Portland State
UNIVERSITY

# Product Design Specifications Report

***Winter 2011***

# 2011 Human Powered Vehicle Challenge


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## Introduction

The American Society of Mechanical Engineers has sponsored and hosted an annual Human Powered Vehicle (HPV) design competition and race for engineering students for several decades. The challenge in this event is to apply sound engineering and design principles to build an HPV that is efficient, practical, agile, attractive, and safe. PSU has a strong recent history with this event, taking three third place finishes and one second place finish in the past five years.

The race part of this competition is what the HPV is designed to do, and it consists of three events. The sprint/drag event tests acceleration and top speed by either a head-to-head drag race tournament or an individual top speed sprint, chosen at the discretion of the hosting school. Practicality and reliability are keys in the utility endurance event which is a road course race with rider exchanges and obstacles such as speed bumps and grocery pick-ups. Finally, the speed endurance event is a LeMans style road race where vehicles with speed, handling and reliability excel. To produce a well rounded vehicle that can manage all of these events an effective design method must be employed, and the design competition assesses this by judging design reports and presentations.

(For official HPVC Rules: http://files.asme.org/asmeorg/Events/Contests/HPV/25080.pdf)

## Mission Statement

The 2011 PSU HPV design team's goal is to design, test, and fabricate a human powered vehicle to win the 2011 Human Powered Vehicle Challenge (HPVC) sponsored by the American Society of Mechanical Engineers and Knovel Corporation.

## Guide to This Document

This PDS document contains the product requirements stated by customers and the resulting goals developed by the HPV design team. Customer requirements include objectives that the final product should strive to meet, as well as limits on what the product can be or do. The design goals developed are engineering metrics, targets for these metrics, and methods to evaluate whether these targets have been achieved. Also included is a risk assessment for the project and a schedule of tasks.

## Customer Identification

This project is not directly industry sponsored, so the team did not have an easily defined list of customers. A customer list was developed based on groups the team must interact with for direction, and the corresponding aspects of the project. Table 1 lists the customers, their levels of importance, and their primary concerns.

**Table 1:** Customers of the 2011 HPV project

| Customer | Importance | Concerns |
|---|---|---|
| ASME Competition Rules/Judges | Primary external | Safety, Materials, Documentation, Performance |
| ME capstone class/faculty advisor | Primary internal | Documentation, Performance, Schedule |
| Design Team | Primary internal | Performance, Manufacturing, Safety, Budget, Materials, Practicality, Maintenance |
| SALP/ASME PSU | Secondary external | Safety, Budget, Materials, Legal |
| Race Team | Secondary internal | Performance, Maintenance, Safety, Practicality |

## Customer Interviews and Feedback

The ASME HPVC competition rules are the primary source of constraints and design goals for the product. This customer is not a person the team could interview, but the competition rules were available beginning September 2010 and all team members have read the rules and have access to reference copies. These rules are attached to this report in Appendix A.

Since all documentation and scheduling must conform to the requirements of the PSU mechanical engineering capstone class series, this is our primary customer for these aspects. The design team meets weekly in class with Dr. Faryar Etesami, the ME capstone coordinator, and in design team meetings with our faculty advisor Dr. Derek Tretheway.

Funding and procurement for this design project comes primarily from the PSU student ASME chapter through SALP, the Student Activities and Leadership Program. Design team member Tad Bamford is an officer in PSU ASME, and so acts as team liaison to these organizations.

Construction and use of the product will be done by the design and race teams, so these are our closest internal customers that provide the most immediate feedback loops.

## Product Design Specifications Table

Within a Product Design Specification are the design aspects and the customers' needs and requirements. The design aspects are then prioritized according to the final desired performance of the product. Top speed, acceleration, maneuverability, and ease of use are shown as high importance. The design aspects are then refined into comparable engineering metrics for verification that it has met the needs of t**h**e customers (Table A-1, Appendix A).

## House of Quality

The House of Quality is primarily used to numerically compare the customers' needs and requirements with respect to the properties of existing vehicles. A scale of 1 to 10 is used to evaluate the importance of each constraint. Each constraint is then compared to performance criteria and ranked on a scale of 1 to 5, with 5 being the highest. As shown in Table B-1 in Appendix B, the performance, cost, safety and maintenance were the most important criteria.

## Risk Management

The HPV is designed for performance and will have a higher risk of failure than other commuting vehicles. The risk assessment matrix, as shown in table 2, lists the potential hazards, the respective danger level of each, a mitigation plan to reduce the risk, and a final danger level after application of the mitigation plan. The risk levels are the product of a likelihood level from 1-5 and a consequence level of 1-5. This results in an overall risk scale of 1-25 with 25 being the most dangerous. On this scale a risk level of six or below was chosen as acceptable risk.

## Project Schedule:

Since the HPVC event occurs before the deadlines of the ME capstone class, May 13, 2011, this project is on an accelerated timeline. Consequently some of the milestones listed have already been reached. An overview of the major design milestones are as follows:

- Internal and External research (Jan. 12$^{th}$)
- Concept Evaluation and Selection (Jan. 24$^{th}$)
- Detailed Design Completed (Feb. 28$^{th}$)
- Review of Detailed Design (March 4$^{th}$)
- Carbon Wheels Completed (March 8$^{th}$)
- Frame Completed ( March 8$^{th}$)
- Fairing Completed (April 25$^{th}$)
- Prototyping and Testing (April 30$^{th}$)

A Gantt chart that provides greater detail of the schedule is provided in Appendix B.

## Conclusions:

The 2011 PSU HPV team aims to win the HPVC in Bozeman, MT in May 2011. To accomplish this, customers were identified and their needs were assessed to create design goals for the vehicle that is to be constructed. Having defined these goals with target values for engineering metrics, the design team can now focus on creating a product that meets these specifications. This final design should focus on maneuverability, stability, speed, and ease of use. These design characteristics put a high priority on manufacturing, materials, weight, cost, and safety. If the guidelines created here are carefully followed,

PSU HPV will produce a vehicle of exceptional speed, handling, reliability, and comfort that will overcome all of the competition in Bozeman.

## Appendix A: Product Design Specifications Table

**Table A-1:** Product Design Specifications

| *Priority* | *Requirement* | *Customer* | *Metric* | *Target* | *Target Basis* | *Verification* |
|---|---|---|---|---|---|---|
| Performance | | | | | | |
| 3 | Top Speed | ASME/Self | Mph | 40 mph | Industry Expert | Dynamic Modeling |
| 3 | Acceleration | ASME/Self | Mph/s | 0-15 mph, 5sec | Industry Expert | Testing |
| 3 | Maneuverability | ASME/Self | Small turn radius | 15 ft | Competition Rules | Dynamic Modeling |
| 2 | Weight | ASME/Self | Lbs | <40 lbs | Benchmarking | Testing |
| 1 | Fairing (C.S. Area) | ASME/Self | Ft^2 | <4 ft^2 | Fluid Analysis | CFD |
| 1 | Fairing (Cd) | ASME/Self | Coefficient of Drag | <.12 | Fluid Analysis | CFD |
| 1 | Braking Distance | ASME | 20ft from 15mph | <20 ft | Competition Rules | Testing |
| 2 | Ground Clearance | Self | Inches | 7 inch | Industry Expert | Testing |
| 3 | Maximum Stable Speed | Self | Mph | 40 mph | Industry Expert | Testing |
| Practicality | | | | | | |
| 2 | Comfort | ASME/Self | Yes/no | Yes | Benchmarking | Testing |
| 1 | Packing | ASME/Self | Height x Width x Depth | 4’x4’x8’ | Transport Vehicle | Design |
| 3 | Ease of Use | ASME/Self | Yes/no | Yes | Benchmarking | Testing |
| Maintenance | | | | | | |
| 2 | Reliability | Self | Service Life | 5 yrs | Benchmarking | Strength of Materials |
| 2 | Accessibility to Components | Maintenance | No. of people to refurbish | 2 | Benchmarking | Manufacturing |
| 2 | Availability of Parts | Maintenance | Time until parts are accessible | 2-3 days | Benchmarking | Manufacturing |
| 2 | Uses Standard Tools | Maintenance | Yes/no | Yes | Benchmarking | Manufacturing |
| 2 | Maintenance Interval | Maintenance | Miles | 500 | Benchmarking | Maintenance |
| 2 | Maintenance Time | Maintenance | Minutes | 90 | Benchmarking | Maintenance |
| Materials | | | | | | |
| 1 | Aesthetics | ASME/Self | Yes/No | Yes | Market Analysis | Competition Score |

**Legend: High = 3 Medium = 2 Low = 1**

**Table A-1 (Continued):** Product Design Specifications

| *Priority* | *Requirement* | *Customer* | *Metric* | *Target* | *Target Basis* | *Verification* |
|---|---|---|---|---|---|---|
| Documentation | | | | | | |
| 3 | PDS | Self | Deadline Date | Feb. 2nd | Course Requirement | Course Evaluation |
| 3 | Progress Report | Self | Deadline Date | Mar. 7th | Course Requirement | Course Evaluation |
| 3 | Final Report | ASME/Self | Deadline Date | May 13th | Competition Rules | Course Evaluation /Competition Score |
| Safety | | | | | | |
| 3 | Visibility (Horizontal) | ASME/Self | Degrees | 180 | Competition Rules | Testing |
| 3 | Visibility (Vertical) | Self | Degrees | >45 | Benchmarking | Testing |
| 3 | Rollover Protection System Top Load | ASME/Self | Lbs | 600 lbs | Competition Rules | Testing |
| 3 | Rollover Protection System Side Load | ASME/Self | Lbs | 300 lbs | Competition Rules | Testing |
| 2 | Rider Restraint | ASME/Self | Pass/Fail | Pass | Competition Rules | Testing |
| 3 | Frame Safety | Self | Factor of Safety | F.S.>1.5 | Benchmarking | Testing |
| Budget | | | | | | |
| 3 | Materials/ Fabrication | Self | US Dollars | <$3500 | Funding Cap (SALP) | Final Documentation |
| 3 | Travel | Self | US Dollars | <$2000 | Funding Cap (SALP) | Final Documentation |

**Legend: High = 3 Medium = 2 Low = 1**

## Appendix B: House of Quality

**Table B-1:** House of Quality

| Customer | | Engineering Requirements | | | | | | | | Competition | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Needs | Importance | Speed | HPV Geometry | Turning Radius | Drag | Frame Strength | Braking Distance (@15mph) | High-Speed Stability | Low-Speed Stability | 2010 | 2008 |
| Performance | 10 | ***** | ***** | ***** | ***** | **** | **** | **** | **** | ***** | ***** |
| Material | 8 | *** | ***** | * | ** | ***** | - | - | - | ***** | - |
| Weight | 7 | ***** | - | - | - | ***** | ***** | ** | ** | ***** | **** |
| Shape | 5 | * | ***** | - | ***** | *** | - | - | - | - | - |
| Cost | 10 | *** | - | - | **** | **** | *** | *** | * | *** | ** |
| Safety | 10 | *** | ** | - | - | ***** | ** | ***** | *** | *** | ***** |
| Ergonomics | 3 | - | ***** | ** | ** | - | - | *** | * | *** | * |
| Aesthetics | 2 | - | ***** | - | *** | ** | - | - | - | *** | * |
| Maintenance | 4 | - | *** | - | * | ***** | * | - | - | *** | - |
| **Competition** | | | | | | | | | | | |
| 2008 | | 45 mph | | <25ft | <.14 | 1.5 | <20ft | <5 degrees | N/A | | |
| 2010 | | 35 mph | - | <25ft | <.1 | 1.5 | <20ft | - | - | | |
| Target(2011) | | 40 mph | - | <15ft | <.12 | 1.5 | <20ft | - | - | | |

**Legend:** **High Importance = *****  **Low Importance = ***

## Appendix C: Technical Risk Assessment Matrix

**Table C-1:** Technical Risk Assessment Matrix

| Activity or Event | Potential Risk | Risk Level = (possibility 1-5)*[severity 1-5] | Mitigation Plans | Revised Risk Level |
|---|---|---|---|---|
| Budget Management | Project goes over budget | **(1)[3]=3** | Initial budget plans to be constructed with 20% safety margin. All funds are routed through SALP and PSU ASME for fiscal oversight. Additional funding such as corporate sponsorships to be sought. | ***(1)[3]=3*** |
| Manufacturing | Hand or face injury due to shop fabrication | **(3)[3]=9** | MCECS requires students who use shop to pass safety class and students are observed by shop professional, Mike. Students always work in pairs. MCECS requires students who use shop to complete 20 hrs of safety training as well as 15 hours of supervised work in the shop. Student access ultimately signed off on by 3 ME staff members and shop supervisor. | ***(2)[3]=6*** |
| Manufacturing | Inhaling of toxic fumes due to composite lay-up and use of Epoxy resin | **(2)[4]=8** | Strictly follow all safety guidelines as stated on the chemicals used for composite lay-up. Safety guidelines created by manufacturer and federal government. | ***(2)[2]=4*** |
| Competition | Injury due to travel to event, most likely in an auto-crash | **(2)[4]=8** | All drivers to attend PSU driving school. | ***(1)[4]=4*** |

**Table C-1 (Continued):** Technical Risk Assessment Matrix

| Activity or Event | Potential Risk | Risk Level = (possibility 1-5)*[severity 1-5] | Mitigation Plans | Revised Risk Level |
|---|---|---|---|---|
| Competition | Vehicle breaks down during competition | **(4)[2]=8** | Adequate tools and spare parts to be budgeted and brought to competition. Vehicle to be completed a minimum of 3 weeks prior to competition so testing can be performed to refine unreliable components. | ***(2)[1]=2*** |
| Competition | While at the event, a member of the team becomes injured | **(3)[3]=9** | Require individual health insurance for all students on trip. Students possibly chaperoned by ME faculty advisor during trip. The group is not responsible for financing the faculty to attend. School hosting the event is required to have trained emergency staff on hand at event. | ***(2)[2]=4*** |
| Time Management | Project not completed in time | **(3)[3]=9** | Project schedule planned with 3 week padding to account for setbacks. Design milestones clearly established. | ***(2)[3]=6*** |
| Manufacturing | Difficulty procuring parts and materials | **(2)[3]=6** | Use purchasing system implemented by ASME PSU. Order all parts and materials taking a minimum of 2 weeks extra lead time for SALP purchasing turnaround. | ***(1)[2]=2*** |

## Appendix D: Gantt chart (Project Schedule)

### Table D-1: Gantt Chart

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Project Design Spec (PDS) | 66 days | Mon 11/1/10 | Mon 1/31/11 |
| 2 | External Research | 44 days | Fri 10/15/10 | Wed 12/15/10 |
| 3 | Internal Search | 38 days | Mon 11/22/10 | Wed 1/12/11 |
| 4 | Concept Evaluation/Selection | 7 days | Fri 1/14/11 | Mon 1/24/11 |
| 5 | Design Review | 6 days | Mon 1/24/11 | Mon 1/31/11 |
| 6 | Detail Design | 46 days | Wed 1/12/11 | Wed 3/16/11 |
| 7 | Order Wheel Material | 7 days | Thu 1/27/11 | Fri 2/4/11 |
| 8 | Order Tubing | 6 days | Fri 2/4/11 | Fri 2/11/11 |
| 9 | Order Build Kit | 6 days | Fri 1/28/11 | Fri 2/4/11 |
| 10 | Machine Mold/Wheels | 10 days | Mon 2/7/11 | Fri 2/18/11 |
| 11 | Fairing Design | 32 days | Mon 1/24/11 | Tue 3/8/11 |
| 12 | FEA of Frame/Fairing/Tires | 11 days | Tue 2/1/11 | Tue 2/15/11 |
| 13 | Fairing Design Selection | 3 days | Thu 2/17/11 | Mon 2/21/11 |
| 14 | Tube Bending/Welding | 10 days | Mon 2/28/11 | Fri 3/11/11 |
| 15 | Progress Report | 4 days | Tue 3/15/11 | Fri 3/18/11 |
| 16 | Prototyping/Testing | 39 days | Wed 3/2/11 | Mon 4/25/11 |
| 17 | Documentation | 32 days | Mon 3/28/11 | Tue 5/10/11 |