Human Powered Vehicle (HPV)

A Senior Design Project for Mechanical Engineering Students at NDSU

Supported by ND Space Grant

Mentored by:

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Attending Yearly at ASME HPV Competitions

ASME Human Powered Vehicle Challenge (HPVC)

- **"ASME's HPVC provides an opportunity for students to demonstrate the application of sound engineering design principles in the development of sustainable and practical transportation alternatives. In the HPVC, students work in teams to design and build efficient, highly engineered vehicles for everyday use—from commuting to work, to carrying goods to market."**

http://www.asme.org/Events/Contests/HPV/Human_Powered_Vehicle.cfm

ASME HPVC is a Yearly Competition

- **Official HPVC Website**:
  http://www.asme.org/Events/Contests/HPV/Human_Powered_Vehicle.cfm

- **2011 Human Powered Vehicle Competition**

HPVC East

Indianapolis Motor Speedway
Indianapolis, IN
April 29 - May 1, 2011

HPVC West

Montana State University
Bozeman, MT
May 13 - 15, 2011

ASME
SETTING THE STANDARD

NDSU
North Dakota State University
College of Engineering and Architecture
MECHANICAL ENGINEERING

Human Powered Vehicle Challenge

- Design and build a human powered vehicle to compete in the Human Powered Vehicle Challenge
- Four Events of Competitions are based on
  - Design
  - Sprint/Drag
  - Utility
  - Endurance
- Emphasis is on Utility

ASME ELIGIBILITY & REQUIREMENTS

- All participants must be current student members of ASME and enrolled as full-time students in an engineering program of study. Any student who was enrolled in an engineering program during the previous semester or quarter, but graduated no earlier than six months prior to the competition date, is eligible to participate.

- The first stage of the competition involves the preparation of a comprehensive design report. The second part includes a design presentation and a series of performance events (sprint/drag race, utility endurance, and speed endurance),held over the course of a weekend. Guidelines and more detailed requirements (including safety measures and tests)can be found in the full competition rules.

Three Race Events

- Sprint Race
  - Male & Female Riders
  - To achieve the highest speed
- Endurance Race
  - 65 Kilometers, 40.4 Miles
  - 20 Kilometer Max, 5 Kilometer Minimum
- Utility Race
  - To carry load with under various race conditions

Design Constraints

- Braking
- Steering
- Rollover protection system
- Safety harness
- Event requirements
- Practicality
- Time

ASME Competition Background

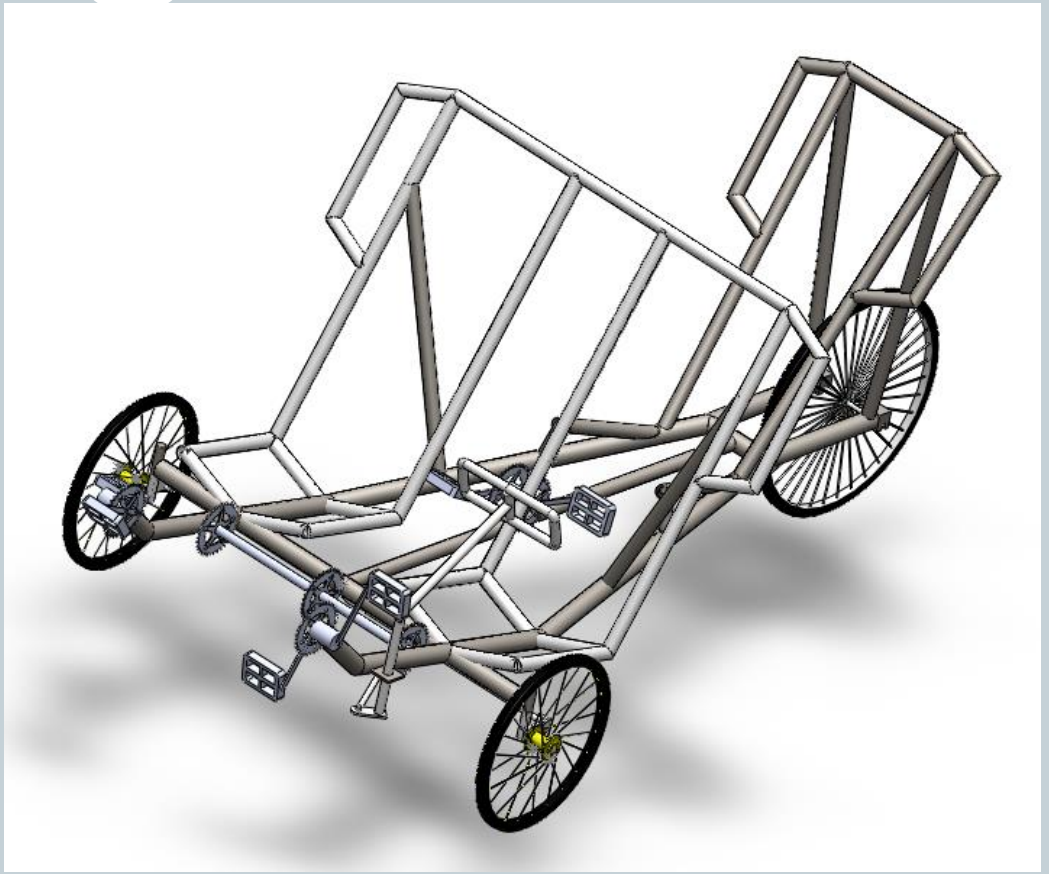
- Competition Rules
  - Vehicle Classes
  - Safety Requirements
  - Fairing Requirements
- Competition Events
  - Design
  - Sprint
  - Utility
  - Endurance

HPV2011- Design Alternatives Considered

- Number of riders
- Seat placement
  - 1 in front 2 in back
  - Back seat facing the rear
- Materials considered
  - Chromoly
  - Low Carbon Steel
- Steering
  - Back vs. front wheel steering
  - Back vs. front driver
  - Rack and pinion vs. tie rods
- Drivetrain
  - Power and gearing 2 wheel axel vs. Rear wheel

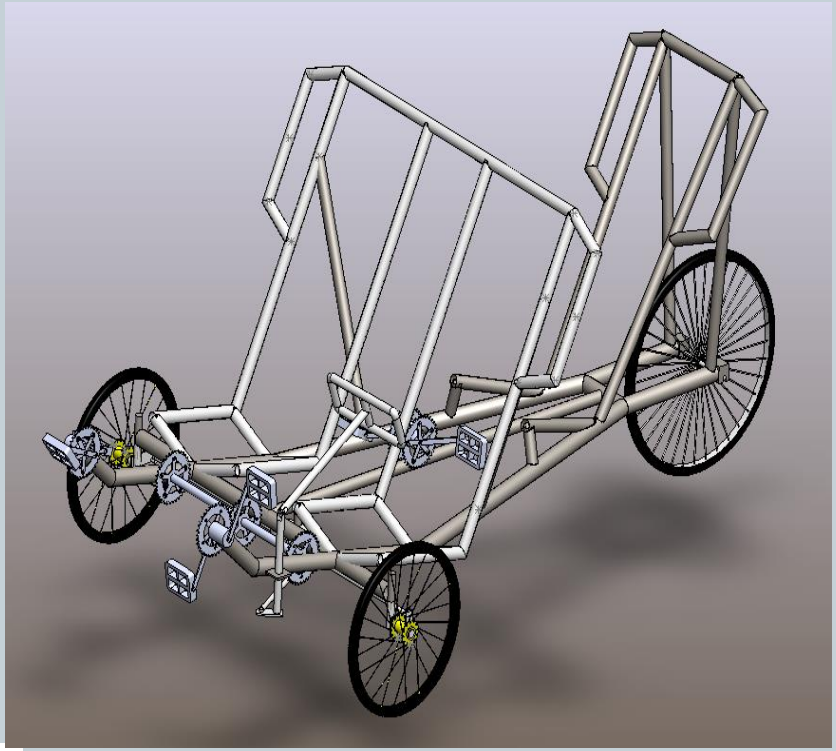
HPV2011-Design/Analysis

- Frame
- Steering
- Drive-train
- Fairing



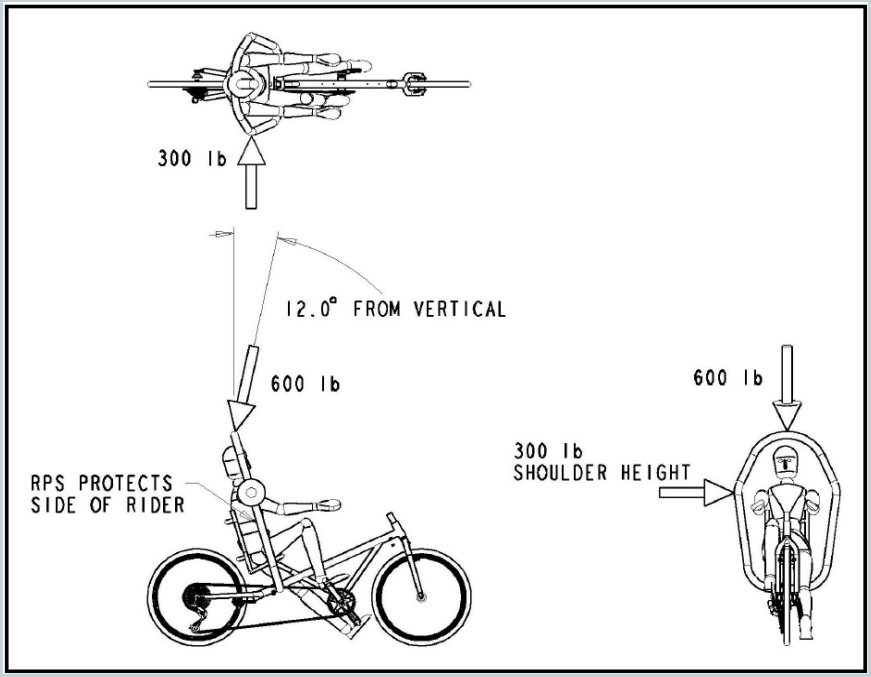
Design, Characterization, and Construction

- Roll bar/Frame modifications
  - Center bar added to sure up design
  - Redesigned frame decreased deflection by 37.5%



ASME Regulations on Frame Analysis

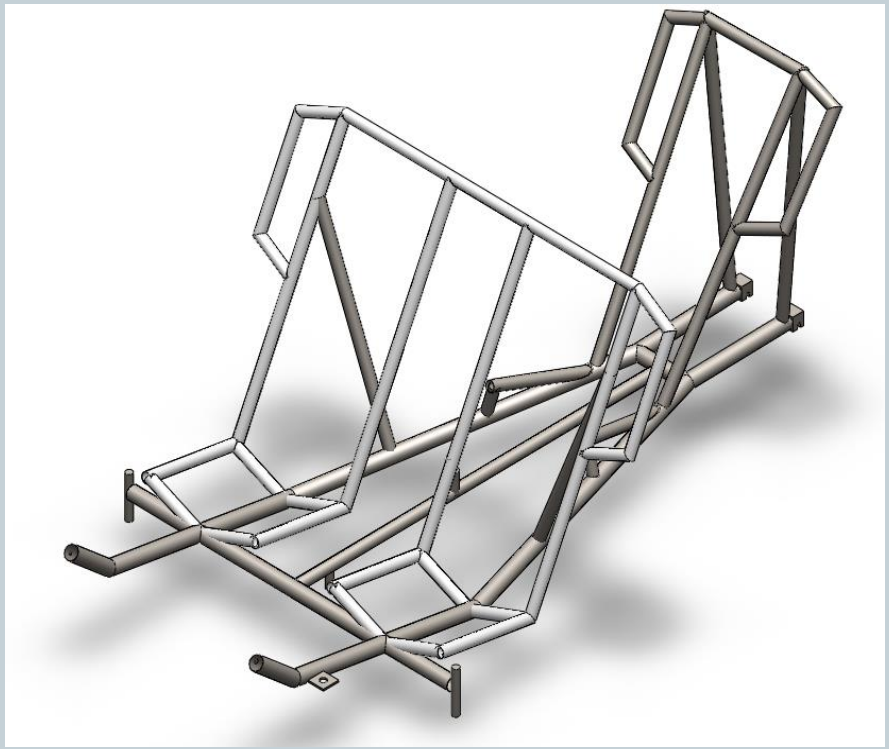
- **Objective**
  - Analyzed frame to ensure compliance with HPVC Rules
- **Rules**
  - 600lb vertical load on each roll bar
    - **Elastic Deformation less than 2”**
  - 300lb horizontal load on each roll bar
    - **Elastic Deformation less than 1.5”**

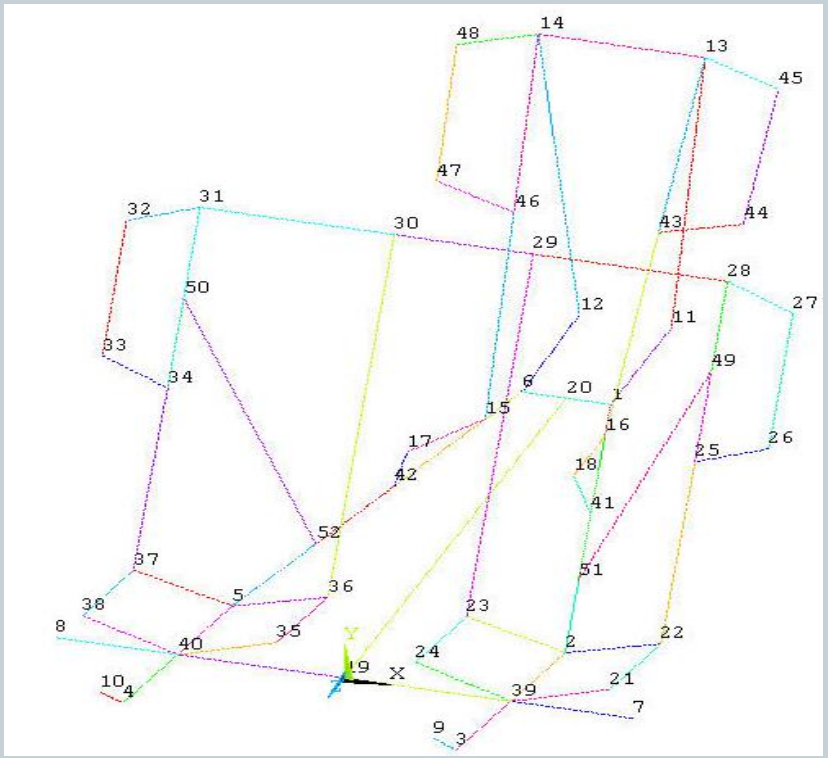


Frame

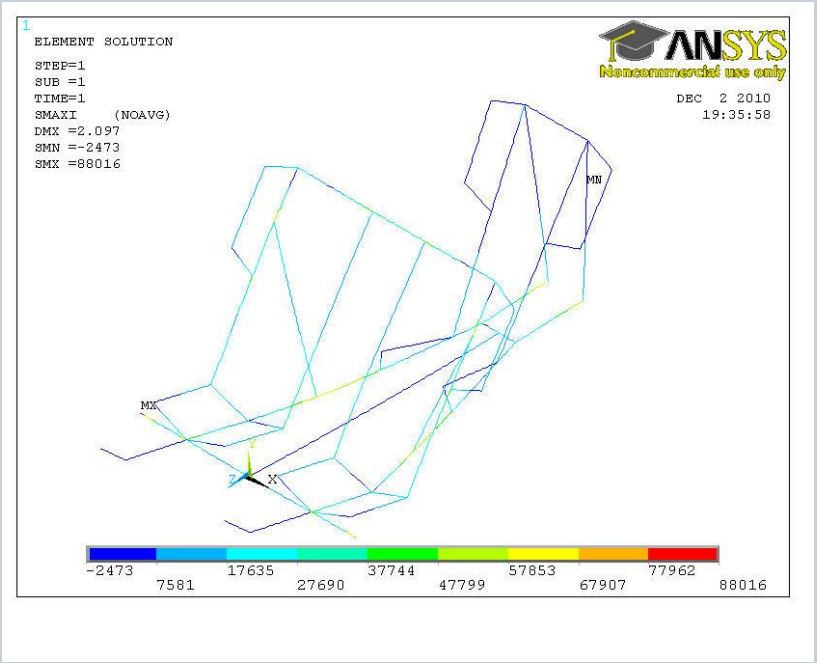
- 1035 CD Steel Tubing
  - Main Structural Frame-1.5” OD, 0.065” Wall Thickness
  - Seats and Control arm-1” OD, 0.065” Wall Thickness
- TIG Welded

Finite Element Analysis of the Frame

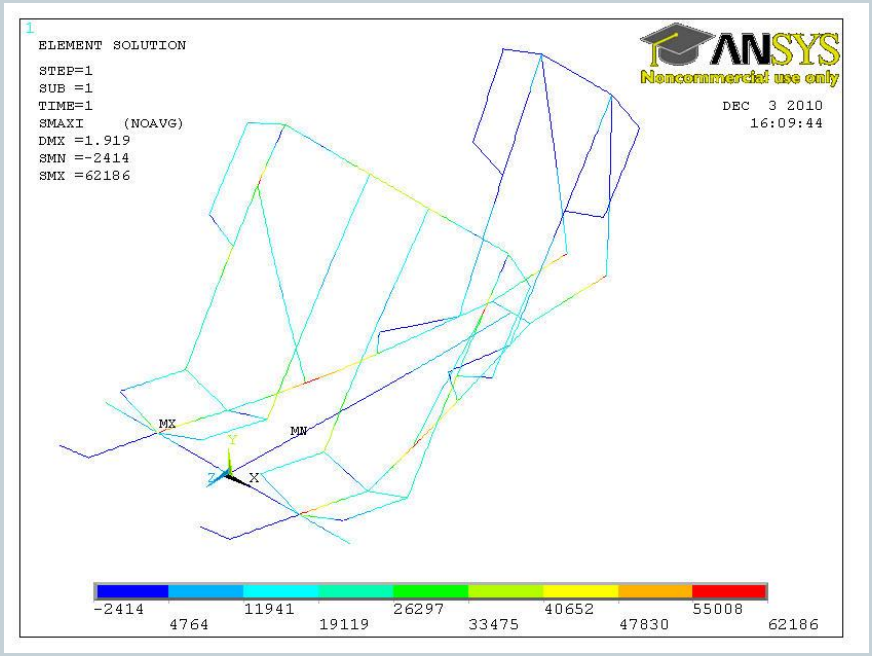




Determine the max Stresses
under Various Loading Conditions



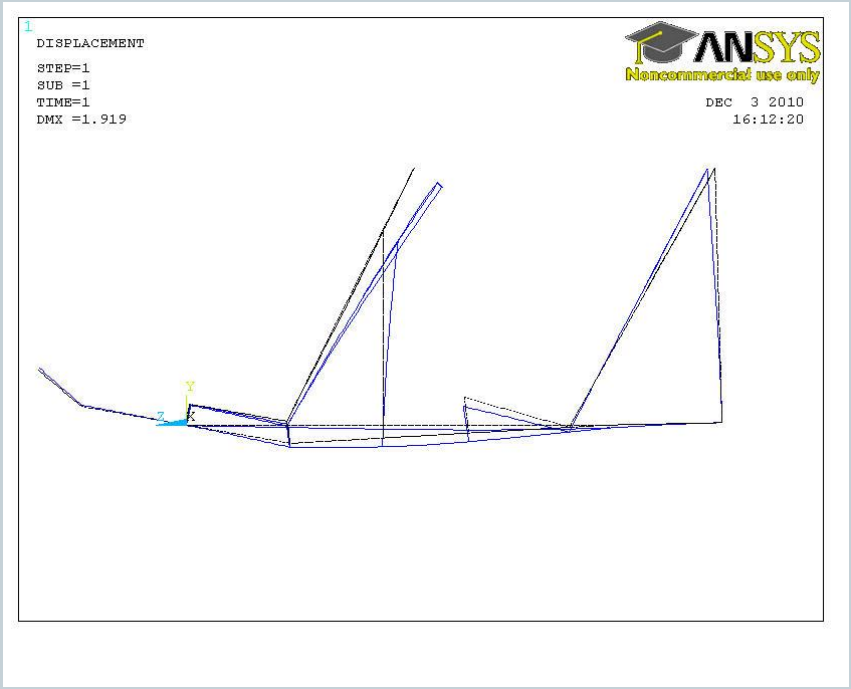
Max stress – 88ksi
Yield Strength of 1035 Steel- 65.3ksi



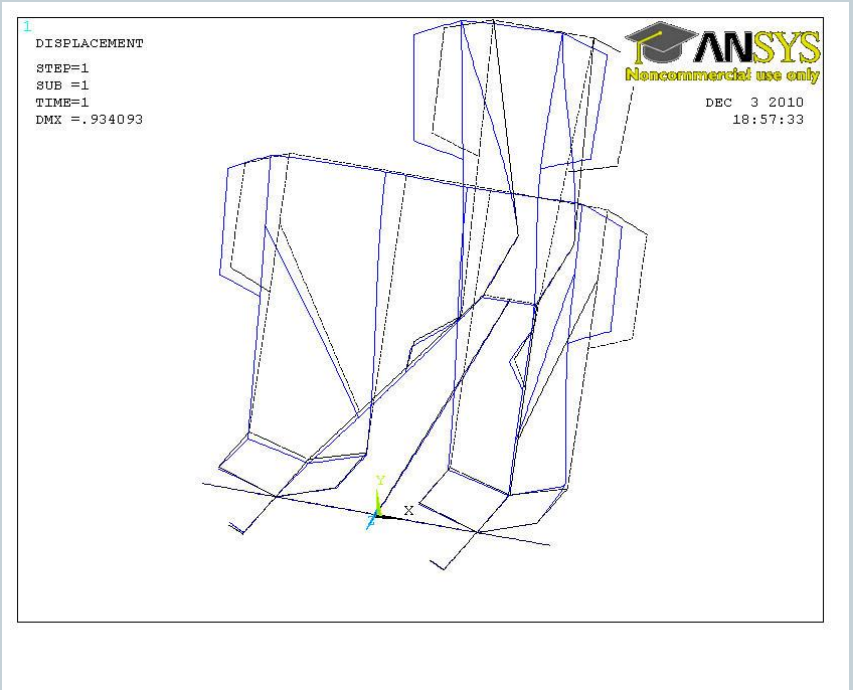
Max stress – 62.2ksi
Yield Strength of 1035 Steel- 65.3ksi

FEM Analysis- Max Deflection

under 600 lb Vertical and 300 lb Horizontal Load

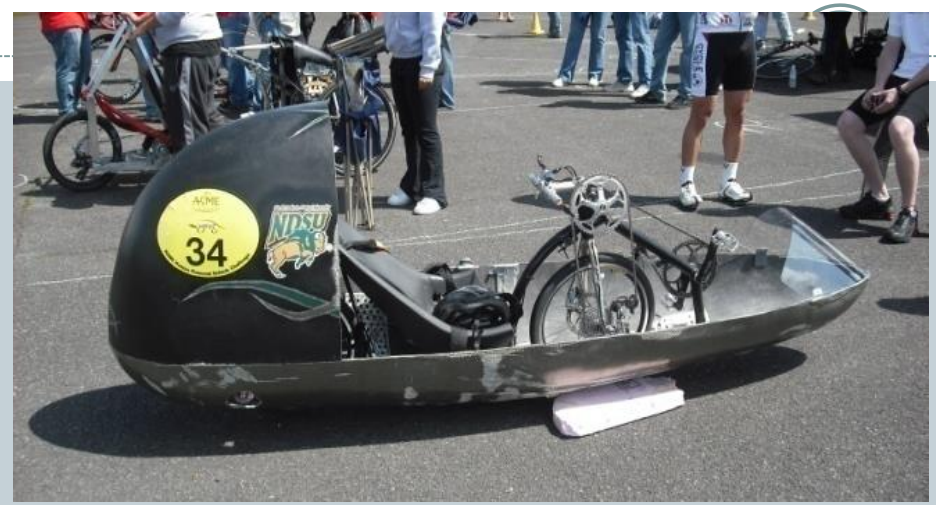


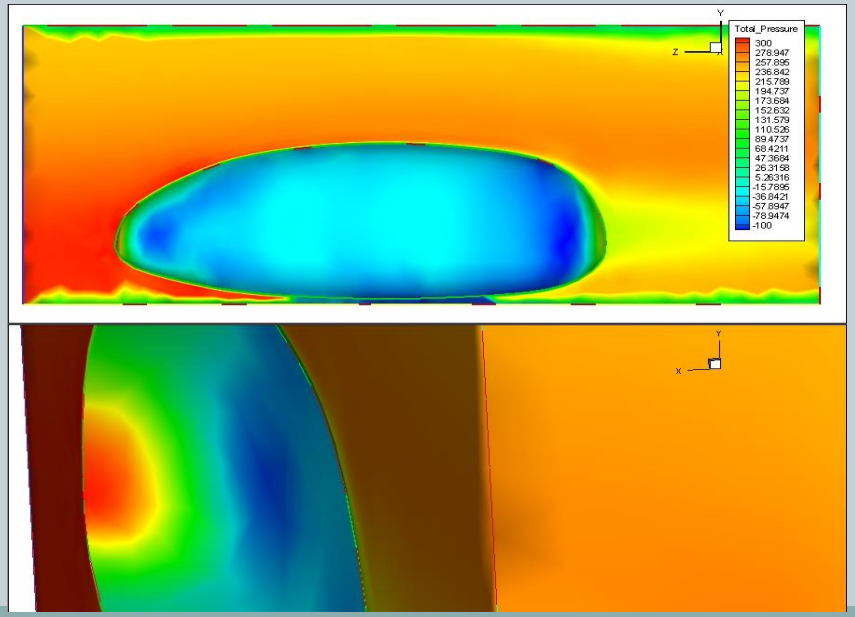
Max deflection – 1.919”
Maximum allowable deflection - 2”

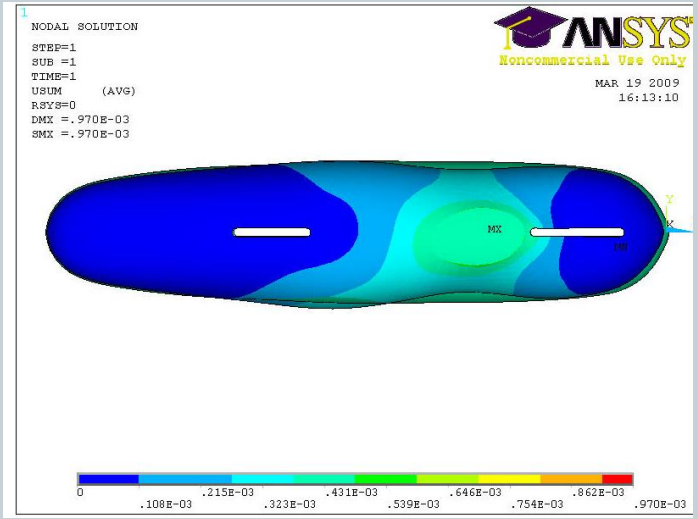


Max deflection – 0.93”
Max allowable deflection – 1.5”

CFD Analysis of Fairing System and Deformation Analysis







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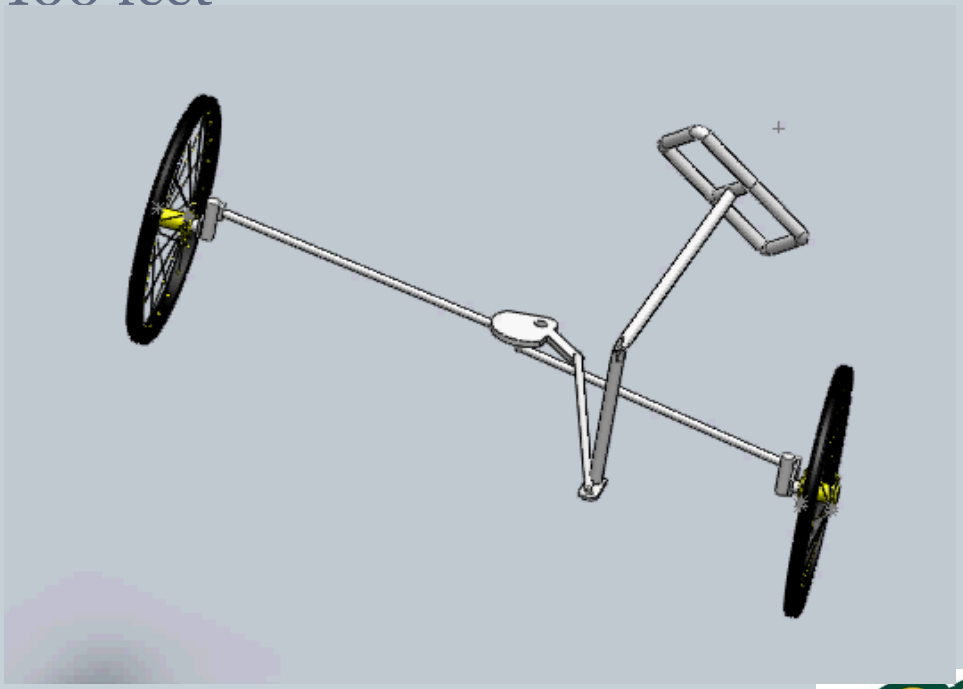
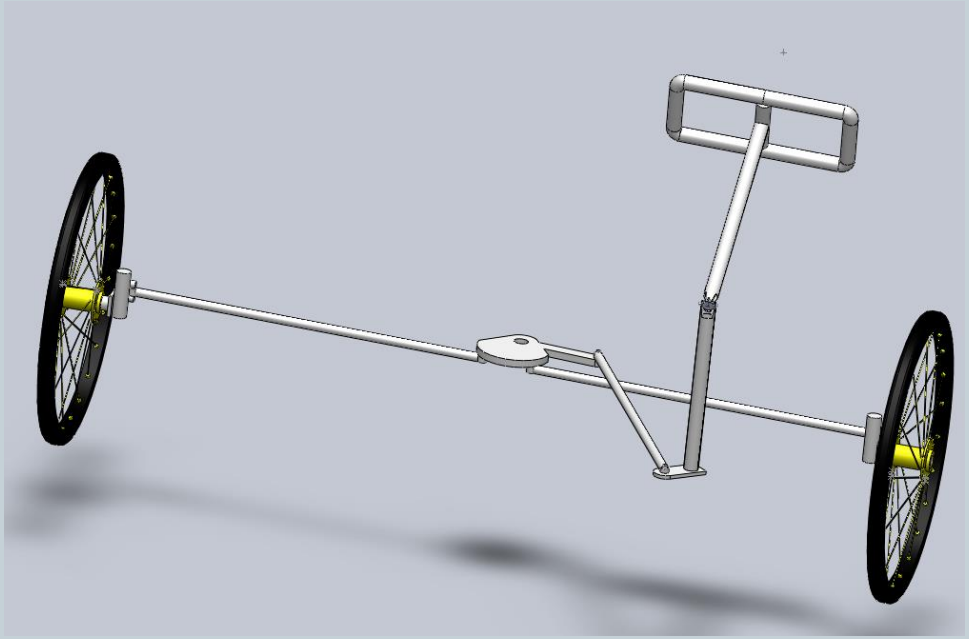
HPV 2011-Steering Design

- Objective
  - Design steering to comply with HPVC Rules
- Constraints
  - Travel in a straight line for 100 feet
  - Turning radius of 25 feet
  - Driver placement
  - Light weight



HPV 2011- Steering Design

- Tie rod assembly
- AISI 1035 Steel
- Static analysis on concrete
- Assumed no mechanical losses



HPV 2011-Drivetrain

- Problem: Combine the power of 3 people pedaling to one drive wheel

- Analysis Completed
  - Maximum Stresses
    - Sprocket teeth
    - Rotating shaft (Torsional & Bending)
  - Maximum Tension in Chain

- Material Selection and part dimension

HPV2011-Drive-train

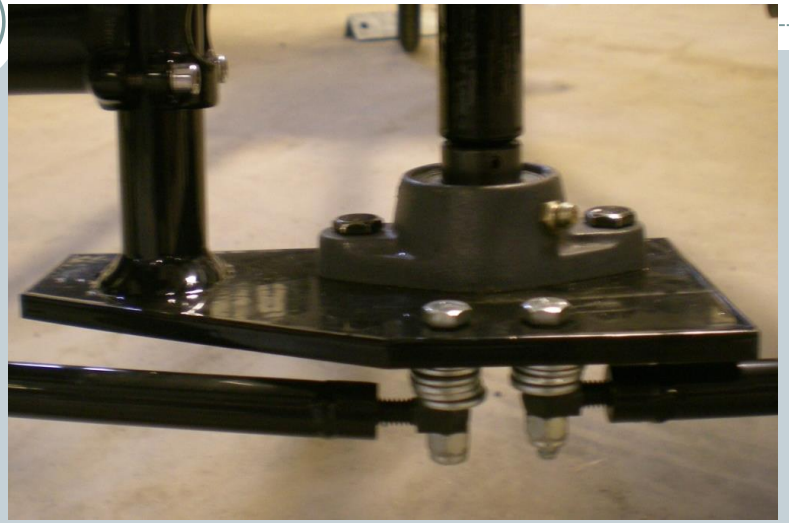
- Maximum Loading Condition
  - 400lb pedaling force by each rider
- Gear Stress
  - Max average stress in a gear tooth = 50ksi
    - Material Chosen: 2000 series aluminum
- Shaft Stress
  - Rotating shaft was assumed to be made from 1035 cold-drawn steel
    - Yield strength of 65.3ksi
    - Calculated minimum diameter from stress due to bending = 1 inch
    - Max torsional stress = 29.26ksi
- Chain Force
  - Max driving force on the chain = 2000lb
  - Material chosen: ANSI #40 chain, tensile strength 3130lb

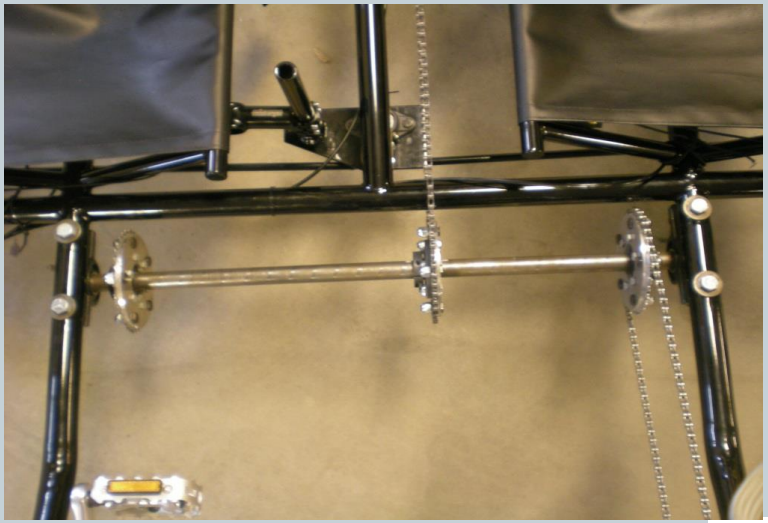
HPV 2009-Drag Estimates

- Drag Coefficient of HPV
  - 0.35
    - Low estimate due to additional sources of drag
- Drag Coefficient of Bicycle Racer
  - 0.88
- Drag Coefficient of Toyota Prius
  - 0.26

http://auto.sohu.com/piclib/toyota/toyota/prius/big/Toyota_Prius008.jpg

HPV2011-Construction



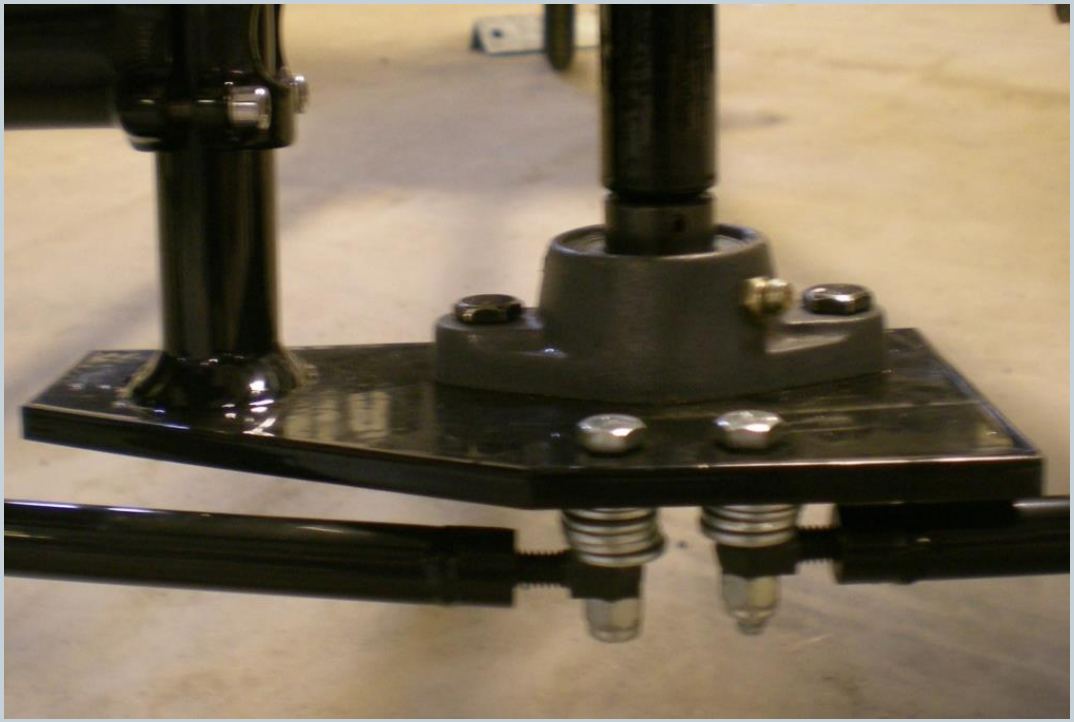


Wheel Attachment

- Bicycle Headset
- Steel Block for spindle
- Brake bracket

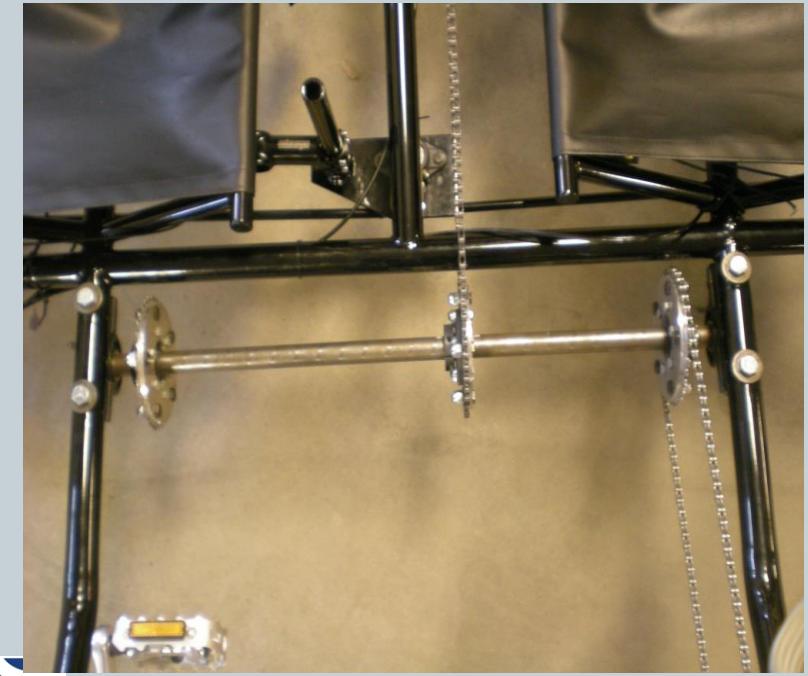
Steering

- Steering plate
- Tie rods
- Steering Arm

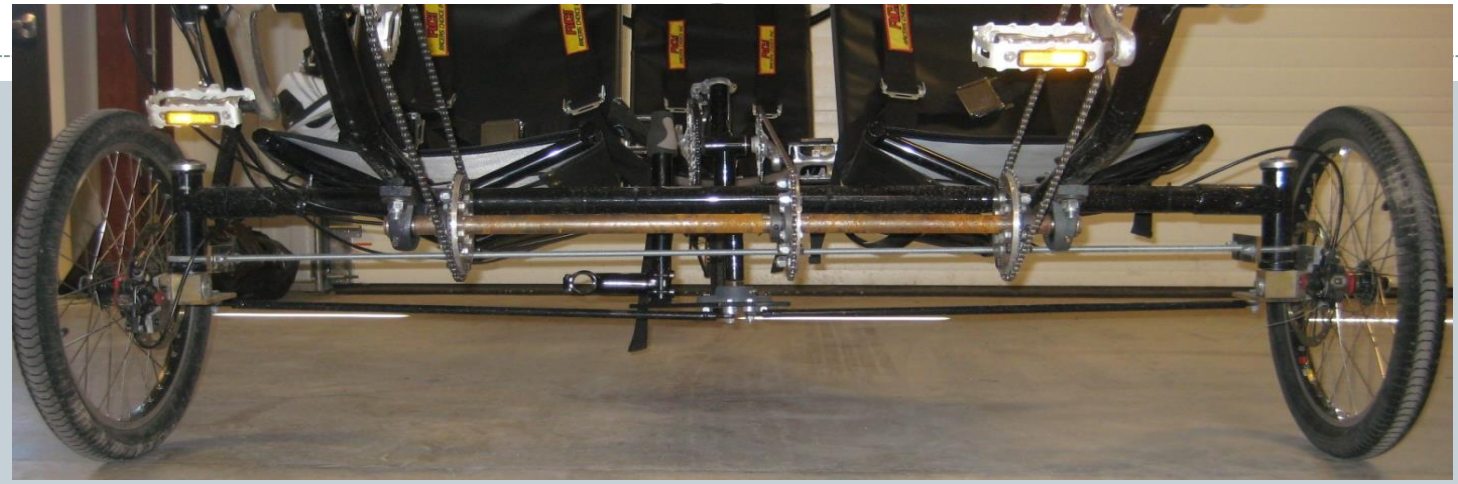


Drivetrain

- Aluminum Adapter Plates
- Linkage Bar
- Idler Sprockets



Testing and Modifications



- Idler sprocket need and design
- Camber reduction
- General testing
- ASME Requirements
  - Come to a stop from 15 mph in 20 feet or less
  - Turning radius of 25 feet or less
  - Travel in a straight line for 100 feet

HPV2011- Budget

Budget				
Description	Quantity	Price Each	Delivery (15%)	Total Price
Frame				
Steel Tubing 2"x6'x.049"	7	$18.16	$19.50	$149.50
Steel Tubing 1"x6'x.049"	20	$10.18	$30.60	$234.60
Drive Train				
Pedals	3 (sets)	$20.00	$9.00	$69.00
Crank set	2	$40.00	$12.00	$92.00
Tandem Crank	1	$150.00	$22.50	$172.50
Chain	5	$20.00	$15.00	$115.00
Sprockets	3	$25.00	$11.25	$86.25
Cassette 7 Gear	1	$175.00	$26.25	$201.25
Derailleur Front	1	$53.00	$7.95	$60.95
Derailleur Rear	1	$60.00	$9.00	$69.00
Shifters	2	$50.00	$15.00	$115.00
Wheels				
Hubs	2	$67.00	$20.10	$154.10
Rims	2	$66.00	$19.80	$151.80
Tires and Tubing	4	$50.00	$30.00	$230.00
Tire Assembly Labor	1	$40.25	n/a	$40.25
Rear Tire	1	$100.00	$15.00	$115.00
Steering System				
Steel Tie Rods	4	$15.00	$9.00	$69.00
Bearing	1	$13.09	$1.96	$15.05
U-Joint	2	$15.00	$4.50	$34.50
Collar	1	$15.00	$2.25	$17.25
Steel Plate 12"x12"x0.25"	1	$40.00	$6.00	$46.00
Hub Mount	2	$40.00	$12.00	$92.00
Swivel Piece 8"x6"X0.25"	2	$10.00	$3.00	$23.00
Accessories				
Handlebar Caps	2	$7.00	$2.10	$16.10
Hardware				
Bearings	4	$75.00	$45.00	$345.00
Misc/Hardware		$50.00	$7.50	$57.50
Brakes				
Brake Handles	1 (set)	$20.00	$3.00	$23.00
Cable Housing	1 (25' roll)	$18.00	$2.70	$20.70
8" (203mm) Disk Brakes	2	$75.00	$22.50	$172.50
Brake Cable	4	$2.00	$1.20	$9.20
Misc				
Seats	3	$15.00	$6.75	$51.75
Safety Harness	3	$75.00	$33.75	$258.75
Faring				
Epoxy Kit	1	$75.00	$11.25	$86.25
Labor for 5 axis mill		$300.00	n/a	$300.00
Labor				
Powder Coating Service		$100.00	n/a	$100.00
Machining		$300.00	n/a	$300.00
Seat Labor		$50.00	n/a	$50.00
Unexpected Labor		$50.00	n/a	$50.00
Sum				
Total				**$4,193.75**

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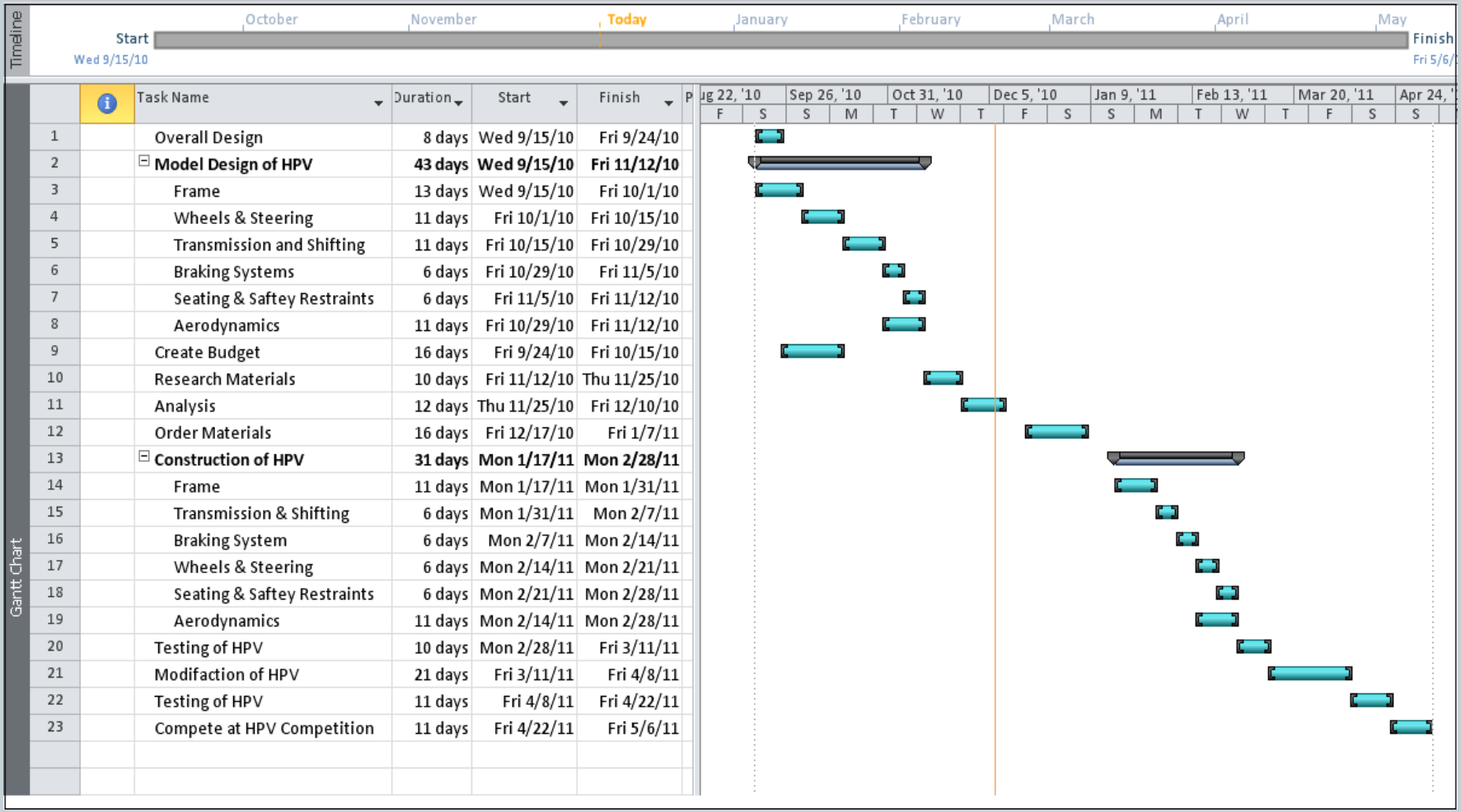
NDSU North Dakota State University

2011 HPVC Trip Budget

Competition Costs			
Description	Quantity	Price Each	Total Price
Travel	1750 miles	$0.50	$875.00
Hotel Room	3rooms-3nights	$112.00	$1,008.00
U-Haul Trailer	1	$300.00	$300.00
Registration	1 vehicle	$170.00	$170.00
Registration	9 people	$20.00	$180.00
Helmets	3	$45.00	$135.00
Food	10 people-3 days	$25/day	$750.00
ASME Membership	10 people	$25/person	$250.00
Total			$3,668.00

- Total budget = $7861.75
- Grant from North Dakota Space Consortium
  - $8000.00

HPV2011- Project Gantt Chart



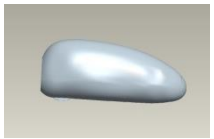
	Task Name	Duration	Start	Finish
1	Overall Design	8 days	Wed 9/15/10	Fri 9/24/10
2	**Model Design of HPV**	**43 days**	**Wed 9/15/10**	**Fri 11/12/10**
3	Frame	13 days	Wed 9/15/10	Fri 10/1/10
4	Wheels & Steering	11 days	Fri 10/1/10	Fri 10/15/10
5	Transmission and Shifting	11 days	Fri 10/15/10	Fri 10/29/10
6	Braking Systems	6 days	Fri 10/29/10	Fri 11/5/10
7	Seating & Saftey Restraints	6 days	Fri 11/5/10	Fri 11/12/10
8	Aerodynamics	11 days	Fri 10/29/10	Fri 11/12/10
9	Create Budget	16 days	Fri 9/24/10	Fri 10/15/10
10	Research Materials	10 days	Fri 11/12/10	Thu 11/25/10
11	Analysis	12 days	Thu 11/25/10	Fri 12/10/10
12	Order Materials	16 days	Fri 12/17/10	Fri 1/7/11
13	**Construction of HPV**	**31 days**	**Mon 1/17/11**	**Mon 2/28/11**
14	Frame	11 days	Mon 1/17/11	Mon 1/31/11
15	Transmission & Shifting	6 days	Mon 1/31/11	Mon 2/7/11
16	Braking System	6 days	Mon 2/7/11	Mon 2/14/11
17	Wheels & Steering	6 days	Mon 2/14/11	Mon 2/21/11
18	Seating & Saftey Restraints	6 days	Mon 2/21/11	Mon 2/28/11
19	Aerodynamics	11 days	Mon 2/14/11	Mon 2/28/11
20	Testing of HPV	10 days	Mon 2/28/11	Fri 3/11/11
21	Modifaction of HPV	21 days	Fri 3/11/11	Fri 4/8/11
22	Testing of HPV	11 days	Fri 4/8/11	Fri 4/22/11
23	Compete at HPV Competition	11 days	Fri 4/22/11	Fri 5/6/11

Human Powered Vehicle

Zach Stock, Jenna Wurzer, Taylor Zimmerman
North Dakota State University, Mechanical Engineering, Fargo, ND
Advisor: Dr. Ghodrat Karami

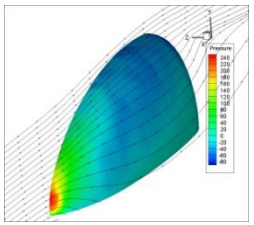
Objective: Create a Human Powered Vehicle to compete in the ASME HPV competition
-Vehicles compete in a sprint race and endurance race and are scored on overall design
-Rules include safety regulations on braking, turning radius, and roll bar requirements

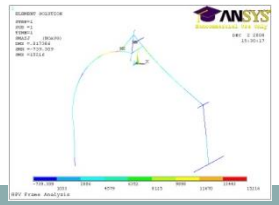
Design
-Two Wheel Design – Higher speed possibilities
-Front Wheel Drive– More efficient power transfer
-Full Composite Monocoque Fairing – Potentially lighter product
-Telescoping Landing Gear- Assist the rider during start and finish



Prototype
-Front subframe geometry was determined, including rake and trail
- Dimensions were determined based on ergonomics and packaging for the full fairing

Analysis
-ANSYS CFD software was used to examine potential fairing designs and aerodynamic properties
-ANSYS FEA software was used to analyze the bottom part of the fairing to determine it could act as the main structural component of the design
-ANSYS software was used to provide a stress analysis on the geometry of the front subframe
-Test pieces were made of the top and bottom structural area to test the capabilities of the fairing to act as the required roll bar. They withheld a 600lb static load with only 0.3in of deflection



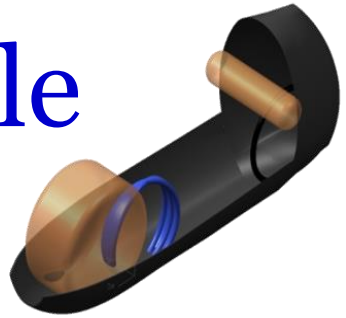


Construction
-Composite layup was determined by the amount of strength and stiffness needed
-Top and bottom fairing composed of plain carbon weave, plain Kevlar weave, twill carbon/Kevlar weave, and varying thickness of

Competition
-Team ranked19th overall
-Sprint trial top male speed was 29.85 mph (5th place) and top female speed was 21.75 mph (6th place)
-Due to technical difficulties, team placed 22nd in the endurance race with 15 completed laps
-Fairing withstood multiple crashes with the vast majority of the damage bei

Human Powered Vehicle

GROUP MEMBERS: PETE BARFKNECHT, MIKE GREGORYK, MATT STEGMILLER

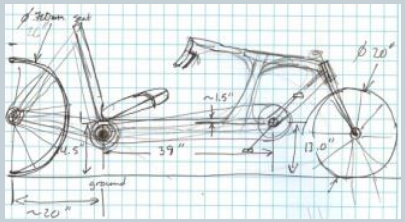


Project Background

Human Powered Vehicles (HPV) are aerodynamic, highly engineered vehicles. Some land-based HPV's have achieved speeds of over 80 mph. ASME sponsors the Human Powered Vehicle Competition in hopes of finding a design that is suitable for everyday use.

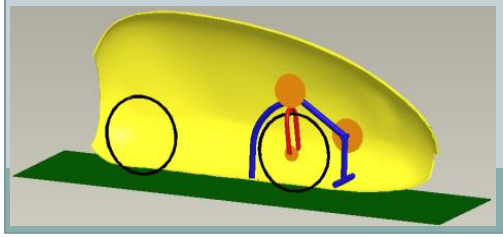
Initial Design

The initial design was a rear wheel drive two-wheeled vehicle, this was decided based on the drawbacks of the previous three-wheeled design.



Modified Design

The final design uses a front wheel drive system to save space and weight. A full carbon fiber fairing and monocoque frame will also be used to save weight and add strength.

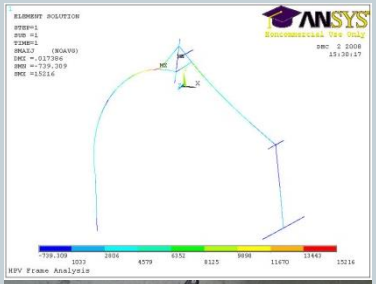


Proof of Concept

A prototype of the final design was built to address any unforeseeable issues and finalize bike dimensions and geometry.

Analysis

Several Finite Element Analyses were performed on the front subframe using ANSYS to determine the stresses. The results were used to help decide the required material and size. Chrome-Molybdenum steel alloy was chosen.



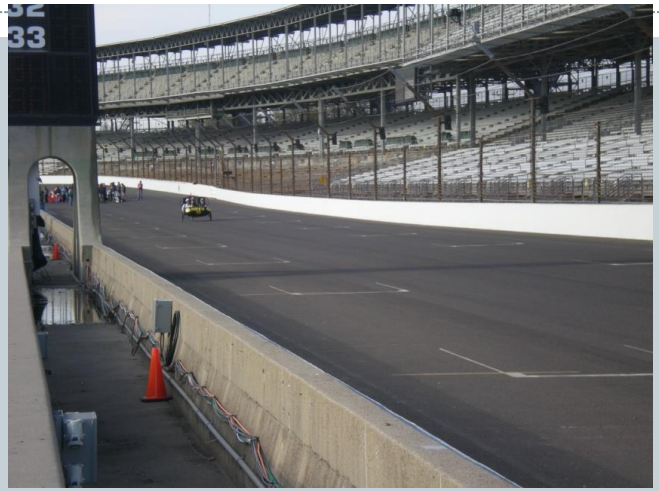
HPV 2011 Group and ASME Competition

- HPV 2011- Awarded for unique and innovative design

Bryan Boe
Cody Dienslake
Troy Gilyard
Drew Honeyman
Joey Lovell

Competition

- Design Event
  - 13th out of 20th
- Sprint Event
  - Male Team Top Speed 22.5mph
    - 14th out of 20
- Utility Event
  - 8th out of 20th
- Overall
  - 12th out of 20th



Competition

- Speed-Endurance Event
  - 2.5 hour endurance race on a one mile track
  - 33 laps were completed
  - Average speed of 13.2mph
  - 13^{th} out of 20^{th}
  - Durability of vehicle led to better performance

2011 Competition

- Utility Endurance
  - 26 laps were completed
  - 1 laps worth of deductions
  - Average speed of 10.42mph
  - 8th out of 20th

Budget and Gantt Chart

- Initial Budget was $8,000
- Total Cost was about $7,861

ASME Competition

ASME Competition

HPV 2011-Acknowledgements

- Dr. Karami
  - Mentor
- Santhosh K. Seelan
  - University of North Dakota Space Consortium
- Kirk Bottelberghe
  - Former HPV Competitor
- Larry Skagen
  - Skagen Custom Frames
  - Island Park Cycles
- Crary Industries
- Shannon
- Dr. Blackmore
- Female Team
  - Krystal Gatz
  - Kelsey Moriarity
  - Vanessa O'Gara

Questions?