PORTLAND STATE UNIVERSITY
Maseeh College of Engineering and Computer Science
Mechanical and Materials Engineering Department

2006 HUMAN POWERED VEHICLE

PRODUCT DESIGN SPECIFICATIONS

FEBRUARY 6, 2006

2006 PSU-HPV RACE TEAM

HEIDI TINNESAND
ROBERT JACKSON
CARY HERTERT
KENNY BRAUN
BRIAN HAYS

PSU Faculty Advisors

Sean S. Kohles, PhD
Derek Tretheway, PhD

TABLE OF CONTENTS

INTRODUCTION

Past, present and projected energy prices have led to a search for alternatives to the gas-powered automobile. One of these alternatives is human power, which is older than the automobile. However, current modes of human transportation are not innovative or efficient enough to be directly competitive with automotive transportation. One of these is bicycle transportation, and although its form has been perfected over the past hundred and fifty years, it has yet to provide the right balance of amenities to make it a convincing alternative to the car.

One of the biggest areas for improvement from the modern bicycle is to reduce the drag induced on the rider due to wind resistance. This can be best accomplished by fully enclosing the bicycle and rider in an aerodynamic fairing. This increases the riders' efficiency and provides shelter from inclement weather, both of which make the bicycle a more attractive alternative to the automobile.

In an effort to motivate innovation and provide opportunities for student engineers in design and manufacturing, the American Society of Mechanical Engineers (ASME) created the Human Powered Vehicle (HPV) Challenge.

The competition entries are judged based on speed, endurance and elegance of design. The vehicles are timed through a 100m straight section for the sprint[1], timed over a 40km criterion-style course for the endurance[2], and graded on safety, innovation, and presentation for the design categories[3].

As a group of Portland State University senior mechanical engineering students, we have chosen to combine the Senior Capstone Project and the HPV Challenge.

SCOPE

This Product Design Specification (PDS) document clearly defines the following for the PSU-HPV:

- The design requirements
- The design constraints (metrics and targets)
- The priority of constraints
- The customers (both internal and external)

When possible this PDS will identify the linkage of the specification to the wants and desires of the customer.

MISSION STATEMENT

Our mission is to produce a safe, innovative, and competitive human-powered vehicle, in order to win the speed and endurance categories of the ASME Western Regional HPV Competition[4] in spring of 2006.

PROJECT PLAN

A Gantt chart detailing the PSU-HPV project is given in Appendix A. Due to combining the ASME-HPV Challenge and the Capstone Project Design Sequence, this project is on an advanced timeline. As such, some requirements listed in the project plan have already been completed. However, in order to conform to the Capstone Project Design Sequence (ME 491/2/3) standard, they are listed as if they are yet to occur.

The major milestones for the HPV project are:

- Completed frame: January 9
- Completed fairing: April 12
- Finished competition vehicle: April 19
- ASME – HPV Challenge (competition): April 28-30
- Final design and working prototype demonstrated at the Capstone Project Design Presentations: final week of May or first week of June, depending on ME 493 course schedule

IDENTIFICATION OF CUSTOMERS

The following is a list of the external customers of the HPV, in order of priority:

1. PSU-HPV 2006 Race Team
2. Future PSU-HPV Race Teams
3. PSU Mechanical and Materials Engineering (MME) Department

The primary customer of the HPV is the PSU-HPV 2006 Race Team. Since the ultimate testing of the completed prototype takes place at an established competition, it is in the best interest of the primary customer to make decisions aimed towards scoring high marks with the competition judges.

The additional external customers (future PSU-HPV Race Teams and the PSU MME Department) benefit mainly from the development of a platform vehicle, upon which future innovations (to the 2006 final design) can be designed and built. The legacy of this project, then, is both the final vehicle as built, as well as the documentation of our design process and analysis.

The MME department also benefits from the exposure gained by a high scoring vehicle in the regional competition and local press releases. Thus the unified goal of the external customers is for the 2006 Race Team to produce a high-scoring design.

Internal customers include:

1. PSU-HPV 2006 Race Team
2. Faculty Advisors for ME492
3. PSU-HPV Sponsors
4. ASME-HPV Judges

The 2006 Race Team is the primary external customer. They also comprise the design team, fabrication department, and shippers of the HPV. As such, they comprise the bulk of the internal structure of the project.

Secondary to the Race Team are the faculty advisors who ensure that designs adhere to product development deadlines, testing deadlines, and stay under budget. Other internal customers are the sponsors who have graciously donated time and resources toward completion of the HPV and the ASME-HPV judges

who both specified the design constraints and will be judging the PSU-HPV and ranking it with other 2006 West Coast Competition entrants.

CUSTOMER FEEDBACK

Customer feedback for this project comes primarily from the PSU-HPV Race Team, and is incorporated into design decisions. At weekly design team meetings held between September and December of 2005, needs were identified, options were compared, and decisions were made in order to move the project forward. This initial process was intensive and self-directed, without the involvement of PSU Faculty advisors.

This process differs from that outlined by the Capstone Project Design Sequence (ME 491/2/3) in that we did not have external customers to consult and survey for design requirements. Due to this difference, the customer needs were identified primarily by the competition constraints, industry expert guidance, and the individual inputs of the design team members.

DESIGN AND LEGAL

All original designs are the property of the 2006 PSU-HPV design team. Designs used for inspiration and pre-engineered products will be cited accordingly. Applicable codes and standards for this project are the competition rules; as such all requirements have been met.

TESTING

We are planning to perform a Finite Element Analysis of the frame and a Computational Fluid Dynamics analysis of the fairing design.

PRODUCT DESIGN SPECIFICATIONS

HIGH PRIORITY

Criterion	Performance	
Requirement	Speed	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Exceed top speed of last year's winner	Miles per hour	> 45
Target Basis	2005 Race Results	
Verification Method	Measurement by time trial	

Criterion	Performance	
Requirement	Turning Ability	
Primary Customer	PSU-HPV 2006 Race Team, ASME-HPV Judges	
Metrics & Targets	**Metric**	**Target**
Turning radius	Feet	< 25
Target Basis	Competition Rules	
Verification Method	Design review, Measurement	

Criterion	Performance	
Requirement	Steering	
Primary Customer	PSU-HPV 2006 Race Team, ASME-HPV Judges	
Metrics & Targets	**Metric**	**Target**
Accuracy	Degrees per foot[5]	0°/100'
Target Basis	Competition Rules	
Verification Method	Measurement	

Criterion	Performance	
Requirement	Aerodynamically favorable boundary layer separation	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Boundary layer separation	% pressure recovery	100
Target Basis	Aerodynamics Research	
Verification Method	Test with tufts of yarn taped in a grid pattern and look for reversing or flutter[6]	

Criterion	Life in Service	
Requirement	Needs to last through testing, training, competition	
Primary Customer	PSU-HPV 2006 Race Team, Future PSU-HPV Race Teams	
Metrics & Targets	**Metric**	**Target**
	Days	April 30, 2006
Target Basis	Budget constraint, purpose of this HPV	
Verification Method	Inspection	

Criterion	Documentation	
Requirement	ASME/ Senior Capstone Papers	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
		Documentation of engineering process
Target Basis	ME 492/3 Course requirements	
Verification Method	Measurement	

Criterion	Cost	
Requirement	Under budget	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Fabrication	$	< 4100
Transportation to Competition, Entrance fees	$	< 1000
Target Basis	Amount of funding raised	
Verification Method	Direct Comparison, Measurement	

Criterion	Size and Shape	
Requirement	Optimal aerodynamics	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Minimize Frontal area	Square feet	3.77
Maximize Pressure Recovery	Chord separation point	X=L
Target Basis	Research in Aerodynamics	
Verification Method	Measurement, Windtunnel testing	

Criterion	Safety	
Requirement	Rider Safety	
Primary Customer	PSU-HPV Race Team	
Metrics & Targets	**Metric**	**Target**
Safe Operating Conditions		Free of sharp edges and pinch points
Stopping Distance	mph, feet	From a speed of 15 mph to 0 mph in 20 feet or less
Target Basis	Competition Rules	
Verification Method	Inspection, Measurement	

Criterion	Materials	
Requirement	Adequate Strength	
Primary Customer	PSU-HPV Race Team	
Metrics & Targets	**Metric**	**Target**
Mitigation of failure	Safety Factor (S_y/σ_y)	2
Target Basis	Industry standard, Engineering Analysis	
Verification Method	Finite Element Analysis	

MEDIUM PRIORITY

Criterion	Performance	
Requirement	Stability	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Vehicle does not flip under normal turning conditions	mph	10
Target Basis	Competition research	
Verification Method	Empirical Analysis, Vehicle Testing	

Criterion	Environment	
Requirement	Rider Comfort	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Internal Temperature	° F	< 10° over outside temp
Target Basis	Rider Comfort	
Verification Method	Measurement	

Criterion	Weight	
Requirement	Light as possible	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Frame weight	lbs	30
Fairing weight	lbs	20
Target Basis	Power Availability, Expert opinion, Industry Standards	
Verification Method	Measurement	

Criterion	Aerodynamic Performance	
Requirement	Surface Roughness	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Surface Roughness	inches	0.004
Target Basis	Aerodynamics Research	
Verification Method	Reported fairing material properties	

Criterion	Aesthetics	
Requirement	Visual Appeal	
Primary Customer	PSU-HPV 2006 Race Team, PSU-HPV Sponsors	
Metrics & Targets	**Metric**	**Target**
Fairing Appearance	Unquantifiable – Subject to judges interpretation	Clean lines, Smooth surface of uniform school colors
Frame Appearance	Unquantifiable – Subject to judges interpretation	Frame to be powder coated
Target Basis	Competition research	
Verification Method	Direct Comparison to competition, Sponsor feedback	

LOW PRIORITY

Criterion	Documentation	
Requirement	Beginning of a legacy project	
Primary Customer	PSU-HPV 2006 Race Team, Future PSU-HPV Race Teams	
Metrics & Targets	**Metric**	**Target**
		Documentation of engineering process for future PSU-HPV Teams
Target Basis	Increase PSU MME programs awareness	
Verification Method	Measurement	

Criterion	Maintenance	
Requirement	Minimal or No maintenance	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Before competition	Hours	< 1
During competition	Minutes	0
Target Basis	Direct Comparison with standard recumbent trike	
Verification Method	Measurement	

Criterion	Size, Shape and Weight	
Requirement	Must fit in transportation method	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
HPV to be transported from PDX to SLO		
Ford 15 Passenger Van (with no seats)	Inches	51.7 wide 48 tall 140 long
Standard Long Bed Pick-up	Inches	50 wide 60 high (approx.) 97.4 long (tailgate closed)
Subaru Outback roof-rack	Inches	69.7 wide (limited by width of car 60 high (approximate limit from height of bridges on roadway) 188.7 long (limited by length of car)
Subaru Outback roof-rack	lbs	100 (from Subaru Outback sales brochure)
Enclosed Utility Trailer (need dimensions)	Inches	56 wide 64 high 96 long
Target Basis	Auto Manufacturers Specifications (Ford.com, Uhual.com)	
Verification Method	Measurement	

Criterion	Ergonomics	
Requirement	Rider Interface and Access	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
maximum rider shoulder width	Inches	20
maximum rider x-seam length	Inches	45
Ease of entry and exit	Seconds	< 10
Target Basis	Research in competitors designs	
Verification Method	Measurement	

Criterion	Shipping and Transportation	
Requirement	Ease of Transportation	
Primary Customer	PSU-HPV 2006 Race Team	
Metrics & Targets	**Metric**	**Target**
Ease of loading and unloading (weight)	Lbs	60
Ease of loading and unloading (time)	Minutes	15
Target Basis	Practicality	
Verification Method	Measurement	

HOUSE OF QUALITY

Criterion	Priority	Parameters and Performance													Competitors	
		Speed (0-5)	turning ability	rollover speed	Aerodynamics (0-5)	Low Speed Stability (0-5)	Frame Strength	Faring Weight	Frame Weight	Roll bar	Internal Temp	Rider Exchange Time	Stopping Distance	Harness	A: Cat Trike Speed	B: Chico State "Mocha Chico"
Performance	High	4	4	4	5	5		5							2	4
Cost	High				5										3	1
Size and Shape	Med.														4	5
Materials	High						2		5	5					2	5
Environment	Med.										3				3	4
Weight	Med.							5		3					5	3
Aesthetics	Med.														2	5
Ergonomics	Low											5			5	3
Safety	High									5			5	5	3	5
Competition																
A		30	13 ft		2	5	4	5	3	0	3		5	0		
B		42.7 mph	<20 ft.	4	4	5	4	5	5	5	2	5	4	5		
Target		45 mph	<25 ft	10 mph	5	5	SF=2	65 lbs.	35 lbs	Y	above extern	< 10 sec	<20 ft	Y		
Method of verification		M	M	M	O	O	A	M	M	O	M	M	M	O		

M = Measured O = Observed A = Analysis

CONCLUSIONS

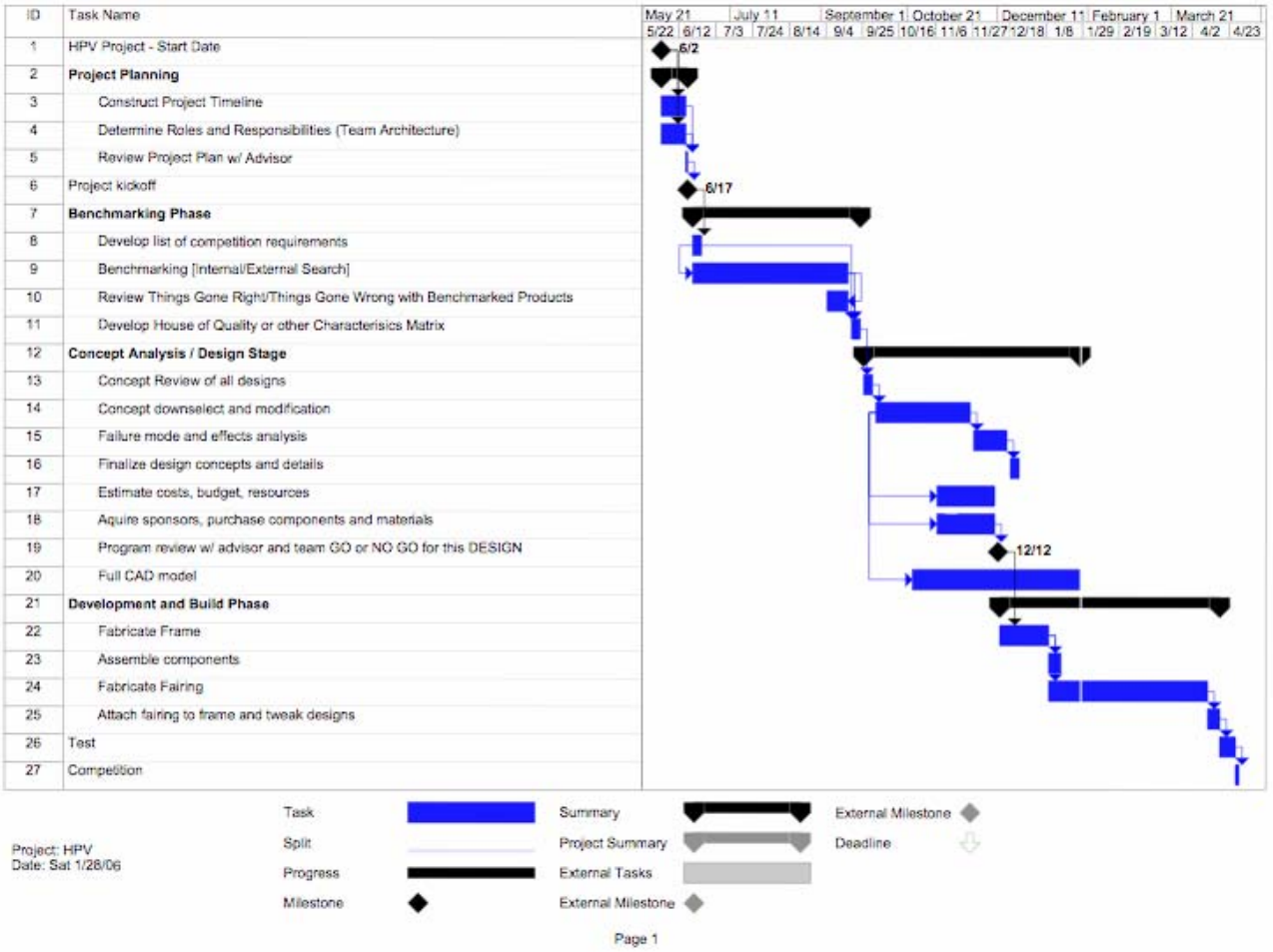
The 2006 PSU-HPV is an ambitious and rewarding project. The challenges inherent in designing a competitive HPV from the ground up are substantial, and thus will require extensive time and energy to meet.

The ultimate purpose of the 2006 HPV is to accommodate a team of riders, each doing their best to maintain the vehicle at its' maximum velocity for the duration of their time on the course.

It must be ergonomically, aerodynamically, and mechanically suited for both the sprint and criterion courses, and capable of safely carrying a rider at speeds upwards of 40 mph. The HPV must be strong enough not to fail due to testing, training, or competition, be built within budget, and delivered in time to compete.

In summary, our design goal is to build the lightest, strongest, and fastest human powered vehicle within the constraints of our budget, the contest rules and the structure of the PSU MME Design Capstone Project sequence (ME 491/2/3).

APPENDIX A – GANTT CHART



APPENDIX B – PDS CHECKLIST

Criteria	Pages
Performance	4,7
Environment	7
Life in service	5
Quantity	n/a
Cost of production per part (material and labor)	n/a
Size and Shape	5,9
Weight	9,7
Maintenance	8
Installation	n/a
Ergonomics	9
Safety	6
Materials	5,6
Manufacturing facilities	n/a
Shipping	10
Packaging	n/a
Aesthetics	8
Quality and Reliability	see “Life in Service”
Applicable codes and standards	n/a
Testing	5
Company constraints and procedures	n/a
Documentation	5
Legal (Related patents)	5
Competition products	5
Timelines	see Appendix A
Disposal	n/a

APPENDIX C – FOOTNOTES

[1] The Sprint competition: Vehicles will be timed through a 100m light gate after a 600m flying start. The fastest vehicle will win the event, but not necessarily the competition.

[2] The Endurance competition: A criterion course composed of straight away sprints, hair pin turns and s-turns involving multiple laps for a forty kilometer total. The shortest completion time will win the event, but not necessarily the competition.

[3] The last event is the utility event which includes an obstacle course, unaided stopping and starting, and payload retrieval. The PSU HPV team will not be designing for competition in this event and is merely mentioned to complete the definition of the ASME HPV challenge.

[4] The Western Regional ASME HPV challenge is to be held in San Louis Obispo California at California Polytechnic Institute (last year's winners).

[5] The vehicle must be able to travel in a straight line without wander, drift, or "crabwalking".

[6] This is a visual method of flow type verification, a fluttering tuft of yarn will indicate a turbulent boundary layer, whereas a linearly flowing tuft will indicate laminar flow. This is not a design method, so much as a verification method.