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Team 512: Human Powered Vehicle

Kyler A. Marchetta;Tyler C. Schilf;Tristan R. Enriquez;Jacob A. Thomas.

FAMU-FSU College of Engineering 2525 Pottsdamer St. Tallahassee, FL. 32310

Abstract

The goal of the Human Powered Vehicle project is to develop a vehicle that is safe, practical, agile and fast. The vehicle must contain the rider within a roll protection system, including an overhead roll bar, to prevent injury during collisions with obstacles or other riders in the competition. The rule book for the competitions as well as previous competition vehicles were refereed to so that a list of customer needs and design targets were created. The engineering design process was followed to develop a vehicle suitable for the competition and consumers. The design that was chosen features three wheels, a laid-back rider position, streamlined roll protection and other components of a standard recumbent trike. A standard design was chosen because the sponsor of the project wanted the design to be completed and competition ready by April of 2019. Starting with essentially nothing, the team needs to streamline the production of the human powered vehicle to be competition ready. Once a competition suitable human powered vehicle is designed and constructed, the next year of engineers that work on this project will have a design to build upon themselves. They can modify the vehicle in any way they find suitable and improve upon what team 512 has done.

Keywords: Recumbent Tricycles, ASME, Racing, Bicycles

Acknowledgement

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- Keith Larson
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Notation

HPV	Human Powered Vehicle
HPVC	Human Powered Vehicle Competition
ASME	American Society of Mechanical Engineers

Chapter One: EML 4551C

1.1 Project Scope

1.1.1 Project Description

The objective is to produce a vehicle that can compete in the Human Powered Vehicle Competition (HPVC) where a rider will mechanically power and control the vehicle through their input force. The HPVC will be emulated at the FAMU FSU College of Engineering, and comparing our results with the results from the competition in April 2019.

1.1.2 Key Goals

The main goal for this project is to design, test and construct a HPV that will satisfy all the competition requirements. An existing frame will be utilized in the new HPV and the HPV will appeal to the design, speed and endurance events. The team will focus on the design event because attempting to produce a faster vehicle that teams with much larger budgets will be difficult. However, making the vehicle competitive in the speed and endurance events remains in the scope. By the deadline, the HPV will effectively accomplish the competition objectives that include design documentation and the physical HPV.

1.1.3 Primary Market

- The HPV is designed for the HPV competition

1.1.4 Secondary Market

- Individuals in need of personal transportation in cities, suburbs, rural areas and third world countries.

1.1.5 Assumptions

The team will test the existing frame, wheels and materials (shown in figure 1) for safety and performance, so they can be utilized. The team will use standard, pre-fabricated, parts rather than custom machined parts at the FAMU-FSU engineering college unless required. The HPV is produced within the allocated budget. Unused materials that were purchased last year are utilized.

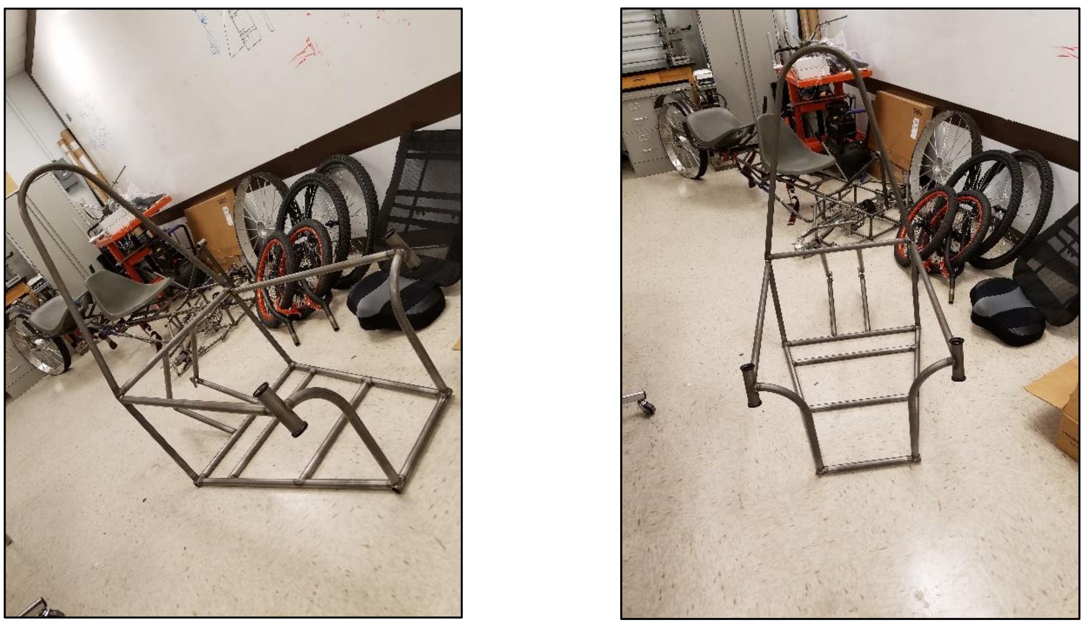


Figure 1: *Existing HPV frame*

1.1.6 Stakeholders

Stakeholders include the FAMU-FSU College of Engineering, HPV Competition judges, the advisor Mr. Keith Larson and sponsor Jess Ball (Contact to be made after concept selection is completed). These individuals need to be satisfied throughout the progression of the project.

1.2 Customer Needs

The Human Powered Vehicle Challenge is a competition, therefore many of the needs that dictate the project outcomes are the HPVC rules. The rules must be satisfied to successfully complete the project and compete in the events. The team identified Additional needs by assessing what individuals in secondary markets may want in an HPV. Some important requirements are extracted from the 2019 rule book and interpreted needs are posted underneath these requirements in green.

= Requirement = Interpreted Need

1.2.1 HPVC Rules (General Requirements)

- Have at least one Human Powered Vehicle (HPV)
  A single HPV is designed for all competition events that are entered
- Compete in Design, Men & Women Speed, and Endurance events
  The HPV meets requirements of the three main competitions
- Exhibits proper numbers and decals
  The HPV is decorated with necessary decals and numbers
- HPV displays school name
  The FAMU-FSU College of Engineering logo is displayed
- HPV is Innovative
  Clever design techniques and user-friendly accessories are utilized to impress judges
- Can stop in a short distance at speed
  The braking system on HPV is sturdy and reliable
- Has brakes on front wheels

All front tires will have brakes

- Roll-over protection system (RPS)
  The frame needs to include a roll cage to prevent the driver from injury during rollovers.
- Secured driver in HPV by safety belts or shoulder harness
  In the event of a Collison, the driver is not ejected from the vehicle.
- All surfaces of the HPV are free of sharp edges or protrusions
  When designing the HPV, the team must not produce parts with potentially hazardous extrusions.
- Participants need fully enclosed shoes and properly fitted helmets
  Proper safety equipment is purchased and equipped on the rider
- All team members are registered for competition before deadline
  The team registers for the event when registration period begins
- No driver shall have multiple entries in any single event
  Team enters a single time in each event
- Aero devices, energy storage device, vehicle modifications
  The inclusion of these devices is considered once base requirements are met
- All competition paperwork and preliminary tasks need to be completed prior to deadline
  The team tracks what needs to be done outside of the actual design and complete those tasks as needed

Table 1: *Important document deadlines for competition*

Competition Document Requirements		
Document	**Method of Submission**	**Due Date**
Vehicle Registration	Every team must register online via E-Fest website	14 days before report deadline
Design Report	Electronic submission via event website	45 days before competition
Individual Registration	Every team member must register online via E-Fest website	1st day of competition
Individual Ride Log	Every rider must submit online via event website	1 week before competition
Performance Safety Video	Electronic submission via event website	1 week before competition
Performance Safety Video	Submit only if an exemption is requested and submit to Head Judge	1 week before competition
Protests	Submit to Head Judge only if required	In accordance with 11. G

Table 1 shows a list of paperwork and documentation that must be completed for the competition. These customer requirements are outside of the actual design requirements of the HPV but are still equally important for they determine competition eligibility of the design.

Additional needs are referenced from the 2019 HPVC Rules

1.2.2 Secondary Market Needs

Secondary market needs were established by researching hypothetical statements that individuals from four distinct environments would make regarding a personal transportation vehicle. These statements are found in the colored blocks with interpreted needs located directly below them. This section of needs is what guided the generation of design concepts. Not only does the HPV need to be competitive in the HPV challenge but it must also be appealing to outside markets.

1.2.2.1 Large Cities

"It will be safe to use alongside traffic."

- The HPV is noticeable and agile

"It can carry personal items."

- The HPV includes storage space

"It can be parked and stored in small spaces."

- HPV is sleek and compact

1.2.2.2 Third World Countries

"It is not expensive."

- The HPV is made of inexpensive materials and is cheap to produce

"Can avoid obstacles in road."

- HPV traverses uneven terrain and can turn quickly

"It can carry goods to market"

- HPV includes a protected cargo area

1.2.2.3 Rural Areas

"It can go long distances any time of day."

- The HPV is designed comfortably and includes features such as rain protection and headlights/brakelights

"It can drive on dirt roads."

- HPV traverses uneven/unpaved surfaces

"It can tow additional cargo."

- HPV has towing features such as a hitch as well as high torque powertrain capabilities

1.2.2.4 Suburban Areas

"Can ride it on a sidewalk."

- The HPV is slender enough to fit on sidewalks of a typical suburban neighborhood

"Is not very heavy and can store in garage."

- The design is lightweight and fits nicely in a garage

"Its easy to spot incoming traffic."

- HPV has a good field of view and rearview capabilities

1.2 Functional Decomposition

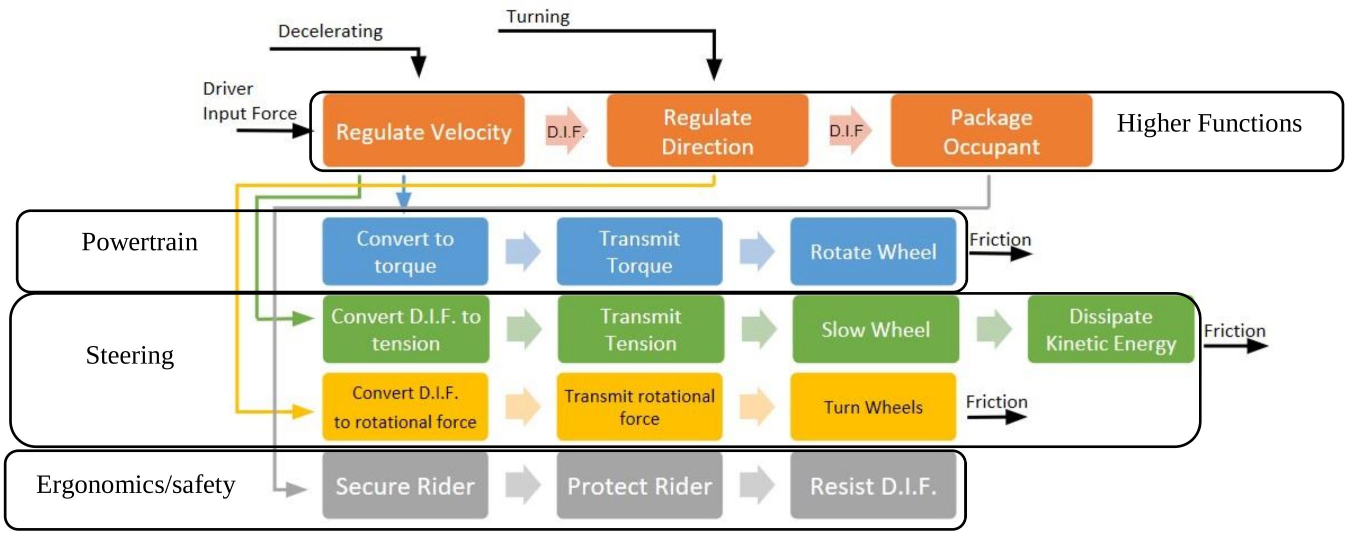


Figure 2: *Functional Decomposition of Human Powered Vehicle*

The HPV is broken down into three main subsystems (Steering, Powertrain and Ergonomics/safety). The steering system encompasses all functions that actuate the direction of the vehicle as well as decelerate the vehicle. Braking was incorporated into the steering system because the two parts of the design work closely with one another. The powertrain system incorporates functions that transfer power from the rider to the ground. The ergonomics and safety system include functions that keep the rider within the vehicle and away from potential hazards. These systems must be incorporated into the final design to effectively create a vehicle that is competition ready and safe to use. Once conceptual design begins, the functions are broken down into more specific actions and further into vehicle components. This will come later in the design process, but it is important that the functional model of the vehicle is thoroughly understood by all members such that targets may be defined.

1.3 Target Summary

Table 2 (below) presents a list of relevant metrics associated with different functions of the final design and each metric has an associated target value. The final design will satisfy each of the targets specified in the table. Some of the target values cannot be exceeded at risk of the design being unsatisfactory for the competition regulations. For example, the braking distance metric has a target value of 4.0 meters and the competition requires that the HPV stops in 6.0 meters at 25 km/hr. If the HPV can stop in less than 6.0 meters there will not be an issue, but if the braking distance exceeds 6.0 meters then the design has failed. Critical targets are displayed using bolded text. These targets are focused on closely because if they are not met early in the project the design will likely fail. These targets will be referenced each week as design of the HPV progresses so that design revisions can be made if needed. Whether or not the target is being met during the design process will be kept track of in the status column of the table. *Good* means that the target is either being met or the design is within 5% of the target goal. *Satisfactory* means the design is within 10% of the target. *Bad means* the design is not within 15% of the target and needs immediate rework at risk of failure. The status indication may change from week to week but should not exceed 15% deviation from the respective target.

Table 2: *Targets (critical targets are bolded)*

Targets						
Function	Metric	Target	Method of Determination of Metric	Method of Determination of Target	Measurement Technique	Status
Braking	**Competition Braking Distance (m)**	**Brake in 4.0 m at speed of 25 km/hr**	**This metric is Specified in the 2019 rule book**	**The target value is below the required braking distance at a speed of 25 km/hr. The average braking distance for a recumbent bike at this speed was researched leading to this target braking distance.**	**Accelerate vehicle to 25 km/hr (measured with bike speedometer) and then lock brakes. Measure distance from point of brake application to complete stop.**	**Not Specified**
	Number of Brakes (n)	**Every front wheel has a brake**	**This metric is Specified in the 2019 rule book.**	**The rules state that all front wheels must have a break, therefore the HPV will incorporate a braking mechanism on all front wheels.**	**Visual (counting)**	**Not Specified**
	Top Speed Braking Distance (m)	Brakes in less than 40 ft at top speed	Customer Needs/Wants. Safety Concerns	Realistic safe braking distance for suburban riding	Accelerate to top speed and fully apply brakes	Not Specified
Steering	**Turning Radius (m)**	**Turning radius of 6.0 m**	**This metric is Specified in the 2019 rule book.**	**The specified target is the shortest turning radius required of all competitions.**	**Completely turn the wheels of the vehicle at rest. Then travel half a circle and measure the radial distance between start and stop position**	**Not Specified**
Powertrain	**Straight Line Control**	**Travel in straight line at a speed of 8 km/hr without steering for 30 m**	**This metric is Specified in the 2019 rule book**	**The rules require that the vehicle travel in a straight line at a certain speed for 30 m. Therefore, this is a target for the design.**	**Accelerate to 8 km/hr (measured using bike speedometer) and then travel for 30 m. Measure the vehicle path offset from straight line.**	**Not Specified**
	Top Speed(km/hr)	40 km/hr (25 mph)	Vehicle is fast relative to competitors to perform well in endurance and speed events	Averaged top speed of competitive vehicles in 2017 competition	Have all team members attempt to accelerate the vehicle to the fastest they can go and measure the speed	Not Specified
Safety	**Top Load Resistance(N)**	**2670 N applied to the roll bar (RPS) directed towards the**	**This metric is Specified in the 2019 rule book**	**The odds of a rollover of a design like this commercially is unlikely. Therefore, the HPV is designed**	**These loads will be applied to the CAD frame using Creo Mechanism. If it is determined through simulation**	**Not Specified**

		rear 12 degrees from vertical and the reactant force is applied to the seat belt, seat or roll bar attachment.		**to satisfy the competition requirements and nothing more.**	**that the frame will not fail under this loading the design will progress. The frame will later be tested in a real-life application that is to be determined.**	
	Side Load Resistance(N)	**1330 N is applied horizontally to the side of the roll bar at shoulder height, and the reactant force is applied to the seat belt, seat or roll bar attachment.**	**This metric is Specified in the 2019 rule book**	**The odds of tip over where such a great force is applied is unlikely commercially. Therefore, the HPV is designed to satisfy the competition requirements and nothing more.**	**These loads will be applied to the CAD frame using Creo Mechanism. If it is determined through simulation that the frame will not fail under this loading the design will progress. The frame will later be tested in a real-life application that is to be determined.**	**Not Specified**
	Harness Webbing Width(mm)	25 mm	Specified in the 2019 rule book	Specified in the 2019 rule book	Specifications sheet and caliper	Not Specified
	Frame Prevents Significant Body Contact with Ground	**The frame prevents all body parts from contacting flat surfaces in the event of a crash when contained within frame**	**This metric is specified in the 2019 rulebook.**	**2019 rule book requires that the body does not make significant contact with the ground**	**Restrain a driver in the vehicle and tip the vehicle over. Observe if any body parts meet ground when kept within the frame.**	**Not Specified**
	Helmet Specs.	Meets CPSC Safety Standards	Specified in the 2019 rule book	Specified in the 2019 rule book	Helmet Specification Sheet	Not Specified
	RPS Specs.	**RPS fully protects driver in continuous hoop.**	**Specified in the 2019 rule book**	**Specified in the 2019 rule book**	**Ensure the Roll Bar prevents driver from meeting ground and is a single part.**	**Not Specified**

This table contains the more important targets of the design. Additional targets can be found in the appendix. Methods for testing some of the targets will be developed later and targets are subject to small changes in the initial stages of the design but will quickly solidify

1.4 Concept Generation

The first three concepts listed include sketches and were the most promising concepts of the 98 generated. These concepts were believed by the team to be the most efficient and practical designs proposed that will accomplish all the goals of the competition if assembled correctly. Following the first three are three additional concepts that the team believed are possible design solutions as well and do not include conceptual sketches. These six concepts will move on to the concept selection process and one of them will be selected as the final design. The final design is not limited to what is stated in the below descriptions and small changes are likely to occur. However, the major systems of the vehicle specified in the concept description are the ones the team will move forward with. The full list of concepts can be found in appendix D.

Concept 42.

Concept 42 retains the same frame style as provided by the previous year's team except for the roll bar which has been reduced to peak just over the max height of the target rider. The powertrain system consists of foot pedals located ahead of the front wheels on an adjustable mount. The pedals drive a train that is routed underneath the frame using sprockets and/or a chain tube. The chain will connect to the rear wheel via a multiple gear system taken from a mountain bike with a derailleur. The gear shifting mechanism will be located on the handle grips. The steering system uses hydraulics that push tie rods that ultimately turn the wheel. The hydraulics are actuated by wide grip handlebars located next to the rider with an interface under the seat attached to the frame base. The wheels are mounted through the kingpins in their current configuration and the wheels are attached to forked mounts. The brakes will be attached to these forks and squeeze the wheel rim when brakes are applied. The levers that actuate the brakes are located on the handlebars where the riders hand is located. A forked mountain bike suspension will be mounted to the frame in the back to provide a smoother ride and this suspension will also be the location of rear wheel attachment. The seat will be mounted to the frame in a laid-back position (of about 150 degrees) and a 4-point restraint will secure the rider to the vehicle. This design will likely not include fairings, but fairings may be added on later if the team feels it will improve the vehicles performance or comfort. Additional components that do not immediately affect vehicle performance, such as lights or a speedometer, may be included in this design as well. Figure 3 presents a conceptual sketch of the proposed design to provide an idea of what the final design may look like.

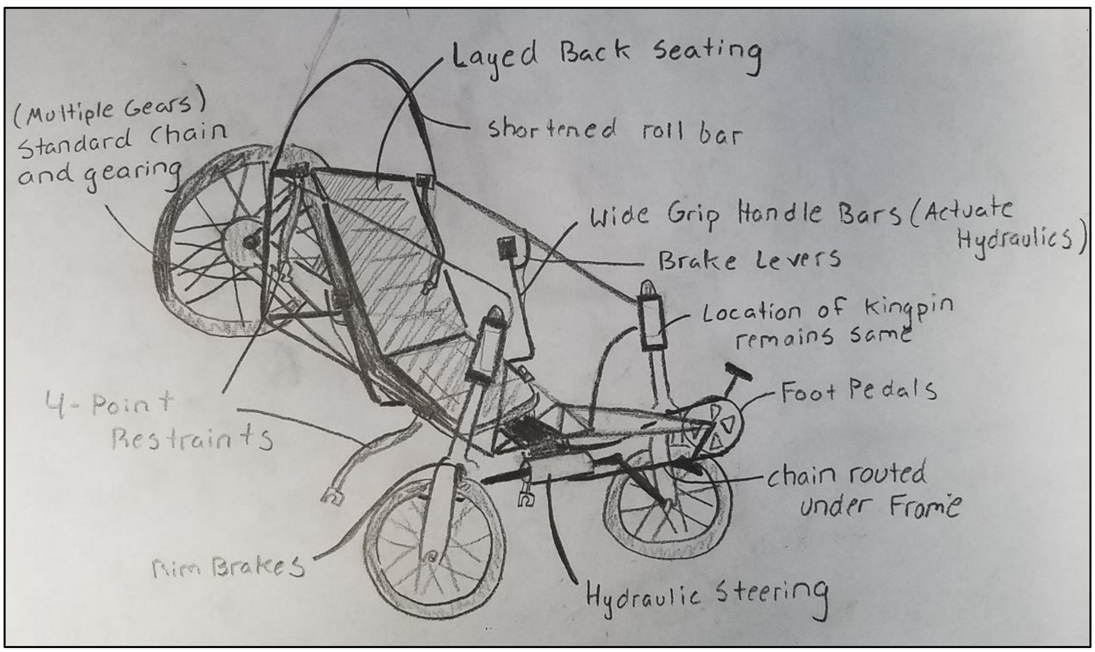


Figure 3: *Conceptual sketch of concept number 42*

Concept 85.

Concept 85 requires rework of the frame. The roll bar will be lowered to a height that will peak just over the max height of the target rider. The current mount for the kingpins will be removed to free space for the rider’s legs and lower the kingpins. The shoulder height side bars will be removed and reattached to the bottom of the frame as shown in the figure to provide the rider with more room to lay back. The kingpins are now mounted to the sides of the front corner of the frame using two additional rods welded to the frame. The front wheels are attached to forked mounts off a bicycle and this fork will have a shaft welded onto the side of it at an angle. This shaft will then pass through the kingpin. The kingpin will be angled in such a way that it is collinear with the contact point between the wheel and the ground. The wheels are steered using a tiered steering system which is connected to a wide U-shaped set of handlebars. The connection point between the handlebars and the tie rod steering mechanism will be located under the seat mounted to the frame. The powertrain system consists of foot pedals located ahead of the front wheels on an adjustable mount. The pedals drive a train that is routed underneath the frame using sprockets and/or a chain tube. The chain will connect to the rear wheel via a multiple gear system taken from a mountain bike with a derailleur. The gear shifting mechanism will be located on the handle grips. The brakes for this vehicle are cable brakes mounted to the forked wheel mounts in the front. The brakes will squeeze the rim of the front tires when actuated by a lever attached to the handle of the handlebars. The seat will be mounted to the frame I a laid-back position of approximately 150 degrees and the vehicle will use a 5-point restraint system. The restraints will pass over the rider’s shoulders, between their legs and across their waist. The rear wheel will be mounted to a forked suspension system taken from a mountain bike which will be mounted to the frame. Fairings may be added over the front wheels, the pedals and over the pedal mount area to reduce drag and comfort rider. Additional components that do not immediately affect vehicle performance, such as lights or a speedometer, may be included in this design as well. Figure 4 presents a conceptual sketch of the proposed design to provide an idea of what the final design may look like.

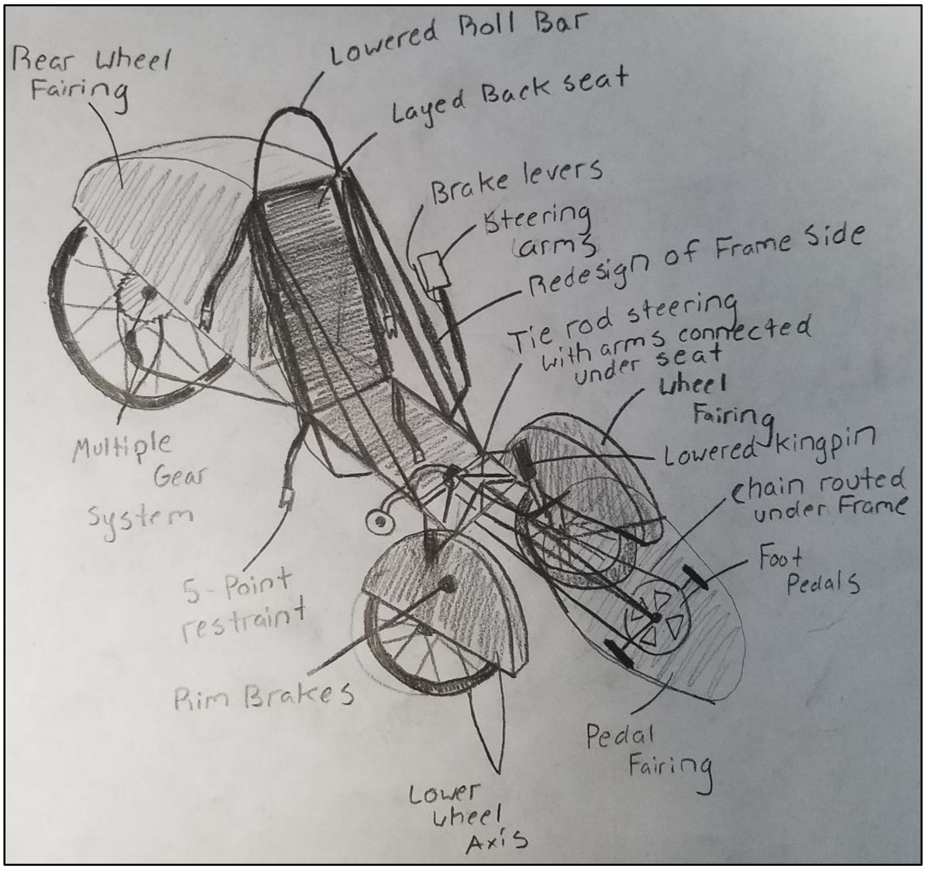


Figure 4: *Conceptual sketch of concept number 85*

Concept 92.

This concept sticks with the three-wheel design of the previous year but with some frame adjustments. The roll bar will be reduced and peak just over the max height of the targeted riders.

The kingpins will be welded in a new position just outside of and above the base of the frame by two other members extending outwards from the side of the frame base. This will provide more leg room for the rider and will lower/widen the stance of the vehicle. The wheel forks of the front two wheels will be welded to the sides of the kingpins at desired angles to optimize our steering potential. The kingpin's central axis will be collinear with the point of contact between the front wheel and ground for control. These front wheels will also have disc brakes on them for exceptional braking power. The third wheel will be in the rear mounted to a forked suspension system from a mountain bike. The drivetrain will have chain system going underneath the frame with sprockets and chain tube to guide it along the way to the rear wheel. There will be a multiple gear system incorporated to the rear wheel (and possibly the front pedals) using the gear system from a mountain bike. There will be foot pedals mounted at the front of the vehicle to transmit torque into the chain system to power the rear wheel. The steering mechanism will have a tie rod system also underneath the frame connecting the two front wheels. This linkage is actuated by a wide, U-shaped handlebar that is connected to the steering linkage under the seat. A five-point safety harness mounted at the shoulders, hip and bottom of the vehicle will used to secure the rider in the vehicle. A full fairing with open sides will be mounted onto the nose and roll bar of the vehicle. Additional components that do not immediately affect vehicle performance, such as lights or a speedometer, may be included in this design as well. Figure 5 presents a conceptual sketch of the proposed design to provide an idea of what the final design may look like.

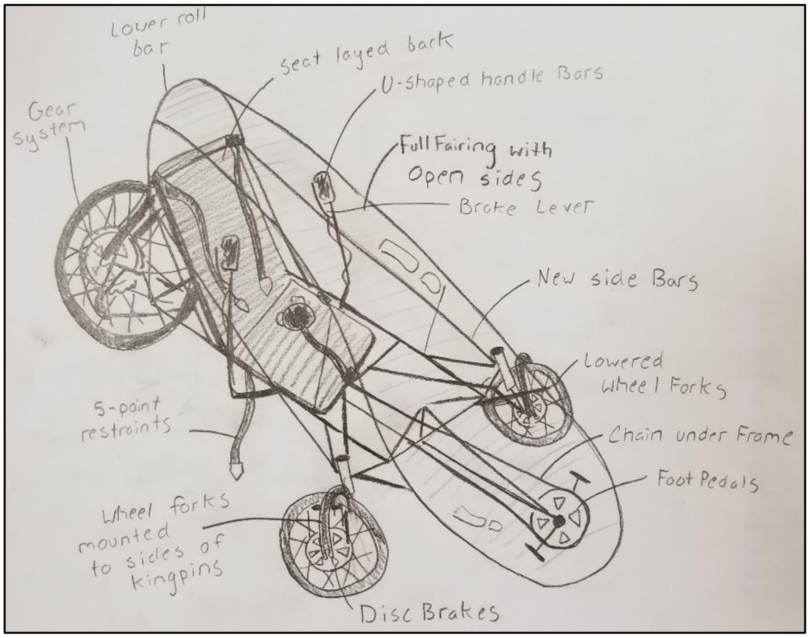


Figure 5: *Conceptual sketch of concept number 92*

Concept 87.

Concept 87 has two wheels in the front that are steered with a rack-and-pinion tie rod steering system. The wheels are actuated by the driver through a steering wheel and column. The rider is sitting more upright (about 110 degrees) so that the steering wheel can be operated comfortably. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame) and out wider. The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairings are located on nose of vehicle, over the front wheels, and on the back and rear wheel. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Concept 58.

The steering configuration of concept 58 will be like what the frame provided from last year's team which is equipped with direct steering. Power is transmitted to the rear wheel using foot pedals located in the front of the vehicle on an adjustable mount and a belt that runs underneath the frame. The vehicle will use a CVT transmission. Safety restraints will be like that in a car (3-point seatbelt). The vehicle will use a leaf spring suspension on the front wheel. Disc brakes are fixed to the two front wheels and actuated by levers on the steering handles. The rider will be sitting at an angle of approximately 120 degrees so that they can reach the direct steering handlebars. Fairing will be located over pedals to direct air around rider. The roll bar will be lowered to a point that it still protects the rider during rollover but is not over-protrusive.

Concept 24.

Concept 24 will use two front wheels and one rear wheel with the front wheels being moved to a lower and with wider stance. There will be a partial fairing extending from the front of the vehicle over the top of the body and connecting with the roll bar. The roll bar will be lowered significantly but still protect tall riders from injury. This design will incorporate a tie rod steering mechanism connecting the front tires. Adjustable foot pedals mounted in front of the vehicle will deliver power to the rear wheel with a chain and multiple gear system. The vehicle will have a 3-point restraint that passes between driver's legs and disc brakes on front wheels. The vehicle will use handlebars to turn and the brake levers that actuate the disc brakes will be located on these handlebars. The rider has a casual laid-back position of approximately 130 degrees. The roll bar will be lowered to a point that it still protects the rider during rollover but is not over-protrusive.

1.5 Concept Selection

1.5.1 House of Quality

The first step of concept selection was to determine the relevant engineering characteristics and customer needs. The customer needs collected were compared to one another with a binary pairwise comparison shown in table 3. The customer needs were compared to each other one by one to see which was more important. The more important customer requirement was given a 1 and the other was given a 0. This was repeated for every combination of customer requirements. At the end of the process, the scores for each customer requirement were added up and totaled on the right side of the table.

Table 3: *Binary Pairwise Comparison for Human Powered Vehicle Requirements*

Binary Pairwise											Total
	1	2	3	4	5	6	7	8	9	10	
1. Protects Rider/Robust		1	1	1	1	1	1	1	1	1	**9**
2. Turns Quickly	0		1	1	1	1	1	1	0	1	**7**
3. Light weight	0	0		1	0	1	1	1	0	1	**5**
4. Visually Appealing	0	0	0		0	1	0	0	0	0	**1**
5. Comfortable/Non-Obstructive	0	0	1	1		1	0	1	0	1	**5**
6. Affordable	0	0	0	0	0		0	1	0	1	**2**
7. High Top Speed	0	0	0	1	1	1		1	0	1	**5**
8. Low drag	0	0	0	1	0	0	0		0	0	**1**
9. Brakes quickly	0	1	1	1	1	1	1	1		1	**8**
10. Easily Maintained	0	0	0	1	0	0	0	1	0		**2**
Total	**0**	**2**	**4**	**8**	**4**	**7**	**4**	**8**	**1**	**7**	n - 0 = 9

The results of the comparison in Table 3 provided the weighting factor for each customer requirement to be used in the house of quality found in table 6. Protecting the rider received the highest weighting factor, followed by braking and turning quickly, while visually appealing and low drag had the lowest weight. This makes sense because those design aspects were not as valued to the customer as the others. The engineering characteristics associated with the human powered vehicle are located along the top of the house of quality with the customer requirements along the left side. The level of relation between each customer requirement and engineering characteristic was assessed and expressed using a 0, 1, 3 and 9 exponential rating system. 9 meaning the association between the engineering characteristic and customer requirement is very significant, and 0 meaning there is no relation. The scores for each engineering characteristic were totaled and recorded at the bottom of the house of quality. These scores were translated into relative weights and then the characteristics were ranked based on their level of importance based on their relative weight percentages. The results of the Human Powered Vehicle house of quality can be seen in figure 6.

Table 4: *Streamlined House of Quality for Human Powered Vehicle*

		Engineering Characteristics																			
Units		MPa	m/s	m	m	kg	m^2	W	W	Cd	m	m	N	N	N	s	deg	USD	N/A	m^3	
Customer Requirements	Importance Weight Factor	Strength	Speed	Braking Distance	Turning Radius	Weight	Foot Print Area	Cruisng Power on 0% Grade	Cruising Power > 0% Grade	Drag Coefficient	Height	Length	Brake Force	Pedal Force	Steering Force	Enter/Exit Time	Rider Position	Cost	Complexity	Rider Cabin Space	Column Totals
Protects Rider/Robust	**9**	9	0	9	9	1	0	0	0	0	3	0	1	0	1	1	3	1	3	1	378
Turns Quickly	**7**	0	1	1	9	9	3	0	0	1	3	3	1	0	9	0	1	0	1	0	294
Is lightweight	**5**	3	9	9	3	9	1	3	9	0	1	1	0	3	3	0	0	9	3	0	330
Visually Appealing	**1**	1	0	0	0	0	0	0	0	3	3	3	0	0	0	1	9	3	9	3	35
Comfortability	**5**	1	0	0	0	0	1	1	1	3	3	3	3	3	3	3	5	3	3	9	225
Affordability	**2**	9	3	3	0	3	0	0	0	9	0	0	0	1	0	0	0	9	9	0	92
High Top Speed	**5**	0	9	0	0	9	0	3	3	9	1	1	0	3	1	0	1	9	3	0	260
Low Drag	**1**	0	9	0	1	0	9	9	3	9	3	3	0	1	0	3	1	9	9	3	72
Brakes Quickly	**8**	0	1	9	1	9	1	0	0	3	1	1	9	0	0	0	0	9	9	0	424
Easily Maintained	**2**	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	9	9	1	50
Raw Score (1153)		120	120	211	168	246	48	44	68	127	87	60	103	48	107	28	74	234	205	62	2160
Relative Weight %		5.556	5.556	9.769	7.778	11.389	2.222	2.037	3.148	5.880	4.028	2.778	4.769	2.222	4.954	1.296	3.426	10.833	9.491	2.870	100.000
Rank Order		7	7	3	5	1	16	18	13	6	11	15	10	16	9	19	12	2	4	14	

The house of quality allowed the most vital engineering characteristics to be determined. The five most important characteristics from the ones used in the table (highlighted ranks) were weight, cost, braking distance, complexity and turning radius. Since these characteristics were the most important when compared with the customer needs, they will be used to compare our designs in the following Pugh charts.

1.5.2 Pugh Matrices

The Pugh charts used to compare the 6 design concepts against one another to narrow the number of plausible concepts down to 2 so that a final decision can be made. The first datum used will be a popular consumer product that fulfills many of the project objectives. This product is the GT20 recumbent tricycle. This tricycle is light with accurate steering, a tight turning circle and is easy to enter and exit due to its shape. The six possible concepts compared in the Pugh charts are listed below with short descriptions.

42. Same wheel position, wide handlebars, foot pedals, Rear wheel driven by chain and multi gear system, hydraulics turn wheel, rim brakes, forked rear suspension, no fairing.

85. Lowered and reworked frame/wheels, Tie rod steering linkage with wide grip handlebars, foot pedals and multi gear system, rim brakes, forked rear suspension, fairing over front and back.

92. Same stance as 85, disc brakes, forked rear suspension, rear wheel driven by multi gear system and chin under frame, foot pedals at front, wide grip tie rod steering, full fairing with open sides.

87. Rack and pinion steering, steering wheel and column, upright rider position, foot pedals and chain with multi gear system, fairings on pedals and front wheels and rear wheel, rim brakes.

58. Direct steering like previous year, foot pedals with belt and CVT, leaf spring suspension, disc brakes with levers on handles, fairing over pedals.

24. Same stance as 85, full fairing with open sides, tie rod steering with wide grip handlebars, pedals with chain and multiple gear system, disc brakes with actuation from handlebars.

These concepts are now placed into the first Pugh chart along with the GT20 to see which concepts fair the best. Concepts that are worse than the datum in a specific engineering characteristic received a minus, ones that were similar received an S and those that were better received a plus. The plusses and minuses were then totaled. Table 5 shows the first concept comparison.

Table 5: *First Pugh chart with GT20*

	Datum Comparison	Design Concepts Numbers					
Engineering Characteristics	Green Speed GT20	42	85	92	87	58	24
Weight	Datum	-	-	-	-	-	-
Cost	Datum	-	+	+	-	-	+
Braking Distance	Datum	-	-	S	-	S	S
Complexity	Datum	-	+	S	-	-	S
Turning Radius	Datum	+	S	S	+	S	S
Total (+)		1	2	1	1	0	1
Total (-)		4	2	1	4	3	1

Concept 42 and 87 performed the worst during this comparison with four minus’s each and only one plus. These concepts will be thrown away because they clearly cannot compete with the other concepts. Since concept 85 performed the best with 2 plusses and two minuses, this will become the new datum. The next Pugh chart, shown in table 6, compared concept 85 with concept 92, 58 and 24.

Table 6: *Second Pugh chart with concept 85 as datum*

	Datum Comparison	Design Concepts Numbers		
Engineering Characteristics	Concept 85	92	58	24
Weight	Datum	-	-	S
Cost	Datum	-	-	-
Braking Distance	Datum	+	+	+
Complexity	Datum	S	-	S
Turning Radius	Datum	S	-	S
Total (+)		1	1	1
Total (-)		2	4	1

Concept 58 was the worst concept during this comparison with a total of 4 minuses. This concept will be thrown away because concept 92 and 24 fared much better in the comparison. Concept 24, 92 and 85 will be carried on to a final Pugh chart where 24 will be the datum.

Table 7: *Final Pugh chart comparing the final three concepts*

	Datum Comparison	Design Concepts Numbers	
Engineering Characteristics	24	85	92
Weight	Datum	-	-
Cost	Datum	S	-
Braking Distance	Datum	-	S
Complexity	Datum	-	-
Turning Radius	Datum	S	S
Total (+)		0	0
Total (-)		3	3

The results of the final Pugh chart show concept 85 and 92 receiving an equal number of plusses and minuses. Since concept 92 received minuses in cost and complexity, which are the two highest weighted engineering characteristics, this concept will be thrown away rather than concept 85 which received an S in cost. This leaves the final two concept numbers 24 and 85. Concept 24 included disc brakes and no suspension while concept 85 included rim brakes and rear suspension. The analytical hierarchy process (AHP) then utilized to aid in the finalization of the team's concept decision.

1.5.3 Analytical Hierarchy Process

The first step of the AHP was to complete a weighted comparison matrix like the binary pairwise comparison table but with weights rather than just 0 and 1. This is shown in table 8 for the 5 most important engineering characteristics which are the concept selection criteria.

Table 8: *AHP comparison matrix*

	Weight	Cost	Braking Distance	Complexity	Turning Radius
Weight	1.00	0.20	0.11	5.00	0.14
Cost	5.00	1.00	0.33	7.00	0.20
Braking Distance	9.00	3.00	1.00	9.00	3.00
Complexity	0.20	0.14	0.11	1.00	0.11
Turning Radius	7.00	5.00	0.33	9.00	1.00
Total	22.20	9.34	1.89	31.00	4.45

After the table was completed, each entry in the table was normalized and rows were averaged to obtain the criteria weights. The bottom row of the table was to ensure that the normalization calculations were done correctly (all columns must sum to zero). The criteria weights highlight which concept selection criteria were the most important.

Table 9: *Normalized Criteria Comparison*

	Weight	Cost	Braking Distance	Complexity	Turning Radius	Criteria Weights
Weight	0.045	0.021	0.059	0.161	0.032	0.064
Cost	0.225	0.107	0.176	0.226	0.045	0.156
Braking Distance	0.405	0.321	0.529	0.290	0.674	0.444
Complexity	0.009	0.015	0.059	0.032	0.025	0.028
Turning Radius	0.315	0.535	0.176	0.290	0.225	0.308
Totals	1.000	1.000	1.000	1.000	1.000	1.000

The criteria comparison shows that braking distance was the most valued, followed closely by turning radius and the others were significantly less weighted. Since main difference between concept 24 and 85 is the braking type, these two design alternatives were compared again using a series of comparison matrices shown in table 10.

Table 10: *Design alternative priorities calculations using alternative braking methods*

Weight			Normalized Weight			
	Disc Brakes	Rim Brakes		Disc Brakes	Rim Brakes	Design alternative priorities
Disc Brakes	1.00	5.00	Disc Brakes	0.83	0.83	0.83
Rim Brakes	0.20	1.00	Rim Brakes	0.17	0.17	0.17
Sum	1.20	6.00	Sum	1.00	1.00	1.00
Cost			Normalized Cost			
	Disc Brakes	Rim Brakes		Disc Brakes	Rim Brakes	Design alternative priorities
Disc Brakes	1.00	0.11	Disc Brakes	0.10	0.10	0.10
Rim Brakes	9.00	1.00	Rim Brakes	0.90	0.90	0.90
Sum	10.00	1.11	Sum	1.00	1.00	1.00
Turning Radius			Normalized Turning Radius			
	Disc Brakes	Rim Brakes		Disc Brakes	Rim Brakes	Design alternative priorities
Disc Brakes	1.00	3.00	Disc Brakes	0.75	0.75	0.75
Rim Brakes	0.33	1.00	Rim Brakes	0.25	0.25	0.25
Sum	1.33	4.00	Sum	1.00	1.00	1.00
Braking Distance			Normalized Braking Distance			
	Disc Brakes	Rim Brakes		Disc Brakes	Rim Brakes	Design alternative priorities
Disc Brakes	1.00	7.00	Disc Brakes	0.88	0.88	0.88
Rim Brakes	0.14	1.00	Rim Brakes	0.13	0.13	0.13
Sum	1.14	8.00	Sum	1.00	1.00	0.13
Complexity			Normalized Complexity			
	Disc Brakes	Rim Brakes		Disc Brakes	Rim Brakes	Design alternative priorities
Disc Brakes	1.00	0.20	Disc Brakes	0.17	0.17	0.17
Rim Brakes	5.00	1.00	Rim Brakes	0.83	0.83	0.83
Sum	6.00	1.20	Sum	1.00	1.00	1

Using the priority values calculated in table 10, a final rating matrix was formed in table 11. This matrix holds all the priority values with their respective design alternative and selection criteria.

Table 11: *Final rating matrix for disc brakes and rim brakes associated with two final concepts*

Final Rating Matrix		
	Disc Brakes	Rim Brakes
Weight	0.83	0.17
Cost	0.1	0.9
Turning	0.75	0.25
Braking	0.88	0.13
Complexity	0.17	0.83

1.5.4 Final Decision

All that is left is to transpose this final rating matrix and matrix multiply it by the criteria weight vector. The criteria weight vector is the last column of table 9 on the right. The calculation is shown below and yielded the results seen in table 12.

```
Final_Rating = [.83 .17; .1 .9; .75 .25; .88 .13; .17 .83];

Criteria_Weight = [.064; .156; .444; .028; .308];

Decision = (Final_Rating.') *(Criteria_Weight)
```

```
Decision =

    0.4787          //Disc Brakes

    0.5216          //Rim Brakes
```

Table 12: *Final Concept Decision*

Results	
Concept	Alternative Value
Concept 24	0.48
Concept 85	0.52

The analytical hierarchy process determined the best of the two designs that would meet the concept selection criteria. This turned out to be concept 85, likely because cost was a highly weighted selection criteria and rim brakes were inexpensive since the team already own them. This concept is the winner of the concept selection process and team agrees it is a viable design with good potential for a successful project when compared to other designs on the market and the other 97 concepts. The team will now move forward with this idea and begin the embodiment design of the human powered vehicle proposed in this concept. A bill of materials will be created, and these materials will be ordered so that manufacturing of the human powered vehicle may begin once the required parts and materials have been determined.

1.8 Spring Project Plan

The following plan describes and explains the necessary actions that must be taken in the spring, in the form of a work breakdown structure, of 2019 to successfully complete the project before the American Society of Mechanical Engineers Human Powered Vehicle Competition on April 5^{th}. The actions are listed and explained in a chronological order leading up to the competition date and beginning January 7^{th}. Each action also has an allocated teammate assignment to perform each action to ensure that each of these actions is completed. These assignments can be seen after each item. Member allocation was based on duties assigned in the project code of conduct. Critical project actions within the spring project plan below that will cause significant delays if not completed on time are denoted with a red text note after the action.

Table 13: *Dates of Importance*

End of January 2019	All parts are ordered and delivered.
End of February 2019	Human Powered Vehicle is built
End of March 2019	Project Testing/ fine tuning
April 5th – 7th 2019 (East Lansing, Michigan State University, Michigan)	E-Fest North ASME HPV Competition

***********************<u>January</u>*********************

1st Advisor Biweekly Meeting (January 7th-11th) - Meet with Mr. Larson to discuss general timeline for the semester and any other discrepancies within our project. *Member: Tyler*

Critical Action: *Need to establish recurrent meetings with faculty advisor!*

Begin Senior Design Website (January 7th) - Format for website will be developed (remain empty until updated); Team Members, Deliverables, CAD, etc. *Member: Tristan*

Critical Action: *This will create a delay if not completed on time!*

Order head tubes, pedal boom and pedal boom sleeve (January 7th) – The headtubes need to be ordered so they can be welded to the steel tube which mounts to the front of the frame. This steel tube can then be welded to the frame, ready for the pedal mounting components. The pedal boom sleeve and pedal boom tubes need to be ordered so that they can later be welded to the frame after the tube that holds the wheels has been welded. *Member: Jacob*

Critical Action: *This will create a serious project delay if not completed on time!*

Submit work order for frame seating attachment (January 7th) - The seat is already owned. The seat, however, needs to be fixed to the frame using a steel mounting block that will be welded to the base of the frame. This work order will call for the welding of this steel mounting bracket onto the frame. Once this bracket is welded, the exact position of the seat will be known and then the attachment points for the back of the seat can be located. *Member: Kyler*

Critical Action: *This will create a serious project delay if not completed on time!*

Apply for Graduation (January 9th**) -** Apply for graduation and ensure graduation readiness.

Submit work order for seat back attachments (January 10th) - This work order will be submitted so that the attachment locations for the rear of the seat can be added to the frame. These locations will completely fix the seat to the frame. These mounting locations will be on the rising structural components leading up to the frame and below the perpendicular crossbar just below the roll bar. Once the seat is completely fixed to the frame additional rider position measurements can be made and the roll bar can be welded to the frame. This will provide complete assurance that the roll bar is tall enough will defend the tallest rider against rollover. *Member: Kyler*

Attend STEM Career Fair (January 15th) - Get a job! *Team 512*

Submit work order for roll bar attachment (January 15th)**-** Now that the seat has been placed on the frame, the exact height of the roll bar required is known and can be welded to the frame. *Member: Tyler*

Endurance Obstacles Posted for Endurance Event (January 20th) - Once the obstacles are identified for the endurance event, the team can focus on the specifics of fine tuning the vehicle for each component of the endurance event. *Member: Tyler*

Vehicle Registration (January 22nd) - Vehicle must be registered to enter competition. *Member: Tyler*

Critical Action: *This will create a serious project delay if not completed on time!*

Submit work order for head tube implementation on frame (January 20th)**-** The head tubes have been received and a work order can now be submitted to have these welded to the steel tube that will eventually support the wheels. Then the steel tube will be welded to the frame. Now the frame is only missing the pedal mounting components. *Member: Tristan*

Critical Action: *This will create a serious project delay if not completed on time!*

Order powertrain and steering components (January 20th)**-** The recumbent wheels will be ordered, the steering handles and clamps will be ordered, and any other components needed to mount the wheels on the frame and connect them will be ordered. The components for the powertrain, such as any additional chain/sprockets will be ordered. *Member: Jacob*

Critical Action: *This will create a serious project delay if not completed on time!*

Submit work order to implement the pedal mounting components (January 20th)**-** The pedal sleeve tube will have the necessary holes drilled into it and will be welded to the frame. The pedal boom will have the necessary holes drill into it and will be sleeved into the larger steel tube welded to the frame. At this point the pedals will be attached to the pedal boom. *Member: Jacob*

2nd Advisor Biweekly Meeting (January 21st-25th) - Discuss any headway and new information on the project *Member: Tyler*

Submit work order to implement frame components necessary for powertrain attachments (January 25th) - Chain sprockets and brake line routing pins will be welded in their respective locations on the frame. These parts will be necessary to implement the powertrain and braking system. *Member: Jacob*

Order restraints and frame attachment components (January 27th)**-** The parts necessary to implement the restraint system on the vehicle will be ordered. This includes the web restraints, restraint attachment points and the buckle that connects the upper restraint to the lower one. *Member: Kyler*

Update Senior Design Website (January 31st) - Update the website with more content from progress on the project. *Member: Tristan*

***************************February** ************************

Project Analysis (February 1st-19th) - Perform these required design analyses for submission in report. *Member: Tyler*

a. Roll protection System Analysis
    i. Can it handle the top load?
    ii. Can it handle the side load?
b. Structural Analysis
    i. Can the frame handle significant impact loads from the ground?
    ii. Can the frame handle significant impact loads from the sides?
c. Aerodynamics Analysis
    i. Drag Coefficient?
    ii. Pedal fairing significance
d. Cost Analysis
e. Other Analysis

Critical Action: *This will create a serious project delay if not completed on time!*

Submit work order to add restraint attach point locations to frame (February 3rd)**-** The restraint system attachment points will be welded to the frame. *Member: Kyler*

*********************FRAME COMPLETED** (February 5th)*****************

3rd Advisor Biweekly Meeting (February 4th-8th) - Discuss any headway and new information on the project *Member: Tyler*

Design Report Submission Opens (February 5th) - Window to submit opens for submission. Report format is given, maximum is 26 pages. 2.5% deduction per day late from total score. *Member: Tyler*

Organization:

1. ASME Report Cover Page and Vehicle Description Form (no page number)
2. Title Page (no page number)
3. 3-view drawing of vehicle (no page number)
4. Abstract (page i)
5. Table of Contents (page ii)
6. Design (Page 1, start of page limit)
    a. Objective
    b. Background
    c. Prior Work
    d. Design Specifications
    e. Concept Development
7. Analysis
    f. Roll protection System Analysis
    g. Structural Analysis
    h. Aerodynamics Analysis
    i. Cost Analysis
    j. Other Analysis
8. Testing
    a. Developmental Testing
9. Conclusion
    a. Comparison – Design goals, analysis, and testing.
    b. Evaluation
    c. Recommendations – Final page towards total page count
10. References

Critical Action: *This will create a serious project delay if not completed on time!*

Implement steering and rear wheel components into HPV (February 6th) - Steering knuckle, stem, front wheels, handle bars, tie rod linkage, travel radius of handlebar; all implemented into frame configuration. *Member: Tristan*

Implement braking components into HPV (February 10th) - Add disc brakes, calipers, brake lines, brake levers. *Member: Tristan*

Order powertrain, steering and ergonomic accessories (February 10th) **-** Any additional accessories needed for the frame will now be ordered. This may include the speedometer, lights, parcel delivery basket, wheel fairings or any other cosmetic components. *Member: Tyler*

Order aerodynamic components (February 15th) **-** The pedal fairing is the last thing ordered for the frame. *Member: Tyler*

Implement powertrain components into HPV (February 15th) - The pedals, chain, chain tubes, derailleur and gears will be added to the frame. *Member: Jacob*

Implement ergonomics/safety components into HPV (February 15th)- The restraints, guards and buckles will be added to the frame. *Member: Kyler*

4th Advisor Biweekly Meeting (February 18th-22nd) - Discuss any headway and new information on the project *Member: Tyler*

Design Report Submission Closes (February 19th) - Window for submission closes at 11:59 PM. 2.5% deduction from total score for every day report is submitted late. *Member: Tyler*

Implement cosmetic components (such as pedal fairing) into HPV (February 20th) - The pedal fairing, wheel fairings, decals and panels will be added to the frame. *Member: Kyler*

Submit work order to implement accessories (February 18th) **-** Work order, if additional frame mounts are necessary to add accessories. *Member: Kyler*

Team member registration for the HPVC competition (Early: Up until March 15th; **Regular**: March 16th to April 8th) – Each Team member must register for the ASME HPV competition individually to enter the competition. *Member: Tyler*

Critical Action: *This will create a serious project delay if not completed on time!*

Update Senior Design Website (February 28th) - Update the website with more content from progress on the project. Final Design. *Member: Tristan*

*************************<u>**March**</u>***************************

Submit work order to add aerodynamic components (March 1st) **-** This will be the final addition to the frame. Also, the most expensive addition to the design.

********************Design Completed **(March 10th)** ********************

Begin Testing (March 1st-29th) - *Member: Tyler*

1. Brake from 25 km/hr in 6m
    a. Test 10 times, average results
        i. Test on asphalt
        ii. Test on concrete
        iii. Test on grass
        iv. Test on dirt
2. Turn within 8m radius
    a. Test 10 times, average results
        i. Test on asphalt
        ii. Test on concrete
        iii. Test on grass
        iv. Test on dirt
3. Straight line stability for 30m moving at 5-8 km/hr
    a. Test 1o times, average results
        i. Test on asphalt
        ii. Test on concrete
        iii. Test on grass
        iv. Test on dirt

Critical Action: *This will create a serious project delay if not completed on time!*

5th Advisor Biweekly Meeting (March 4th-8th) - Discuss any headway and new information on the project. *Member: Tyler*

FAMU-FSU Spring Break (March 18th-22nd) *Team 512*

6th Advisor Biweekly Meeting (March 25th-29th) - Discuss any headway and new information on the project. *Member: Tyler*

Submit Performance Safety Video (March 29th) - Maximum of 5 minutes. Must show vehicle performing 3 safety requirement tests and their safety analysis and features. The 3 tests include: 1. Braking, 2. Turning, 3. Forward Motion. Features: 1. Vehicle Occupant, 2. Bystanders, 3. Vehicle builders during construction. Must show completion or noncompletion of the safety tests. Must explain briefly explain how team will modify vehicle to pass on the date of safety inspection. Any features/components/systems that were designed to mitigate these hazards should be described. (Engineering principles that were used). Address how occupant head and appendages are protected in the case of crash, fall over, or inversion. Teams are required to have 1 additional safety feature of the team's choosing, which improves the safety of the team's specific design and configuration. RPS, helmet, and restraints do not count towards this. Must be less than 500 MB, in .mp4 format. *Member: Tyler*

Critical Action: *This will create a serious project delay if not completed on time!*

Submit individual ride log (March 29th) - Minimum 30 minutes of ride time logged per driver/stoker that will compete in the event. Log includes: Diver's name, date, duration in hours and minutes, location of each ride or vehicle test. *Member: Tyler*

Submit safety exemption form (March 29th) - ** Not required: Only used if team is requesting an exemption from a specific safety requirement. Must be submitted in writing using the Requested Exemptions to the Safety Certification form, sent to Head Judge at hpvcasme@gmail.com. *Member: Kyler*

Submit Protest (March 29th) - Intent to protest must be announced within 15 minutes of causative action and the written protest must be submitted within 30 minutes of previous announcement. Oral protests are not honored. Date, protesting team vehicle number, protesting school, other vehicle(s) if applicable, event during which protested action occurred, nature of protest (ex: rule violation, error in scoring, etc.), description of incident/statement of protest. After protest, receive judge's action. *Member: Tyler*

Update Senior Design Website (March 31st) - Update the website with more content from progress on the project. *Member: Tristan*

****************************April****************************

Finalize Senior Design Website (April 1st) - Complete the website and make it presentation quality. *Member: Tristan*

Critical Action: *This will create a serious project delay if not completed on time!*

Senior Design Day Preparation (April 10th) - Begin rehearsal for senior design day and gather documentation. *Member: Tyler*

Senior Design Day (April 18th)- Prepare all documents and presentation material needed for the senior design day presentation. Present the completed project to academic peers and advisors. *Member: Tyler*

Critical Action: *This will create a serious project delay if not completed on time!*

Finals Week (April 29th to May 3rd) - Prepare for and take finals. *Team 512*

Graduation (May 3rd) - Graduate from the FAMU-FSU College of Engineering. *Team 512*

Note: Dates and action items are subject to change. This document only includes anticipated dates and actions. In the future, new action items may arise and will be incorporated into the plan accordingly. ***WORK CONTINUES MONDAY JANAURY 7th TO ENSURE PROJECT REMAINS ON TRACK.***

Chapter Two: EML 4552C

2.1 Spring Plan

The initial goal for the spring plan is to develop a set of governing equations of our HPV. These were found to be the combined forces of friction, weight/gravity, acceleration/inertia, and aerodynamic drag. These forces can be mathematically changed to represent the power input from the rider and then integrated to find the energy consumed by the rider. From this analysis, we can formulate assumptions into how to improve the vehicle for the competition and general use for the rider.

$$Force\ of\ Weight\ = F_g = mg\cos\theta$$

$$Force\ of\ Friction = F_{fr} = \mu_N mg\sin\theta$$

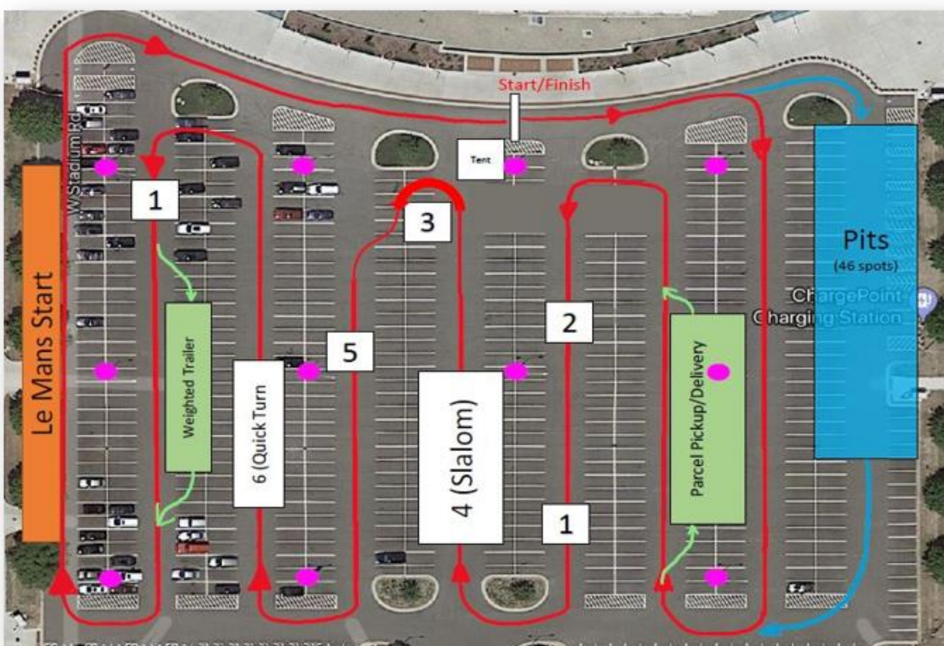
$$Force\ due\ to\ Acceleration\ = F_a = ma$$

$$Force\ of\ Drag\ = F_d = \frac{1}{2}C_d\rho v^2 A$$

The equations above show the variables that can be physically manipulated by the team to improve/decrease the energy consumption of the rider. Through data analysis, we can determine which variables are the most cost effective to change.

Using data from emulation of the competition events, we can generate Force over Velocity graphs and Power over time graphs to show mathematically where we can apply changes. Developing case studies will be the next step where we compare our HPV to other variations such as the Google sponsored Aerovelo Eta HPV. The case studies will take our data and create a model to represent the changes made. Changing the frame material would be example of such a case study. Once these case studies are produced, we can show where the best changes can be made for our HPV.

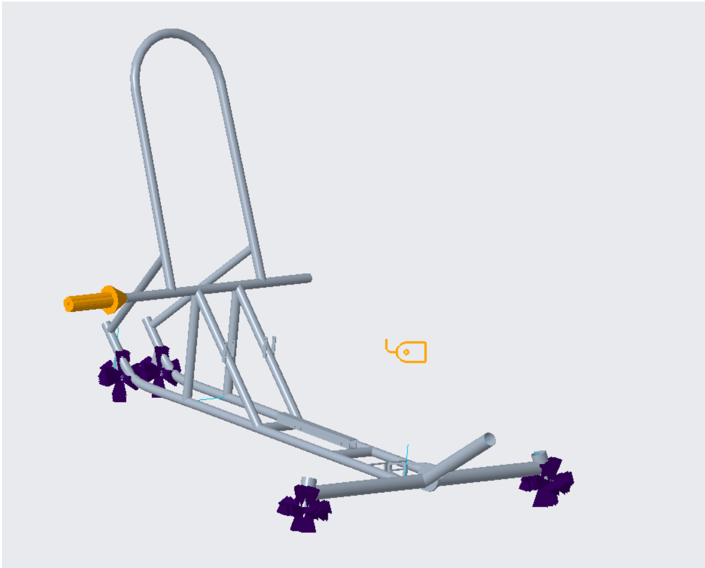
Emulating the competition is the next step. Below shows the track for the endurance event at the competition in Michigan. We will create a track of similar makeup in the parking lot of the College of Engineering.

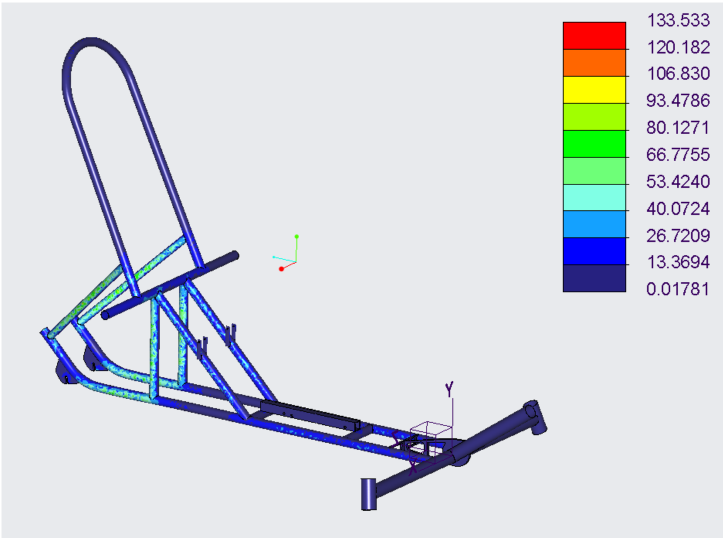


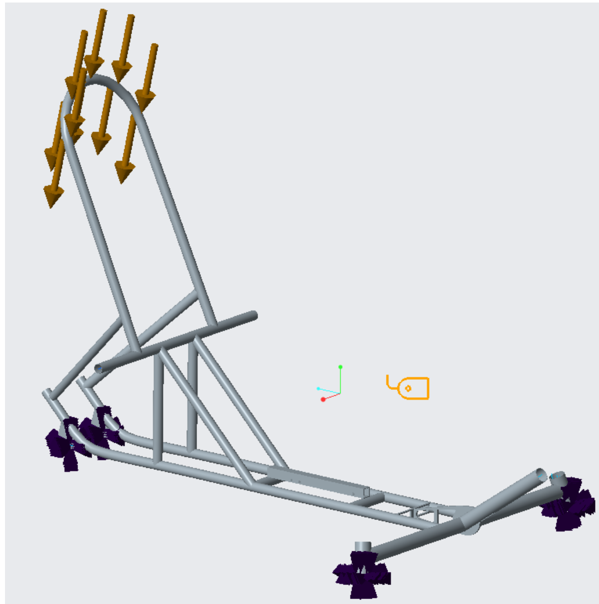
Except for the Le Mans Start and the pits, our emulated track will be the same. It can be seen in the next figure.

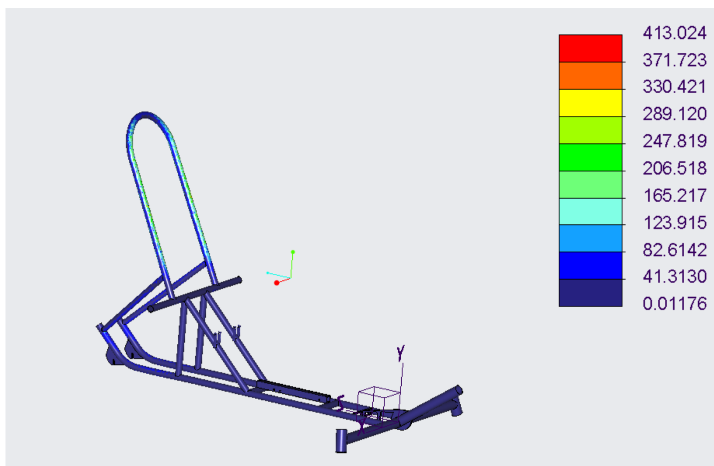

Engineering Library

2.2 Frame Design and Testing

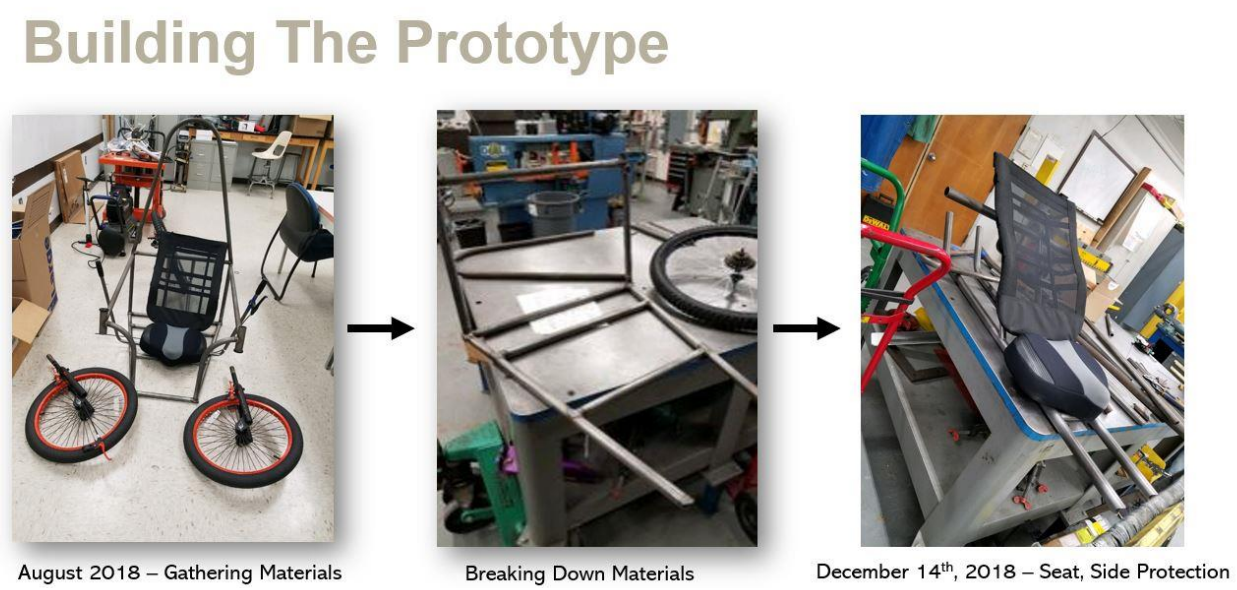


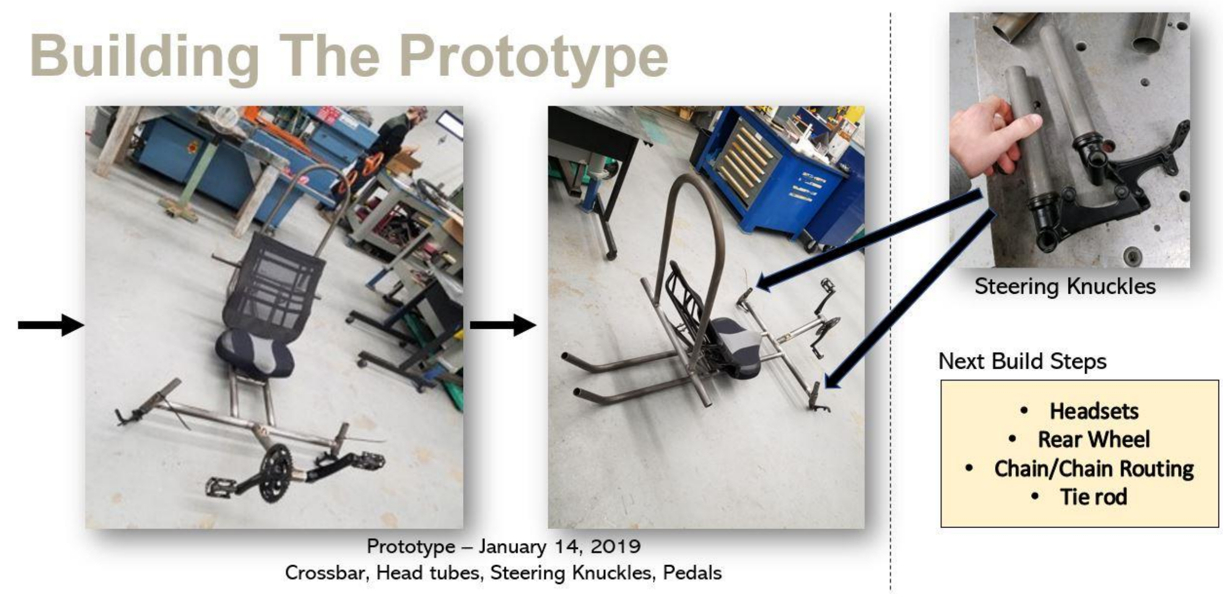

133.533
120.182
106.830
93.4786
80.1271
66.7755
53.4240
40.0724
26.7209
13.3694
0.01781
Y



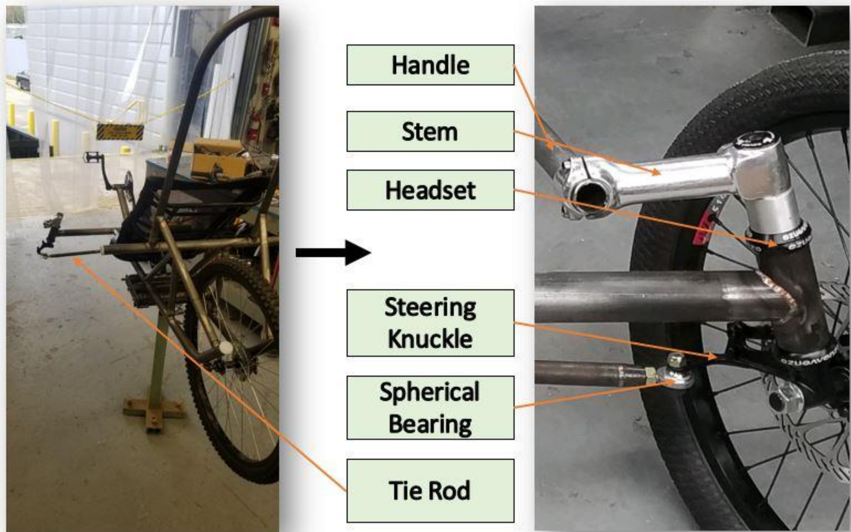

413.024
371.723
330.421
289.120
247.819
206.518
165.217
123.915
82.6142
41.3130
0.01176
y

2.3 Build Plan





Building The Prototype

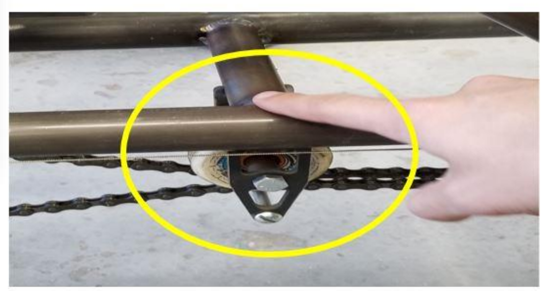


Rear Wheel Implemented

Steering Components Implemented

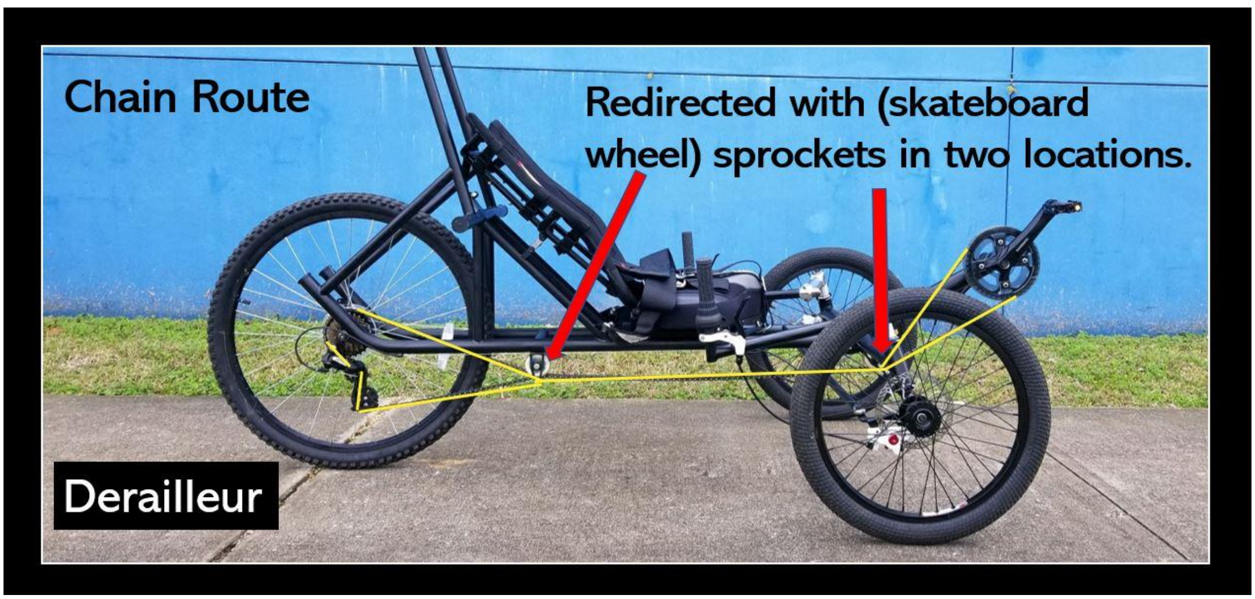
Building The Prototype

Chain Routing with brackets
(Two redirection points)



Final Touches

- Disc Brakes Implemented.
- Handlebars installed.
- Brake lines routed and activated.
- Gear shifter implemented.
- Restraints Installed.
- Derailleur cable routed and activated.



Appendices

Appendix A: Code of Conduct

2.1 Mission Statement

"*Our design team is committed to preserving an innovative work environment where communication and mutual understanding between team members are highly encouraged. The team strives to achieve the best design through uninhibited input of ideas from all team members to provide the most attractive product possible to our customer. We believe that true innovation cannot be achieved without communication.*"

2.2 Team Roles

2.2.1 Project Manager

The project manager oversees all subsystems of the design and assists each subsystem as needed. They will keep each on track and make sure the design of each system is consistent with the goals of the overall design. They keep the team on track by scheduling meetings and keeping a timeline as well as communicating with Mr. Larson, Dr. McConomy and other individuals. The project manager is the main speaker of the team and therefore must talk fluently and understand all components of the project to answer questions accurately.

2.2.2 Ergonomics Engineer

The ergonomics engineer will lead the design of all components that are in direct contact with the driver. These components include the seating, harnesses, and any buttons as well as the location of components such as the steering wheel and pedals. This member will focus on making the vehicle as user friendly and comfortable as possible for the driver. The ergonomics engineer may also design paneling or protection from the elements (i.e. sun, rain, etc.) for the driver.

2.2.3 Steering Engineer

The steering engineer will lead the design of the components having to do with the agility of the vehicle such as steering and braking. This will include the steering wheel down to the connection with the turning wheels as well as the braking system on braking wheels. This may also include suspension systems if utilized.

2.2.4 Powertrain Engineer

The powertrain engineer will design the power transmission components from the driver to the wheels of the vehicle. This includes, but is not limited to, the pedals, drivetrain, chain-routing and wheels.

2.2.5 Other Duties Assigned

Table 3: *Additional Duties*

	IT	Notetaking/Minutes	Systems/Analysis	Aero	Safety/Quality	Finance	CAD
Tristan	X		X			X	

Jacob		X		X	X		
Kyler		X			X	X	X
Tyler	X		X	X			X

Duties not included above that are required later in the project timeline will be assigned to members with responsibilities that match closely with the new duty.

2.3 Communication

The methods of communication between team members include the messaging app, GroupMe, where members will be able to communicate issues when they are not available in person. In addition, there will be a shared Google Drive folder in which members can remotely access material and provide feedback for works in progress, as well as continue these works and upload current material in real time. Tuesday and Thursday post-lecture meeting times will be utilized to ensure members are current and up to date with their assignments in addition to general team meetings held on Sunday evenings. Additional meeting times and work events will be scheduled accordingly if problems occur or when assignments are updated. All team members are not only encouraged, but are required, to actively participate in regular communication. Responses to team messages are expected within 24 hours of the creation of the message. If messages are directed to a specific team member, that member should respond within 6 hours of the message creation.

2.4 Dress Code

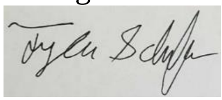
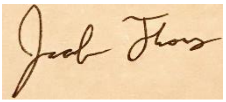
Business professional attire will be required for all professional presentations. Business casual attire will be required for meetings with the sponsor or any other individuals of higher importance. Casual attire is permitted for normal working events (such as team meetings) and meeting with the academic advisor. The proper safety equipment must be worn where necessary, such as in the machine shop (this includes heavy closed-toe shoes and goggles).

2.5 Attendance Policy

Any absence from a meeting time (class time, assigned, etc.) will require a valid excuse of absence and written documentation. Two absences will place a team member under probation and any additional absences will cause the team to seek disciplinary action for that members negligence. It should be understood by all team members that this is an extensive project that requires the efforts of each member. Also, failure to regularly acknowledge and respond to electronic messages may result in probation and the pursuit of disciplinary action.

2.6 Statement of Understanding

By signing this document, the members of Team 512 agree to the guidelines stated above and will abide by the code of conduct set forth by the group at risk of their course grade.

Name	Role	Signature	Date
Tyler Schilf	Project Manager		09/18/2018
Jacob Thomas	Powertrain Engineer		09/18/2018
Tristan Enriquez	Steering Engineer		09/18/2018
Kyler Marchetta	Ergonomics Engineer		09/18/2018

Appendix B: Work Breakdown Structure

1. **Module 1: Project Definition**
    1. Project Scope
        1. Project Description(Tyler)
            1. Understand project
            2. Summarize project
        2. Key Goals(Tyler)
            1. Analyze what needs to be done
            2. Analyze what has already been done
        3. Markets(Kyler)
            1. Understand the primary market
            2. Understand the secondary market
        4. Assumptions(Tristan)
            1. Establish project assumption based upon what is known
            2. Use assumptions to better define scope
        5. Stakeholders(Jacob)
            1. Understand who is involved
            2. Discuss their hierarchy of importance
    2. Charter
        1. Code of Conduct(Tyler)
            1. Mission Statement
                1. Understand Team Intentions
                2. Understand Team Outcomes
            2. Assign Team Roles
                1. Assess Strengths and Weaknesses
                2. Understand Personality Traits
                3. Understand what roles are needed
                    1. Assign Leader
                    2. Assign Steering Engineer
                    3. Assign Drive-train Engineer
                    4. Assign Ergonomics Engineer
            3. Communication
                1. Research forms of communication
                2. Download the appropriate communication applications
                3. Learn to use applications
            4. Establish Meeting Dress-Code
                1. Identify the meetings to be had

            2. Gather appropriate attire for meetings
        5. Establish Attendance Policy
            1. Identify when team members are free
            2. Schedule recurring meetings
        6. Statement of Understanding
            1. Make Members Aware of the Project Agreements
            2. Team Signature
3. Advisor Meet and Greet(Tyler)
    1. Reach out to advisor; establish initial meeting
        1. Establish frequency of recurring visits
        2. Obtain introductory information
4. Sponsor Meet and Greet(Tyler)
    1. Reach out to sponsor; establish initial meeting
        1. Establish frequency of recurring meetings
        2. Discuss project scope
            1. Go over who are the Stakeholders
            2. State the Assumptions
            3. Define the Goals

2. Module 2: Customer Needs/Wants

1. Work Breakdown Structure(Tristan)
    1. Look through Assignment Modules
        1. Gauge how each assignment will be completed
        2. Establish what tasks within each assignment need to be completed
2. Customer Needs
    1. Look through ASME HPV Rule Book
        1. General Information(Tristan)
            1. Analyze the Competition objectives
            2. Locate competition venue
            3. Assess the competition scheduling
        2. Competition Rules(Kyler)
            1. Establish number of vehicles to be entered
            2. Check the Events being held
            3. Deem any vehicle modifications to be used
            4. Adhere to aerodynamic device rules
            5. Comply with vehicle cosmetic rules
            6. Inspect the forms of scoring
            7. Understand the use of energy storage devices
        3. Safety(Jacob)
            1. Meet all safety requirements
            2. Satisfy the braking requirements
            3. Introduce the roll-over protection
            4. Follow through with safety equipment requirements

4. Entry and Registration(Tristan)
    1. Assess Team eligibility
    2. Adhere to vehicle construction requirements
    3. Comply with driver requirements
    4. Understand submission of entries
    5. Determine entry fees
    6. Inspect if registration assistance is needed
        1. Ask the College of Engineering for Registration assistance
5. Assess Events(Tristan)
    1. Go over rules for the design event
    2. Assess rules for the Innovation event
    3. Look over rules for the Speed event
        1. Men Time
        2. Women Time
    4. Study the rules of the Endurance Event

2. Define three Personas(Kyler)
    1. Research how our design can impact the three personas
        1. Third world countries
            1. Design for inexpensive transportation
            2. Design for harsh environments
        2. Mega Cities
            1. Design for high traffic
            2. Design for tight turning
        3. Rural areas
            1. Design for long distances
            2. Design for comfort
3. Clearly establish the needs of our customer(s) for the project
    1. Concise summary of customers' needs
        1. Include questions asked to the customer(s)
        2. Record responses from the customer(s)
        3. Detail how the need is turned into a specification

3. Pre-Advisor Meeting 1(Tyler)
    1. Record Advisor meeting minutes
    2. Record action items
4. Post Advisor Meeting 1(Tyler)
    1. Submit Advisor meeting minutes
    2. Schedule next meeting

3. Module 3: Functions

1. Functional Decomposition
    1. Establish Product Specifications(Tyler)
        1. Base specifications on the main challenges at the competition

2. Determine functions of the product from specifications(Kyler)
    1. Vehicle designed for our persona(s)
    2. Vehicle has an innovative design
    3. Vehicle operation for a speed test
    4. Vehicle operation for an endurance test
2. Pre-Senior Design Professor Meeting(Tyler)
    1. Record SDP meeting minutes
3. Post Senior Design Professor Meeting(Tyler)
    1. Submit SDP Meeting minutes
4. Targets(Tyler)
    1. Establish targets
        1. Define standard units that will be used (SI/Standard)
    2. Benchmark targets on all functions
    3. Include summary in Appendix of Evidence Manual
5. VDR 1(Tristan/Tyler)
    1. Submit VDR1
    2. Submit VDR1 Rev 2
    3. VDR1 Final Due 10-04-18

4. Module 4: Concepts

1. Concept Generation
    1. Brainstorm
        1. Steering(Tristan)
        2. Powertrain(Jacob)
        3. Ergonomics/Safety(Kyler)
        4. Overall(Tyler)
            1. Record 100 concepts
            2. Justify elimination of concepts
2. Pre-Advisor Meeting 2(Tyler)
    1. Schedule Meeting
    2. Record Advisor meeting minutes
3. Post Advisor Meeting 2(Tyler)
    1. Submit Advisor meeting minutes
4. Pre-Senior Design Professor Meeting 2(Tyler)
    1. Schedule meeting
    2. Record SDP meeting minutes
5. Post Senior Design Professor Meeting 2(Tyler)
    1. Submit SDP meeting minutes
6. VDR2(Kyler/Jacob)
    1. Collect and summarize the progress of the team thus far
    2. Incorporate the important works into the PowerPoint
    3. Submit VDR2 11-12-18

5. Module 5: Fall Closing

1. Bill of Materials(Tyler/Jacob)
    1. Determine what parts need to be purchased
    2. Keep track of all expenses
    3. Create a bill totaling all expenses
2. Risk Assessment(Tristan)
    1. Reassess all project specifications
        1. Safety requirements met
        2. Specify reasons for design choices
        3. Address any design flaws
        4. Analyze total cost of project
3. Spring Project Plan(Tyler)
    1. Establish Plan with Team
        1. Ensure work required to begin spring semester is completed
        2. Complete further work based on agreed schedule
4. Pre-Advisor Meeting 3(Tyler)
    1. Schedule meeting
    2. Record Advisor meeting minutes
5. Post Advisor Meeting 3(Tyler)
    1. Submit Advisor meeting minutes
6. Submit VDR 3(Tyler)
7. VDR3 (Poster)(Trisatn/Kyler)
    1. Collect and summarize the progress of the team thus far
    2. Incorporate the important works into the PowerPoint
    3. Poster due 12-6-18

Appendix C: Targets Catalog

Targets						
Function	Metric	Target	Method of Determination of Metric	Method of Determination of Target	Measurement Technique	Status
Braking	**Competition Braking Distance (m)**	**Brake in 4.0 m at speed of 25 km/hr**	**This metric is Specified in the 2019 rule book**	**The target value is below the required braking distance at a speed of 25 km/hr. The average braking distance for a recumbent bike at this speed was researched leading to this target braking distance.**	**Accelerate vehicle to 25 km/hr (measured with bike speedometer) and then lock brakes. Measure distance from point of brake application to complete stop.**	**Not Specified**
	Number of Brakes (n)	**Every front wheel has a brake**	**This metric is Specified in the 2019 rule book.**	**The rules state that all front wheels must have a break, therefore the HPV will incorporate a braking mechanism on all front wheels.**	**Visual (counting)**	**Not Specified**
	Top Speed Braking Distance (m)	Brakes in less than 40 ft at top speed	Customer Needs/Wants. Safety Concerns	Realistic safe braking distance for suburban riding	Accelerate to top speed and fully apply brakes	Not Specified
Steering	**Turning Radius (m)**	**Turning radius of 6.0 m**	**This metric is Specified in the 2019 rule book.**	**The specified target is the shortest turning radius required of all competitions.**	**Completely turn the wheels of the vehicle at rest. Then travel half a circle and measure the radial distance between start and stop position**	**Not Specified**
Powertrain	**Straight Line Control**	**Travel in straight line at a speed of 8 km/hr without steering for 30 m**	**This metric is Specified in the 2019 rule book**	**The rules require that the vehicle travel in a straight line at a certain speed for 30 m. Therefore, this is a target for the design.**	**Accelerate to 8 km/hr (measured using bike speedometer) and then travel for 30 m. Measure the vehicle path offset from straight line.**	**Not Specified**

	Top Speed(km/hr)	40 km/hr (25 mph)	Vehicle is fast relative to competitors to perform well in endurance and speed events	Averaged top speed of competitive vehicles in 2017 competition	Have all team members attempt to accelerate the vehicle to the fastest they can go and measure the speed	Not Specified
Safety	**Top Load Resistance(N)**	**2670 N applied to the roll bar (RPS) directed towards the rear 12 degrees from vertical and the reactant force is applied to the seat belt, seat or roll bar attachment.**	**This metric is Specified in the 2019 rule book**	**The odds of a rollover of a design like this commercially is unlikely. Therefore, the HPV is designed to satisfy the competition requirements and nothing more.**	**These loads will be applied to the CAD frame using Creo Mechanism. If it is determined through simulation that the frame will not fail under this loading the design will progress. The frame will later be tested in a real-life application that is to be determined.**	**Not Specified**
	Side Load Resistance(N)	**1330 N is applied horizontally to the side of the roll bar at shoulder height, and the reactant force is applied to the seat belt, seat or roll bar attachment.**	**This metric is Specified in the 2019 rule book**	**The odds of tip over where such a great force is applied is unlikely commercially. Therefore, the HPV is designed to satisfy the competition requirements and nothing more.**	**These loads will be applied to the CAD frame using Creo Mechanism. If it is determined through simulation that the frame will not fail under this loading the design will progress. The frame will later be tested in a real-life application that is to be determined.**	**Not Specified**
	Harness Webbing Width(mm)	25 mm	Specified in the 2019 rule book	Specified in the 2019 rule book	Specifications sheet and caliper	Not Specified
	Frame Prevents Significant Body Contact with Ground	**The frame prevents all body parts from contacting flat surfaces in the event of a crash when contained within frame**	**This metric is specified in the 2019 rulebook.**	**2019 rule book requires that the body does not make significant contact with the ground**	**Restrain a driver in the vehicle and tip the vehicle over. Observe if any body parts meet ground when kept within the frame.**	**Not Specified**
	Helmet Specs.	Meets CPSC Safety Standards	Specified in the 2019 rule book	Specified in the 2019 rule book	Helmet Specification Sheet	Not Specified

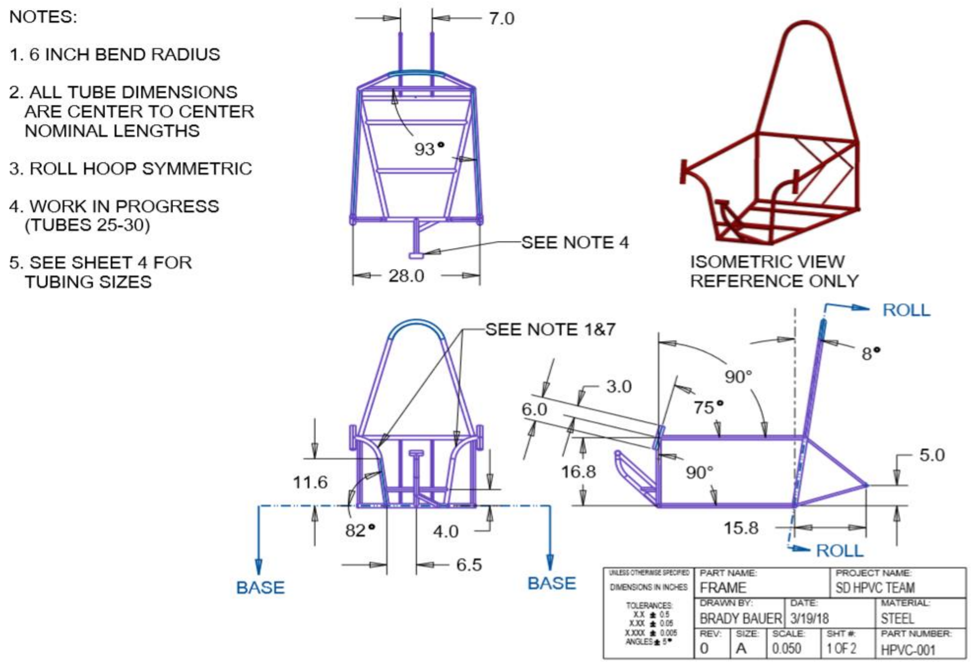
	RPS Specs.	RPS fully protects driver in continuous hoop.	Specified in the 2019 rule book	Specified in the 2019 rule book	Ensure the Roll Bar prevents driver from meeting ground and is a single part.	Not Specified

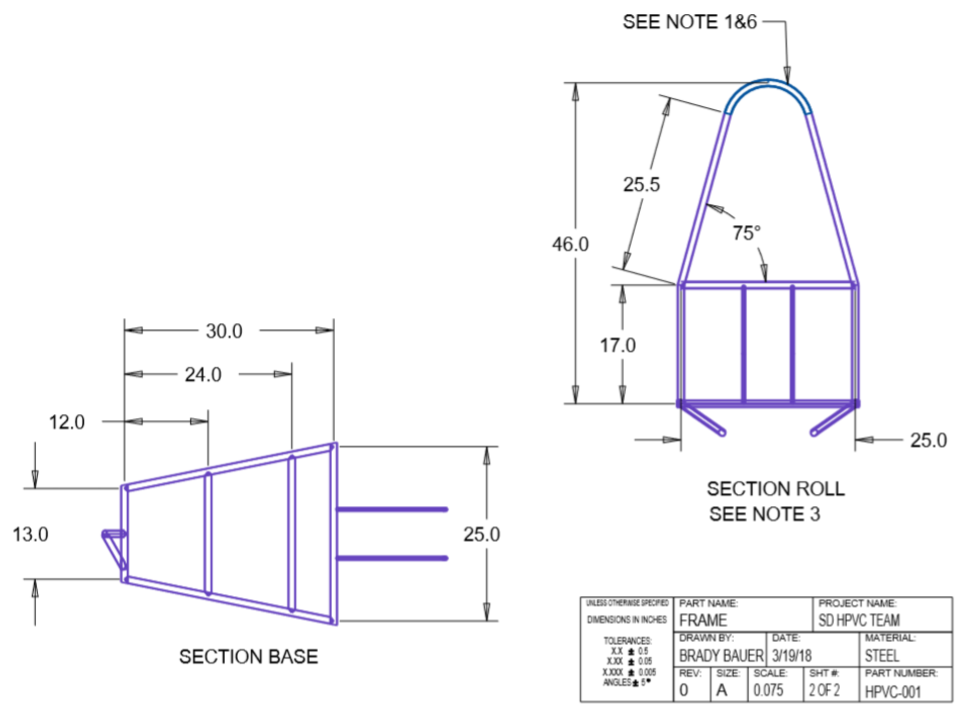
Additional Targets

Entry and registration	All Drivers Designated	Anyone that is competing is registered	Specified in the 2019 rule book	Yes or No	Ensure competing drivers are reported	Not Specified
	One Female and One Male driver competing	At least one female will compete	Specified in the 2019 rule book	Yes or No	Determine if a female driver is available	Not Specified
	Entry Documentation and Fees turned in	Turned in 60 days	Specified in the 2019 rule book	Specified in the 2019 rule book	Completed or Not	Not Specified
	Design Report Turned in	26 pages long. Follows provided format. Turned in 45 days before competition.	Specified in the 2019 rule book	Specified in the 2019 rule book	Completed or Not	Not Specified
	Presentation	6 minutes long. Present RPS analysis, testing results, safety analysis and any design updates. Completed 10 days before competition.	Specified in the 2019 rule book	Specified in the 2019 rule book	Completed or Not	Not Specified
	Safety Video	Completed a week before competition. 5 minutes long. Completes 3 performance tests. 500 mb video .mp4 file.	Specified in the 2019 rule book	Specified in the 2019 rule book	Completed or Not	Not Specified
Secondary Events	Light Brightness (Lumens)	Headlights are white with brightness of 300 lumens. Tail light is red with 10 lumen brightness.	Specified in the 2019 rule book	Minimum required brightness	Specification sheet for lights	Not Specified

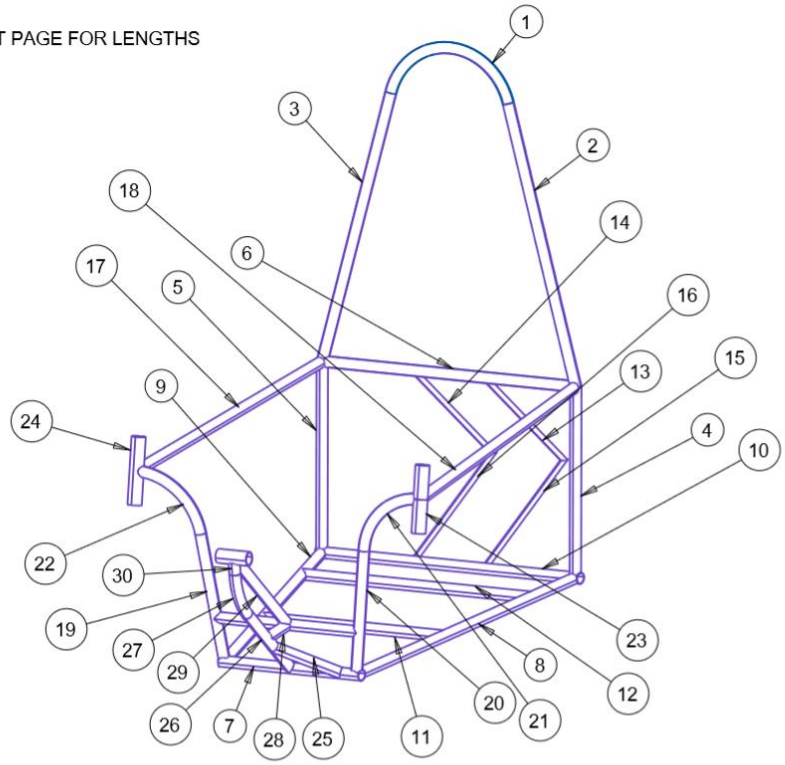
	Parcel Delivery (Kg)	Vehicle efficiently carries a 5.5-kilogram payload	Specified in the 2019 rule book	Minimum required parcel load	Secure load to vehicle and see if it can be carried without significant shifting during delivery	Not Specified
	Weighted Trailer hitch dimensions(inches)	Ground clearance 14 inches. Ring has 2-inch inner diameter. Ring has 1/4-inch gauge.	Specified in the 2019 rule book	Specified in the 2019 rule book	Ensure dimensions match rule book dimensions and can carry 57 kilograms	Not Specified
	Hill Climb (% Grade)	Capable of handling a 15% Grade	Specified in the 2019 rule book	Customer Needs/Competition Requirements. Vehicle is competitive	Drive the vehicle uphill and determine if the climb can be maintained	Not Specified
Body	Aero Device	Device is substantiated in design report. Device is not hazardous.	Specified in the 2019 rule book	Rule book requirements	Ensure device is justifiable and secured properly to the vehicle	Not Specified
	Decals	School name is displayed. 10 cm tall and contrasts with background. Vehicle has panel that is 35 cm wide and 30 cm high to fit provided decals	Specified in the 2019 rule book	Specified in the 2019 rule book	Measure the decal display area with a ruler and ensure decals will fit	Not Specified
	Vehicle Weight (kg)	54 kgs	Customer Needs/Wants. Safety Concerns	Researched average weight of a recumbent bicycle and accounted for the RPS system and restraints	Weigh the HPV with a scale	Good
Powertrain	Average driver input power (Watts)	85 Watts	Vehicle requires power to move	Power required to maintain a velocity of 16 mph with 0 grade	Method to be determined	Not Specified
Ergonomics	Driver entry and exit from vehicle (s)	Driver can enter and exit vehicle in 4 seconds	Customer requirements	Customer requirements	Measure entry and exit time with a stopwatch	Not Specified
Body	Occupant restraint force (kg)	Occupant restraint system supports 88 kgs	Customer requirements	Customer requirements	Method to be determined (Creo Mechanism)	Not Specified

Appendix C: FA17/SP18 Frame Specifications





SEE NEXT PAGE FOR LENGTHS



NOTES:
ALL LENGTHS IN INCHES
ALL BENDS HAVE 6" RADIUS
THE FOLLOWING TUBES CAN BE ONE BENT TUBE: (1,2,3). (20,21). (19,22). (26,27,30).
TUBE SIZES:
1" OD, 0.083" WALL THICKNESS: 1,2,3,4,5,6,17,18,19,20,21,22,25,26,27,28,29,30
1" OD, 0.049" WALL THICKNESS: 7,8,9,10,11,12
1.25" OD, 0.095" WALL THICKNESS:23,24
0.5" OD, *0.083" WALL THICKNESS: 13,14,15,16
*UNSURE OF EXACT WALL THICKNESS ORDERED

TUBE #	LENGTH	CHORD LENGTH	ARC LENGTH
1		11.58	15.65
2	25.48		
3	25.48		
4	17.00		
5	17.00		
6	25.00		
7	13.00		
8	30.59		
9	30.59		
10	25.00		
11	17.80		
12	22.60		
13	17.94		
14	17.94		
15	16.62		

TUBE #	LENGTH	CHORD LENGTH	ARC LENGTH
16	16.62		
17	32.40		
18	32.40		
19	11.73		
20	11.73		
21		7.90	8.63
22		7.90	8.63
23	6.00		
24	6.00		
25	6.40		
26	10.27		
27		4.59	4.71
28	4.00		
29	12.75		
30	1.52		

Appendix D: Brainstorming and Concept Generation

The following tables are a compilation of design ideas generated by the team during a set of two brainstorming sessions outside of the actual concept generation. Concepts were generated by drawing inspiration from theses tables of ideas produced over two consecutive days of thinking. The table 1.D is less organized then table 2.D with a more random assortment of ideas that could potentially be incorporated into a final design. Table 2.D is clearly sectioned into different systems/functions of the final design and grants more specific solutions to different systematic design problems. Systematic solutions and other ideas from brainstorming were then assembled in various ways to form an extensive list of design possibilities.

Table 1.D: *First brainstorming session*

Brainstorming Day One							
Power Transmission and Storage	Steering and Control	Braking	Body and Frame	Wheels	Aerodynamic Devices	Lighting and HUD	Safety and Seating
Multi Gear Transmission	Ackerman's Steering	Disc Brake	Bottom Cover	2 wheels in front, 1 in back	Windshield	radio	Rollercoaster style shoulder harness
Push Pedals	Rack and Pinion	Magnetic Braking	Side Panels	2 wheels in back, 1 in front	Carbon fiber shell (full fairing)	speedometer	3-point seatbelt
Chain	Under seat Steering	Brake pads (2 that hug wheel) Standard Braking	Add second wheel mount to rear	2 in front, 2 in back	spoiler(wings)	headlights/tail lights	2-point shoulder straps
Belt	Handles go directly to both tires on two shafts	Hydraulic Braking	Angle the roll cage	2 wheels (bicycle)	Front fairing that connects to roll bar (sides open)	stereo	Seat with no back (sitting straight up)

Hand Pedals	Handles control single shaft that split to both tires	Foot Brake	Trailer Hitch behind rear wheel	6 wheels, 4 in front 2 in back	plexiglass transparent shield	interior lighting	Laying back seat
Train Cart Up and down motion	Steering wheel	Coaster Brakes	Head light and tail light	6 wheels, 4 in back 2 in front	Side panels only	Tire Pressure Gauge	Lying on stomach
Rowing Machine Motion	bicycle handlebar steering	Hand braking	Pedal Mount in front with adjustable position	Self-sealing tires	canopy	HUD Helmet	Neck rest
Front wheel drive	Two levers (push and pull)	Direct Braking using pedals	Storage Area (Basket)	composite wheels	wheel covers (quarter panels/fenders)	GPS MAP	Arm rests
Rear Wheel Drive	Single Lever	ABS Braking	Hook (for carrying stuff)	Snowmobile style tread	foldable windshield	Blind spot detection device	2 shoulder straps that join and connect with strap between legs
Single Gear Transmission	Rear wheel steering	Use brake heat to heat steering wheel	Cupholder	Not a circular wheel?	Retractable windshield	Fly wheel Fan for cooling rider	
Battery charged by wheel rotation	tilting wheels	Emergency Brake	Mounts for idler gears to route chain	solid wheels	Full tube fairing(transp arent)	Phone Charger using flywheel	
Wind Turbine Energy Storage	shock absorbers on front wheels	lever brakes on steering handles	Seat adjustment mounts	Wheels with round panels		Electrical Fan	
Regenerative Braking	shock absorbers on back wheel		Harness Mounts				
Adjustable pedals	Steer with feet		kickstand (2 wheels)				
parking brake	Hydraulic Suspensions		rear/sideview mirror				
Chain tube	Magnetic Suspension		Flag				
Regenerative flywheel for storing energy when stopping and then accelerating	Steering wheel lock		Cooler Mount				
Use fly wheel to power battery and other electrical components	Disc Brake Lock		Flywheel and alternator mount				

Continuously variable transmission	Grips for handles		if two wheels are used, kickstand with two wheels on either side				
Multiple chains instead of one	Push and pull levers		Rain Protection				
Derailleur for gear transmission			Side Doors				
Tandem bike			Side Step				
			Flat bed				
			lockable glove box				
			umbrella storage				
			Locking mechanism built into chain				
			Horn				
			Passenger seating				
			Sidecar				

Table 2.D*: Second Brainstorming Session*

BRAINSTORMING IDEAS DAY TWO (more systematic approach)						
Systems	Concepts					
Steering (Wheels and Connections)	Two front wheels in current position	Two front wheels in lowered position located on outside of turning shaft rather than underneath (Recumbent Style)	One front wheel that steers with one in back (Bicycle)	One front wheel that steers with two in back	Two rear wheels that steer with one in front (Tricycle)	Two wheels in the back. Two wheels in the front that steer (ATV style)
Steering Configuration for two wheels in front	Tie Rod steering with rack and pinion (Steering wheel or handle bars)	Tie rod steering with direct steer (Handle bars)	Pully cables steer wheels	Hydraulic tie rod steering	Direct Steering from kingpin	
Power Transmission to drivetrain	Foot Pedals on driving wheel	Foot pedals on adjustable mount (in front of rider)	Hand pedals (in front of rider)	Rowing motion	Push and pull motion	
Power Transmission to driven wheel	Chain and gear system	Chain and CVT system	Belt and CVT system	Chain and CVT with flywheel for energy regeneration	Drive shaft to wheel with gearing	Drive Shaft to wheel with no gearing

Restraint Type	Two Straps over shoulders with connection between two vertical straps (4-point harness)	Two straps over shoulders connected between legs (3-point harness)	Two straps over shoulders, one between legs, and tow over the pelvic area (5-point harness)	Strap across body like a car (3-point harness)	Rollercoaster style Shoulder harness	
Suspension	No Suspension	Leaf Springs(Front/Rear)	Coil Overs(Front/Rear)	Upright Fork Suspension(Front/Rear)	High single pivot suspension(Front/Rear)	
Braking System	Disc Brakes	Cable Rim gripping brakes	Hydraulic Brakes	Magnetic Brakes		
Brake Location	Foot Brakes	Brakes on driver input turning mechanism	Brakes in different location			
Rider Position	Very Layed Back (150 deg)	Layed Back casually (120 deg)	Upright position (100 deg)			
Additions	LEDS Powered by capacitor for headlight and taillight	Speedometer	Towing hitch behind rear wheel(s)	Aerodynamics over front and wheels		

Concept Generation

The following is an extensive list of possible HPV solutions imagined by the team during the concept generation process. These concepts were generated using the brainstorming tables of system ideas displayed above combined with additional ideas that were brought up at the time of concept generation. The concepts were then reviewed one by one to assess if they could accomplish the desired functions in a feasible and practical way within the allocated budget and time constraints. Once this list was narrowed down to ten concepts, the concepts were refined and then assessed more closely to see which designs were most ideal to move on to the concept selection process. The number of concepts was narrowed down to three by the end of the concept generation and refinement process.

Note: Many of the concepts, if not all of them, require some extent of frame rework to apply the components proposed in each concept. It is redundant to specify exactly what will be changed about the frame but that will be specified once the possible concepts have been reduced to three. Also, some concepts may have components that are ideal but other components that are not. If there is a case where a concept is ideal but lacks a certain component that another concept has, the two concepts may be combined to extract the best design possibility. Finally, additional (nonstructural) components will not be specified in each concept listed below. These additional components can be added after the design has been chosen without affecting the performance of the vehicle.

Each concept was reviewed individually by each teammate and voted “yes” or “no” upon. Once the individual review was over the team went through the concepts once again and made a final decision on what the team thought was good or bad about each concept. Two “no’s” would cause a concept to be thrown away. Three “no’s” would be reviewed again if there were less than twelve concepts that received four “yes’s” (Concepts with unanimous yes decisions are printed in green text). Finally, the team selected twelve of the concepts to move on to the next selection process which compared the most ideal concepts more closely.

1. One front steering wheel with two chain and gear powered rear wheels. Power transmission will come from a push and pull motion and steering will come from a tie rod mechanism. Brakes will be applied to the rim of the wheels like regular rim brakes for a bike. Will utilize a much-laid back position and a 3-point harness with 2 straps over the shoulder. No suspension.

   Team Votes:
   Tyler: No Tristan: No Kyler: No Jacob: No

Decision: Having a front wheel that steers would be very unstable. Push and pull powered vehicle would be inefficient compared to pedals.

2. Using the current wheel position of 2 in front and 1 in the rear to have a direct steer mechanism going through the kingpins of the front wheels. This will have an adjustable mount for foot pedals on the front with a chain and gear system reaching the rear wheel to move the bike. Use a high single pivot suspension system in the front two wheels. Utilize front tire rim brakes. Casually laid-back position.

   Team Votes:
   Tyler: No Tristan: Yes Kyler: Yes Jacob: Yes

   Decision: This is a promising concept but not as specific as some of the other designs were.

3. Use two front and one rear wheel like current design but lower position and widen stance of the front tires. Use a tie rod mechanism to provide steering for the front tires, with wide grip handle bars. Have an adjustable foot pedals at front of the bike using a chain and CVT system linked to the rear wheel. No suspension implemented. Have disc brakes on the front tires and have a casual laid-back position.

   Team Votes:
   Tyler: Yes Tristan: Yes Kyler: Yes Jacob: Yes

   Decision: This concept will move onto the next phase.

4. Use two front and one rear wheel like current design but lower position and widen stance of the front tires. Use a pulley cable steering mechanism for front two tires. Have an adjustable foot pedals at front of the bike using a chain and CVT system linked to the rear wheel. Use coil overs on the front tires for suspension. Have disc brakes on the front tires. Use a casual laid-back position.

   Team Votes:
   Tyler: No Tristan: No Kyler: No Jacob: No

   Decision: Pulley cable steering would be inefficient and difficult to produce.

5. Use two front and one rear wheel like current design but lower position and widen stance of the front tires. Have hydraulic tie rod steering to the front tires. Use a rowing motion to provide power to rear wheel through a belt and CVT system. No suspension. Have disc brakes on front tires. Use a casual laid-back position.

Team Votes:

Tyler: No Tristan: No Kyler: No Jacob: No

Decision: Rowing motion is not an ideal form of power transmission.

6. Have two rear wheels that steer with one wheel in the front. Will have a tie rod mechanism using push and pull motion to turn front wheel. Have foot pedals on adjustable mount in front. Use a belt and CVT system to power rear wheels. Use hydraulic brakes on rear wheels. Have casual laid back position.

   Team Votes:

   Tyler: No Tristan: Yeah Kyler: Yes Jacob: Yes

   Decision: The team will be moving forward with other concepts. Combo of belt and CVT may be costly.

7. Have one wheel in front and two in rear. Adjustable foot pedal driving the front wheel with a chain and gear system. Use a tie rod with rack and pinion mechanism to steer rear wheels. Have a 3-point harness and disc brakes on front tire. Use a casual laid-back position.

   Team Votes:

   Tyler: No Tristan: yeah Kyler: Yes Jacob: Yes

   Decision: The team will be moving forward with other concepts. This concept was not very specific.

8. Use current frame but obtain two upright fork suspension units for two front tires. Use current mountain bike rear wheel. Use a tie rod with rack and pinion steering mechanism and a chain and gear system with an adjustable foot pedal. Have disc brakes on front tires. Use a 3-point harness. Use a casual laid-back position.

   Team Votes:

   Tyler: No Tristan: yeah Kyler: Yes Jacob: Yes

   Decision: The team will be moving forward with other design concepts.

9. Current frame setup with two front tires and one rear wheel with a tie rod steering mechanism and rowing motion application. Rowing motion applied through belt drive to

rear wheels. Have a 3-point harness, and no suspension. Use regular rim brakes on front tires. Have a casual laid-back position.

Team Votes:

Tyler: No Tristan: no Kyler: No Jacob: No

Decision: Rowing motion is not an ideal form of power transmission.

10. Have one wheel in front and one wheel in the rear. Use a direct steering mechanism at the front wheel, also foot pedals on an adjustable mount going to a chain and gear system to rear wheel. Have a 3-point harness, and hydraulic brakes at both front and rear wheels. Keep a very laid-back position

    Team Votes:

    Tyler: Yes Tristan: yeah Kyler: No Jacob: No

    Decision: This was not one of the more valued two wheeled designs. Hydraulic braking may be over complex.

11. Have one wheel in front and one wheel in the rear. Use a pulley cable steering mechanism for front tire and have foot pedals on an adjustable mount to provide power through a chain and gear system. Have a 3-point harness. Use magnetic brakes on front tire and regular rim brakes on rear tire. Have a very laid-back position.

    Team Votes:

    Tyler: No Tristan: no Kyler: No Jacob: No

    Decision: Magnetic braking would require significant energy storage. Magnetic braking would cause significant weight increase as well. Pulley cable steering system would be inefficient and impractical.

12. Use current frame with two wheels in front and one in rear. Use a hydraulic tie rod steering mechanism with hand pedals transmitting power through a chain and gear system. Use a 3-point harness. Have a high single pivot suspension at rear wheel. Have disc brakes at front tires powered from feet. Have an upright position.

    Team Votes:

    Tyler: No Tristan: yes Kyler: Yes Jacob: Yes

    Decision: The team will be moving forward with other design concepts.

13. Use one wheel in front to directly steer and have 2 wheels in rear powered by foot pedals with chain and gear system. Have an upright fork suspension on front tire and disc brakes on rear tires powered from the direct steering mechanism. Have an upright position and a 3-point harness.

Team Votes:

Tyler: No	Tristan: yes	Kyler: Yes	Jacob: Yes

Decision: The team will be moving forward with other design concepts.

14. Have one wheel in front and one in rear. Have direct steering on front wheel with disc brakes on both wheels powered from the direct steering mechanism. Have a foot pedal with a chain and gear system to the rear wheel. Have a 3-point harness and a coil over on the rear wheel for suspension. Have an upright position but more leaned forward like position on a sports motorcycle.

Team Votes:

Tyler: No	Tristan: yes	Kyler: Yes	Jacob: No

Decision: Would require considerable frame rework.

15. Have two wheels in front and 2 wheels in rear with a tie rod/rack and pinion steering mechanism. Have foot pedals power a drive shaft to wheels with gearing. Have a 3-point harness and coil overs on all 4 wheels. Have disc brakes on all 4 wheels that can be applied from the steering mechanism. Have an upright position.

Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

Decision: Very complicated and unnecessary. Four-wheel design adds unnecessary weight and adds more friction to system.

16. Have one wheel on front and one in the rear, with a full fairing over the entire body. Use a hydraulic tie rod steering mechanism for the front wheel while using and adjustable foot pedal to transfer power through a belt system to rear wheel. Have a 3-point harness and have hydraulic brakes on both tires. Use a very laid-back position.

Team Votes:

Tyler: No	Tristan: yes	Kyler: Yes	Jacob: No

Decision: Hydraulic steering system and full fairing would be very costly and complex. Two-wheel designs are difficult to stabilize due to weight.

17. Have one wheel on front and two in the rear, with a full fairing over the entire body. Use a tie rod steering mechanism with rack and pinion. Have foot pedals powering a drive shaft to rear wheels. Have a rollercoaster style harness, and coil over springs on the rear wheels for suspension. Have a casual laid-back position.

    Team Votes:

    Tyler: No   Tristan: yes   Kyler: Yes   Jacob: Yes

    Decision: The team will be moving forward with other design concepts.

18. Have two wheels on front and one in the rear, with a full fairing over the entire body. Use tie rod steering for front wheels. Have an adjustable foot pedal to power a chain and gear system to rear wheel. Have a 3-point harness. Have disc brakes on the wheels and applied from the steering mechanism. Use a very laid-back position.

    Team Votes:

    Tyler: No   Tristan: yes   Kyler: Yes   Jacob: Yes

    Decision: The team will be moving forward with other design concepts

19. Have two wheels on front and one in the rear, with a partial fairing going from the front of the vehicle over the top of the body. Use a hydraulic tie rod steering mechanism and a push and pull motion to transmit power through a chain and CVT system to rear wheel. Have a 4-point harness. Use coil over springs on front wheels and hydraulic brakes on the wheels. Have a casual laid-back position.

    Team Votes:

    Tyler: No   Tristan: yes   Kyler: Yes   Jacob: No

    Decision: Hydraulic steering and CVT transmission is over complicated. Push/pull motion would be impractical for power input.

20. Have one wheel on front and two in the rear, with a partial fairing going from the front of the vehicle over the top of the body. Use a tie rod steering mechanism for rear wheels and have foot pedals on driving front wheel. Have a 4-point harness. Have disc brakes on rear wheels powered through the steering mechanism. Have a casually laid-back position.

Team Votes:

Tyler: No Tristan: yes Kyler: Yes Jacob: Yes

Decision: The team will be moving forward with other design concepts

21. Have two wheels on front and two in the rear, with a partial fairing going from the front of the vehicle over the top of the body. Use tie rod steering with handle bars to front wheels. Have an adjustable foot pedal powering a drive shaft to rear wheels. Have a 4-point harness. Use cable rim brakes on all four wheels and have a casual laid-back position.

   Team Votes:

   Tyler: No Tristan: yes Kyler: Yes Jacob: No

   Decision: Drive shaft would be difficult to incorporate in the design. Four-wheel design adds excess weight to vehicle and adds friction to system.

22. Have two wheels on front and two in the rear, with a full fairing over the body. Using a pulley cable steering mechanism on rear wheels. Have foot pedals on front driving wheels. Use a 3-point harness and have disc brakes on all 4 wheels. Have a very laid-back position.

   Team Votes:

   Tyler: No Tristan: No Kyler: Yes Jacob: No

   Decision: Four-wheel design adds excess weight to vehicle and adds friction to system.

23. Have one wheel on front and one in the rear, with a full fairing over the entire body. Use a tie rod steering for rear wheel and have foot pedals on front driving wheel. Have a 3-point harness and have an upright fork suspension on front wheel. Use disc brakes on the wheels and have a casual laid-back position.

   Team Votes:

   Tyler: No Tristan: yes Kyler: Yes Jacob: No

   Decision: Two-wheel designs are more difficult to stabilize over three or four wheel designs. Full fairing provides unneeded weight to vehicle.

24. Use two fronts and one rear wheel like current design but lower position and widen stance of the front tires with a partial fairing going from the front of the vehicle over the top of the body. Have a tie rod mechanism to front tires, adjustable foot pedals to power rear

wheel with chain and gear system. Have a 3-point harness and disc brakes on front wheels. Have a casual laid-back position.

Team Votes:

Tyler: Yes　　Tristan: yes　　Kyler: Yes　　Jacob: Yes

Decision: The team has selected this concept to move on to the next selection procedure.

25. Use two fronts and one rear wheel like current design but lower position and widen stance of the front tires with a partial fairing going from the front of the vehicle over the top of the body. Have a hydraulic tie rod steering mechanism with adjustable pedals to power a belt and CVT system to rear wheel. Have a 3-point harness and hydraulic brakes on front wheels. Have a very laid-back position.

Team Votes:

Tyler: No　　Tristan: yes　　Kyler: Yes　　Jacob: Yes

Decision: The team has decided to proceed with other concepts.

26. Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Team Votes:

Tyler: Yes　　Tristan: yes　　Kyler: Yes　　Jacob: Yes

Decision: The team has selected this concept to move on to the next selection procedure.

27. Two wheels in front, recumbent style. Pulley/cable system is used to turn wheels using wide grip handle bars. Foot pedals on an adjustable mount deliver power to drivetrain. Drivetrain is a chain and gear system that incorporates a flywheel to store energy for a boost when getting back up to speed. 3-point harness is used to restrain occupant. Vehicle has no suspension. Standard rim grip bike brakes slow the vehicle which is controlled by a push/pull lever. Rider is upright at 100 deg.

Team Votes:
Tyler: No Tristan: no Kyler: Yes Jacob: No

Decision: Pulley/cable system is overly complicated and inefficient at turning the vehicle. Flywheels are difficult to implement, provide minimal power assistance to driver, and add excess weight to the system. No suspension can lead to wear to frame.

28. Current wheels position. Tie rod steering with direct steer incorporated. Hand pedals in front of driver deliver power to drivetrain. The drivetrain is a belt driven with one gear ratio. Driver uses feet to steer front two tires. 4-point harness is used to restrain driver. Suspension includes leaf springs in the rear of the vehicle. Disk brakes are used to slow the vehicle. Disk brakes connected to hydraulic line that driver must use with one free hand (must stop using one hand to power vehicle to begin braking). Driver is very laid back at 150 degrees.

Team Votes:
Tyler: No Tristan: yes Kyler: No Jacob: No

Decision: Hand pedals are an inefficient means of power input. Feet steering is impractical. The drivetrain system would not provide the added input torque to wheel if additional gears were used to translate the power.

29. Current wheels position. Steering is direct (over kingpin) using handlebars. Foot pedals are used to power drivetrain with a drive shaft going to the rear wheel (chainless bike). Driver restrained by roller coaster style shoulder harness. Suspension includes upright fork suspension in the front and rear. Disk brakes are used to slow the vehicle controlled by cable grips (bicycle style). Rider orientation is upright at 100 deg.

Team Votes:
Tyler: No Tristan: no Kyler: No Jacob: No

Decision: Roller coaster style harness adds excess weight to design. Upright seated position is not ideal for maximum power input from the driver. Using a drive shaft to power the rear wheel would be very difficult to implement.

30. Current wheels position. Tie rod steering with push/pull lever steering. Foot pedals on an adjustable mount power the drivetrain. The drivetrain is a chain and CVT system. 5-point safety harness restraint system used for driver. Vehicle has coil over suspension in front and rear. Hydraulic brakes are used to decelerate. Push/pull lever steering has a grip brake so one hand is free at all times. Driver oriented casually at 120 deg.

Team Votes:

Tyler: No   Tristan: yes   Kyler: Yes   Jacob: No

Decision: A cvt system would be difficult to implement in a design for our vehicle

31. One wheel in front, two wheels in back. Direct steer is incorporated. Tire turning mechanism configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns one of the back-driving wheels. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Team Votes

Tyler: No   Tristan: no   Kyler: No   Jacob: No

Decision: a steering wheel will create an issue with spacing for the occupant into the vehicle.

32. One wheel in front, two wheels in back. Pulley/cable system is used to turn wheel using wide grip handle bars. Foot pedals on an adjustable mount deliver power to drivetrain. Drivetrain is a chain and gear system that incorporates a flywheel to store energy for a boost when getting back up to speed. 3-point harness is used to restrain occupant. Vehicle has no suspension. Standard rim grip bike brakes slow the vehicle which is controlled by a push/pull lever. Rider is upright at 100 deg.

Team Votes:

Tyler: No	Tristan: no	Kyler: Yes	Jacob: No

Decision: Using a cable system isn't practical for a steering mechanism. Slip could affect the cables grip and our steering in general.

33. One wheel in front, two wheels in back. Direct steer incorporated to front wheel. Hand pedals in front of driver deliver power to drivetrain. The drivetrain is a belt driven with one gear ratio. Driver uses feet to steer front tire. 4-point harness is used to restrain driver. Suspension includes leaf springs in the rear of the vehicle. Disk brakes are used to slow the vehicle. Disk brakes connected to hydraulic line that driver must use with one free hand (must stop using one hand to power vehicle to begin braking). Driver is very laid back at 150 degrees.

Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

Decision: The hand pedal system is another impractical system for our design. The force generated from feet is far stronger than from the hand.

34. One wheel in front, two wheels in back. Steering is direct (over kingpin) using handlebars. Foot pedals are used to power drivetrain with a drive shaft going to the rear wheel (chainless bike). Driver restrained by roller coaster style shoulder harness. Suspension includes upright fork suspension in the front and rear. Disk brakes are used to slow the vehicle controlled by cable grips (bicycle style). Rider orientation is upright at 100 deg.

Team Votes:

Tyler: Yes	Tristan: yes	Kyler: No	Jacob: No

Decision: A 4-wheel design will have a considerable weight to move across the road. A drive shaft is also impractical for a vehicle of this nature.

35. One wheel in front, two wheels in back. Push/pull lever steering. Foot pedals on an adjustable mount power the drivetrain. The drivetrain is a chain and CVT system. 5-point safety harness restraint system used for driver. Vehicle has coil over suspension in front and rear. Hydraulic brakes are used to decelerate. Push/pull lever steering has a grip brake so one hand is free at all times. Driver oriented casually at 120 deg

Team Votes:
Tyler: No Tristan: yes Kyler: Yes Jacob: Yes

Decision:

36. Two wheels in front, two wheels in back. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Team Votes:
Tyler: No Tristan: yes Kyler: Yes Jacob: No

Decision: 4 wheels unnecessary

37. Two wheels in front, two wheels in back. Pulley/cable system is used to turn wheels using wide grip handle bars. Foot pedals on an adjustable mount deliver power to drivetrain. Drivetrain is a chain and gear system that incorporates a flywheel to store energy for a boost when getting back up to speed. 3-point harness is used to restrain occupant. Vehicle has no suspension. Standard rim grip bike brakes slow the vehicle which is controlled by a push/pull lever. Rider is upright at 100 deg.

Team Votes:
Tyler: No Tristan: no Kyler: Yes Jacob: No

Decision: 4 wheels unnecessary, pulley/cable design not efficient.

38. Two wheels in front, two wheels in back. Tie rod steering with direct steer incorporated. Hand pedals in front of driver deliver power to drivetrain. The drivetrain is a belt driven with one gear ratio. Driver uses feet to steer front two tires. 4-point harness is used to restrain driver. Suspension includes leaf springs in the rear of the vehicle. Disk brakes are used to slow the vehicle. Disk brakes connected to hydraulic line that driver must use with one free hand (must stop using one hand to power vehicle to begin braking). Driver is very laid back at 150 degrees.

Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

Decision: 4 wheels unnecessary

39. Two wheels in front, two wheels in back. Steering is direct (over kingpin) using handlebars. Foot pedals are used to power drivetrain with a drive shaft going to the rear wheel (chainless bike). Driver restrained by roller coaster style shoulder harness. Suspension includes upright fork suspension in the front and rear. Disk brakes are used to slow the vehicle controlled by cable grips (bicycle style). Rider orientation is upright at 100 deg.

Team Votes:

Tyler: No	Tristan: yes	Kyler: No	Jacob: No

Decision: 4 wheels unnecessary.

40. Two wheels in front, two wheels in back. Tie rod steering with push/pull lever steering. Foot pedals on an adjustable mount power the drivetrain. The drivetrain is a chain and cvt system. 5-point safety harness restraint system used for driver. Vehicle has coil over suspension in front and rear. Hydraulic brakes are used to decelerate. Push/pull lever steering has a grip brake so one hand is free at all times. Driver oriented casually at 120 deg.

Team Votes:

Tyler: No Tristan: yes Kyler: Yes Jacob: No

Decision: 4 wheels unnecessary.

41. Current wheel's position. Rack and pinion used to steer. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Team Votes:

Tyler: No Tristan: yes Kyler: Yes Jacob: Yes

Decision:

42. Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a wide grip handle bar. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Team Votes:

Tyler: Yes Tristan: yes Kyler: Yes Jacob: Yes

Decision: The team has selected this concept to move on to the next selection procedure.

43. Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 150 deg.

Team Votes:

Tyler: Yes	Tristan: yes	Kyler: Yes	Jacob: Yes

Decision: The team has selected this concept to move on to the next selection procedure

44. Current wheel's position. Tie rod steering. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system with a CVT that turns the back-driving wheel. A 5-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Team Votes:

Tyler: No	Tristan: yes	Kyler: Yes	Jacob: Yes

Decision: The team has selected this concept to move on to the next selection procedure.

45. Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 3-point safety harness restrains the occupant. The vehicle has high single pivot suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is upright at 100 deg.

Team Votes:

Tyler: Yes	Tristan: no	Kyler: Yes	Jacob: Yes

Decision: Other designs may have been similar or better and are being moved forward in the design selection.

46. One wheel in front, one wheel in back. Direct steering with a handle bar will be used. Foot pedals are mounted, using chain system to power back wheel. 4-point safety harness restrains occupant. Vehicle has upright fork suspension in front and rear. Handlebars have bike brake grips. Driver oriented at 120 deg.

Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

Decision: A 2-wheel design will require major adjustments to the frame.

47. One wheel in front, one wheel in back. Direct steering with a handle bar will be used. Foot pedals are mounted on front driving wheel, delivering power directly to front tire. 5-point safety harness restrains occupant. Vehicle has coil over suspension in front and rear. Handlebars have bike brake grips. Driver oriented at 120 deg.

Team Votes:

Tyler: Yes	Tristan: no	Kyler: No	Jacob: No

Decision: 2-wheel design not practical.

48. One wheel in front, one wheel in back. Direct steering with a steering wheel will be used. Foot pedals are mounted on front driving wheel, delivering power directly to front tire. 3-point safety harness restrains occupant. Vehicle has upright fork suspension in front and leaf spring suspension in rear. Steering wheel has bike brake grips. Driver oriented at 100 deg.

Team Votes:

Tyler: No	Tristan: No	Kyler: No	Jacob: No

Decision: 2-wheel design not practical.

49. One wheel in front, one wheel in back. Direct steering with a handle bar will be used. Foot pedals are mounted, chain system with CVT and flywheel used for drivetrain. 4-point safety harness restrains occupant. Vehicle has upright fork suspension in front and rear. Handlebars have bike brake grips on handlebar. Driver oriented at 120 deg.

Team Votes:

Tyler: Yes	Tristan: No	Kyler: No	Jacob: No

Decision: Two-wheel design is unstable compared to other configurations.

50. One wheel in front, one wheel in back. Driver is oriented face down. Push/pull steering is used to turn linkages to turn front tire. Belt drive system with one gear ratio powers drivetrain with foot pedals located in rear. Vehicle has coil over suspension in front and rear. Brake grips located on handlebar.

Team Votes:

Tyler: No	Tristan: Yes	Kyler: No	Jacob: No

Decision: Two-wheel design is unstable compared to other configurations. Push/pull steering system would prove to be difficult and inefficient. One gear ratio belt drive system would not provide as much torque to wheels than if gears were used to translate power more efficiently.

51. Steering configuration will be current two wheels in front position design using tie rod steering with direct steer. Power will be transmitted to the bike via foot pedals on driving wheel using chain and gear system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. Front and rear coil over suspensions with disc brakes activated by the pedals will be used. The rider will be laid back at 120o. A speedometer will be attached.

Team Votes:

Tyler: Yes	Tristan: No	Kyler: Yes	Jacob: Yes

Decision: Other designs may have been similar or better and are being moved forward in the design selection.

52. Steering configuration will be one front wheel that steers with two in the back using hydraulic tie rod steering. Power will be transmitted to the bike via foot pedals on driving wheel using a belt and CVT system. Safety restrains will be similar to that in a car. Suspension will be front and rear upright fork suspension using disc brakes activated by mechanism on turning configuration. The rider will be laid back at 120o. A speedometer will be attached.

Team Votes:
Tyler: No Tristan: No Kyler: No Jacob: No

Decision: Belt and CVT systems are complicated.

53. Steering configuration will be current two wheels in front position design using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using chain and gear system. Safety restraints will be two straps over shoulder connected between legs. No suspension system will be used. Cable rimmed gripping brakes will inputted. The rider will be laid back at 150o. A towing hitch will be attached behind rear wheel.

Team Votes:
Tyler: No Tristan: No Kyler: Yes Jacob: Yes

Decision: While meeting most criteria, better configurations are available. Suspension systems help improve the quality of the ride for the driver and help with longevity of the design.

54. Steering configuration will be one front wheel that steers with two in the back using direct kingpin steering. Power will be transmitted to the bike via foot pedals on adjustable mount using chain and gear system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. Front and rear coil over suspension with cable

rimmed gripping brakes will be inputted by the steering mechanism. The rider will be laid back at 150o. A towing hitch will be attached behind rear wheel.

Team Votes:
Tyler: No Tristan: Yes Kyler: Yes Jacob: Yes

Decision: Other designs may have been similar or better and are being moved forward in the design selection.

55. Steering configuration will be current two wheels in front position design using tie rod steering with direct steer. Power will be transmitted to the bike via hand pedals using a chain and gear system. Safety restraints will be a rollercoaster style shoulder harness. No suspension will be used. Cable rimmed brakes will be inputted by the steering mechanism. The rider will be laid back at 120o. Aerodynamic coverings will be pace over front and rear wheels.

    Team Votes:
    Tyler: Yes Tristan: No Kyler: No Jacob: No

    Decision: Hand pedals are an inefficient means for power input towards the vehicle. Rollercoaster style harness would provide excessive weight.

56. Steering configuration will be two wheels in the back and two wheels in the front that steer using direct steering from kingpin. Power will be transmitted to the bike via foot pedals using a chain and CVT system with a flywheel for energy regeneration. Safety restraints will be similar to that in a car. Suspension will be front and rear high single pivot suspension. Disc brakes activated by the pedals will be used. The rider will be at 100o. A speedometer will be used.

    Team Votes:
    Tyler: No Tristan: No Kyler: Yes Jacob: No

    Decision: Four-wheel designs are significantly heavier than 2 or 3 wheel design. Four-wheel designs also provide additional friction to system. Use of a chain and CVT system with a flywheel would ultimately prove to be overly complicated and expensive.

57. Steering configuration will be one front wheel that steers with one in the back with direct steering from kingpin axis. Power will be transmitted to the bike via foot pedals on driving wheel using chain and gear system. Safety restrains will be two straps over shoulder connected between legs. No suspension will be used. Cable rimmed gripping brakes will inputted. The rider will be laid back at 100o. A towing hitch will be attached behind rear wheel.

    Team Votes:
    Tyler: Yes Tristan: No Kyler: Yes Jacob: Yes

    Decision: Other designs may have been similar or better and are being moved forward in the design selection.

58. Steering configuration will be current two wheels in front position design using tie rod steering with direct steer. Power will be transmitted to the bike via foot pedals on adjustable mount using a belt and CVT system. Safety restraints will be a strap across the body like a car. Front and rear leaf spring suspension will be used. Disc brakes activated by the foot pedals will be used. The rider will be laid back at 150o. A towing hitch will be attached.

    Team Votes:
    Tyler: Yes Tristan: Yes Kyler: Yes Jacob: Yes

    Decision: The team has selected this concept to move on to the next selection procedure.

59. Steering configuration will be two rear wheels that steer with one in front using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using a chain and gear system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. No suspension will be used. Disc brakes activated by the foot pedals will be used. The rider will be laid back at 120o. A speedometer will be used.

    Team Votes:
    Tyler: No Tristan: Yes Kyler: Yes Jacob: Yes

Decision: Other designs may have been similar or better and are being moved forward in the design selection.

60. Steering configuration will be two rear wheels that steer with one in front using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using a chain and gear system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. No suspension will be used. Disc brakes activated by the foot pedals will be used. The rider will lay back at 100o. A towing hitch will be used.

    Team Votes:
    Tyler: No Tristan: No Kyler: No Jacob: No

    Decision: It was determined that single rear wheel designs were preferred over dual rear wheel designs.

61. Steering configuration will be two rear wheels that steer, with one in front using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using a chain and gear system. Safety restraints will over one shoulder similar to a car. No suspension will be used. Disc brakes activated by the foot pedals will be used. The rider will lay back at 150o. A towing hitch will be used.

    Team Votes:
    Tyler: Yes Tristan: Yes Kyler: No Jacob: No

    Decision: It was determined that single rear wheel designs were preferred over dual rear wheel designs.

62. Steering configuration will be two rear wheels that steer with one in front using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using a chain and CVT system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. No suspension will be used. Disc brakes activated by the foot pedals will be used. The rider will lay back at 150o. A speedometer will be used.

    Team Votes:
    Tyler: No Tristan: No Kyler: No Jacob: No

Decision: It was determined that single rear wheel designs were preferred over dual rear wheel designs. Chain and CVT system would be difficult and inefficient to implement.

63. Steering configuration will be two rear wheels that steer with one in front using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using a belt and CVT system. Safety restraints will over one shoulder like a car. Front and rear leaf spring suspension will be used. Disc brakes activated by the foot pedals will be used. The rider will lay back at 100o. A towing hitch will be used.

Team Votes:

Tyler: No   Tristan: No   Kyler: No   Jacob: Yes

Decision: It was determined that single rear wheel designs were preferred over dual rear wheel designs. Belt and CVT system would be difficult and inefficient to implement.

64. Steering configuration will be one front wheel that steers with two in the back using direct kingpin steering. Power will be transmitted to the bike via foot pedals on adjustable mount using chain and gear system. Safety restraints will one strap over one shoulder like that in a car. Front and rear coil over suspension with cable rimmed gripping brakes will be inputted by the steering mechanism. The rider will be laid back at 120o. A speedometer will be used.

Team Votes:

Tyler: No   Tristan: No   Kyler: Yes   Jacob: Yes

Decision: It was determined that single rear wheel designs were preferred over dual rear wheel designs.

65. Steering configuration will be one front wheel that steers with two in the back using direct kingpin steering. Power will be transmitted to the bike via foot pedals on adjustable mount using chain and gear system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. Front and rear coil over suspension with cable rimmed gripping brakes will be inputted by the steering mechanism. The rider will be laid back at 100o. LEDs powered by capacitor for headlights and taillights will be used.

Team Votes:

Tyler: No	Tristan: No	Kyler: Yes	Jacob: Yes

Decision: It was determined that single rear wheel designs were preferred over dual rear wheel designs.

66. Steering configuration will be one front wheel that steers with two in the back using direct kingpin steering. Power will be transmitted to the bike via hand pedals using a chain and gear system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. Front and rear coil over suspension with cable rimmed gripping brakes will be inputted by the steering mechanism. The rider will be laid back at 100o. A towing hitch will be attached behind rear wheel.

    Team Votes:

Tyler: No	Tristan: No	Kyler: Yes	Jacob: No

    Decision: Hand pedals are impractical means of power input to the vehicle.

67. Steering configuration will be two wheels in the back and two wheels in the front that steer using direct steering from kingpin. Power will be transmitted to the bike via foot pedals using a chain and belt system. Safety restraints will be two straps over the shoulders with connection between two vertical straps. Suspension will be front and rear high single pivot suspension. Disc brakes activated by the pedals will be used. The rider will be at 120o. A speedometer will be used.

    Team Votes:

Tyler: No	Tristan: No	Kyler: Yes	Jacob: No

    Decision: Four-wheel designs are significantly heavier than 2 or 3 wheel design. Four-wheel designs also provide additional friction to system.

68. Steering configuration will be two wheels in the back and two wheels in the front that steer using direct steering from kingpin. Power will be transmitted to the bike via hand pedals. Safety restraints will be like that in a car. Suspension will be front and rear high single

pivot suspension. Disc brakes activated by the pedals will be used. The rider will be at 100o. Aerodynamic coverings will be put over front and rear wheels.

Team Votes:

Tyler: Yes	Tristan: No	Kyler: Yes	Jacob: No

Decision: Hand pedals are not a practical means of power input to the vehicle.

69. Steering configuration will be two wheels in the back and two wheels in the front that steer using direct steering from kingpin. Power will be transmitted to the bike via foot pedals using a chain and CVT system with a flywheel for energy regeneration. Safety restraints will be like that in a car. No suspension will be used. Disc brakes activated by the pedals will be used. The rider will be at 150o. A speedometer will be used.

Team Votes:

Tyler: No	Tristan: no	Kyler: Yes	Jacob: No

Decision: Chain and CVT system with a flywheel was determined to be impractical for the design.

70. Steering configuration will be two wheels in the back and two wheels in the front that steer using direct steering from kingpin. Power will be transmitted to the bike via foot pedals using a chain and CVT system with a flywheel for energy regeneration. Safety restraints will be two straps over shoulders, one between legs, and two over the pelvic area. Suspension will be front and rear upright fork suspension. Disc brakes activated by the pedals will be used. The rider will be at 100o. A speedometer will be used.

Team Votes:

Tyler: No	Tristan: No	Kyler: Yes	Jacob: No

Decision: Four-wheel designs are significantly heavier than 2 or 3-wheel design. Four-wheel designs also provide additional friction to system. Use of a chain and CVT system with a flywheel would ultimately prove to be overly complicated and expensive.

71. Steering configuration will be two wheels in the back and two wheels in the front that steer using direct steering from kingpin. Power will be transmitted to the bike via foot pedals using a chain and CVT system with a flywheel for energy regeneration. Safety restraints will be a rollercoaster style harness. Suspension will be front and rear high single pivot suspension. Disc brakes activated by the pedals will be used. The rider will be at 120o. A towing hitch behind the rear wheel will be implemented.

    Team Votes:

    Tyler: No   Tristan: No   Kyler: No   Jacob: No

    Decision: Four-wheel designs are significantly heavier than 2 or 3 wheel design. Four-wheel designs also provide additional friction to system. Use of a chain and CVT system with a flywheel would ultimately prove to be overly complicated and expensive.

72. Steering configuration will be current two wheels in front position design using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using chain and belt system. Safety restraints will be similar to that in a car. No suspension system will be used. Cable rimmed gripping brakes will inputted. The rider will be laid back at 100o. A speedometer will be used.

    Team Votes:

    Tyler: Yes   Tristan: No   Kyler: Yes   Jacob: Yes

    Decision: The team has decided to move on with other concepts.

73. Steering configuration will be current two wheels in front position design using tie rod steering with rack and pinion. Power will be transmitted to the bike via hand pedals using chain and gear system. Safety restraints will be two straps over shoulder connected between legs. No suspension system will be used. Disc brakes activated by pedals will be implemented. The rider will be laid back at 150o. A towing hitch will be attached behind rear wheel.

    Team Votes:

    Tyler: No   Tristan: no   Kyler: No   Jacob: No

    Decision: Hand pedals are impractical for this design. Low efficiency.

74. Steering configuration will be current two wheels in front position design using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using drive shaft to wheel with gearing. Safety restraints will be strap across body like a car. No suspension system will be used. Hydraulic brakes will be utilized. The rider will be laid back at 120o. A towing hitch will be attached behind rear wheel.

    Team Votes:
    Tyler: No Tristan: no Kyler: No Jacob: No

    Decision: Combination of drive shaft, lack of suspension and hydraulic braking make for an over complicated design.

75. Steering configuration will be current two wheels in front position design using tie rod steering with rack and pinion. Power will be transmitted to the bike via foot pedals on driving wheel using chain and gear system. Safety restraints will be two straps over shoulder connected between legs. No suspension system will be used. Magnetic brakes will be used. The rider will be laid back at 100o. Aerodynamic coverings will be placed over front and rear wheel.

    Team Votes:
    Tyler: No Tristan: no Kyler: No Jacob: No

    Decision: Magnetic brakes require a significant power source. Magnetic brakes would also provide excess weight to design.

76. One wheel in the front and one wheel in the back of the vehicle. The rear wheel is driven through a drivetrain system consisting of multiple gear ratios and chain. The chain is run under the roll cage. Roll bar height is reduced significantly. Front of frame is reworked to free legs more. The chain is driven by pedals located far ahead of the rider who is in a laid-back position. The front wheel is steered with a steering wheel and the driver is restrained with a 3-point seatbelt that runs over shoulders and between legs. A kickstand is used to hold the vehicle upright at low speeds and standstill. A front fairing is used over pedals and front wheel to direct air around the rider. Cable brakes on front wheel.

    Team Votes:

Tyler: No Tristan: yes Kyler: Yes Jacob: No

Decision: Two-wheel design is unstable compared to other configurations.

77. One wheel in the front and one wheel in the back of the vehicle. The rear wheel is driven through a drivetrain system consisting of multiple gear ratios and chain. The chain is run under the roll cage. Roll bar height is reduced significantly. Front of frame is reworked to free legs more. The chain is driven by pedals located far ahead of the rider who is in a laid-back position. The front wheel is steered with a steering wheel and the driver is restrained with a 5-point seatbelt that runs over shoulders and between legs. A kickstand is used to hold the vehicle upright at low speeds and standstill. A front fairing that extends from the front pedals up and over the rider connecting at the roll bar is used. Sides of the vehicle are open for entry and exit. Cable brakes on front wheel.

Team Votes:
Tyler: Yes Tristan: Yes Kyler: No Jacob: No

Decision: Two-wheel design is unstable compared to other configurations. Front fairing provides excess weight to design.

78. One wheel in the front and one wheel in the back of the vehicle. The rear wheel is driven through a drivetrain system consisting of multiple gear ratios and chain. The chain is run under the roll cage. Roll bar height is reduced significantly. Front of frame is reworked to free legs more. The chain is driven by pedals located far ahead of the rider who is in a laid-back position. The front wheel is steered with handlebars and the driver is restrained with a 5-point seat belt that runs over shoulders and between legs. A kickstand is used to hold the vehicle upright at low speeds and standstill. A front fairing that extends from the front pedals up and over the rider connecting at the roll bar is used. Sides of the vehicle are open for entry and exit. Cable brakes on front wheel.

Team Votes:
Tyler: Yes Tristan: Yes Kyler: No Jacob: No

Decision: Two-wheel design is unstable compared to other configurations. Front fairing provides excess weight to design.

79. One wheel in the front and one wheel in the back. The rear wheel is driven by a belt and CVT. The belt is powered by pedals in the front of the vehicle located in front of driver. A

kickstand is used to hold the vehicle upright at low speeds and standstill. A front fairing that extends from the front pedals up and over the rider connecting at the roll bar is used. Sides of the vehicle are open for entry and exit. The rider is secured with a 5-point seatbelt. Cable brakes on front wheel. Roll cage reduction.

Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

Decision: Two-wheel design is unstable compared to other configurations. Belt and CVT power transmission is not efficient and difficult to implement.

80. One wheel in the front and one powered wheel in the back. The front wheel is turned by two long arms that extend to the driver in a laid-back position. No fairings. The rear wheel is powered by a chain and multiple gear system. The vehicle is held up by a kickstand that can be deployed when the vehicle has stopped. Forked suspension on front wheel. Cable brakes on front wheel. Wheel faces will be covered to improve aerodynamics. Roll cage reduction. 5-point seatbelt.

    Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

    Decision: Two-wheel design is unstable compared to other configurations.

81. One wheel in the front and one powered wheel in the back. The front wheel is turned by two long arms that extend to the driver in a laid-back position. Full fairing around vehicle. The rear wheel is powered by a chain and multiple gear system. The vehicle is held up by a kickstand that can be deployed when the vehicle has stopped. Forked suspension on front wheel. Cable brakes on front wheel. Roll cage reduction. 5-point seatbelt.

    Team Votes:

Tyler: Yes	Tristan: no	Kyler: Yes	Jacob: No

    Decision: Two-wheel design is unstable compared to other configurations. Full fairing would prove to add excessive weight to design without providing many aerodynamic advantages.

82. One wheel in the front and one powered wheel in the back. The front wheel is turned by a steering wheel. Front fairing over front wheel and pedals. The rear wheel is powered by a

chain and multiple gear system. The vehicle is held up by a kickstand that can be deployed when the vehicle has stopped. Forked suspension on front wheel. Cable brakes on front wheel. Rear wheel face covered to improve aerodynamics. Roll cage reduction. 5-point seatbelt.

Team Votes:
Tyler: Yes Tristan: no Kyler: Yes Jacob: No

Decision: Steering wheel on two-wheel bike would be impractical. Two-wheel designs are more difficult to stabilize over 3 or 4-wheel designs.

83. One wheel in the front and one powered wheel in the back. The front wheel is turned by two long arms that extend to the driver in a laid-back position. No fairings. The rear wheel is powered by a chain and multiple gear system as well as an energy regenerating flywheel. The vehicle is held up by a kickstand that can be deployed when the vehicle has stopped. Forked suspension on front wheel. Cable brakes on front wheel. Wheel faces will be covered to improve aerodynamics. Roll cage reduction. 5-point seatbelt.

Team Votes:
Tyler: No Tristan: no Kyler: No Jacob: No

Decision: Poor aerodynamics from steering system. Flywheel would not be worth the time and resources to implement; it would be inefficient and would provide excess weight. Two-wheel designs are more difficult to stabilize over 3 or 4-wheel designs.

84. One wheel in the front and one powered wheel in the back. Multiple gear system with a chain. The chain is powered through foot pedals located in front of the vehicle. The rider is in a laid-back position. The steering element is a set of handles that extend back to the rider with brake levers. The brake levers actuate a disc brake on the front wheel. The vehicle has a deployable kickstand for low speed or stooping. Fairing covers the front of the vehicle all the way up to the roll cage with open sides for entry and exit. Roll cage reduction.

Team Votes:
Tyler: No Tristan: No Kyler: Yes Jacob: No

Decision: 2-wheel design is unstable compared to other configurations.

85. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairings are located on nose of vehicle, over the front wheels, and on the back and rear wheel. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Team Votes:
Tyler: Yes Tristan: Yes Kyler: Yes Jacob: Yes

Decision: This design will move onto the next phase.

86. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes that grip the wheel.

Team Votes:
Tyler: Yes Tristan: yes Kyler: Yes Jacob: Yes

Decision: This design will move onto the next phase.

87. Two wheels in the front that are steered with a rack-and-pinion tie rod steering system. The wheels are actuated by the driver through a steering wheel and column. Rider is sitting more upright (about 120 degrees). The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairings are

located on nose of vehicle, over the front wheels, and on the back and rear wheel. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Team Votes:

Tyler: Yes	Tristan: yes	Kyler: Yes	Jacob: Yes

Decision: This design will move on to the next phase.

88. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through steering wheel and a steering column. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairing located over pedals only. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Team Votes:

Tyler: Yes	Tristan: Yes	Kyler: Yes	Jacob: Yes

Decision: This design will move onto the next phase.

89. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with CVT. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes on the front tires.

Team Votes:

Tyler: No	Tristan: no	Kyler: Yes	Jacob: No

Decision: This may be an expensive design. There were better configurations similar to this.

90. Two wheels in front are the powered wheels and do not turn. The wheels are powered by pedals and a chain with multiple gear transmission. Rider is in a laid-back position. Rear wheel is steered through a tiered system and levers. The front wheels have cable brakes on the rims. Fairing covers the front wheels, pedals, and the rear wheel.

Team Votes:

Tyler: No	Tristan: no	Kyler: No	Jacob: No

Decision: Rear steering is unstable.

91. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheels are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with CVT. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes on the front tires.

Team Votes:

Tyler: No	Tristan: No	Kyler: Yes	Jacob: No

Decision: CVT difficult to incorporate and disc brakes are expensive.

92. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheels are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gears. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Forked suspension on the rear wheel. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes on the front tires.

Team Votes:

Tyler: Yes	Tristan: Yes	Kyler: Yes	Jacob: Yes

Decision: This design will go onto the next phase.

93. Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheels are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with CVT. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Forked suspension on the rear wheel. No fairings. Levers on the handle tighten a cable that actuates brakes that clamp onto rim of wheel.

Team Votes:
Tyler: Yes Tristan: Yes Kyler: Yes Jacob: Yes

Decision: This design will go onto the next phase.

94. Two wheels in the front that are steered with a tie rod steering system. The wheels are turned by a steering wheel with rack and pinion. Brakes are hydraulic. Fairing on front only. Power is transmitted through foot pedals and a chain with multiple gears. Rider is in a more upright position. Body is lowered.

Team Votes:
Tyler: Yes Tristan: No Kyler: Yes Jacob: No

Decision: Upright position is not a good position for power transmission.

95. Two wheels in the back that are powered with chain and multiple gear transmission. Rider lays back and applies force to pedals ahead of vehicle. Front wheel steers with lever arms that extend back to rider. Brakes are calipers that grip the rim of the front wheel using force applied to levers on lever arms. Coil over suspension on the rear wheels. Fairing over front wheel that extends up to roll bar with open sides.

Team Votes:
Tyler: No Tristan: No Kyler: Yes Jacob: Yes

Decision: Two wheels in the back is unstable.

96. Two wheels in the front in the same configuration as now. Wheels are turned using rack and pinion steering with tie rods. The wheels are steered using a set of handlebars. Brakes are caliper brakes that grip tire rims. Forked suspension on the back wheel. Rear wheel is powered using pedals, a chain, and multiple gear system.

    Team Votes:

    Tyler: No Tristan: Yes Kyler: Yes Jacob: Yes

    Decision: The team will be moving forward with another design.

97. Two wheels in front with one in back. Rear wheel is powered using chain and CVT. Foot pedals power the chain located in front of vehicle. Fairing covers the pedals and redirects airflow around rider. Forked suspension on rear wheel. Hydraulic brakes on front wheels. Front wheels are steered using hand levers that extend back. Wheels are connected and turned using tie rod steering.

    Team Votes:

    Tyler: No Tristan: no Kyler: No Jacob: No

    Decision: CVT is difficult to incorporate and hydraulic braking would be over complicated.

98. Use current frame stance with two wheels in front and one wheel in the rear. Have a tie rod steering mechanism for front two tires and steered by 2 levers next to the rider's torso. Have a chain and gear system powered from an adjustable foot pedal at front of the vehicle that transmits power to the rear wheel. Have hydraulic brakes on the front two wheels and a 4-point harness for the rider. Have a full body fairing resembling the "ghost" from the *Halo* video game series. Incorporate neon lights to represent the thrusters of the vehicle and help for low light environments.

    Team Votes:

    Tyler: No Tristan: Yes Kyler: Yes Jacob: No

    Decision: If we were targeting HALO enthusiasts then sure, but we will be moving forward with other concepts.

The following are the twelve most promising design concepts the team believes will accomplish the goals most efficiently and effectively. These concepts were then narrowed down again by placing them into a bracket and comparing two at a time, eliminating half of the concepts at each level of the bracket. The concepts were compared with the goals of the project, and targets of the design, in mind.

Concept 3: Use two front and one rear wheel like current design but lower position and widen stance of the front tires. Use a tie rod mechanism to provide steering for the front tires, with wide grip handle bars. Have an adjustable foot pedals at front of the bike using a chain and CVT system linked to the rear wheel. No suspension implemented. Have disc brakes on the front tires and have a casual laid-back position.

Concept 24: Use two fronts and one rear wheel like current design but lower position and widen stance of the front tires with a partial fairing going from the front of the vehicle over the top of the body. Have a tie rod mechanism to front tires, adjustable foot pedals to power rear wheel with chain and gear system. Have a 3-point harness and disc brakes on front wheels. Have a casual laid-back position.

Concept 26: Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Concept 42: Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a wide grip handle bar. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 120 deg.

Concept 43: Current wheel's position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a standard steering wheel. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 150 deg.

Concept 58: The steering configuration of concept 58 will be like what the frame provided from last year's team is equipped with (Direct steering). Power is transmitted to the rear wheel using foot pedals located in the front of the vehicle on an adjustable mount and a belt that runs underneath the frame. The vehicle will use a CVT transmission. Safety restraints will be like that in a car (3-point seatbelt). The vehicle will use a leaf spring suspension on the front wheel. Disc brakes are fixed to the two front wheels and actuated by levers on the steering handles. The rider will be sitting at an angle of approximately 120 degrees.

Concept 85: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairings are located on nose of vehicle, over the front wheels, and on the back and rear wheel. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Concept 86: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes that grip the wheel.

Concept 87: Two wheels in the front that are steered with a rack-and-pinion tie rod steering system. The wheels are actuated by the driver through a steering wheel and column. Rider is sitting more upright (about 120 degrees). The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairings are located on nose of vehicle, over the front wheels, and on the back and rear wheel. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Concept 88: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through steering wheel and a steering column. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairing located over pedals only. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Concept 92: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheels are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gears. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Forked suspension on the rear wheel. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes on the front tires.

Concept 93: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheels are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with CVT. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Forked suspension on the rear wheel. No fairings. Levers on the handle tighten a cable that actuates brakes that clamp onto rim of wheel.

Table 3.D shows the bracket used to narrow the twelve concepts down to three final concepts. These three concepts are not complete, all encompassing, designs but they provide the

functional framework of the design. The final three concepts will be expanded upon into nearly complete designs. These refined designs are presented in the body of the evidence manual.

Table 3.D: *Comparison of twelve possible design concepts*

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<tr><td>3</td><td rowspan="2">24</td><td rowspan="4">42</td></tr>
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Through closer comparison of the twelve concepts, concepts 42, 85 and 92 were selected to move on to concept selection. These designs are expanded upon in the body of the text and include conceptual drawings of the possible design.

Update: *The team decided to limit the design possibilities less during concept generation and proceeded with the concepts in column two of table 3.d rather than only three concepts.*

Concept 42: Current wheel’s position. Hydraulic lines will be used along with tie rods to steer front steering tires. Tires and lines configured with a wide grip handle bar. Foot pedals on a mount deliver power to drivetrain, which is a standard chain and gear system that turns the back-driving wheel. A 4-point safety harness restrains the occupant. The vehicle has no added suspension as well as standard cable bike brakes. The brakes are controlled by a push/pull lever that retracts the cable brake lines. The driver is in a laid-back position at 150 degrees.

Concept 85: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheel are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gear system. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Fairings are located on nose of vehicle, over the front wheels, and on the back and rear wheel. Levers on the handle tighten a cable that actuates brakes that grip the rim of the front wheels.

Concept 92: Two wheels in the front that are steered with a tie rod steering system. The wheels are actuated by the driver through hand levers that extend back to the rider in a laid-back seating position. The two-front wheels are low to the ground (mounted a little higher than the base of the vehicle frame). The rear wheel is driven by a chain with multiple gears. The chain is routed underneath the frame of the vehicle, with half of the chain riding above the frame bottom and the other half running below, guided by small wheels. The chain is powered by foot pedals located at very front of vehicle. Forked suspension on the rear wheel. Fairing covers the pedals and extends up over the rider all the way to the rear wheel with open sides. Levers on the handle tighten a cable that actuates disc brakes on the front tires.

1.6 xxx

References

There are no sources in the current document.