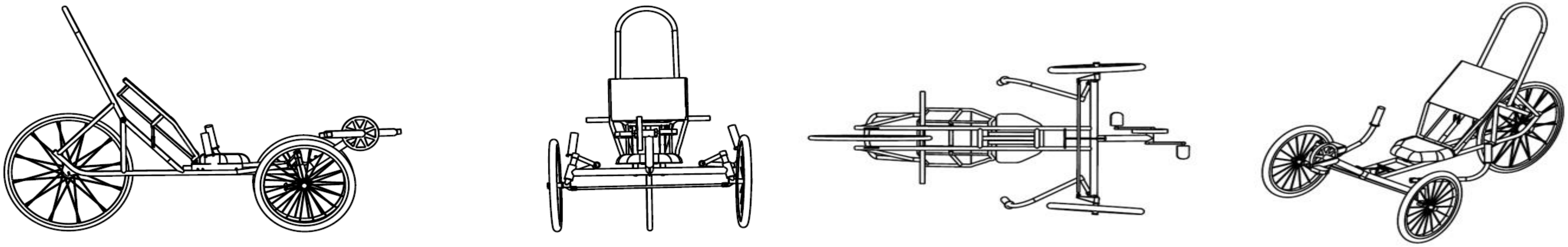
Human Powered Vehicle

Team 512

28-March-2019



ASME
SETTING THE STANDARD

Department of Mechanical Engineering

FAMU-FSU Engineering

The Team

☑


Systems Engineer/
Project Manager

**Tyler
Schilf**

Steering Engineer

**Tristan
Enriquez**

Powertrain Engineer

**Jacob
Thomas**

Ergonomics/Safety
Engineer

**Kyler
Marchetta**

Project Background

Jacob Thomas

Project Sponsors

Jess Ball

Provided Project Budget

Keith Larson

Design Insight

Dr. Shayne McConomy

Engineering Design Support

Justin Pogge

Technical Support

The Objective

Create a wheeled transportation device that is ***safe****,* ***agile****,* ***fast*** *and satisfies the* ***ASME Human Powered Vehicle (HPV) Competition rules****.*

Source: Bing Creative Commons

Source: Bing Creative Commons

Source: Bing Creative Commons

The team will **Emulate** the ASME North American **E-Fest in Lansing, Michigan in April of 2019**.

ASME E-Fests

The Competition (Three Events)

Design

Source: ASME Human Powered Vehicle Website

Methodology
Innovation
Analysis
Documentation

Speed

Source: ASME Human Powered Vehicle Website

Top Speed
Timed Race
Safety is Crucial

Endurance

Source: ASME Human Powered Vehicle Website

Agility
Durability
Stamina

Jacob Thomas

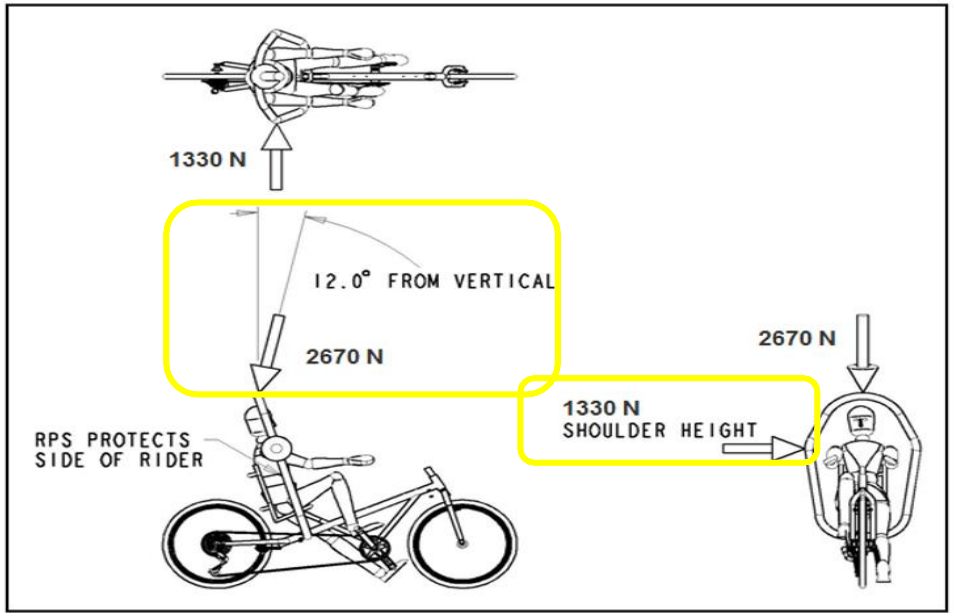
2019 Competition Details


Source: ASME E-Fest Competition North 2018

Important Safety Requirements

(Taken from the Human Powered Vehicle Competition 2019 Rules)

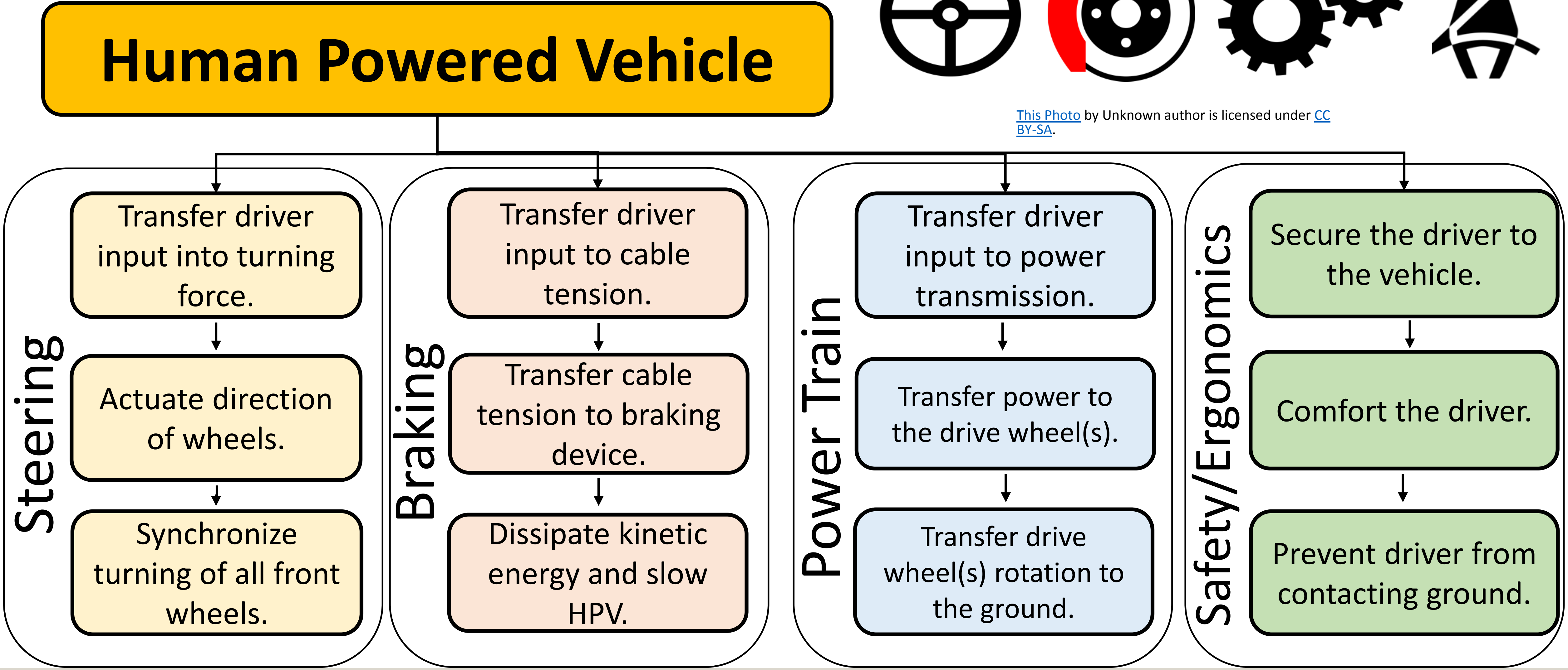
- Vehicle must **stop in 6 m from 25 km/hr.**
- All **front wheels** must have **brakes.**
- Vehicle must **turn** in a radius of **8 m.**
- Able to travel in **straight line** for **30 m at 8 km/hr.**
- Roll Protection System (**RPS**) must be **sound** and defend riders head from collisions.



Source: ASME Human Powered Vehicle Challenge

Functional Decomposition

This Photo by Unknown author is licensed under CC BY-SA.



Human Powered Vehicle

Steering
- Transfer driver input into turning force.
- Actuate direction of wheels.
- Synchronize turning of all front wheels.

Braking
- Transfer driver input to cable tension.
- Transfer cable tension to braking device.
- Dissipate kinetic energy and slow HPV.

Power Train
- Transfer driver input to power transmission.
- Transfer power to the drive wheel(s).
- Transfer drive wheel(s) rotation to the ground.

Safety/Ergonomics
- Secure the driver to the vehicle.
- Comfort the driver.
- Prevent driver from contacting ground.

Jacob Thomas

Design Targets

The Vehicle **turns** in a diameter of **6 meters (19.7 feet)** at low speed.

Straight path (within 4 feet) is **maintained** with driver input for 30 meters (98.4 feet).

Vehicle comes to **complete stop** in **6 meters (19.7 feet)** from a speed of 25 km/hr (15.5 mph).

Vehicle frame sustains a **top and side load** specified in the rulebook (**Top: 2670 N   Side: 1330 N**).

Rider **head and shoulders** do **NOT contact ground** when tipping.

Vehicle **weight** less than **100 pounds.**

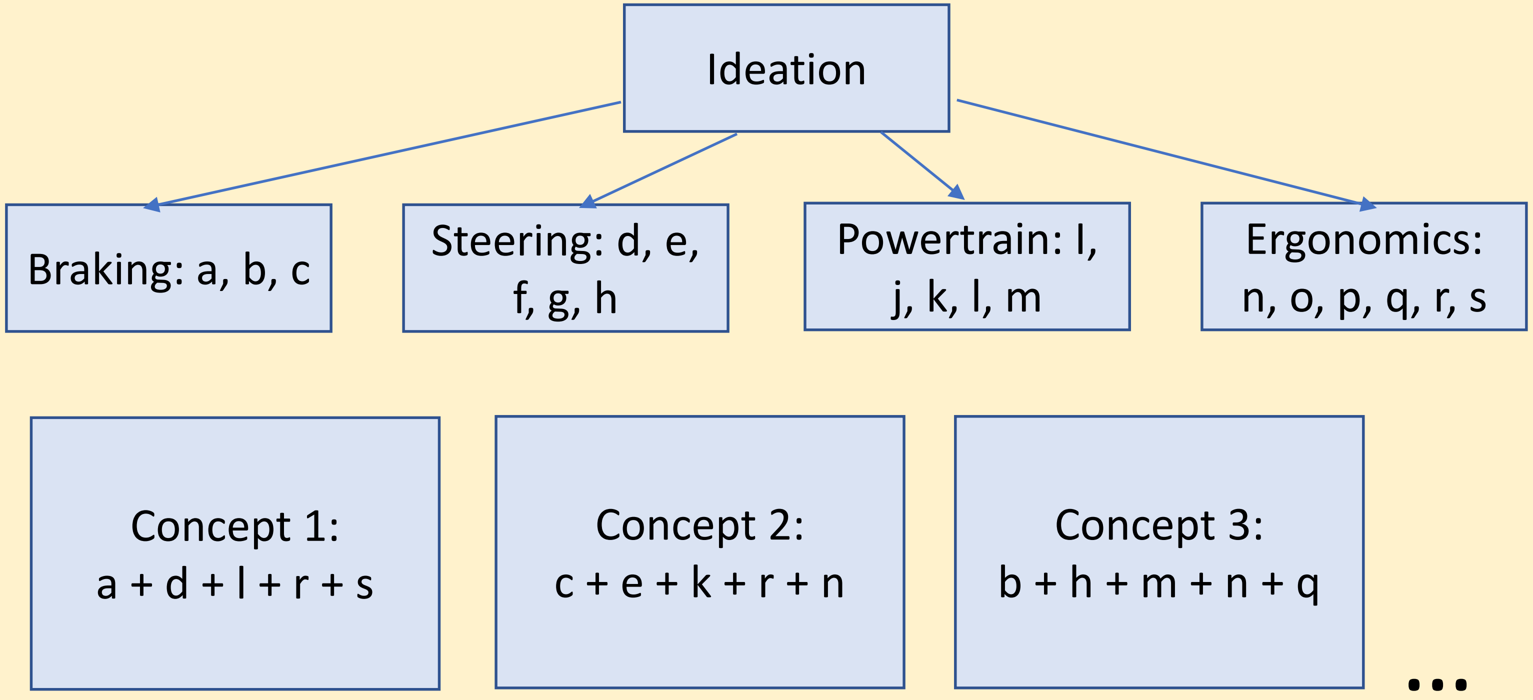
Concept Selection

Outline of how it was done…

Brainstorming

Individual system concepts are brainstormed. (Steering, Braking, etc.)

System concepts are combined in various ways into vehicle design concepts.



Ideation

Braking: a, b, c

Steering: d, e, f, g, h

Powertrain: I, j, k, l, m

Ergonomics: n, o, p, q, r, s

Concept 1: a + d + l + r + s

Concept 2: c + e + k + r + n

Concept 3: b + h + m + n + q

…

Concept Selection

Brainstorming

Individual system concepts are brainstormed. (Steering, Braking, etc.)

System concepts are combined in various ways into vehicle design concepts.

Elimination

Design concepts compared based on their feasibility, practicality and satisfaction of customer needs. (competition rules)

This process limits concept list to six designs.

Six designs advance to Analytical Hierarchy Process. (AHP)

Selection

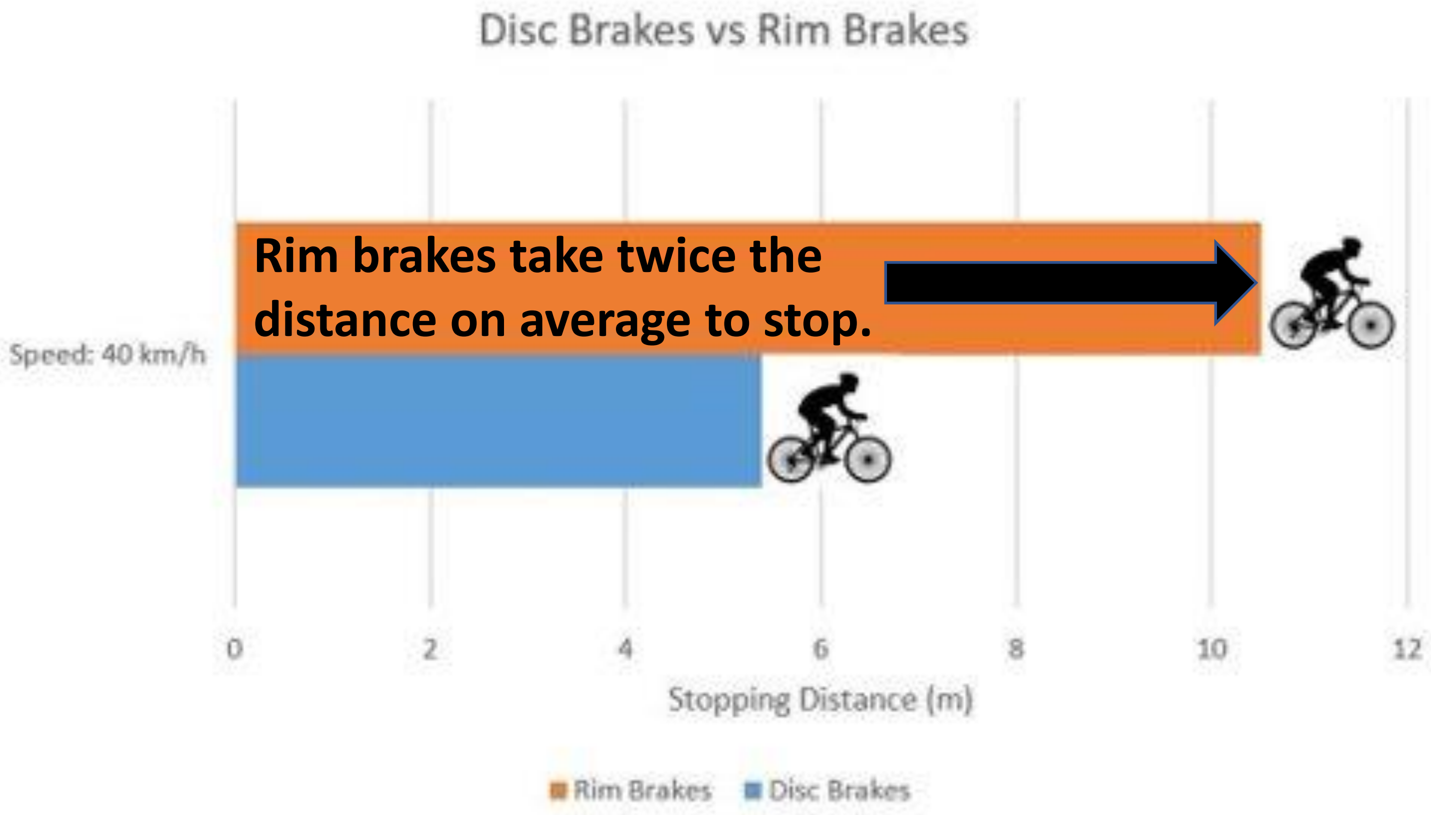
AHP selects the most suitable concept.

Concept 85
- Tadpole recumbent trike
- Direct steering
- Rim brakes*
- 7-speed transmission

Shown: GreenSpeed GT20

Jacob Thomas

Post Concept Selection Braking Decision



Rim brakes take twice the distance on average to stop.

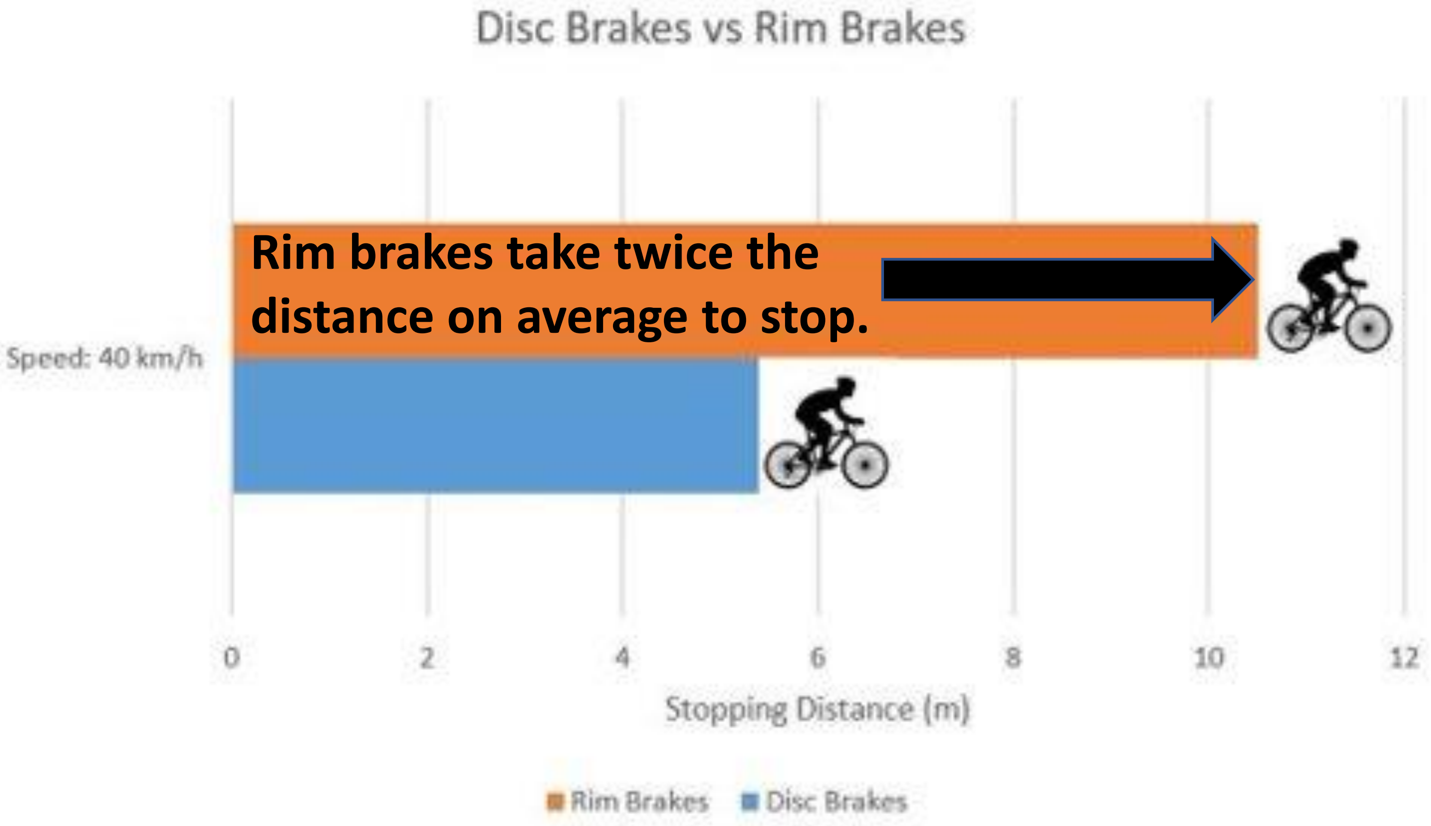
ADVANTAGES

- Braking Distance
- Control
- Safety
- Turning

DISADVANTAGES

- Cost

Post Concept Selection Braking Decision



Disc Brakes vs Rim Brakes

Rim brakes take twice the distance on average to stop.

Selection

AHP selects the most suitable concept

Concept 85

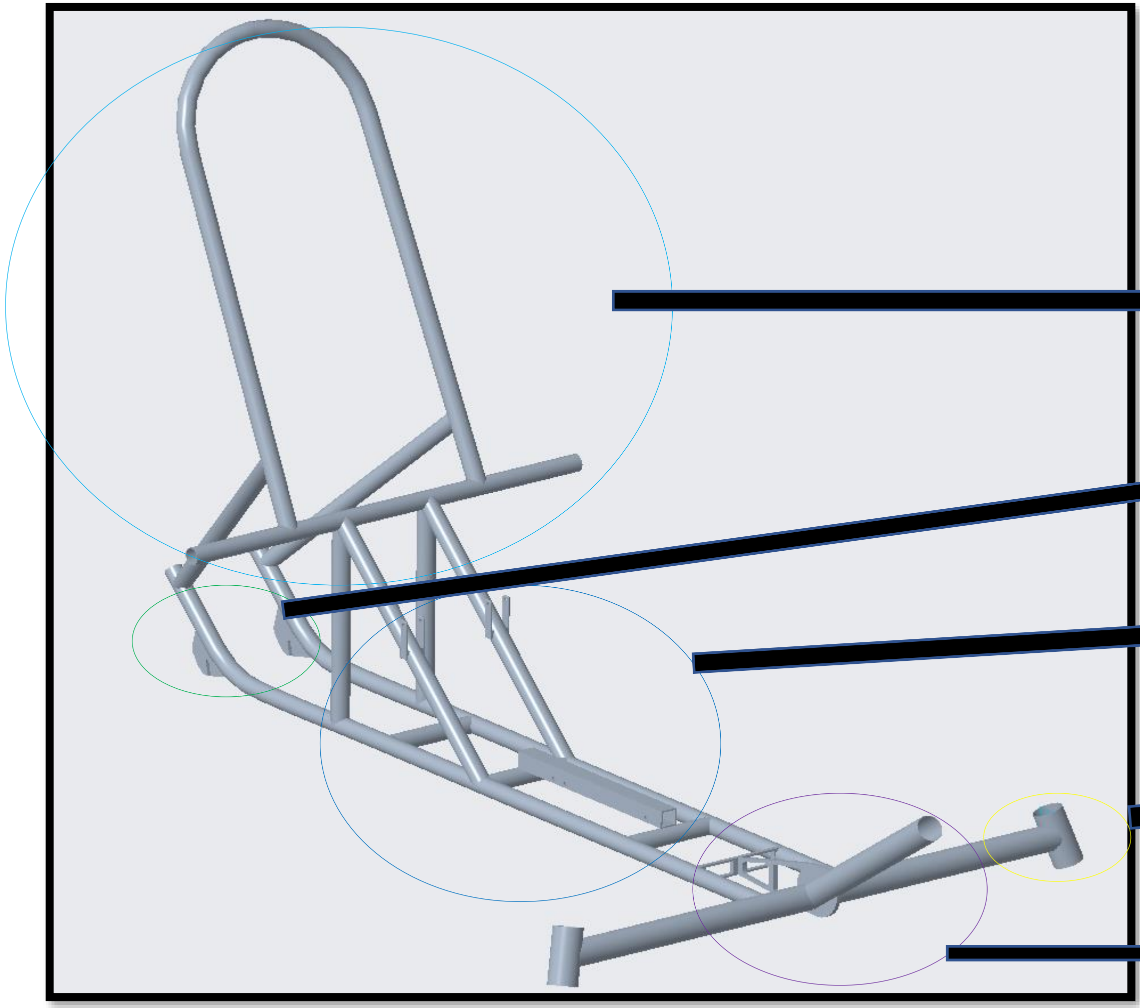
- Tadpole recumbent trike
- Direct steering
- ~~Rim brakes*~~ **Disc Brakes**
- 7-speed transmission

Shown: GreenSpeed GT20

Embodiment Design

Tristan Enriquez

The Frame



Frame designed to meet competition requirements and allow the integration of the systems selected in concept generation.

Roll Protection System

Rear Wheel Mounting Point

Reclined Seat Mounting Points

Head tubes for front wheels
And direct steering

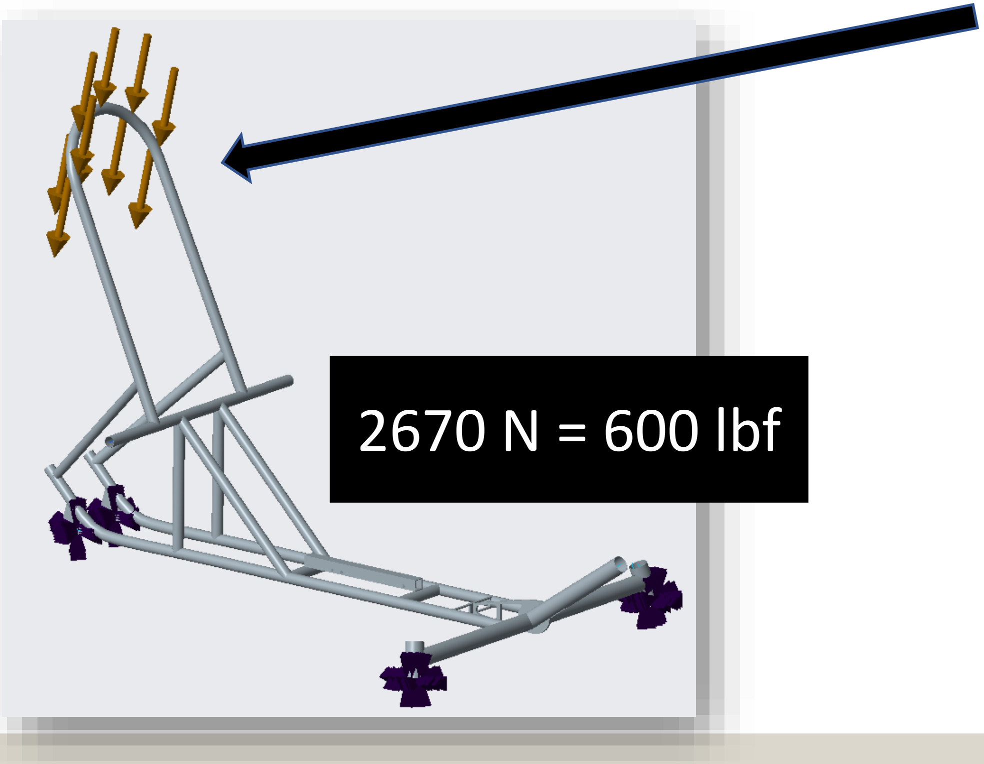
Pedal Boom Mount with Reinforcement

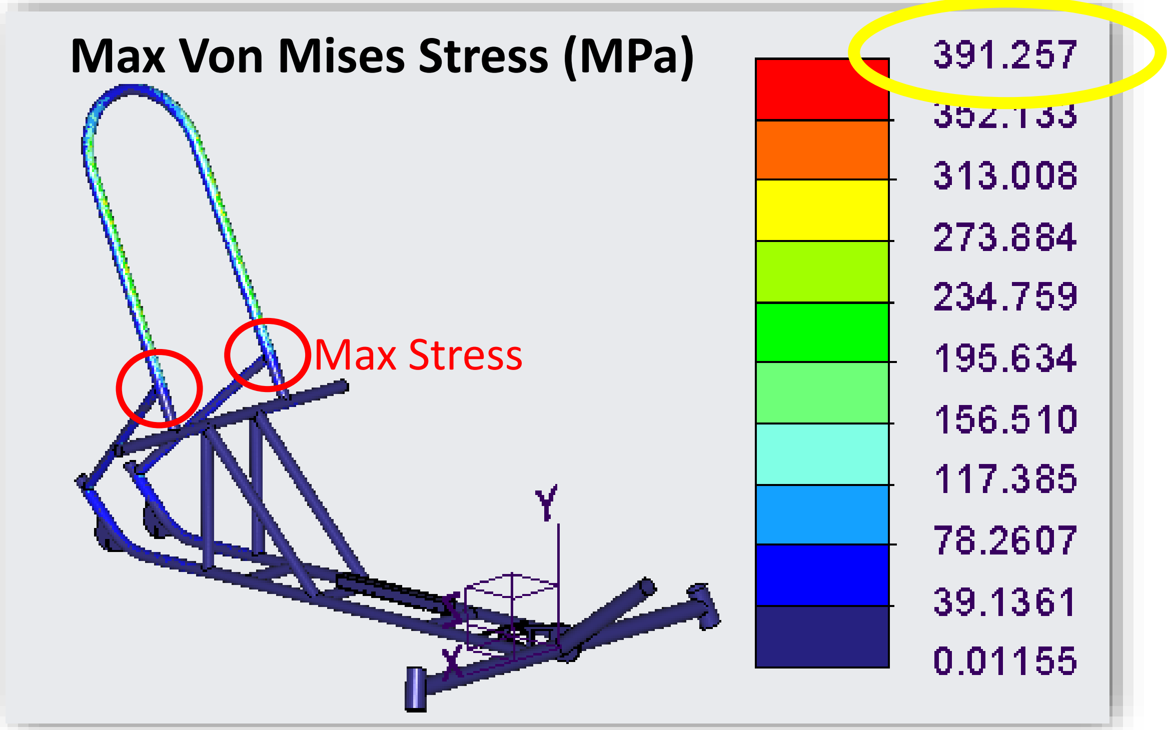
Tristan Enriquez

Frame Analysis(RPS *Top Load*)

Frame analyzed using Finite Element Analysis in Creo Parametric to confirm structural integrity.

2670 N Load at **12 degrees** from vertical applied to **top of roll bar.**

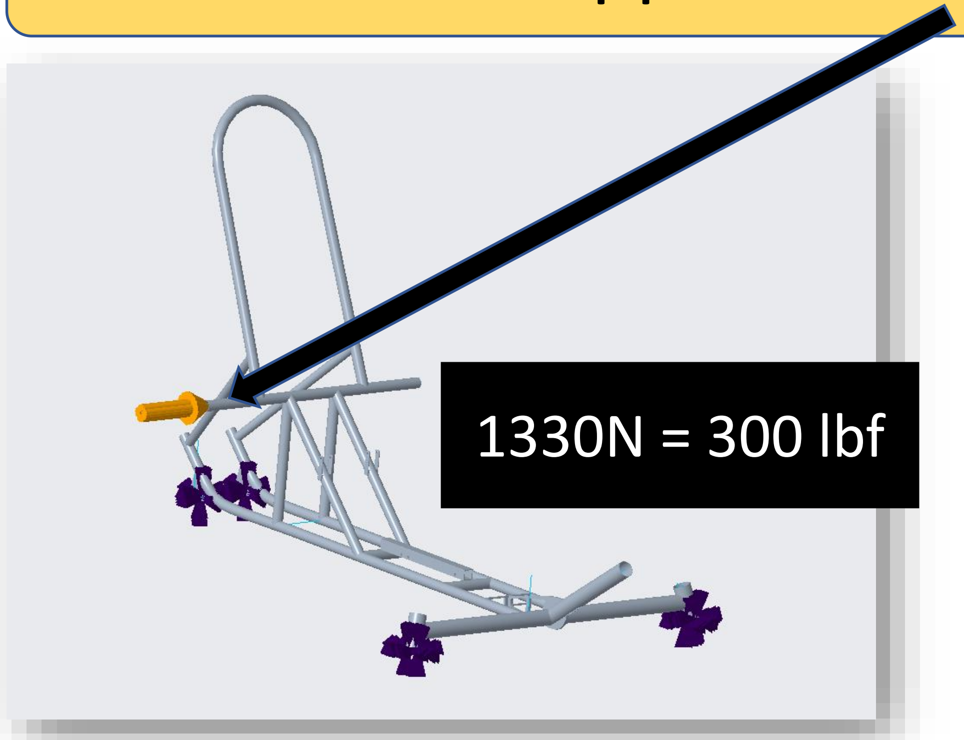

2670 N = 600 lbf



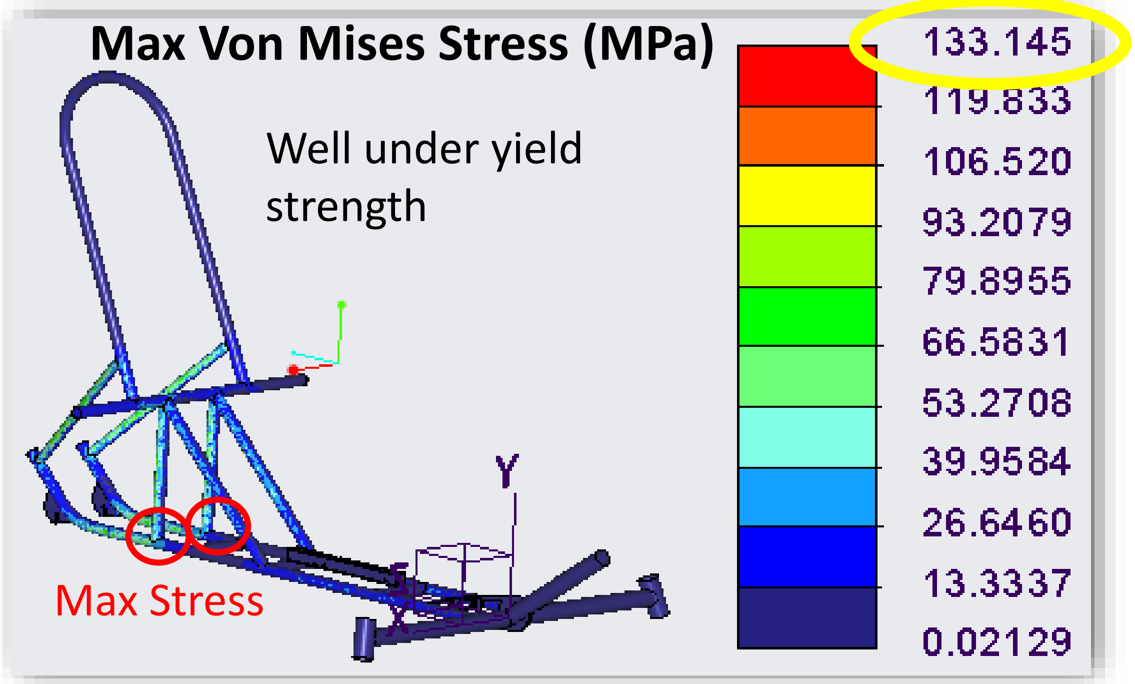
Frame Analysis(RPS Side Load)

Frame analyzed using Finite Element Analysis (FEA) in Creo Simulate to confirm structural integrity.

1330 N Load applied **horizontally** to **side of roll protection.**



1330N = 300 lbf



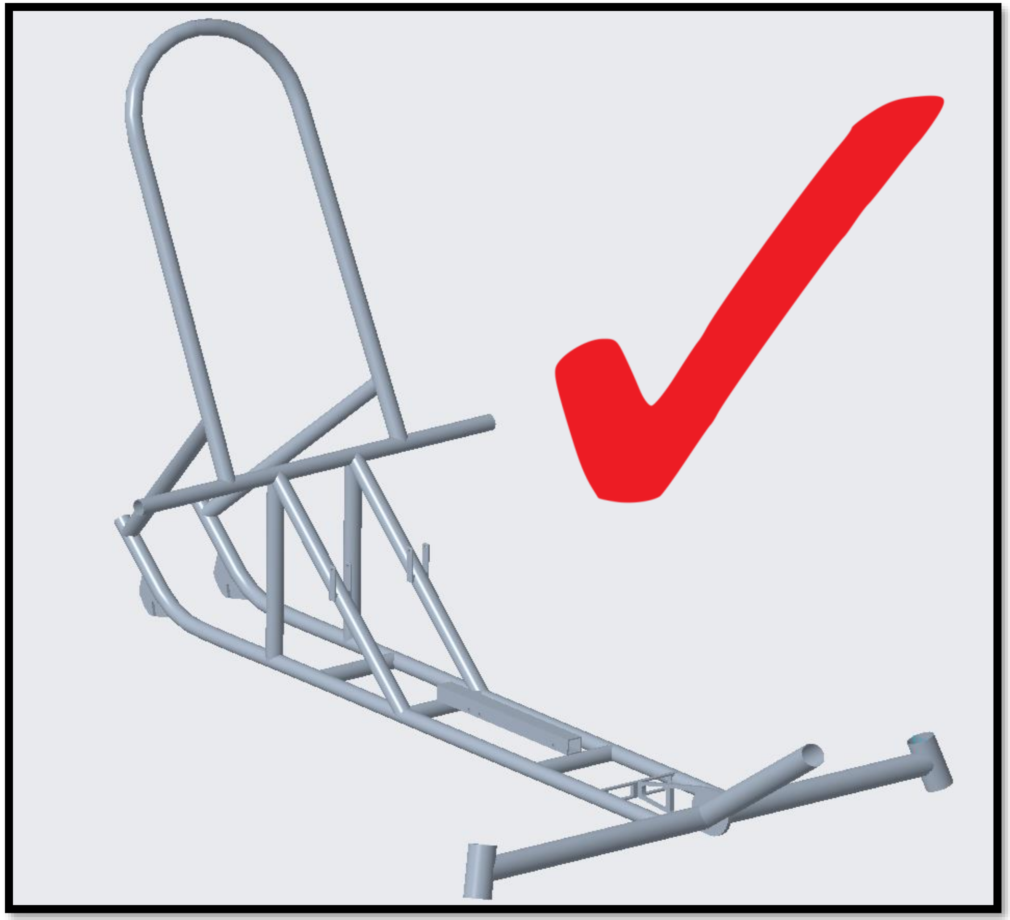
Max Von Mises Stress (MPa)

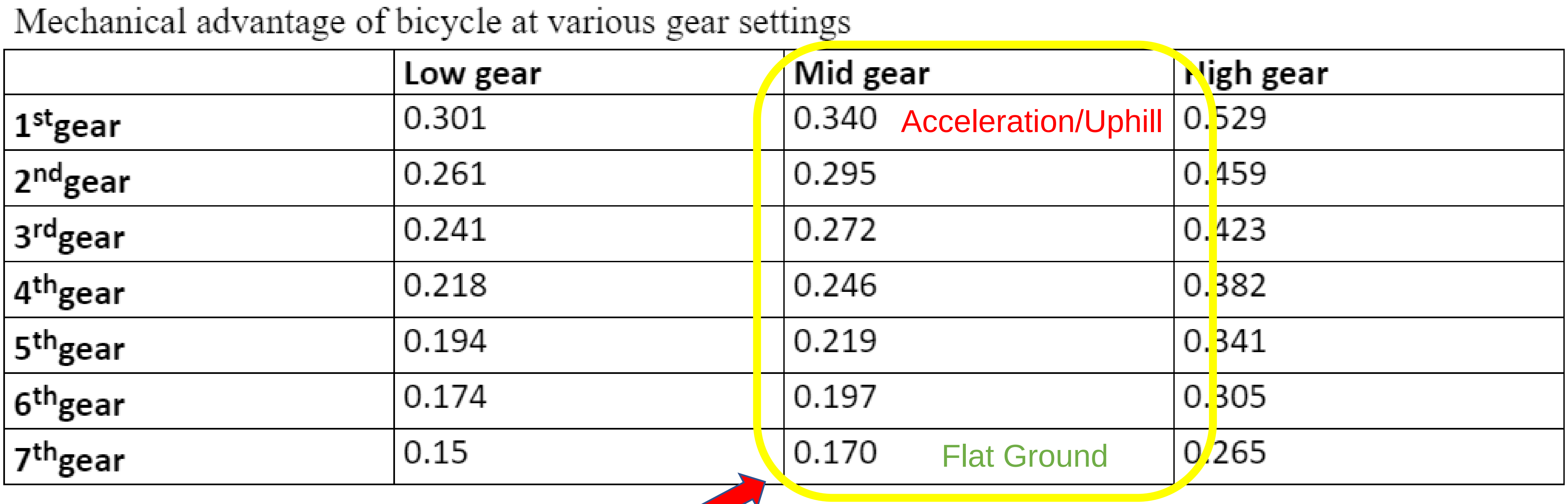
Well under yield strength

Max Stress

The Frame Design Satisfies the Load Requirements.

Steering, Powertrain, Braking, and Safety Systems can now be integrated into the frame.





Mechanical advantage of bicycle at various gear settings

	Low gear	Mid gear	High gear
1st gear	0.301	0.340	0.529
2nd gear	0.261	0.295	0.459
3rd gear	0.241	0.272	0.423
4th gear	0.218	0.246	0.382
5th gear	0.194	0.219	0.341
6th gear	0.174	0.197	0.305
7th gear	0.15	0.170	0.265

Acceleration/Uphill

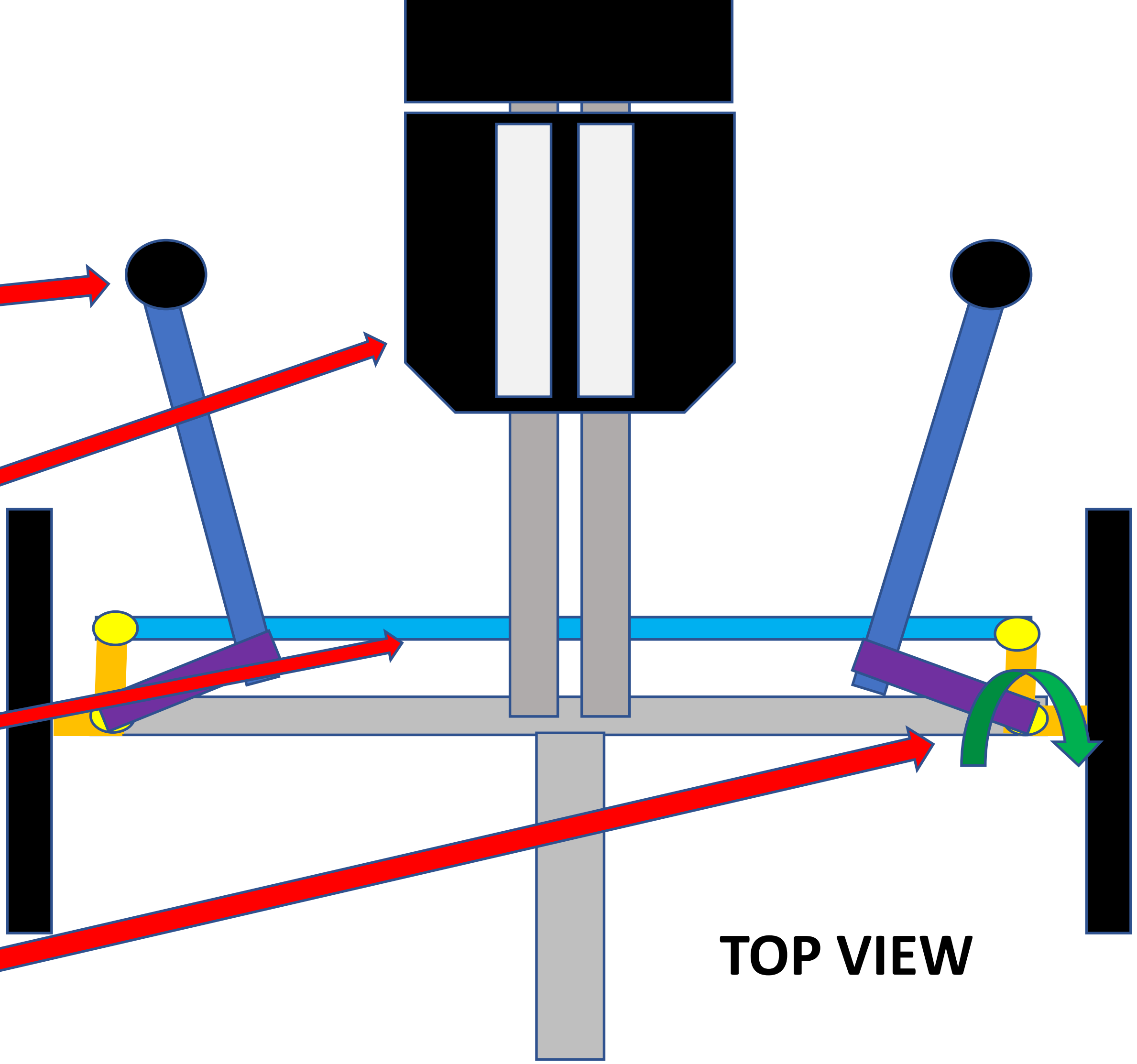
Flat Ground

Second Largest Chainring of Pedals was Utilized

Power-Train Specifications

The vehicle utilizes a 7-speed mountain bike transmission.

Steering System



Handlebars are positioned to the side of the seat.

Handles contact seat to prevent oversteer.

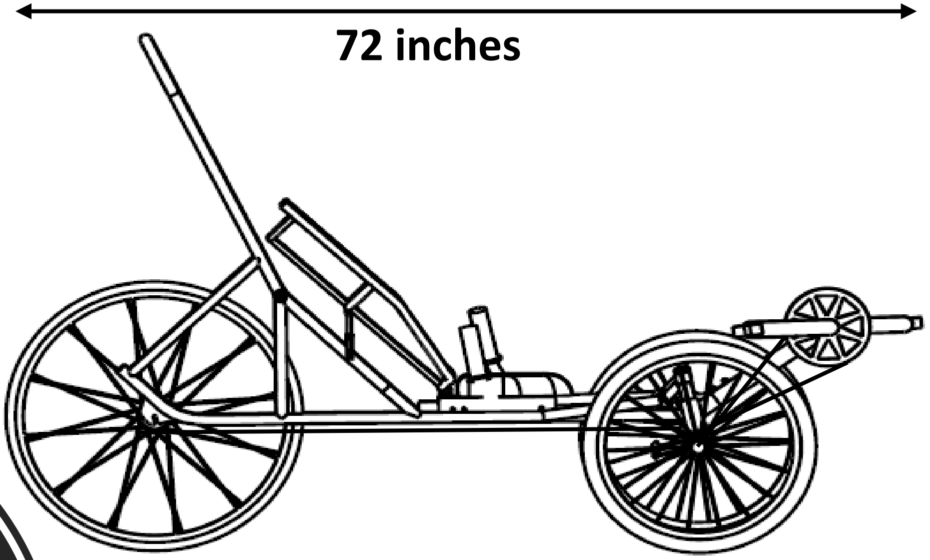
Wheels connected with a tie rod.

Handlebars connected to kingpin axis.

Tristan Enriquez

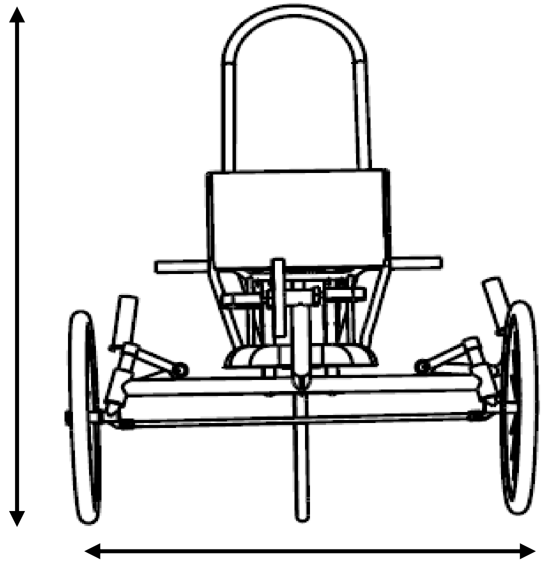
Dimensions

CAD Drawing and Specifications

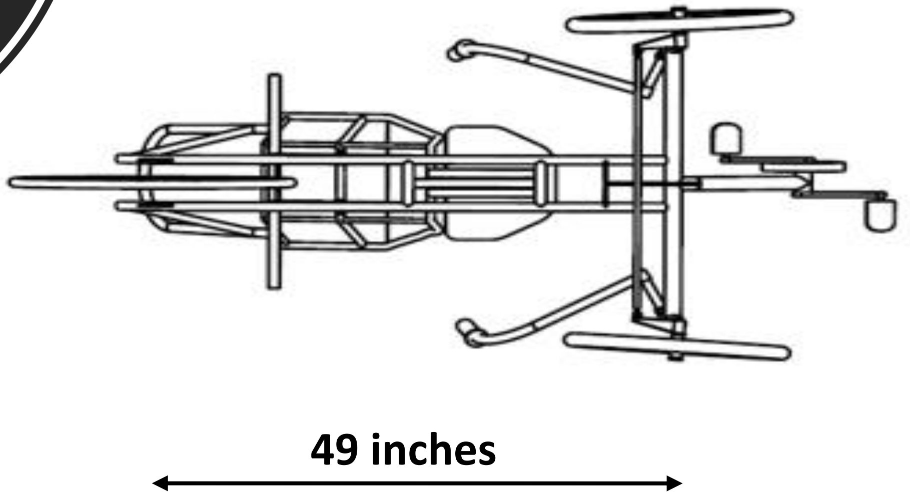


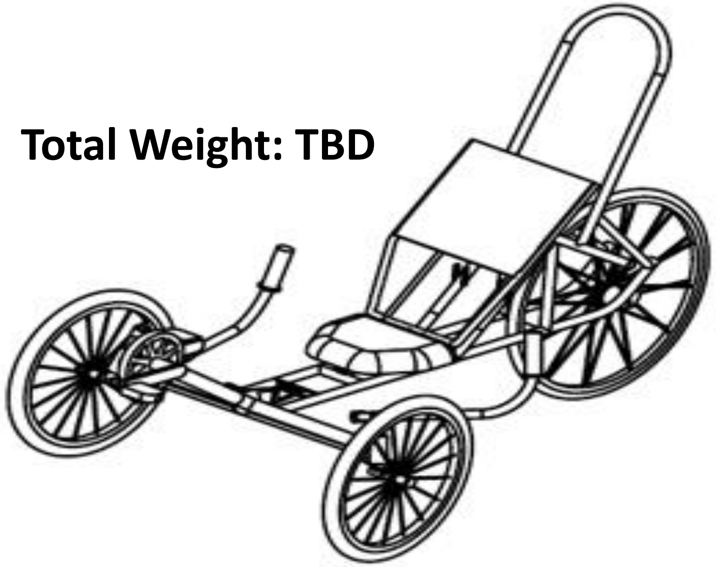
Rear Weight: TBD

Front Weight: TBD



Total Weight: TBD





Tristan Enriquez

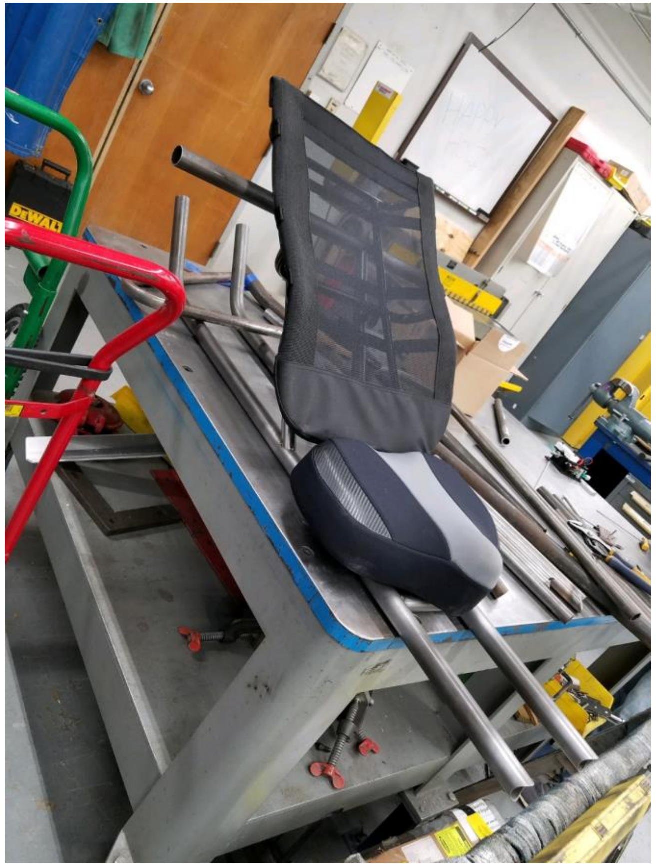
Prototype

Tyler Schilf

Building The Prototype

August 2018 – Gathering Materials

Breaking Down Materials



December 14th, 2018 – Seat, Side Protection

Tyler Schilf

Building The Prototype

Prototype – January 14, 2019
Crossbar, Head tubes, Steering Knuckles, Pedals

Steering Knuckles

Next Build Steps

- **Headsets**
- **Rear Wheel**
- **Chain/Chain Routing**
- **Tie rod**

Building The Prototype

Rear Wheel Implemented

Handle

Stem

Headset

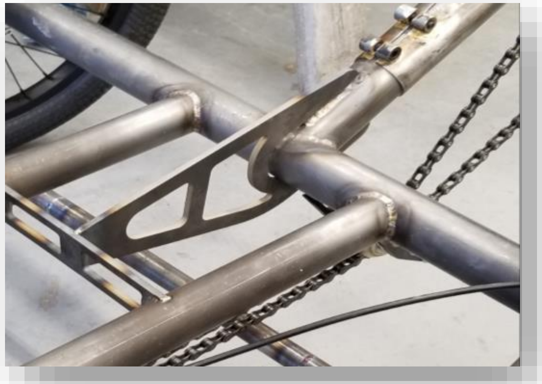
Steering Knuckle

Spherical Bearing

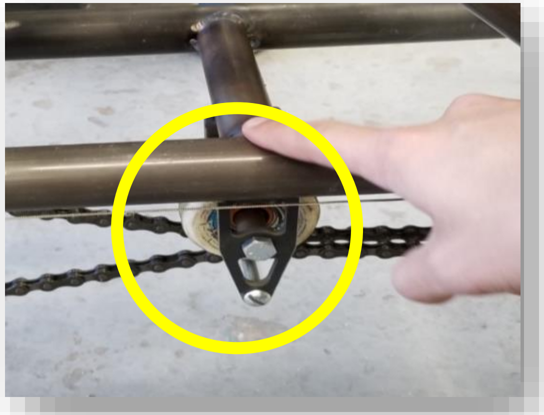
Tie Rod

This Photo by Unknown author is licensed under CC BY-SA.

Steering Components Implemented



Chain Routing with brackets
(Two redirection points)



Tyler Schilf

Chain Route

Redirected with (skateboard wheel) sprockets in two locations.

Derailleur

Final Touches

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

Tyler Schilf

Restraint Attachment Points

4-Points: Behind Head, Left/Right of Pelvis, and Between Legs

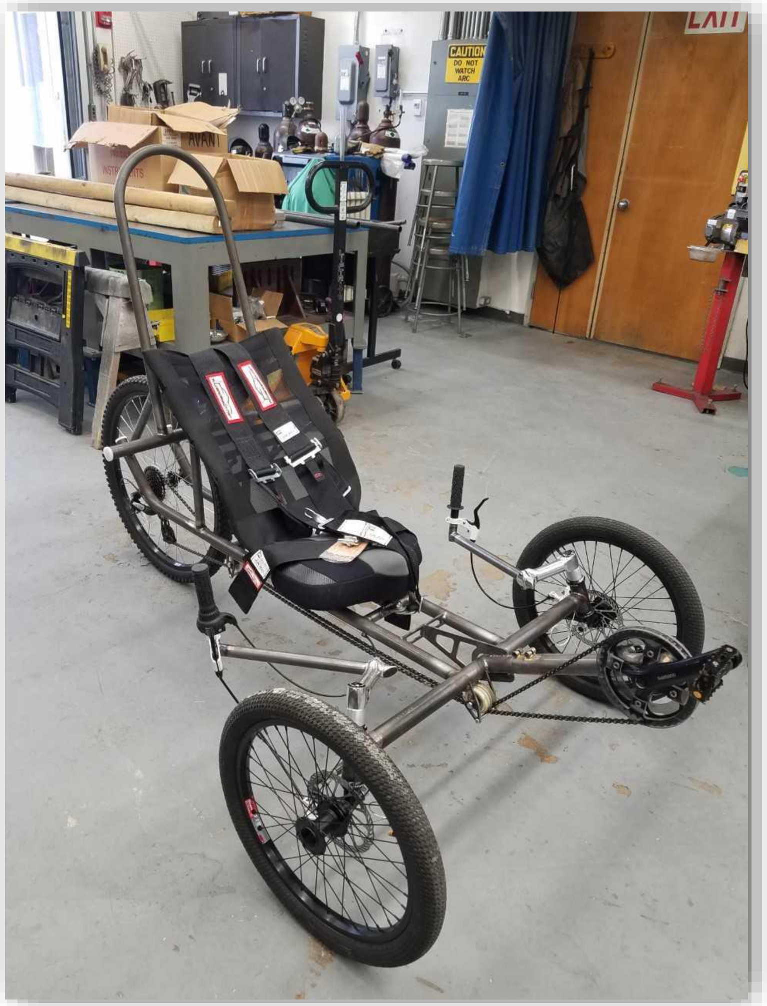
Prototype

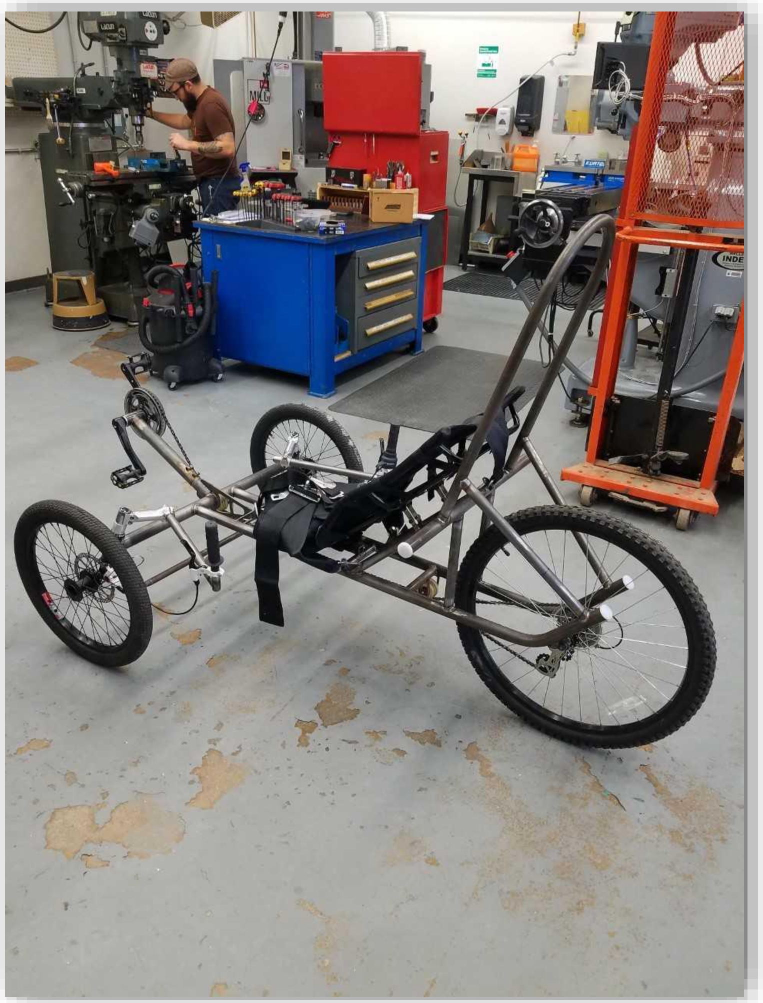
Roll Protection ✓

Steering/Braking ✓

Powertrain ✓

Safety Harness ✓





Prototype "T-BONE"

Painted and Added Name/Number Plate. (#38)

Testing

Tyler Schilf

Design Targets are Checked

Metrics Tested:

Turning

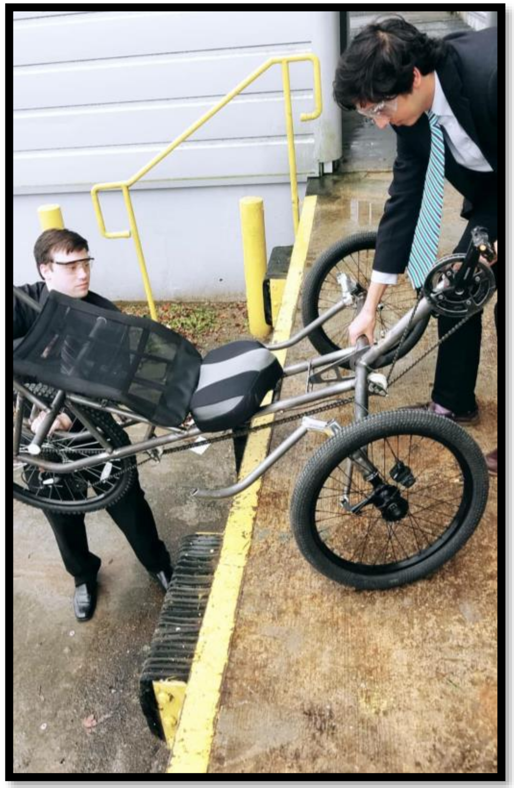
Can the prototype turn in 6 meters?

Braking

Can the prototype stop in 6 meters from 15 mph?

Stability

Can the prototype maintain a straight line?

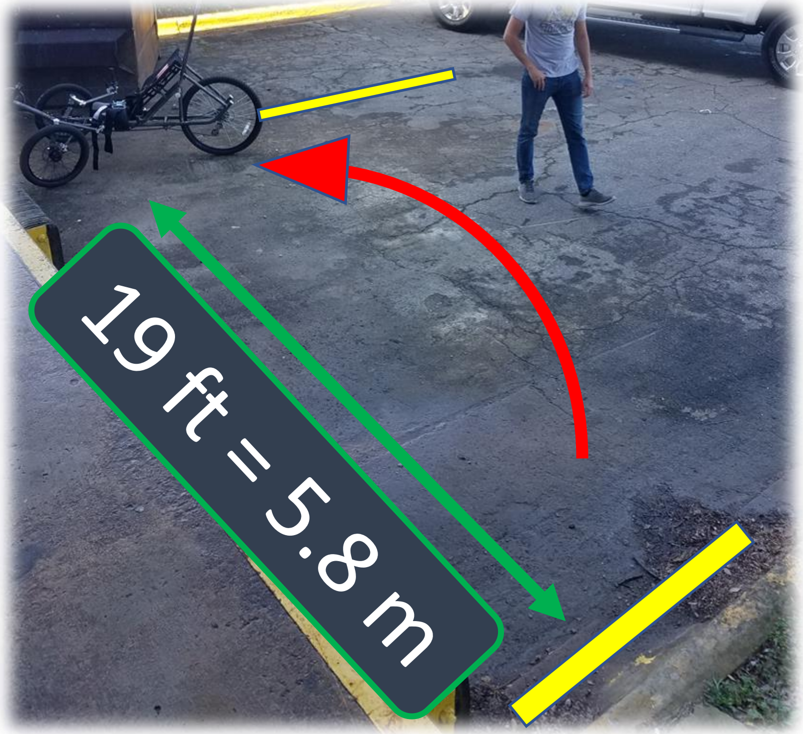


Tyler Schilf

Testing: Turning (**6-meter Target**)

Turn is completed when outside wheel at the end of the turn was parallel with the orientation of the wheel at the beginning of the turn.

Must Complete Turn in **19.8 feet**



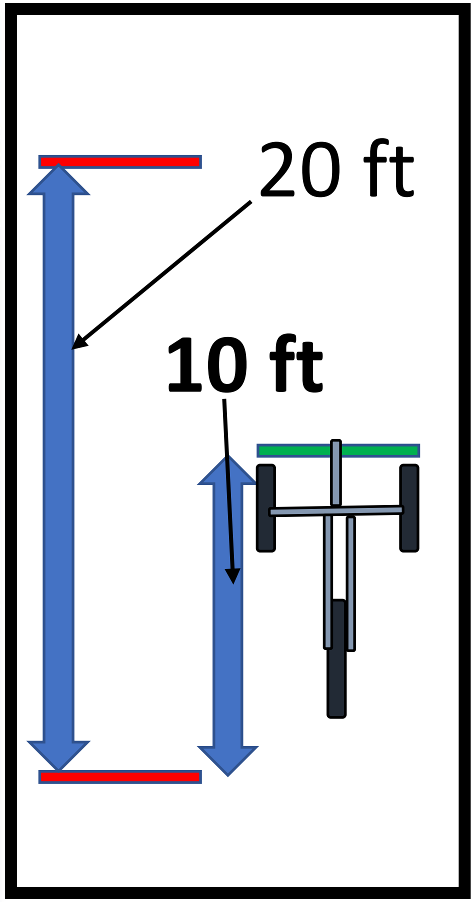
19 ft = 5.8 m

The vehicle can turn within the target turning radius at low speed.

✓

Testing: Braking (6-meter Target)

Vehicle accelerated to velocity of 15 mph and then brought to 0 mph



Vehicle was capable of braking well within the target stopping distance of 6 meters (19.8 ft)

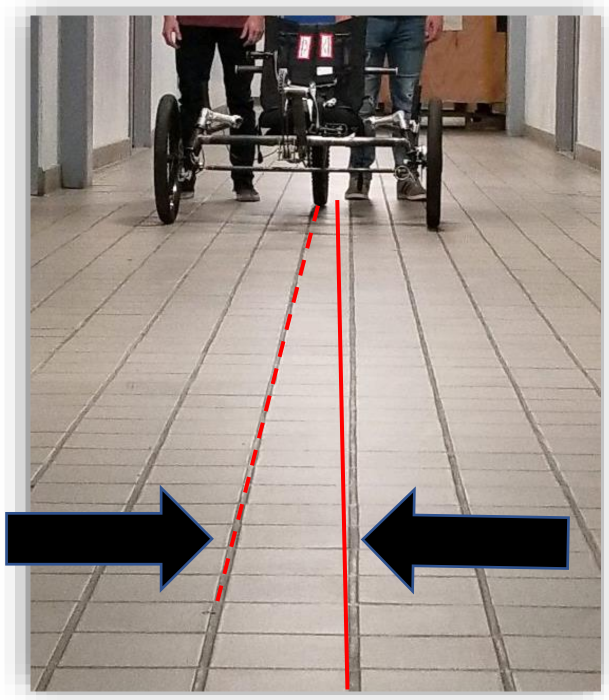
Tyler Schilf

Testing: Stability

Vehicle maintains a straight path with **constant rider input** (**Required by Competition**).

Vehicle continues in relatively straight line for short period **without rider input** **(see below).**

Vehicle deviated 1-foot over 40 ft of travel when pushing it.

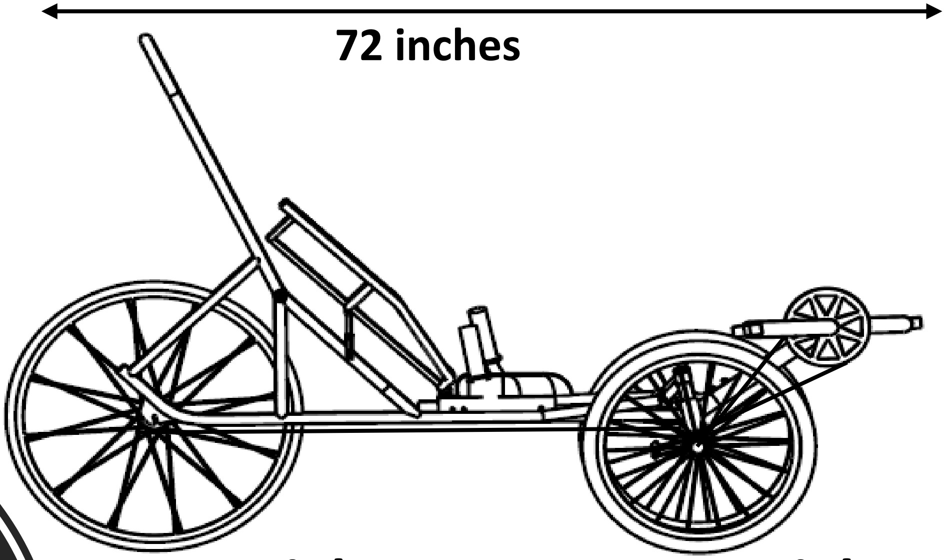


Deviation (dashed)

Centerline Reference (solid)

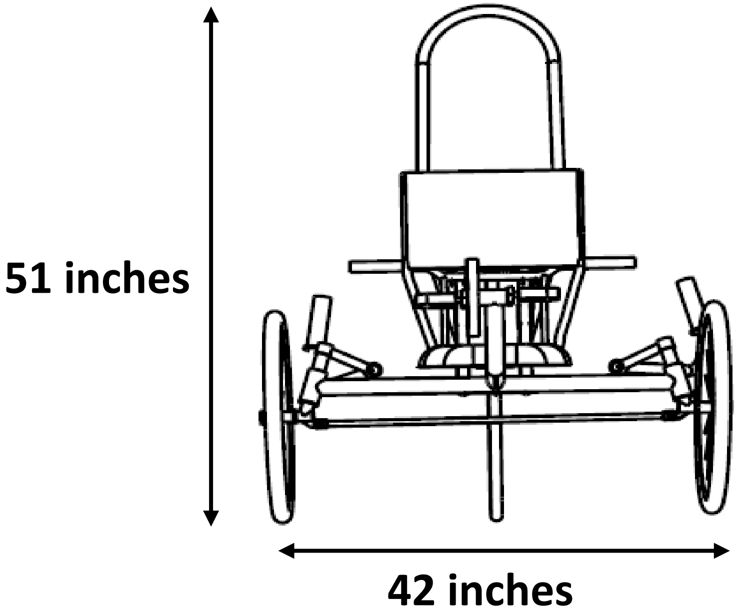
Weight Distribution and Dimensions

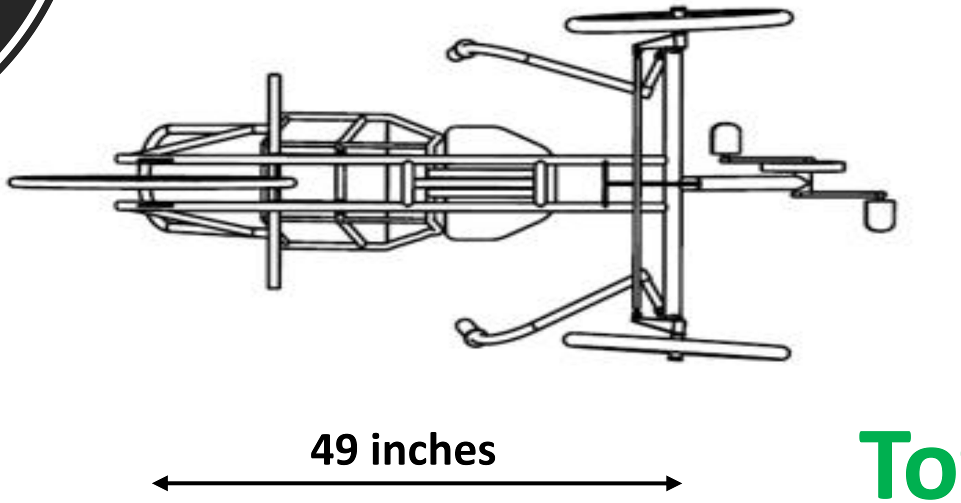
CAD Drawing and Specifications

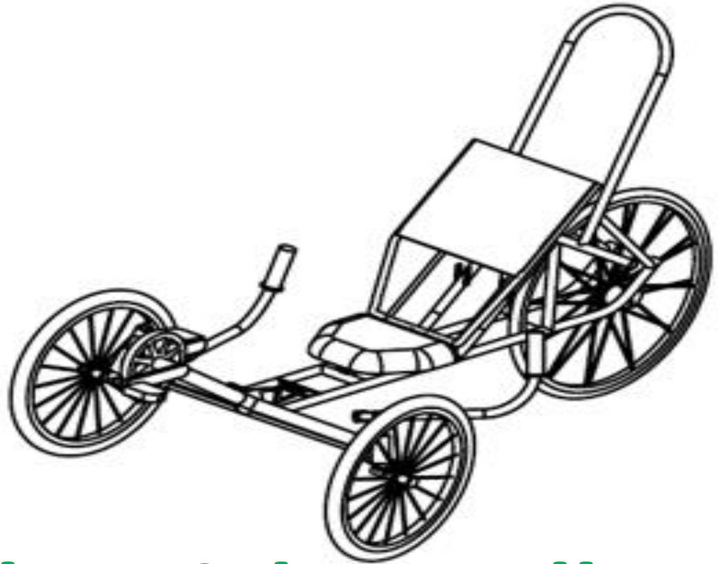


Rear Weight:
30 lbs

Front Weight:
40 lbs







Total Weight: 70 lbs✓

Tyler Schilf

Design Targets

- The Vehicle will turn in a diameter of 6 meters (19.7 feet) at low speed ✓
- Straight path (within 4 feet) is maintained without driver input for 30 meters (98.[illegible] feet) ✓
- Vehicle comes to complete stop in 6 meters (19.7 feet) from a speed of 25 km/hr (15.[illegible] mph) ✓
- Vehicle frame can sustain a top and side load specified in the rulebook (Top: 2670 N Side: [illegible]330 N) ✓
- Rider head and shoulders do NOT contact ground when tipping. ✓
- Vehicle will weigh less than 100 pounds. ✓

Tyler Schilf

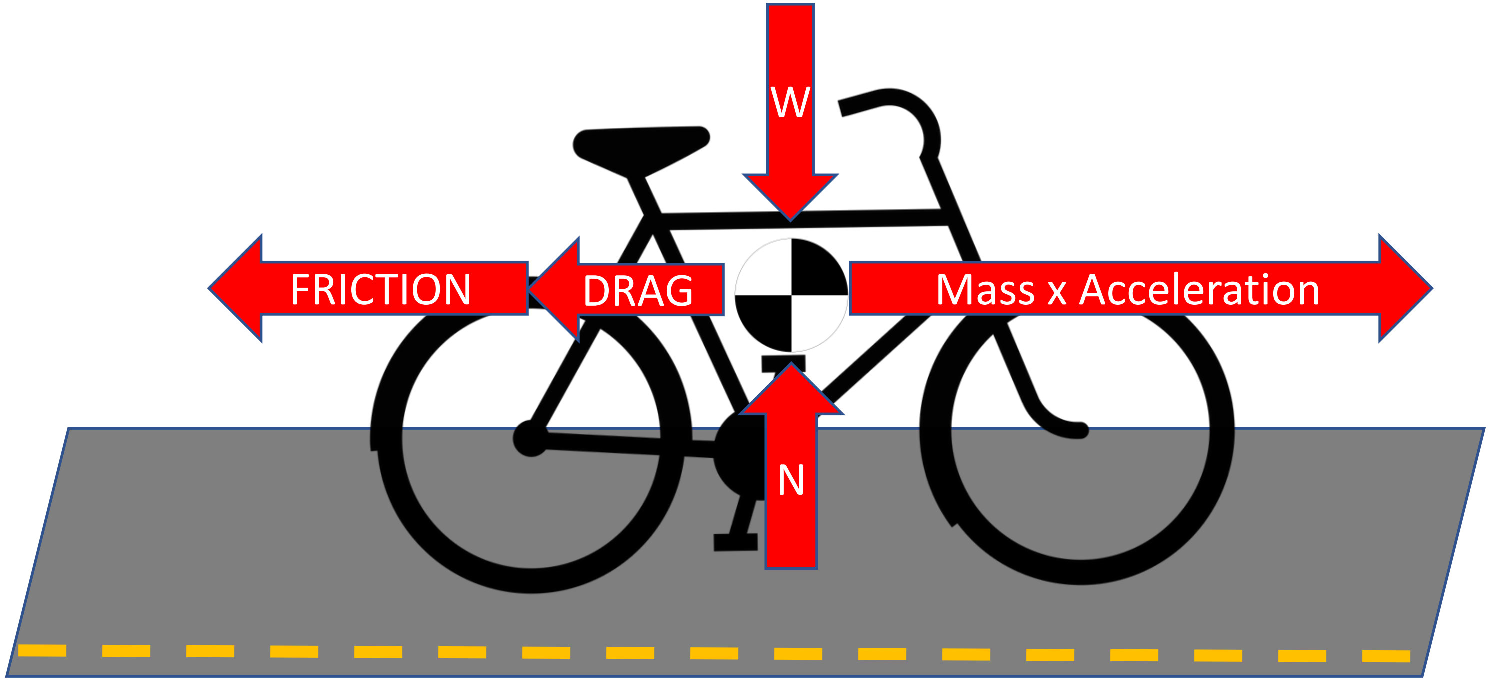
Demonstration Video

Demonstration of the safety and agility of the Human Powered Vehicle.

Performance Testing

Kyler Marchetta

Forces Acting on Vehicle



The forces governing vehicle performance

- Weight (W)
- Inertial Acceleration
- Aerodynamic Drag
- Friction/Rolling Resistance

Dynamic Equation

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

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

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

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

$$Energy = \int_0^t (\underbrace{F_g + F_{fr} + F_a}_{} + F_d) v\,dt$$

Energy to overcome endurance course

Mass appears in these terms

Most sensitive term at high speeds

- The easiest variable to modify to improve performance is MASS
- For our low operating speeds, the most efficient (least expensive) way to increase performance is to reduce mass of the vehicle.

A **performance tracker** will be used to determine the **total energy** required to complete an **endurance course** modeled after the E-Fest competition course.

Performance Tracking

Cost:
500$

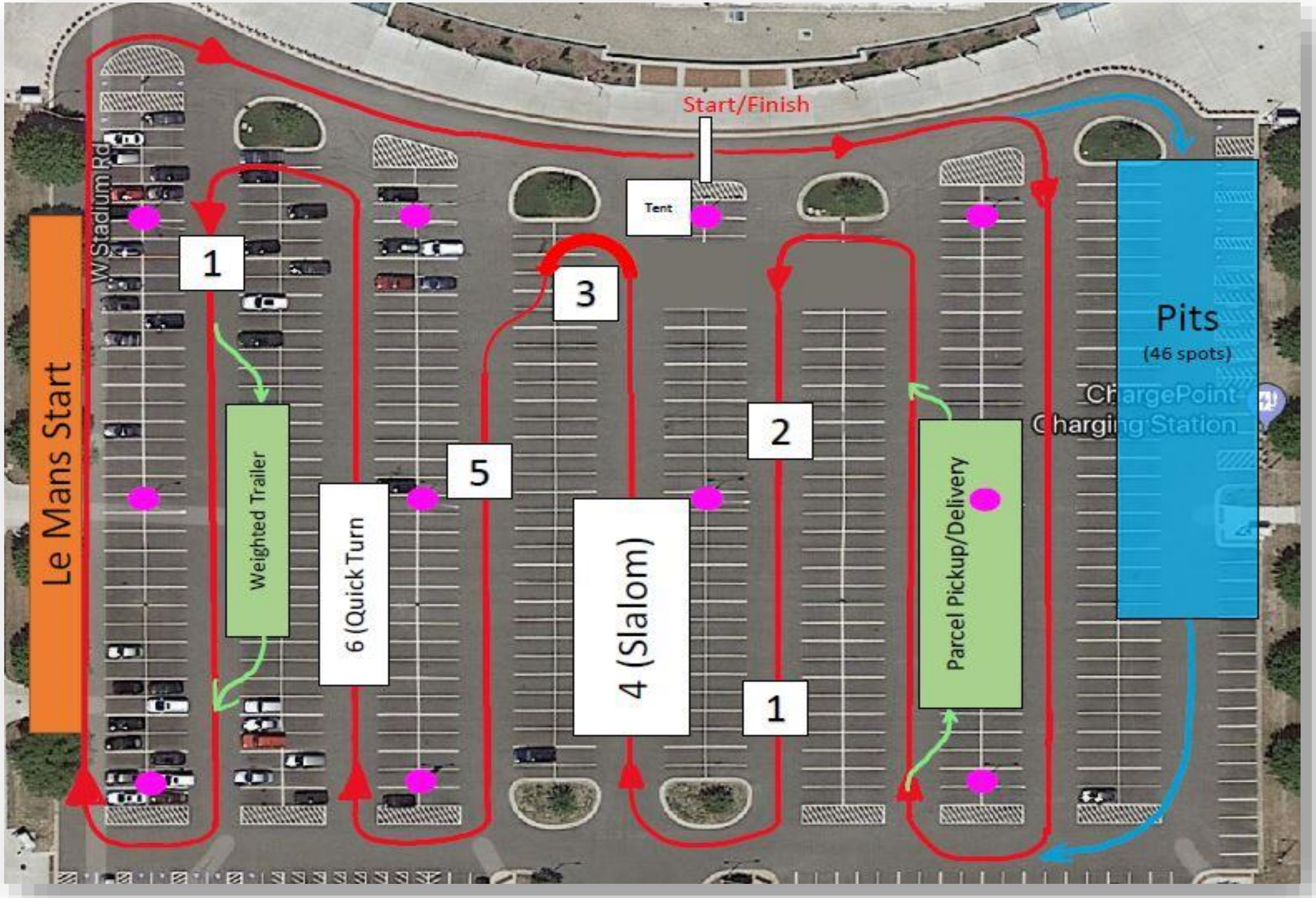
VS.

Includes:
-Position Tracking over time
-Velocity Tracking over time

Cost: Free

The performance tracking device provides higher accuracy and more features.
The App provides the measurements needed (Position/Velocity over time)
The free Track Addict App is the **economical** decision.

2019 Endurance Event Road Map



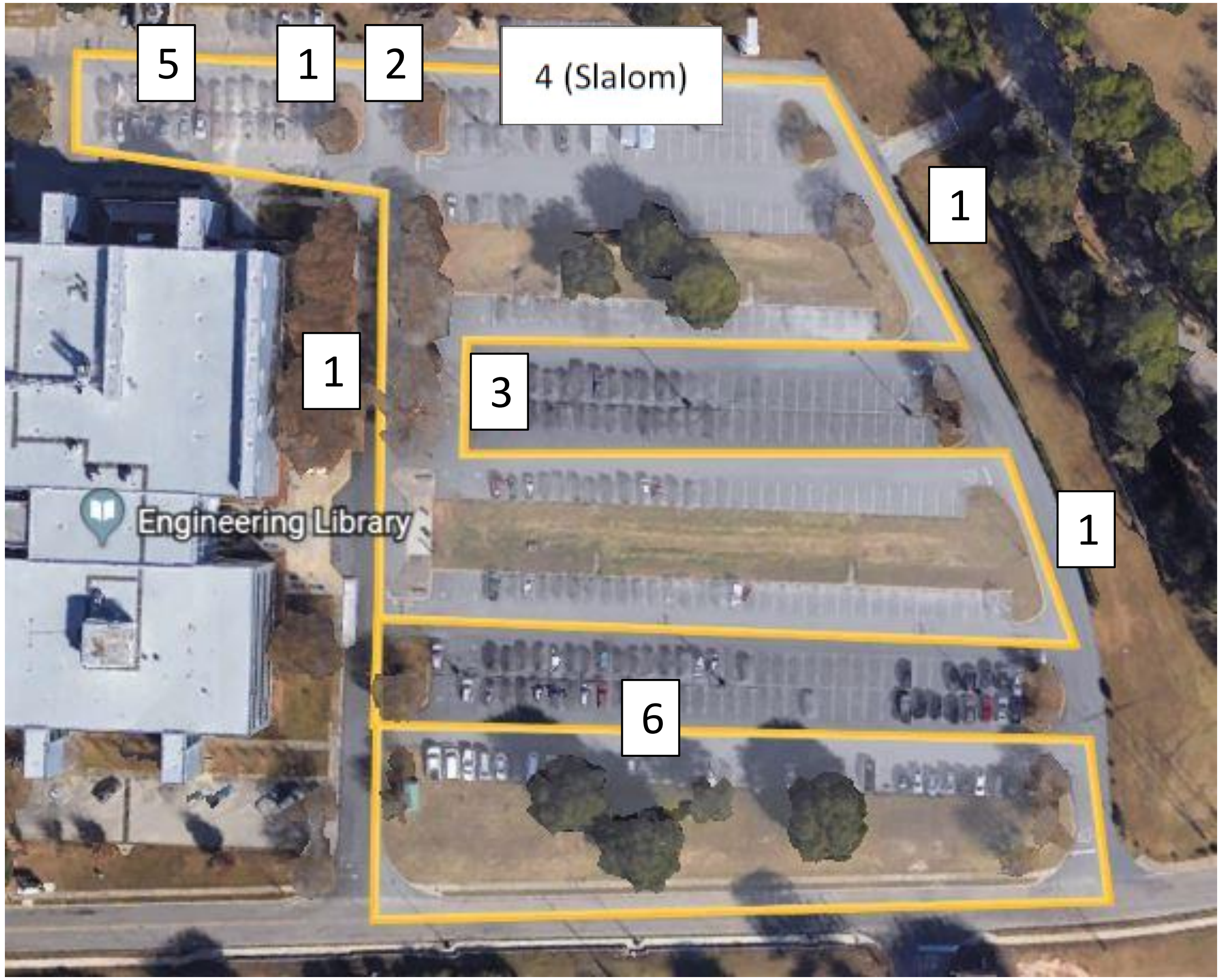
E-Fest Track Configuration

1. Speed bump
2. Stop Sign
3. Hairpin Turn
4. Slalom
5. Rumble Strip
6. Quick Turn

Length: Approximately 1 km

Source: ASME E-Fest competition website

Emulated Endurance Event



Emulated Track Configuration

1. Speed bump
2. Stop Sign
3. Hairpin Turn
4. Slalom
5. Rumble Strip (potholes)
6. Quick Turn

Length: Approximately 1 km

Completion time is compared to competitors and energy expended is determined

Emulated Speed Event

Emulated Track Configuration

A 270-meter distance is mapped.

From rest, the rider accelerates and passes through the finish line.

The time it takes to do this is recorded and compared to competitors

Lessons Learned

The ENTIRE project plan should be made before the build begins.

Purchasing through non-authorized vendors lengthens timeline.

Fixed seat position reduces variability of driver size.

Handlebars should be positioned higher for better grip and better shifter visibility.

References

- Aerodynamic Study of Human Powered Vehicles: https://ac.els-cdn.com/S1877705812016165/1-s2.0-S1877705812016165-main.pdf?_tid=daac4209-90f5-4878-9176-a18baa6dadc1&acdnat=1547847236_78f40660873caa2ae4a6ed0ec6a50d1b
- Aerodynamic Fundamentals for Automotive, Ford Automotive Company: http://www.saea.com.au/resources/Documents/aero101-SAE-A-Seminar.pdf
- Greenspeed Trikes: http://greenspeed-trikes.com/
- Santa Clara University Human Powered Vehicle: https://scholarcommons.scu.edu/cgi/viewcontent.cgi?article=1021&context=mech_senior
- Cheap Bike vs Super Bike: https://www.youtube.com/watch?v=Wdb7KEc7xJI&list=LL8mdyMy93IR5PiSDrSbkjUw&index=62&t=565s
- Recumbent Position Power loss

Questions?

Systems Engineer/
Project Manager

**Tyler
Schilf**

Steering Engineer

**Tristan
Enriquez**

Powertrain Engineer

**Jacob
Thomas**

Ergonomics Engineer

**Kyler
Marchetta**