analyses solid models in Algor FEA software- Used the help menu and experience of team members to learn the software. I also took a class outside of my curriculum requirements in the Finite Element Method._____

Rob Harmer

1. List the skills you needed to execute your responsibilities on the project as outlined in ME 4790.

_____Working knowledge of the FEA software in ProEngineer – Mechanica_____

_____Trust and effective communication with teammates _____

_____Solidworks part and assembly skills and abilities_____

2. List how you gained the requisite skill, or enhanced your existing skill, to the benefit of your design team and the project.

_____I learned how to use Mechanica's structural analyses feature via a one-on-one training session with an old friend. He showed me the ropes of the program as I took notes and asked questions. Additional help was available through online chat rooms and forums. _____

_____Trust and means of effective communication were obtained with time and dedication.

Holding teammates accountable for agreed upon tasks increased all of our trust in each other. Communication standards were established early in the semester since group members would frequently work on the project alone. Updates to files and parts were critical to the progress of this frame's design. _____

_____Solidworks' easily accessible tutorials were the key to learning this software. There are tutorials ranging from very easy to rather advanced. I'm glad I was able to learn this program quickly and hassle-free. _____

Caleb VanderVeen

1. List the skills you needed to execute your responsibilities on the project as outlined in ME 4790.

_____ Good communication skills as well as good interpersonal skills _____
_____ Knowledge of CAD software and modeling and drafting skills _____
_____ Experience with FEA software, particularly Mechanica and Algor _____

2. List how you gained the requisite skill, or enhanced your existing skill, to the benefit of your design team and the project.

_____ I gained interpersonal skills and communication abilities through interaction with the other students on my design team, learning to be open minded when listening to the ideas and thoughts of others. _____

_____ I knew some basic operations various CAD software but had no prior experience with SolidWorks. To learn this program I used the tutorial included with the software, and through many different iterations during the design process learned more about the advanced features possible with this software package. _____

_____ I had very little FEA experience before this design project. To learn Mechanica was really mostly trial and error. Using the rudimentary knowledge I already possessed, I had to gradually learn how to debug certain errors and constrain parts correctly. This at times can be extremely frustrating, but after it was done, I had learned a great deal. _____