ASME Human Powered Vehicle

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Team 14

Final Proposal

Document

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Introduction

There is a need for engineering efficient, reliable human powered vehicles in order for people to commute and transport goods. The goal of this project is to eliminate vehicles by designing safe, efficient, and reliable vehicle that can be powered solely by the vehicles rider. The objective is to design this vehicle so that it meets the ASME Human Powered Vehicle competition officials and that is as light, strong, and fast as possible to win every competition entered. Constraints include not being able to use any vehicles from previous years, and it must be able to compete in both the speed and endurance events at the competition. Vehicles are typically made of metal alloys, composites, or a mixture of both, with a recumbent riding position and have a streamline design to minimize aerodynamic effects.

The main criteria taken into account for the vehicle include the frame design, steering geometry, material of construction, power input, fairing design, and seating position. The most important design considerations were deemed to be strength, weight, efficiency, and ease of manufacturing. The frame will be constructed of aluminum to maximize the strength to weight ratio; it will be comprised of a single backbone support running the entire length of the vehicle with various pieces attached to the main support for mounting wheels, seat, and steering components. The fairing will have a teardrop design following similar principles of an airfoil to minimize drag forces acting upon it. Standard bicycle cranks and foot-pedals will provide the power necessary to propel the vehicle. While the seat will be one piece and adjustable for all team members with a universally adjustable mounting bracket. Steering will be provided with two levers located one on each side of the seat that utilize a push pull motion to laterally turn the front wheels. As of today the project remains on schedule.

Prototype

The purpose of the prototype was to help visualize and determine the proper measurements for the seating position, steering geometry, and pedal position. As well as to provide members of the team with manufacturing experience. The prototype was constructed of steel to minimize cost as well as being easier to produce. Dimensions of the prototype were 6’6” long by 4’ wide. Three design aspects were focused on in particular for the prototype: frame, steering and seat positioning. The frame consisted of one 5’ long square steel pipe to form the backbone of the frame. Attached at 15 degree angles on each side of backbone were round steel pipes which represent where the wheel assemblies would attach. Another round steel pipe was mounted on the top and end of the backbone at a 35 degree angle, representing where the pedal assembly would attach. Along the backbone of the frame, holes were drilled two inches apart in order to pin the seat along the frame. The seat is pinned at two locations as seen in Figures 1 and 2. The steering was mounted on one side of the seat consisting of a lever arm that would be pulled vertically up and down in order to rotate a pivot plate underneath the front of the backbone and thus provide rotation laterally in the wheels.

Figure 1 - Prototype

Figure 2 - Prototype

CAD Model

Figure 3 shows the assembly model of the human powered vehicle using SolidWorks. The design shows the frame with a mounted rollover cage. The design displays three wheels with the positions of the wheels set up as a tripod set up. The pedals are located in front of the rider at the front end of the vehicle. The rider has two levers on each side which work as push and pull motion to turn the vehicle.

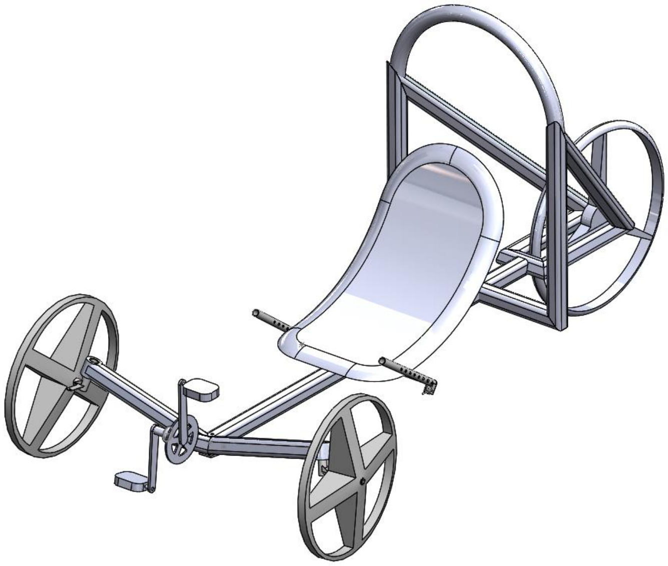

Figure 3 - CAD model

Frame

The current design for the HPV frame aims to improve current designs by incorporating the use of a lightweight material, strengthening the frame, and having a smaller footprint (i.e. shorten the wheelbase and reduce cross sectional area).

Utilizing aluminum versus steel in the design was done purely to help reduce the overall weight of the vehicle. The only downside is that it will require a final heat treating process. It will be constructed using square tubing to help increase the ease of manufacturing as opposed to circular tubing which requires more skill to fabricate.

The frame will be comprised of a single backbone running the length of the vehicle that utilizes triangular trusses in the rear to help add support and stability to the roll cage where the rider will be positioned; yet still minimize the amount of material being used during construction. The arms coming off the front of the vehicle will be welded on in the desired position so that the vehicle has the desired steering geometry. Those arms will also have gusset plates that attach to both the frame and the arms to help add additional support and strength to those members. The entire frame will require a final heat treating process that releases the stresses within the material and resets the crystalline structure of the aluminum stock being used. This will strengthen the final design once construction is fully completed.

The reason for reducing the wheelbase and average cross sectional area is simply to make the vehicle smaller. The theory behind that is by making the vehicle smaller, it is also becoming faster and requires less power to get and keep the vehicle moving at its maximum speed. This will help in both endurance and drag racing events. This is because the rider will have to exert less power to keep the vehicle at a higher average speed than a bigger, heavier vehicle for the endurance event. Having less weight to move also means that the car will require less force to get moving while having have a faster acceleration than a bigger vehicle.

This vehicles wheelbase was shortened by relocating the steering underneath the rider and moving the pedals and rider as far forward as possible. This allowed for the excess to be trimmed off the back and an overall shorter wheelbase. The advantages of having the rider positioned further forward are it puts more weight over the front wheels helps to add stability and more responsive steering.

By taking all those design considerations into account we have designed a frame that has the optimal balance between being lightweight and compact, yet still extremely robust and able to adequately handle all of the abuse we will be subjecting it to during testing and competition. This design will be the driving force behind our team and help to carry us across the finish line.

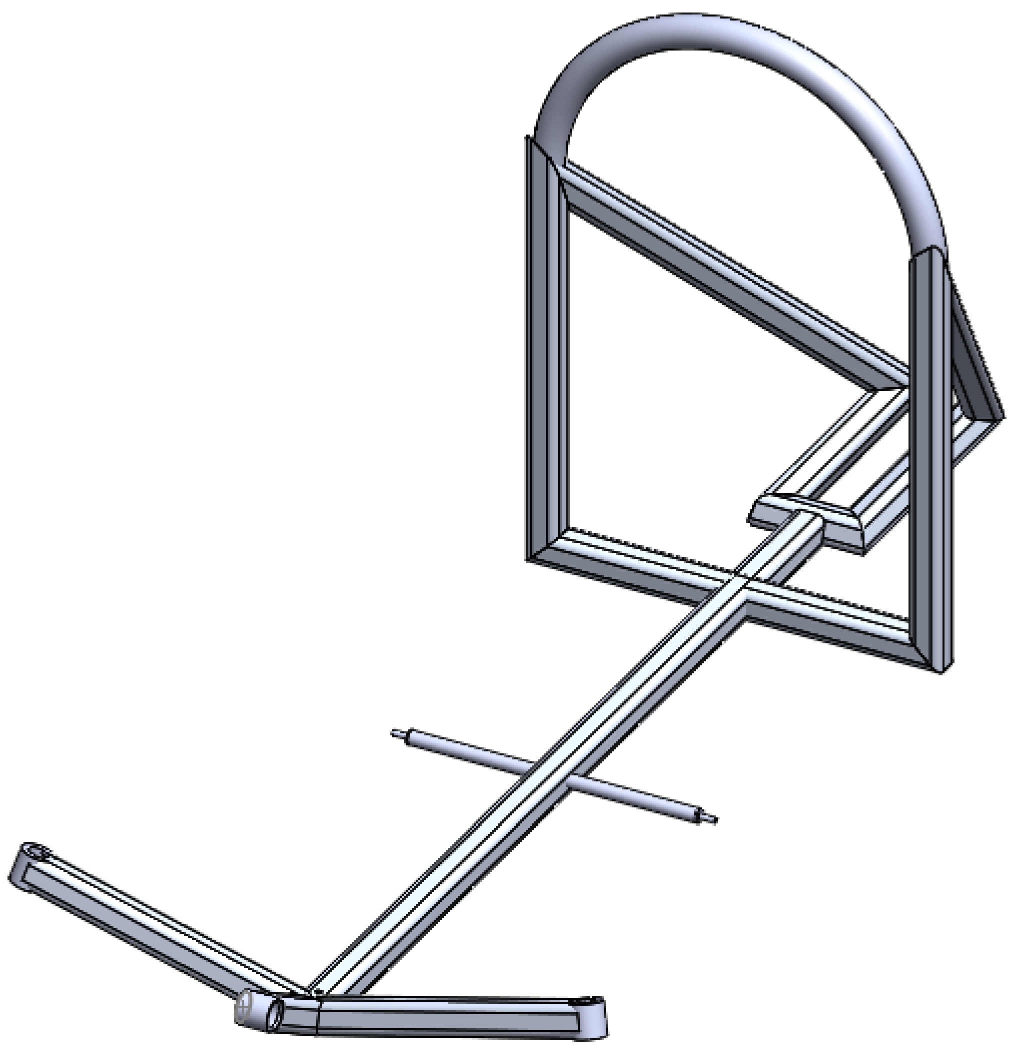

Figure 4 - Frame Model

Seat

The seat will be mounted to the frame using a custom bracket that is able to be placed at any position along the backbone of the frame. This allows for adjustments to be made to compensate for the rider's height as well as their preference for comfort. The seating position is also critical in order to achieve the maximum power being outputted by the rider. This is due to the specific angles at which the rider's legs, hips, and torso are at when the rider is expelling their energy and driving the petals down.

The bracket will mount around the perimeter of the square frame and have a thin rubber sheet between the frame and the bracket to help increase the frictional forces acting on it so that it remains in place and does not move during use. The force required to keep the bracket in place will be supplied by a both that is threaded through the bracket and has a plate attached to the end that will have similar dimensions and meet, as well as being the contacting surface with the frame.

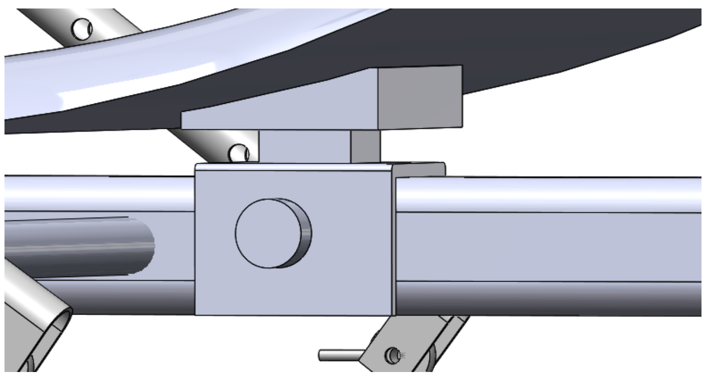

Figure 5 - Seating Bracket

Seat Calculations

To calculate the forces acting on the seat the force being exerted by the bolt (F) is calculated using equation 1.

$$T = 0.2 * F * d \quad [1]$$

Where:
T = torque applied (ft-lb)
F = force exerted by bolt (psi)
d = nominal diameter of the bolt (in)

That force can then be related to the material coefficient of friction to calculate the total frictional force (Ff) resisting the motion of the seat can be seen in equation 2.

$$Ff = \mu * F \quad [2]$$

Where:
μ = coefficient of friction

Calculating force applied by the bolt			*Calculating total frictional force acting on the bracket*			
T = torque (ft-lb)	15		Material	Coefficient Of Friction (µ)	Normal Force(F) (lb)	Fricional Force (Ff)(lb)
C = torque coefficient	0.2		Aluminum-->Aluminum	1.2	300	360
d = bolt diameter (in)	0.25		Rubber-->Rubber	1.16	300	348
F = force Applied (psi)	300		Rubber-->Aluminum	1.18	300	354

Table 1 - Seating Calculations

The calculations above are based on the assumption the bolt is torqued to 15 foot pounds. With that applied torque the bolt will exert a force of 300 psi. Combining that force with the coefficient of friction of the rubber against aluminum results in a total frictional force equaling 354 pounds which is more than adequate to keep the seat securely in place and prevent any movement.

Fairing

The fairing is used to make the vehicle more aerodynamic by reducing the drag force. Previous models have shown a concave tail shows a significant difference in the drag force. Figure 6 displays the fairing design for the human powered vehicle. The fairing is estimated to have a length of 104 inches, width of 40 inches, and a height of 40 inches. The tailstock reduces in height to 26.56 inches while the width reduces to 3.15 inches. The fairing will be made out of carbon fiber due to its high strength to weight ratio.

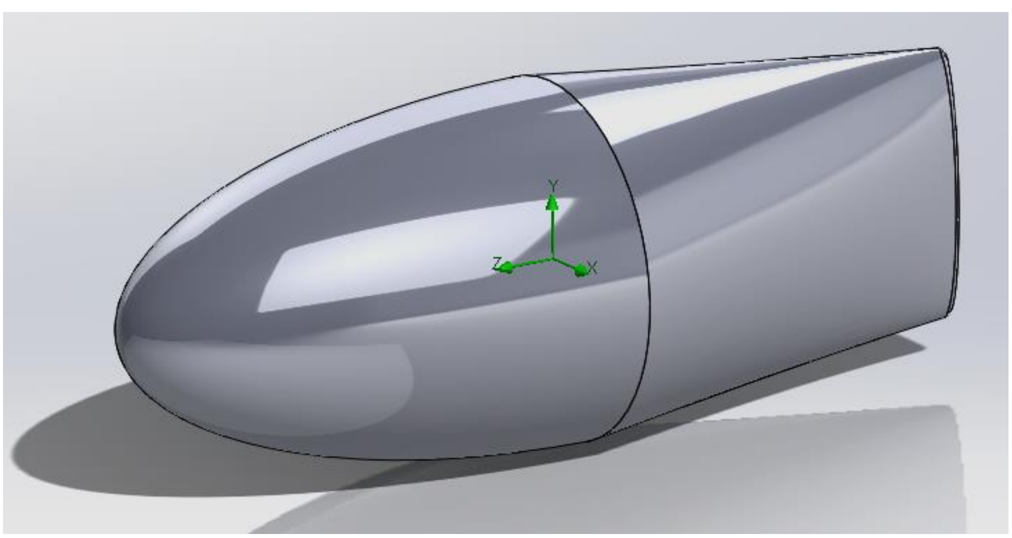

Figure 6 - Fairing

The Computational Fluid Dynamics (CFD) was done using SolidWorks modeling. The following assumptions about the flow were made: the airflow is at 40 mph (18m/s), the moving fluid is air, and the flow is measured externally. Figures 7 shows the CFD from the side view and Figure 8 shows the CFD from the top view. The coefficient of drag was calculated using the following equation:

$$C_d = \frac{2D}{\rho A V^2} \quad [3]$$

Where:
D = Diameter (40 in)
ρ = Density of Air (1.2 kg/m^3)
A = Cross-sectional Area (in^2)
V = Velocity (40mph - 18m/s)

The coefficient of drag from the fairing resulted in Cd = 0.0451. From the result the team had to determine if the result was valid by researching different drag coefficients for shapes. Figure 7 shows the coefficient of drag for different shapes. Comparing the result to the researched shapes the team's coefficient of drag resembles that of an airfoil.

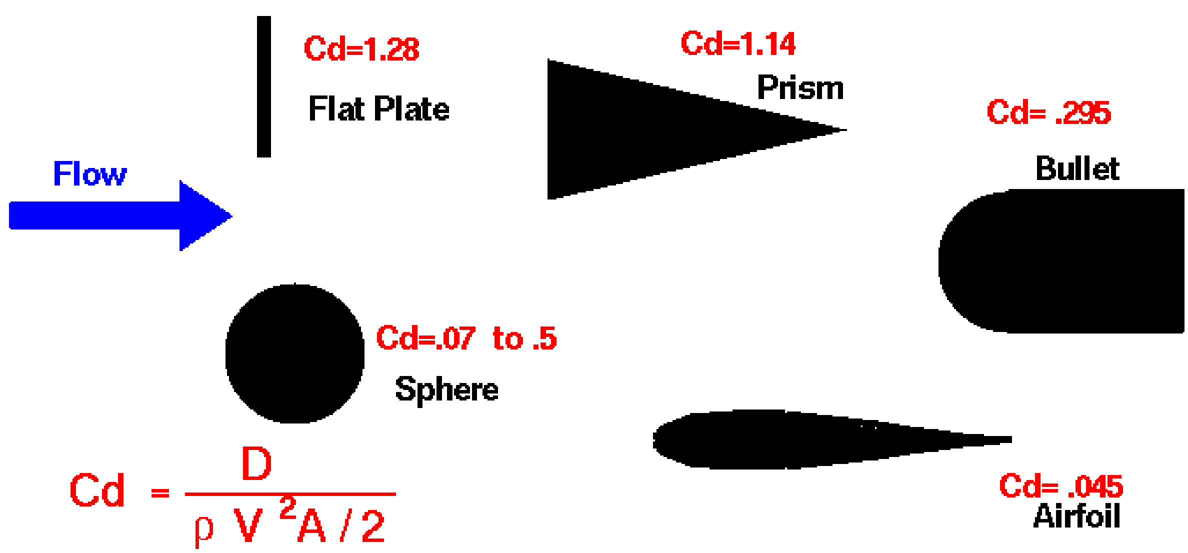

Figure 7 - Various coefficient's of drag

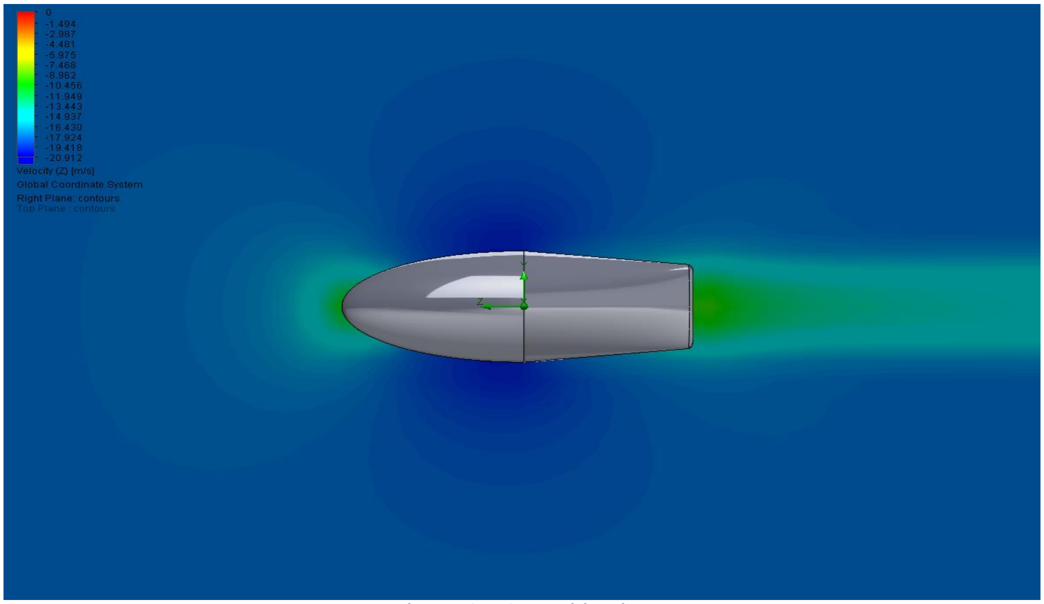

Figure 8 - CFD side view

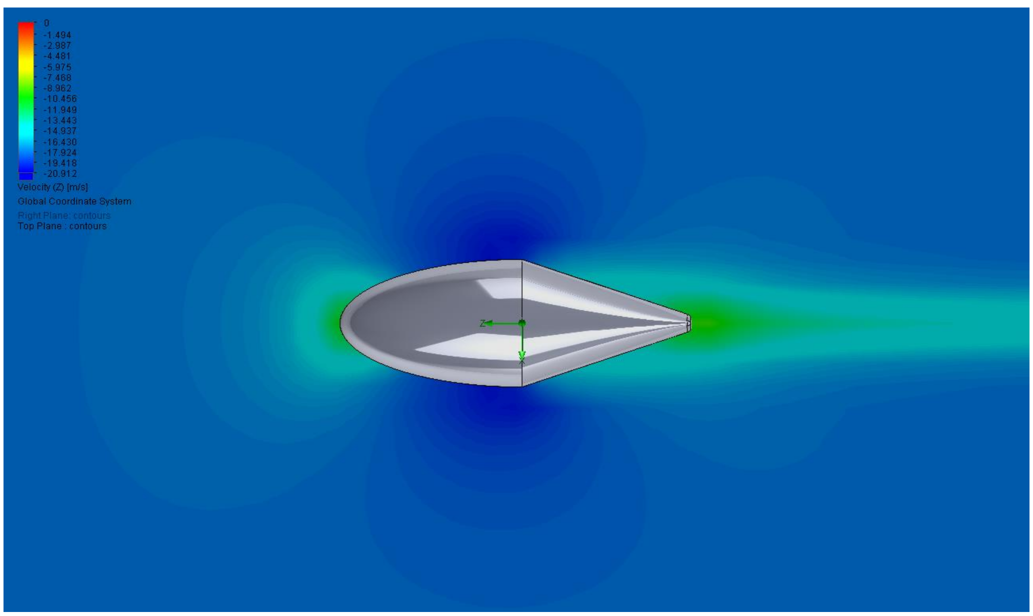

Figure 9 - CFD top view

Steering

The steering geometry is based on Ackermann geometry, in which the linkages are designed to keep all the wheels of the vehicle perpendicular to a single virtual point (Fig. 9). With this arrangement there is, theoretically, no scrubbing of the steered wheels as the vehicle moves in a circle. Therefore, Ackermann geometry provides for maximum tire longevity and vehicle control, and minimal loss of momentum during cornering. Ackermann geometry is approximated on this vehicle by designing the steering hubs such that lines drawn through the kingpins and the tie rod end bolts will intersect in the middle of the rear wheel's axle.

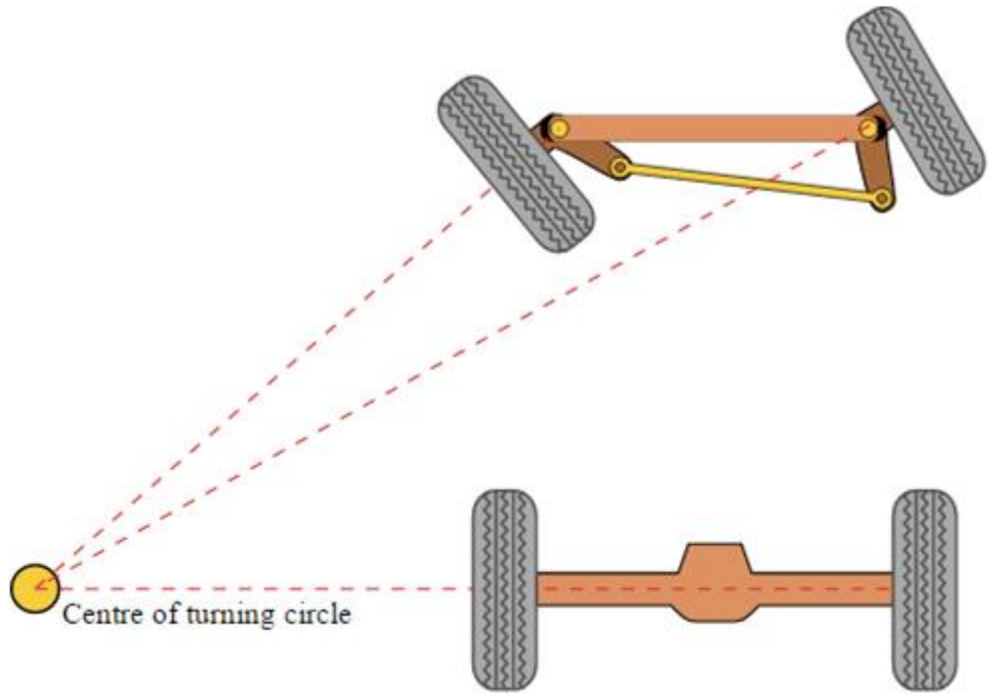

Figure 10 - Ackermann steering geometry

The stability and ease of control of the vehicle lies in the design of the steering hubs. Of particular importance are scrub radius and trail. The scrub radius is the latitudinal distance between the contact patch of the tire and the pivot axis of the kingpin (Fig. 11). If the contact patch is not coincident with that axis (zero scrub radius), the vehicle can experience bump steer, in which an obstacle in front of one tire causes the entire vehicle to veer, and split μ braking, when the braking force is uneven between the front wheels and the vehicle is steered in one direction or the other as a result. Trail is the steering property that allows the vehicle to track straight without any user input, and causes the steered wheels to return to center when no steering input is given. As figure 12 shows, trail is the longitudinal distance between the pivot axis of the kingpin and the contact patch of the tire. As long as the steering axis is in front of the contact patch the friction of the tires on the road will make the wheels track the axis. On this vehicle, trail is established by means of a 12° caster angle, which, with a 20-inch wheel, results in about 2 inches of trail.

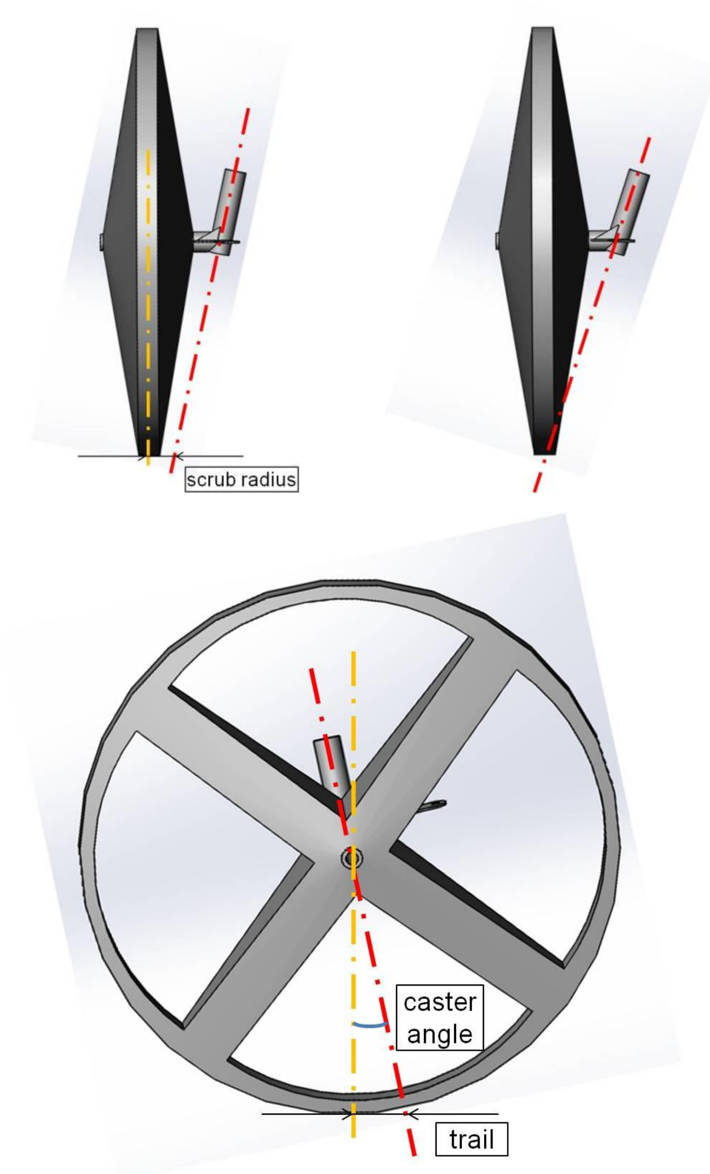

Figure 11 - Steering diagram

TIG Welder

The Tungsten Inert Gas welding apparatus in the machine shop is a crucial part of the fabrication of the HPV. However, there have been issues in the past with the torch cable melting when the user does not turn on the coolant pump before welding. Therefore, the machine has been out of operation for most of this past semester, preventing the team from practicing its use. If the machine is not fixed quickly enough, it will not be possible for the team to fabricate an aluminum frame without hiring a professional welder with their own equipment. Fortunately, the machine shop employees have designed and begun fabricating a coolant system that will prevent any possible overheating of the torch cable, and will have the system in place by the beginning of the spring semester.

Bill of Materials

Bill of Materials			
#	Part Name	Quantity	Price $ (dollars)
1	Aluminum Tubing	27 (ft.)	14.14 per foot
2	Carbon fiber (Fairing)	20 (lb.)	11 per pond
3	Seat	1	130
4	Brakes	3	123.49
5	Pedals	2	31.49
6	Cranks	1	57.49
7	Chain	25 (ft.)	17.99 per ten ft.
8	Wheels	3	35.99
9	Tires	3	31.99
10	Lights	1	11.99
11	Battery	1	7.54
12	Horn	1	14
13	Shifters	2	48.99
		Total	$1,266.69

Table 2 - Bill of materials

Conclusions

The design of the human powered vehicle has reached its final stages in the design process with the frame, seating, steering, and fairing. It has been determined that the frame will be constructed using square aluminum tubing to reduce the overall weight and help improve the ease of manufacturing. The seat will be positioned at an incline and bolted to an adjustable bracket that can be positioned along the entire length of backbone of the frame. The bracket will clamp onto the square frame and allow for a universal seating position that is capable of accommodating all team members. The steering is determined using the Ackermann's geometry which allows the vehicle to turn on at a specific reference point. The fairing will be constructed out of carbon fiber due to its high strength to weight ratio and to reduce the drag force of the vehicle. Once the TIG welder is functional the team will begin construction on the vehicle.

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Appendix A:

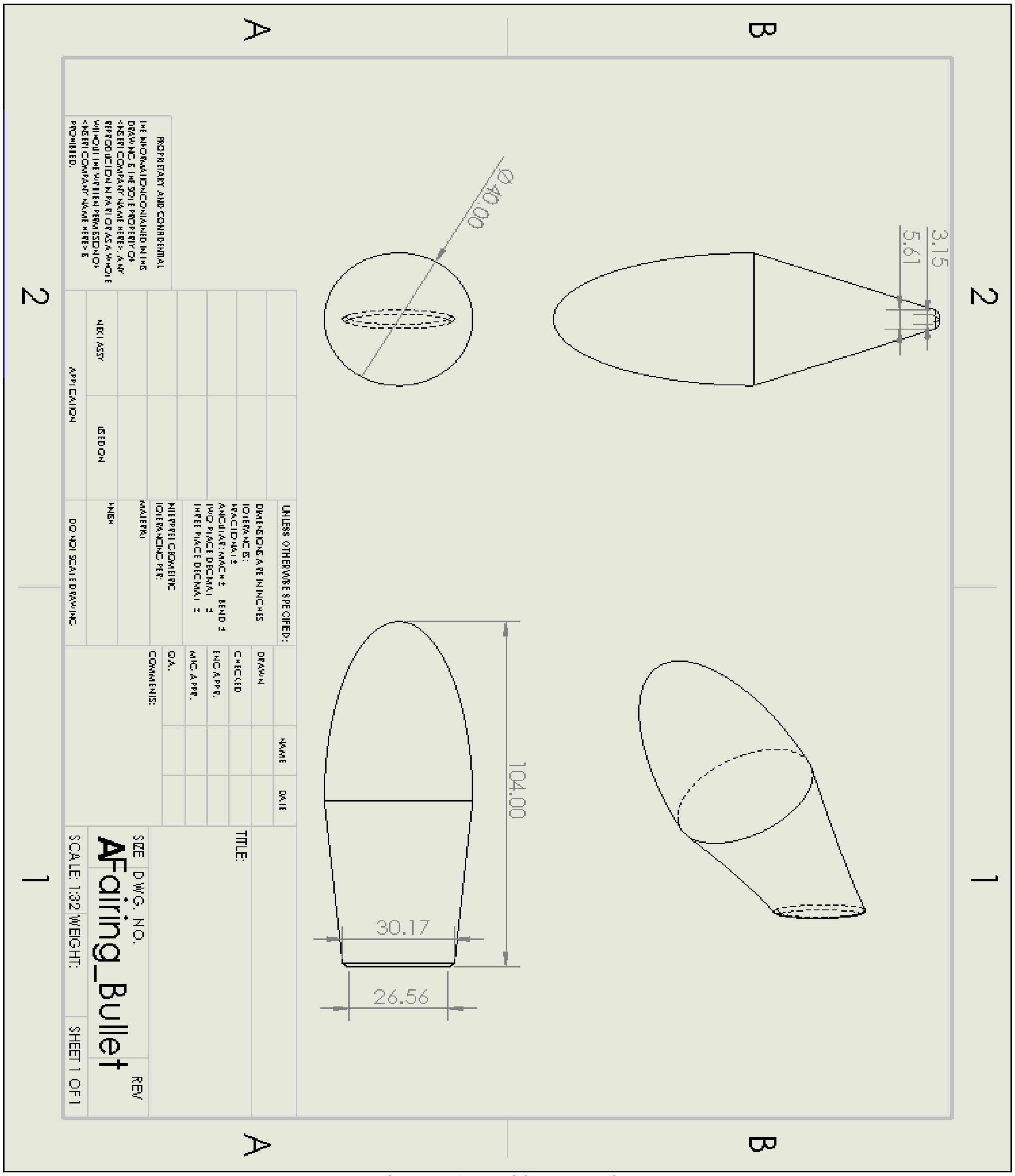

Figure 12 - Fairing overview

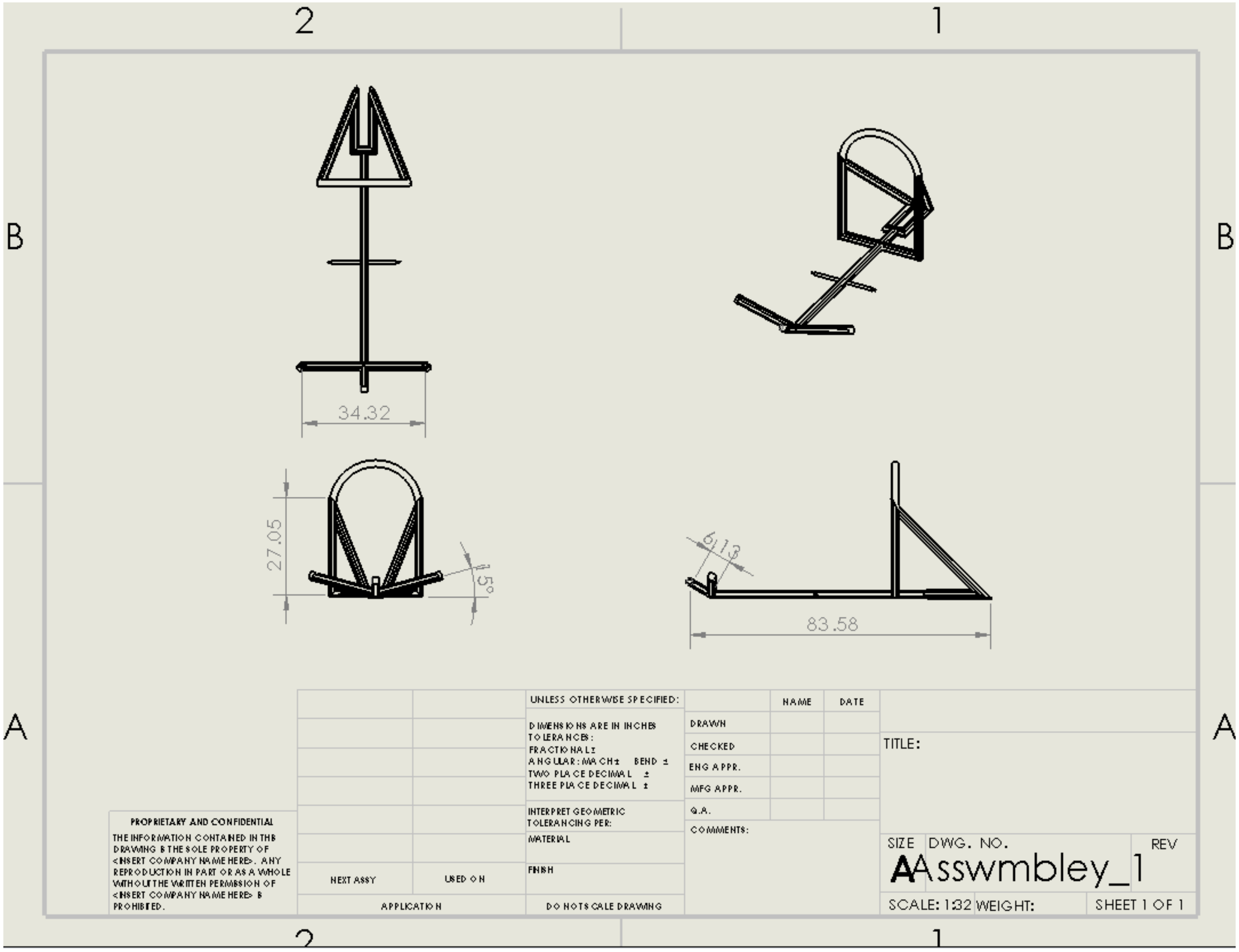

Figure 13 - Frame overview