Portland State University
Maseeh College of Engineering and Computer Science

2008 Human Powered Vehicle

Product Design Specifications Report – Winter 2008

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Introduction

The American Society of Mechanical Engineers (ASME) Human Powered Vehicle (HPV) Challenge is a competition in which engineering students from around the country design, construct, and race an HPV. An HPV can take many forms and varying rider positions, such as upright, recumbent, or prone and can have any number of wheels. The competition consists of three separate events: a 100m sprint race, a 40km grand prix style endurance race, and a judging process for the vehicle's design, safety, and formal presentation.

Because of increasing energy prices and growing concern over vehicle pollution, the HPV Challenge was created to encourage development in human powered technology. The goal of the HPV Challenge is that someday a HPV will be designed that is practical enough for everyday uses such as going to the store or commuting to work. It is true that for years the bicycle has offered a relatively cheap and environmentally friendly alternative for commuters but it is hampered by some major drawbacks. First, the rider is exposed to the elements making use in harsh climates unappealing. Also, many conventional bicycles are limited in their top speeds due to wind resistance and driver strength. These two major drawbacks of the bicycle can be reduced by creating an aerodynamic cover called a fairing. This will reduce the drag coefficient on the bike and shelter the rider.

As senior mechanical engineering students at Portland State University we have chosen to combine the ASME HPV Challenge with our senior Capstone project.

Explanation of This Document

This Product Design Specification (PDS) defines the external and internal customers, the project requirements, design constraints, and the priority of those constraints.

Mission Statement

Our mission is to develop an innovative, light-weight, and aerodynamic HPV to win the overall ASME Western Region HPV Competition.

Project Plan

The major deadlines are set both by ME 492/493 class sequence and the ASME HPV Competition. A Gantt chart of the project timetable was developed and is attached in Appendix A.

The dates of Milestones are:

- ME 492 end of term progress report — March 3rd
- Mechanical / material testing completed — March 8th
- Frame completed — March 14th
- Fairing completed — March 28th
- Fully assembled vehicle — April 4th
- ASME HPV Challenge — April 18th-20th

Identification of Customer

The primary external customer for this project is the PSU HPV Race Team since they will be the end users of the HPV and depend on its performance to win the HPV Western Region Challenge. The primary internal customer is ME 492/493 Capstone Course, which sets many of the projects milestones and presentation requirements. The PSU HPV's faculty advisor is also an internal customer because he ensures the project is on time, on budget, and meets all Capstone requirements. The final internal customer is the PSU HPV team because the project is ultimately a reflection on them.

Customer Feedback

This project differs from other capstone projects in several ways. First is the accelerated timetable. This pushed design meetings and decisions to be made between September and December. Second the primary external customer consisted of the same group of people as the primary internal customer; this gave the design team less resources for design constraints or input. As a result the team relied heavily on their own decision making and the rules of the ASME Western Region HPV Challenge in the design process. Feedback from internal customers comes mainly from weekly design meetings with the PSU HPV team and its faculty advisor. In these weekly meetings design criteria was established, team goals were set, and design decisions were made.

Testing

Bio-mechanical testing will be used to measure the pedaling power output of an HPV rider. Material testing will be used to measure the flexure modulus and density of various composites for the fairing, and aluminum to steel roll bar equivalency (required by ASME).

The bio-mechanical testing is used to calculate power output of each rider using a piezoelectric force transducer built into a pedal and a laser tachometer to measure crank arm revolutions. The data is used to determine the proper gear ratios to achieve a design speed of 45 mph or greater. In addition to power calculations, the forces measured are used to create a finite element analysis model with accurate forces. This allows the frame to be engineered with a lower safety factor and reduced mass.

A three point flexure bend test is performed to test the composites used to construct the aerodynamic fairing, that will have a flexure modulus greater than or equal to that of the

2007 PSU HPV fairing, with a lower density. The flexure modulus specification of greater than or equal to is used since loading forces on a fairing are unknown and the 2007 fairing did not fail. Density is also tested to find a composite that will be lighter than the 2007 fairing composite. Thru external and internal research, the composite will vary from using epoxy or resin, balsa wood or baltek mat core, S2 fiber glass or pre-impregnated carbon fiber, vacuum bagging or air drying and, fiber orientation of 0°- 45° or 0°- 90°.

The ASME HPVC rules specify a chrome molybdenum steel tubing roll bar of 1.5 inches outer diameter and wall thickness of no less than 0.049 chrome molybdenum steel. The 2008 HPV team will use an aluminum roll bar with fracture toughness greater or equal to a chrome molybdenum steel roll bar. The verification of structural properties will be by a micro hardness test to determine the actual elastic modulus of the aluminum roll bar.

Product Design Specifications

High Priority

Criterion	**Performance**	
Requirements	Top Speed	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Top speed in male and female sprint races	MPH	> 45 MPH
Target Basis	Competition research	
Verification Method	Vehicle time trial testing	

Criterion	**Performance**	
Requirements	Braking	
Primary Customer	ASME HPVC Judges	
Metrics and Targets	**Metric**	**Target**
Stopping distance at 15 mph	Feet	=< 20 feet
Target Basis	Competition rules	
Verification Method	Vehicle testing	

Criterion	**Performance**	
Requirements	Strength	
Primary Customer	ASME HPVC Judges	
Metrics and Targets	**Metric**	**Target**
Frame factor of safety	Non-dimensional	> 1.5
Fairing Strength equivalency	Flexure Modulus	Greater than or equal to 2007 PSU HPV fairing
Target Basis	Competition research	
Verification Method	Vehicle testing, design analysis	

Criterion	**Performance**	
Requirements	Crash recovery	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Time	seconds	< 15 s
Target Basis	Competition research	
Verification Method	Vehicle testing	

Criterion	**Performance**	
Requirements	Turning Radius	
Primary Customer	ASME HPVC Judges	
Metrics and Targets	**Metric**	**Target**
Turning ability	Radius in feet	< 25 ft
Target Basis	HPVC Rules	
Verification Method	Vehicle testing	

Criterion	**Performance**	
Requirements	High-speed stability	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Vehicle does not wobble uncontrollably at straight line speeds > 20 mph	Steering axis rotation, degrees	< 5 deg
Target Basis	Competition research	
Verification Method	Vehicle testing	

Criterion	**Performance**	
Requirements	Straight line aerodynamic efficiency	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Coefficient of drag	Non-dimensional	<=.14
Target Basis	Frontal area is an improvement upon Vike Trike II fairing	
Verification Method	Theoretical verification with CFD and achieved with wind tunnel testing	

Criterion	**Performance**	
Requirements	Partial fairing removal for rider entry and exit	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Rider change out time	Seconds	<60s
Target Basis	Improve upon Vike Trike II fairing	
Verification Method	Time Trial	

Criterion	**Documentation**	
Requirements	Fulfill ME 492/493 Class Requirements	
Primary Customer	PSU HPV Design Team	
Metrics and Targets	**Metric**	**Target**
Time		Fulfill ME492/493 class requirements
Target Basis	ME 492/493 class syllabus	
Verification Method	Class grade	

Criterion	**Life In Service**	
Requirements	HPV needs to last through construction, testing, and HPV Challenge.	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Rider change out time	Months	July 2008
Target Basis	Bike must last until HPV Challenge is over	
Verification Method	Inspection	

Medium Priority

Criterion	**Aesthetics**	
Requirements	Visual appeal	
Primary Customer	ASME HPVC Judges	
Metrics and Targets	**Metric**	**Target**
Frame appearance	Points, subject to judges interpretation	30 points
Fairing appearance	Points, subject to judges interpretation	30 points
Target Basis	Competition rules	
Verification Method	Competition design presentation	

Criterion	**Performance**	
Requirements	Maintenance	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Industry standard parts	Common bike tool sizes, percent	= 100%
Ease of access	# of parts to remove to get to desired part	<= 1
Target Basis	Direct comparison to standard recumbent bikes	
Verification Method	Solid modeling, vehicle testing	

Criterion	**Cost**	
Requirements	Stay under budget	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Stay under budget with material and fabrication cost	Dollars	> Budget
Target Basis	Competition research	
Verification Method	Expenditure Accounting	

Criterion	**Safety**	
Requirements	Rider safety	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Visibility	Degrees of vertical and horizontal view	Horizontal > 150 degrees Vertical > 60 degrees
Fairing Strength	Modulus of elasticity	>= Vike Trike II
Target Basis	Rider preference/experience previous fairings adequate strength	
Verification Method	Measurement	

Criterion	**Performance**	
Requirements	Light weight	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Vehicle assembly	lbs	< 50 lbs
Target Basis	Improve upon Vike Trike II fairing and frame	
Verification Method	Measurement with scale	

Low Priority

Criterion	**Ergonomics**	
Requirements	Rider comfort	
Primary Customer	PSU-HPV Team	
Metrics and Targets	**Metric**	**Target**
Comfort	Deg F	> 65 deg
Ventilation	Energy out, Watts	Energy in = Energy out
Target Basis	Competition research	
Verification Method	Vehicle testing	

Table 1: House of Quality

	Customer Needs							
	Performance	Safety	Cost	Weight	Ergonomics	Aesthetics	Target	Verification
Priority	High	High	Medium	Medium	Low	Low		
Engineering Parameters								
Speed	5	1	3	4	4	0	45+mph	Measurement
Braking	5	5	1	0	0	0	<20ft	Measurement
Frame Strength	3	5	3	2	0	0	SF 1.5	Analysis
Turning Radius	4	2	1	0	0	0	<20ft	Measurement
High Speed Stability	5	4	2	1	2	0	<5deg	Analysis
Low Speed Stability	3	4	1	1	2	0	<25ft	Measurement
Crash Recovery	3	4	3	0	1	2	15sec	Measurement
Rider Change Time	4	3	3	1	3	4	<=60sec	Measurement
Drag Coefficient	5	1	3	1	3	4	<=.14	Analysis
Riding Geometry	4	3	1	0	5	3		Analysis
Crash Safety	2	5	4	2	2	1		Measurement
HPV Mass	5	1	0	4	0	2	<25lbs	Analysis
Competition								
Bacchetta Giro 20 TT Recumbent	4	2	4	4	4	5		
HP-Velotechnik Recumbent	5	2	2	4	5	5		

Conclusion

The ASME HPV Challenge provides a unique set of obstacles and rewards as a senior capstone project. This project differs from other capstone projects largely because it is a design competition which is not an industry partnership where a specific product is developed or problem solved. This provides both more freedom to design the HPV as the team sees fit, but also makes many decisions more complicated for the sheer fact that there are so many options.

The goal of this project is to win the ASME Western Region HPV Challenge and complete all course requirements for the PSU senior capstone course. A design is sought that maximizes top speed, efficiency, ergonomics, and maneuverability to field the most competitive HPV within the limitations of the team budget.

Appendix A: Project Timeline

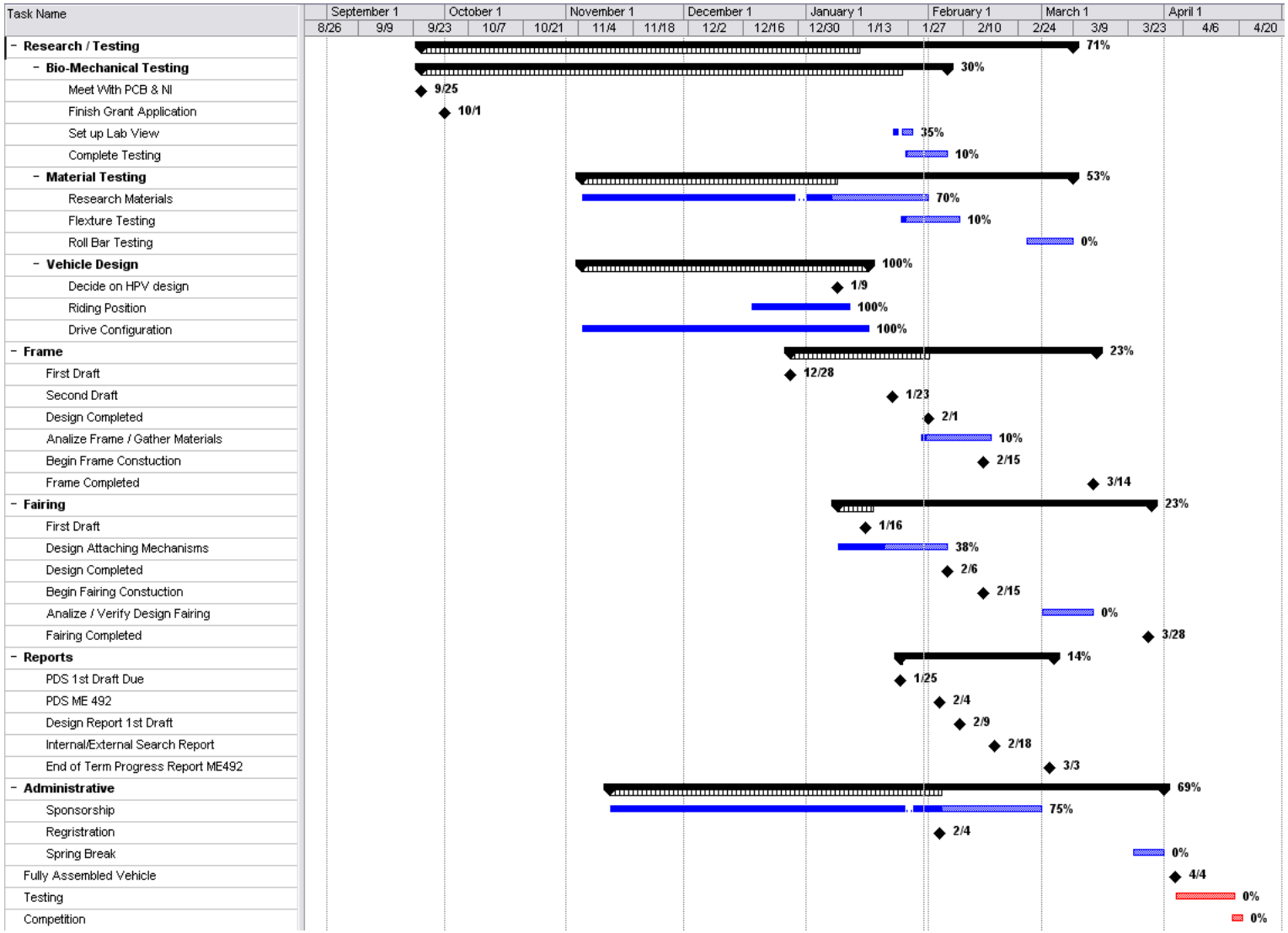

Figure 1: Gantt Chart showing HPV project timeline

Appendix B

Criteria	Need Statement Number
Performance	5,6,7,8
Environment	7
Life in service	4
Quantity	NA
Cost of production per part (material and labor)	NA
Size and Shape	6
Weight	8
Maintenance	7
Installation	NA
Ergonomics (Ease of operation)	8
Safety	6
Materials	5
Manufacturing facilities	NA
Shipping	NA
Packaging	NA
Aesthetics	7
Quality and Reliability	6
Applicable codes and standards	NA
Testing	5
Company constraints and procedures	NA
Documentation	4
Legal (Related patents)	NA
Competition products	4
Timelines	Appendix A
Disposal	NA