Human Powered Vehicle Challenge

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Progress Report

Document

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1.0 INTRODUCTION

For the 2014 Human Powered Vehicle Challenge (HPVC), Team 9 will design, analyze, and construct a vehicle that meets the requirements given by the American Society of Mechanical Engineers (ASME) and the project's client, Perry Wood. To best complete the vehicle, the project was divided into six subsections. These sections include: frame, fairing, steering, drivetrain, ergonomics, and innovation. For each subsection design and analysis work was completed to ensure the best design. Each subsection then refined the design and has begun the construction process. This paper will give an update on design modifications as well as a detailed look into the individual tasks for each team member and subsection.

2.0 PROJECT DESCRIPTION

Team 9 will design and build a human powered vehicle to compete in the HPVC, held by ASME. The competition consists of a design event, a sprint or drag event, an endurance race, and an innovation presentation. The sponsors for this project are Perry Wood, the NAU ASME advisor, and ASME. A goal statement was generated which states the team will "Design a human powered vehicle that can function as an alternative form of transportation." This provides the team a large scope while brainstorming ideas within their sections. A few objectives the team has for the vehicle includes: speed, aerodynamics, and maneuverability.

3.0 DESIGN MODIFICATIONS

The overall vehicle design has remained nearly identical to the design submitted in the project proposal. However, further analysis was completed over winter break and minor design modifications were made. More detail on the modifications made over break can be found in each subsection. The overall vehicle design can be seen in Figure 1.

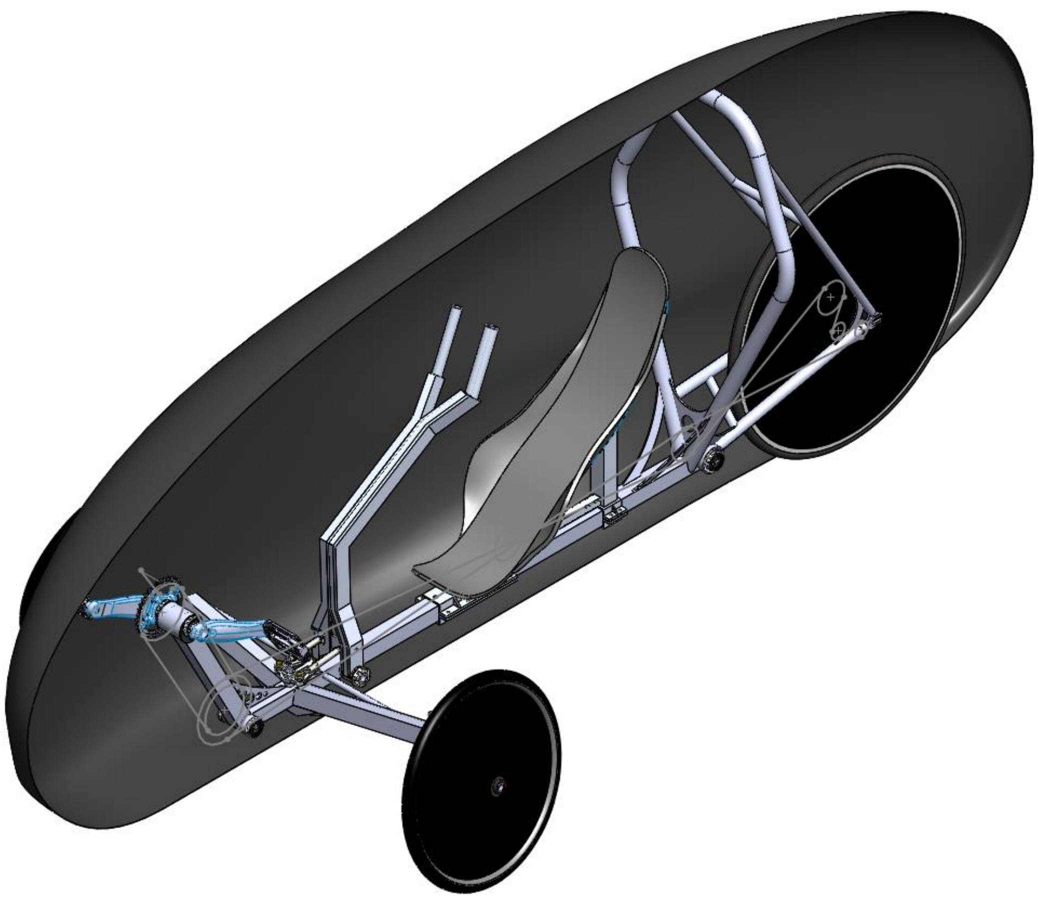


Figure 1- Full Assembly with Fairing Cut Away

3.1 FRAME

Two changes have been made from the last design of the frame. First, one of the rear chain stays had to be moved to accommodate a change in the chain line. This updated design can be seen in Figure 2. New supports and gussets have been added to this area to ensure that this change in geometry is secure. Analysis was also redone to ensure structural stability. Second gussets have been added to several high stress locations to improve factors of safety and minimize deflections.

Figure 2-Updated rear end

Currently all of the frame raw materials have been ordered and received, while remaining under the budget. All of the square tubes have been cut and notched to required specifications. A jig has been fabricated to aid in the construction of the rear triangle components. The gussets and dropouts have all been CNC cut and are ready to be welded into place.

3.2 ERGONOMICS

The ergonomics design includes the comfort, position, and adjustability of the seat to suit all riders. The design of the seat mount has recently been remodeled to reduce weight, incorporate Delrin plastic, and ensure the tallest rider can sit in the needed position. To reduce weight, holes will be cut into the metal to remove parts of the metal bracket that are not needed. Fillets will be used on the sides for strength instead of the gussets that were there originally. To incorporate the Delrin plastic, the inside of the mount will have insets to keep the plastic in place. After the gussets on the frame were added, the distance between the front bracket and the back bracket needed to be reduced to ensure that the tallest rider could sit at the required position. This design can be seen below in Figure 3.

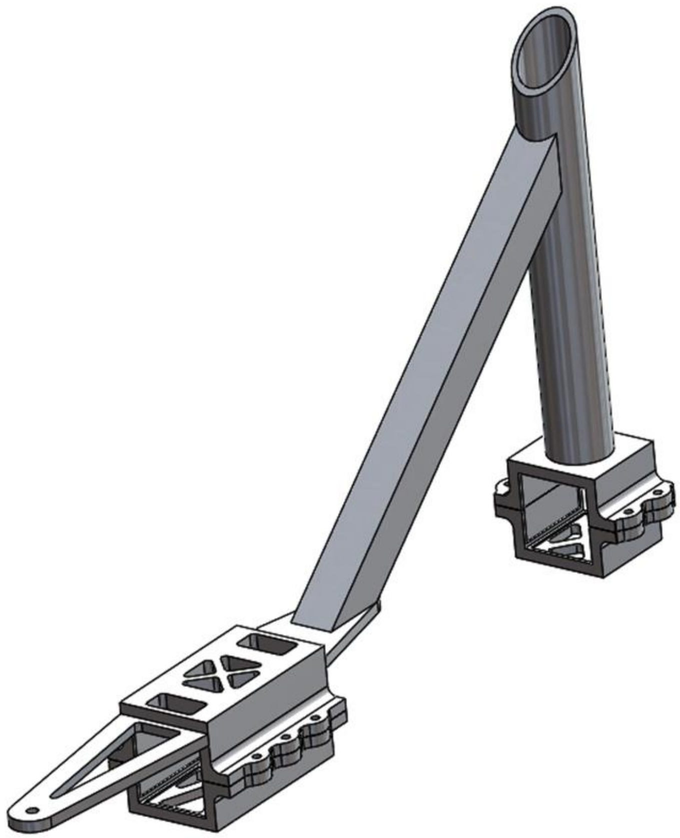


Figure 3- Seat Bracket Redesign

3.3 FAIRING

Over the university winter beak, the team continued to do analysis on different fairing lengths, widths, and heights. It was found that the roll bar was causing a majority of the issues with the increased drag force. Since the roll bar is the same width as the width around the crank arms, the NACA airfoil shape could not be achieved unless the length of the fairing was increased, which in turn increased the width. From there, the shape was optimized as much as possible and had a final drag force of 0.45 pounds at 40 miles per hour. As of now, the final fairing design is nine and a half feet with a maximum width of two feet and final height of 39 inches.

3.4 STEERING

There have been a few modifications to the steering system. The first change to the design was a modification of the bell crank for weight reduction. Since this part was not analyzed in the past semester, analysis was completed to determine the factor of safety given the max force on the part. There were some pockets added to the part to remove material in low stress areas. The initial weight of the bell crank was 0.20 lbs and the final weight after pocking is 0.15 lbs a 25% reduction in weight. The next part that has been modified is the knuckle; this is the part that attaches the front wheels to the frame. It was decided that a second pair of knuckles will be created that will have a steel insert in the axle to help relieve the stress concentration. The steering arms were one of the last components to have modifications applied. Small changes in the dimensioned and gusseted were added to enable the arms to withstand a 50lb side load. Those changes ensured that the arm will not yield if there is an incidental loading during transporting or rider entry or exit. The right steering arm has a solid section with a milled pocket to allow to the chain pass through in both chain line configurations, which will be discussed later on in the paper. This redesign can be seen in Figure 4 below.

Figure 4- Steering Arm Design

3.5 DRIVETRIAN

The drivetrain design has remained largely intact since its final state in the project proposal. However, more work was put into the chain line position after evaluating its clearance with other aspects of the vehicle. The first point of interest was the chain line in relation to the seat bracket. Due to the movement of the seat, a six inch range of movement, the chain needed to be placed so it cleared in all available seat positions. After closer examination, it was determined that the seat needed to rise from 0.63 inches above the frame to 0.75 inches to have clearance in all positions. This clearance can be seen in Figure 5 below.

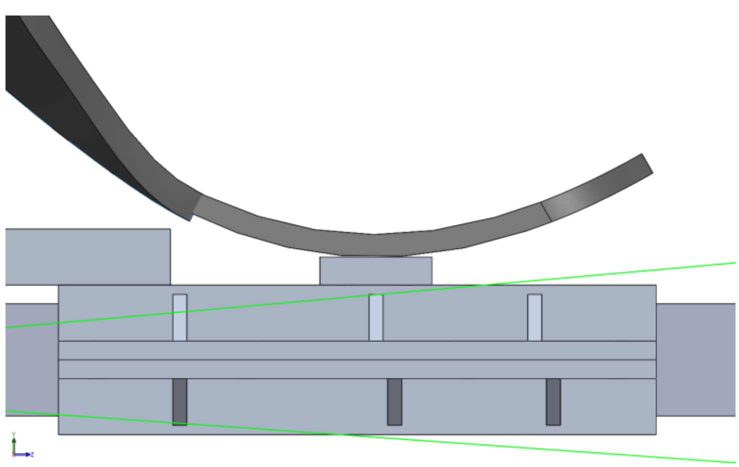


Figure 5-Chainline Position with Seat

The second aspect of drivetrain that featured a design modification was the chain line with respect to the reverse gear. It was discovered that the proposed chain line would turn the reverse gear in the opposite direction needed to function properly. To solve this issue, a new chain line position was established to allow the full functionality of the reverse gear. This configuration can be seen in Figure 6 below. It features a solid loop design between the step up gear and the reverse gear, allowing the reverse gear to spin in the same direction as the rider pedals.

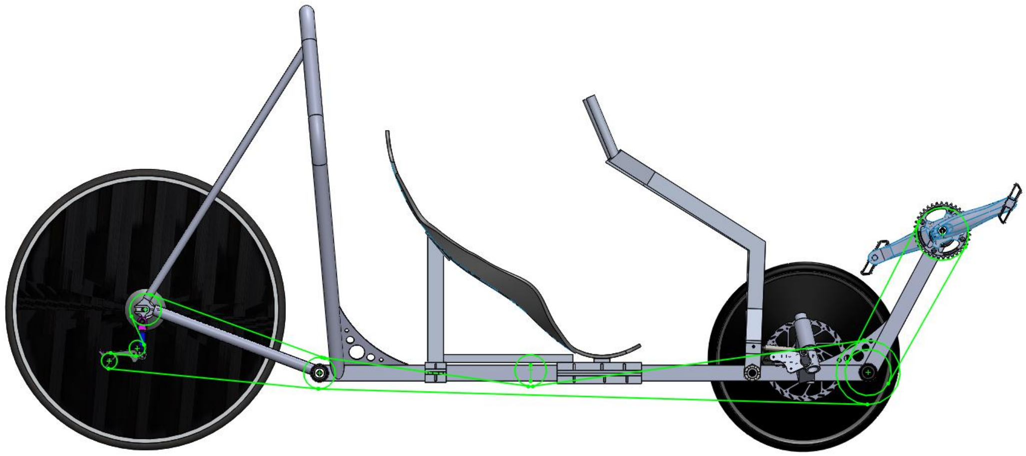


Figure 6- Reverse Gear Chain line Configuration

While this chain line position is ideal for the functionality of the reverse gear it requires a greater amount of chain and travels over more gears. This would lead to a lower overall efficiency for the drivetrain and a slower top speed. Due to this loss of efficiency, the drivetrain has been designed to be able to remove the gear placed under the seat and swap out the chain line with that seen in Figure 7 below.

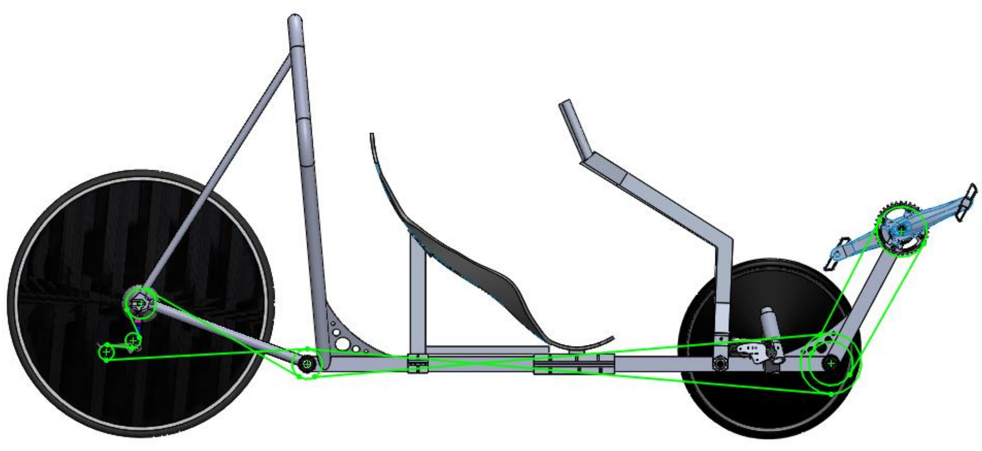


Figure 7-Standard Chain line Configuration

The standard chain line configuration seen in Figure 7 above is identical to that shown in the project proposal. The team still believes this is the best drivetrain configuration for efficiency. To prove the efficiency difference between the reverse gear chain line and the standard chain line, the team plans to hold physical testing of both systems and compare the results. If the reverse chain line proves a lower efficiency, as expected, the team will plan to demonstrate the reverse gear at competition, but not include its functionality during the speed and endurance based events.

3.6 INNOVATION

Lights - Safety:

During the break, circuitry was developed to allow driver inputs to operate the turn signals, head light, brake, and tail lights, as well as an interior convenience light. Combinations of analytical and experimental techniques were used to achieve the desired functionality. Figure 8 shows the testing equipment and work area used to prototype the electrical systems.

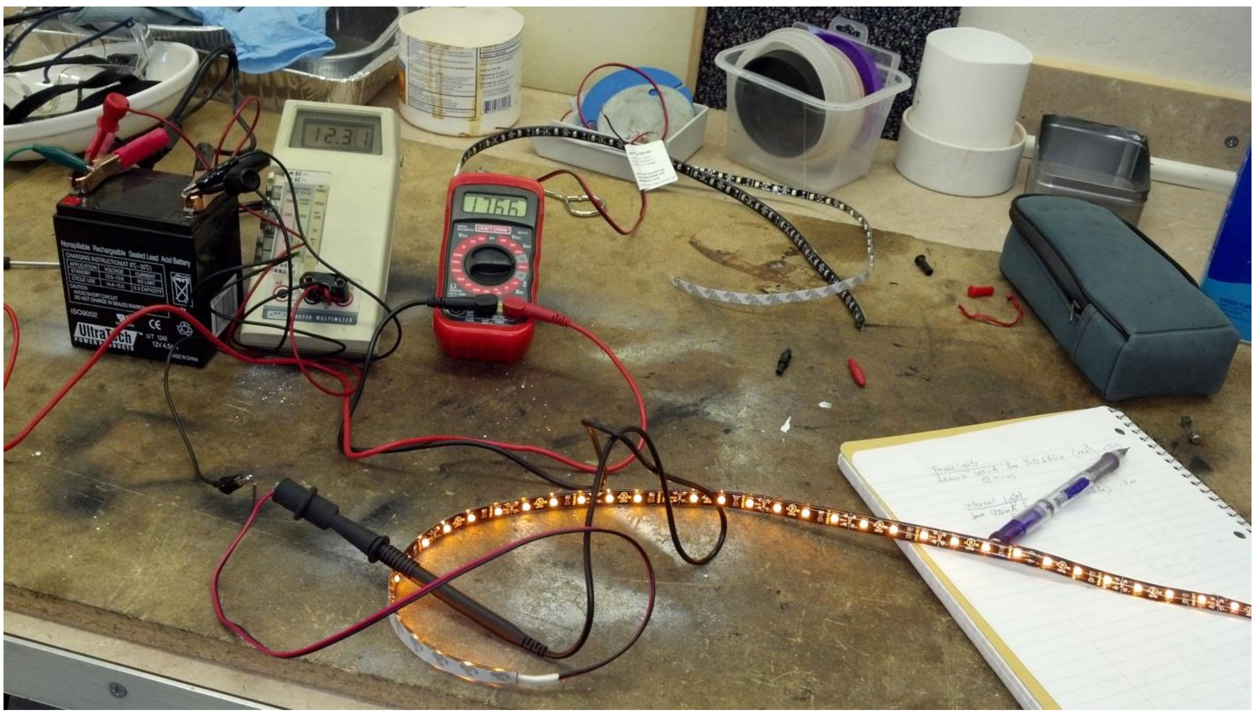


Figure 8-Circuit Test Bench

With exception of the headlight, all lights draw current from the same 12V battery source. The turn signals utilize a 555 timer package to produce the required oscillating illumination. The headlight will be removable and utilizes a self-contained battery source for convenience and use as a high powered hand-held light. A cockpit mounted control panel will house input switches for all the light systems.

Ventilation Ducts – Weather Proofing

After discussion with course administrators, various ventilation duct geometries and locations were explored. Three different duct geometries were selected for comparative CFD analysis as seen in Figure 9 below. Each model utilized the same outlet, a small slit along the rear stagnation line. The tested inlet geometries included: A frontal stagnation point hole emulating helicopter pitot ports, an arrangement of fish gill inspired slits on each side of the fairing, and the originally proposed servo-operated, closeable NACA duct. Each model was put through the same CFD test scenario; 40mph flow with a 0° yaw angle. All air properties were kept constant and assumed to be representative of the competition environment. Pressure distribution plots show adequate inward air flow for each inlet, however, the fish gill geometry performed more poorly than its competitors. Quantitative and qualitative evaluation of the relative drag force induced by the presence of each ventilation duct was the main goal of these tests. Figure 8 shows a comparison of pressure distribution on the surface of each fairing model. Around each fairing model is a cut plot of the surrounding air velocity distribution. Finally, Table 1 shows the resulting longitudinal drag force for each duct.

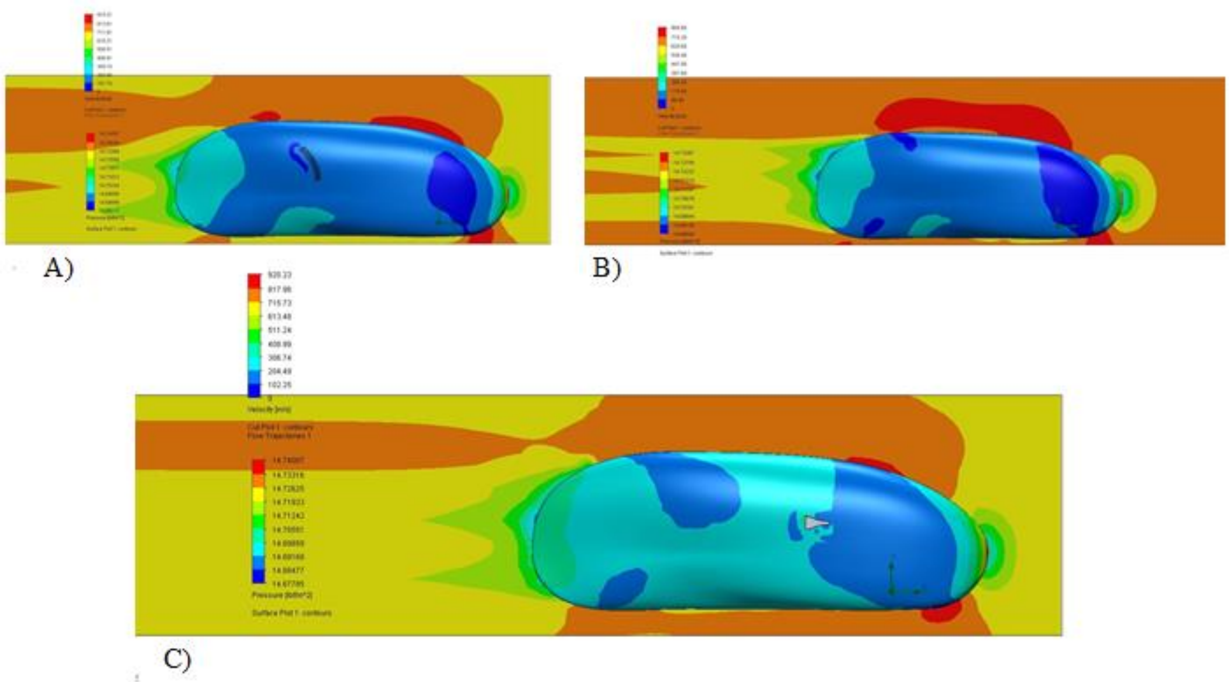


Figure 9-Pressure and Velocity Distributions A) Fish Gills, B) Stagnation Port, C) Closing NACA

Table 1-Comparison of CFD Results

Ventilation Inlet Design	Drag Force (Lbs)	Resulting Speed With 300 Watt Input (MPH)
Closing NACA	1.47	26.5
Stagnation Port	1.54	26.1
Fish Gills	1.67	25.3

The experimental results in Table 1 show the fish gill entrance, at least in the tested position, to cause the most drag on the vehicle. The relatively similar drag forces imparted on the fairing by the remaining design concepts were concluded to be too similar to declare a clearly lower drag design. With this comparable performance and in the interest of time, it was chosen to proceed forward with the previously developed NACA inspired design.

This design employs an additive manufacturing process to create the duct. It is then bonded into a corresponding cut-out in the fairing wall and eventually operated remotely by the rider. Remote operation is achieved with the use of an on board microcontroller which takes input from a cockpit mounted button and outputs a signal to a hobby servo mounted to the duct base. Figure 10 shows an additive manufactured scale model of the duct that was used for tolerance and clearance evaluation. Full scale ducts for evaluating the electromechanical interface are being manufactured currently.

A) **B)**

Figure 10-Scale Model of Ventilation A) Exterior, Closed, B) Interior, Closed

Sustainable Manufacturing

ASME has asked teams to focus on sustainable manufacturing methods during the design and fabrication of their HPVC entries. The team is continuing to evaluate the efficacy of recycled materials in different roles within the vehicle. Recycled materials have been sourced from waste in the manufacturing process of the current and previous human powered vehicles.

4.0 PROJECT SCHEDULE

The team is currently on schedule to complete the build of the vehicle by March 24th. Nearly all materials and components have been ordered and the build is well under way. The team will work to stay on track based on the Gantt chart through the competition in April 2014. The Gantt chart can be found in Appendix A, and displays the current progress on each task listed. In addition to the general tasks listed on the Gantt chart each subsection has a dedicated list of tasks to be completed by the section lead.

4.1 FRAME TASKS

The next component on the frame that needs to be completed is the roll bar bending. After the roll bar is bent, the rear triangle can be mocked up, and cut to the appropriate lengths. Once all these pieces are completed everything is ready to be welded together. The frame is scheduled to have everything but the outriggers welded on it by February 24th.

4.2 ERGONOMICS TASKS

Currently ergonomics is on schedule for the semester. The fiberglass seat and cushion were ordered and arrived before winter break. The materials for the seat brackets have been ordered and manufacturing of the mount pieces will begin as soon as they arrive. The deadline for completion of the seat mount design is the beginning of March. The only pieces left to be ordered include the materials for a headrest and the seatbelt, which will be manufactured and integrated before the deadline for the completion of the vehicle.

4.3 FAIRING TASKS

Before the break, the foam to create the male mold was purchased from Home Depot. The foam bought was Owen Corning Formular 250, a polystyrene foam, in 2’X8’X1” sheets. The fairing model was then cut into one inch cross sections and all forty layers were printed on a large format printer. From there, the plots were cut out and traced on each sheet of foam. Once traced, each shape was roughly cut out using a vertical band saw. The foam shapes are now being glued together with spray adhesive to complete the rough shape of the fairing.

From this point forward, the foam will be shaped to the rough size needed, which is expected to be completed by February 10th. Once shaping is complete, the team will transport the fairing to Nova Kinetics, where the first fiberglass lay-up will begin. The expected finish date for the male fiberglass lay-up is February 16th. At that point we will assist Nova Kinetics in making the male plug as smooth as possible for the female mold lay-up. Once the male plug is smoothed out the female plug will begin with a possible end date of February 24th. On the day of the 24th, the frame will be placed in the female mold to see where the fairing will be split up. Upon the completion of marking the female mold, the carbon fiber lay-up will begin with the intention of completing it by March 16th. Lastly, the fairing will be mounted onto the frame by the 24th of March.

4.4 STEERING TASKS

There is a lot of progress being made towards fabrication of the steering parts. Currently all of the raw materials required to fabricate the steering components are in. Some of the steering components have already been fabricated, including the tabs for the brakes, tabs for the tie rods, the main body of the bell crank, and the steering arm pivot that gets welded onto the frame.

The next parts that still need to be made in order of fabrication are as follows; bell crank pivot for the frame, steer tubes, axles, rectangular tubing for steering arms, pivot shells for steering arms, pivot shell for bell crank, bushings, cutting round tubes, welding knuckles, and welding steering arms. Each of these are in the process of being created.

4.5 DRIVETRIAN TASKS

As the drivetrain moves forward with the construction of the vehicle, there is a series of tasks related to the creation of the prototype. Each of these tasks will be completed by the drivetrain subsection lead with the aid of team. These tasks are listed in chronological order and their timing will happen in line with the rest of vehicle construction.

The next step for drivetrain is to begin the fabrication of the custom machined parts. After the completion of these parts, the drivetrain will be test fitted to the frame. Each configuration of the chain line will then be tested for efficiency. As each element of the vehicle is completed, the drivetrain will confirm that all clearances and designs work seamlessly throughout the vehicle.

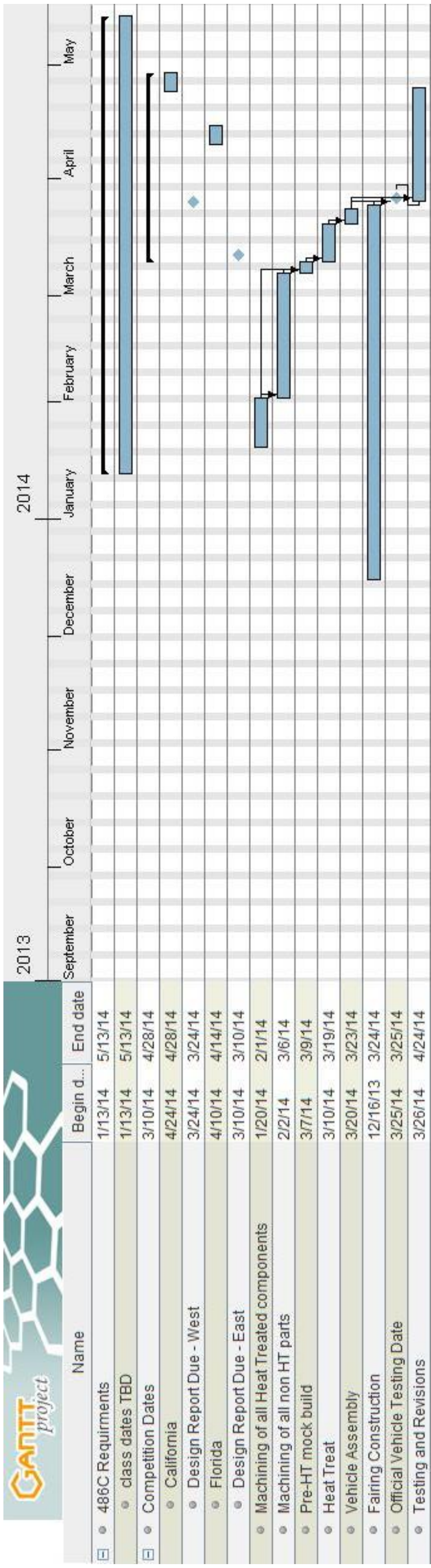
4.6 INNOVATION TASKS

Seamless integration of the ventilation ducts, lights, and rider inputs into the vehicle's carbon fiber fairing will become the main focus moving forward. It is critical that all elements making up the exterior surface of the fairing be as smooth as possible. The junctions between the main fairing and accessories can have a significant impact on the total aerodynamic drag experienced. This can be minimized with clean, smooth transitions. Verification of the electro-mechanical interface between driving servo and ventilation flap will also be a significant focus in the coming weeks. Finally, continued exploration of recycled materials will be a parallel focus.

5.0 CONCLUSION

In conclusion, the 2014 Human Powered Vehicle project is on schedule. During the break, designs were optimized for strength to weight ratio improvement. A second set of steering knuckles was designed as a backup set with improved strength properties. These will be installed in the event original design is deemed insufficient. The seat bracket has also been lightened in low stress areas. The drivetrain chainline has been altered slightly to alleviate clearance issues. The fairing and ventilation ducts were also further optimized for lower aerodynamic drag. All designs are finalized with models and drawings created. 95% of the necessary materials have been received and manufacturing is underway. The team is on track to complete the vehicle by the end of March giving a months' worth of time for testing and practice.

6.0 APPENDIX


GANTT project
Name
Begin d...
End date
2013
2014
September
October
November
December
January
February
March
April
May
486C Requirments 1/13/14 5/13/14
class dates TBD 1/13/14 5/13/14
Competition Dates 3/10/14 4/28/14
California 4/24/14 4/28/14
Design Report Due - West 3/24/14 3/24/14
Florida 4/10/14 4/14/14
Design Report Due - East 3/10/14 3/10/14
Machining of all Heat Treated components 1/20/14 2/1/14
Machining of all non HT parts 2/2/14 3/6/14
Pre-HT mock build 3/7/14 3/9/14
Heat Treat 3/10/14 3/19/14
Vehicle Assembly 3/20/14 3/23/14
Fairing Construction 12/16/13 3/24/14
Official Vehicle Testing Date 3/25/14 3/25/14
Testing and Revisions 3/26/14 4/24/14