HPVC
FALL '22

Team 7: Darren Aguilar, Daniel Jang, Anisha Jayasekara, David Lozano, Sophia Shannon

PROBLEM DEFINITION

- Design, assemble and test an electric recumbent bike for and endurance race

RACE

- 2.5 hour relay
- 1.5km laps
- Patches of rough pavement
- 5% grade uphill, 7% grade downhill
- Cargo parcel
- Hairpin turns & Slalom sections

SAFETY

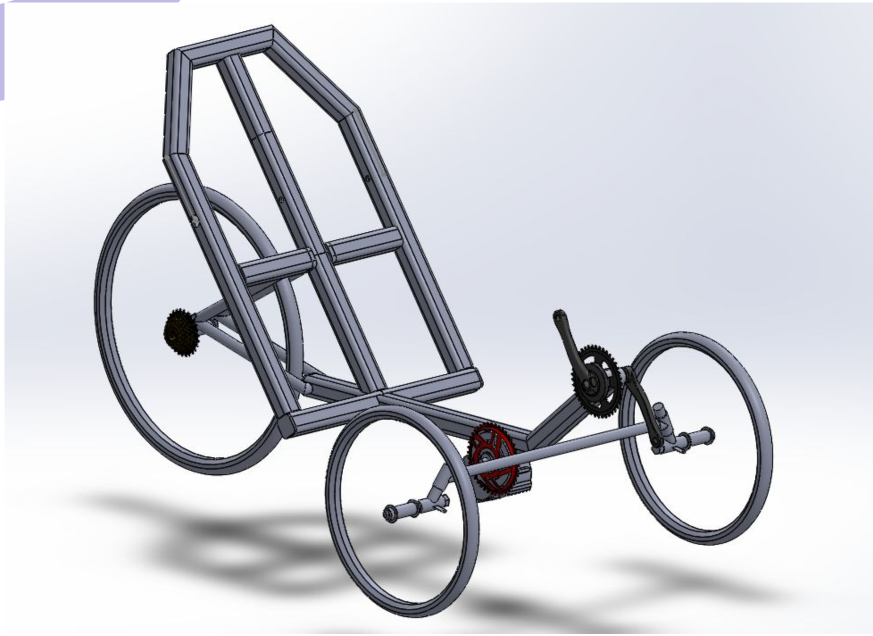
- 25km/hr to 0 within 6m
- 8m turning radius
- Brakes for each front wheel
- Rollover system with 2670N top load, 1330N side load

ELECTRICAL

- One electric motor (500W maximum rating)
- 10 Ah capacity battery
- Battery isolated from driver
- Fireproof

Presentor(s): David Lozano

Current Design Decisions



- Front tadpole wheelbase
- Complex chain drive with mid-drive electric motor
- Hexagonal rollover-protection
- Aluminum 6061 square tubing
- Disc Brakes
- Track-rod steering

Presentor(s): David Lozano

01. STATIC SUBSYSTEM

Keep the rider safe and comfortable

Bike Elements

01. Front

Steering
Breaking
Drivetrain

02. Back

RPB
Rear Wheel
Seat

Stable
Can't tip over

Ergonomic
Riders must be comfortable

Safe
Must keep rider safe

Presentors: Darren

Tubing

	Outer Diameter (in)	Wall Thickness (in)	Cost/in	Rank	Max stress (N/mm^2)	Rank	Max displacement(mm)	Rank	Max strain	Rank	Weight/in	Rank (weight	Mount-ability
	1	0.125	$0.57	1	4.322E+07	17	1.563E-01	17	5.038E-04	17	0.405	1	17
C	1.25	0.125	$1.38	5	2.435E+07	15	8.087E-02	15	3.099E-04	15	0.52	2	16
I	1.5	0.125	$2.20	14	1.674E+07	13	4.913E-02	12	2.064E-04	13	0.635	4	14
R	1.75	0.125	$2.62	16	1.289E+07	10	3.333E-02	7	1.491E-04	10	0.75	6	13
C	2	0.125	$1.57	8	9.258E+06	5	2.435E-02	5	1.124E-04	6	0.866	8	11
U	2.5	0.125	$1.88	11	1.337E+06	2	3.408E-03	2	1.607E-05	2	1.096	10	7
L	3	0.125	$1.47	7	9.650E+05	1	2.422E-03	1	1.152E-05	1	1.33	13	6
A	1.5	0.25	$1.72	9	1.105E+07	7	2.980E-02	6	1.316E-04	8	1.156	12	12
R	1.75	0.25	$1.89	12	8.201E+06	4	1.939E-02	4	8.895E-05	4	1.39	14	10
	2	0.25	$2.70	17	6.035E+06	3	1.373E-02	3	7.209E-05	3	1.617	16	8
S	1	0.125	$0.79	2	3.13E+07	16	9.92E-02	16	3.11E-04	16	0.526	3	15
Q	1.25	0.125	$1.02	3	2.07E+07	14	5.59E-02	13	2.27E-04	14	0.654	5	9
U	1.5	0.125	$1.12	4	1.45E+07	11	3.94E-02	10	1.50E-04	11	0.809	7	5
A	1.75	0.125	$1.76	10	1.13E+07	8	3.41E-02	8	1.35E-04	9	0.956	9	4
R	2	0.125	$1.40	6	1.05E+07	6	3.43E-02	9	1.00E-04	5	1.102	11	3
E	2.5	0.125	$2.03	13	1.20E+07	9	4.64E-02	11	1.24E-04	7	1.426	15	2
	3	0.125	$2.44	15	1.45E+07	12	7.08E-02	14	1.57E-04	12	1.691	17	1

* This is a generalized chart

Main Frame #1 Mountability → Square Tubing

RPB #1 Weight → FEA on Square v. Circular

Rear Forks #1 Affordability → Use rear forks from salvaged bikes

Presentor: Sophia

Tadpole

Courtesy of HPVC - UW Madison

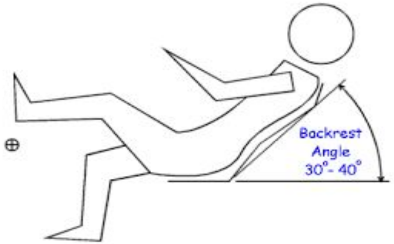
Courtesy of RAD Innovations

- 500m or 60sec penalty if tips over
- Must exit vehicle within 15sec without assistance

Presentor: Darren

Seat

	Cushion 	Hardshell 
Comfortable	●●●	●
Price	●●	●●
Stability	●●	●●●



Courtesy of Jetrike

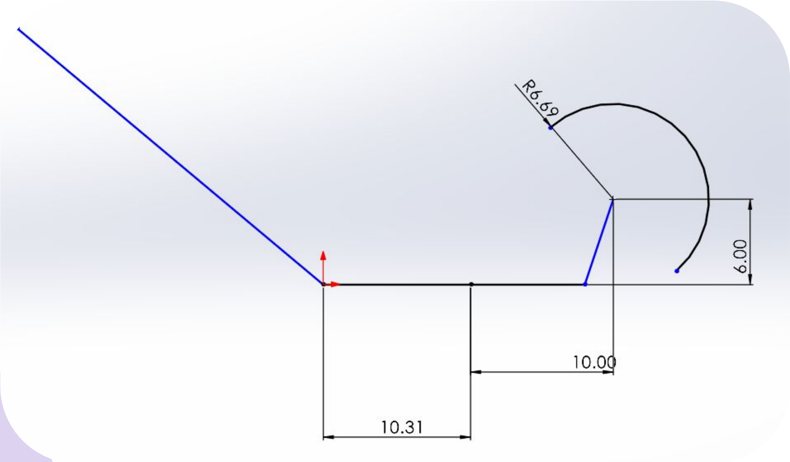
OUR SEAT: VELODREAMER

- Cushion
- Freedom to adjust angle
- Under budget ($150)

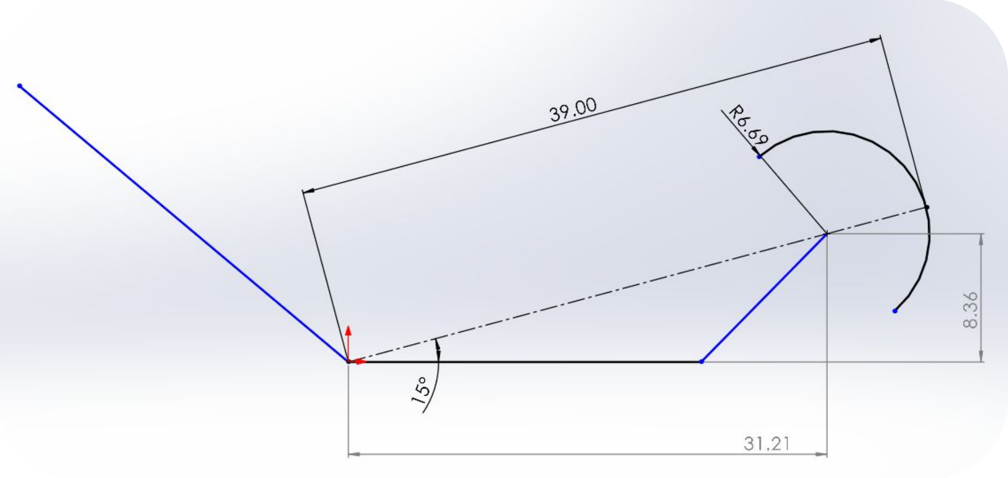
Presentor: Darren

Crankshaft Placement

Original: Based off Jetrike Ratios



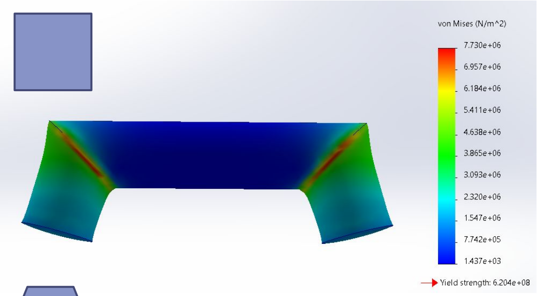
Updated: Based off our rider leg length & Design of Human-Powered Vehicles by March Archibald

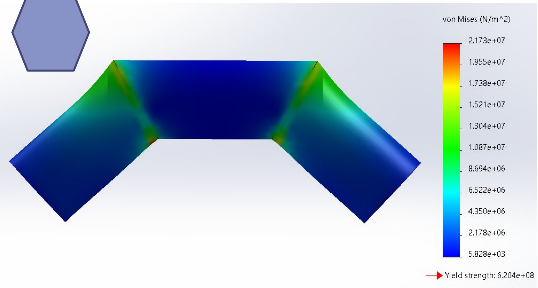


Presentor: Sophia

RPS FRAME SHAPE

Rating: 1-4 (worst to best)





equal: height, length, applied load(2670N), cross-sectional area

		Concepts							
		Triangular		Circular		Square		Hexagonal	
Selection Criteria	Weight (%)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Weld-able & Prototype-able	50%	1	50	2	100	4	200	4	200
Rollover (minimal points of stress)	25%	1	25	4	100	2	50	3	75
Support top load (2670N)	25%	4	100	1	25	2	50	3	75
Total	100%	6	175	7	225	8	300	10	350
Continue?		No		No		No		Proceed	

Presentor: Sophia

02. DYNAMIC SUBSYSTEM

Control and drive the bike efficiently

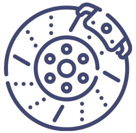
Presentor(s): David Lanzo

Presentor(s): David Lozano, Anisha Jayasekara, and Daniel Jang

MAJOR COMPONENTS

Drivetrain System

Design an efficient drivetrain that can adjust gearing for uphill/downhill riding and reach 30 mph



Braking System

Create a braking system that can go from 25 km/hr to 0 km/hr within 6 m.

Steering System

Construct steering system with maximum turning radius within 8 m and drive straight for 30m at speeds of 5~8 km/hr

Drivetrain Configuration

Rear

8-Speed Flywheel Cassette
11-32T

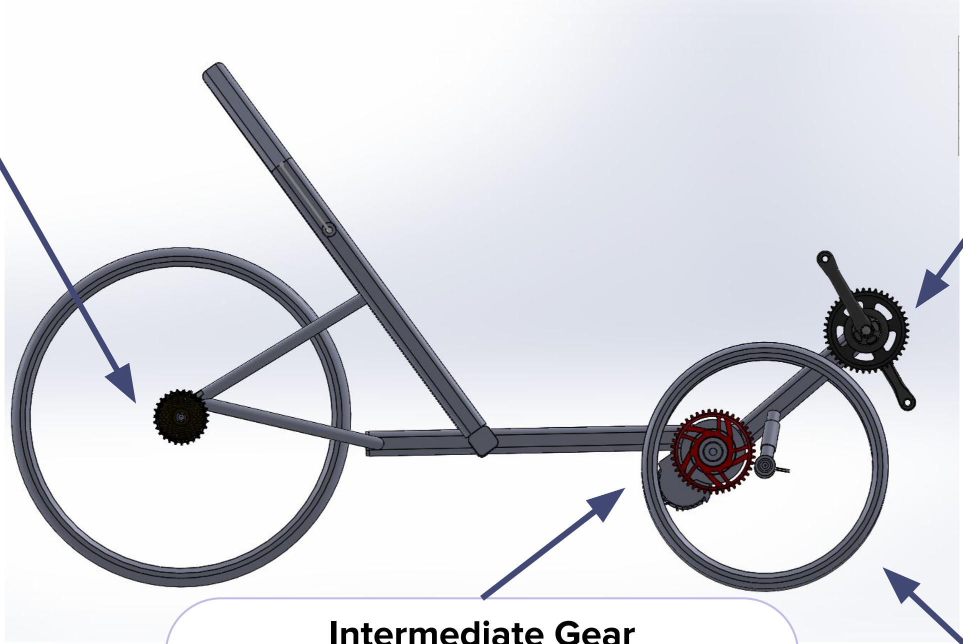
700C Wheel

Hardware

Chain Drive

Motor and crankset on 68mm bottom brackets and shells

Derailleurs on crankset and cassette



Crank

3-Speed Crankset
42-34-24T

170mm Crank Arm

Front Wheels

20” Wheels with Disc Brake Mounts

Intermediate Gear

Bafang BBS02 500W Mid-Drive Electric Motor w/ two Chainrings

30T input/38T output
Gear Ratio = 1.2667

Presentor(s): David Lozano

Drivetrain Verification

Using Chosen Components

$$G_D = \frac{N_{chainring}}{N_{freewheel}} * \frac{N_{mid-output}}{N_{mid-input}} * D_{drive\ wheel} * \pi$$

- 2.0-2.5m development for 5% uphill grades
- 8m> development for speed and 7% downhill grades

GEAR DEVELOPMENT TABLE

# of cassette teeth

# of crank teeth	32	28	24	21	18	15	13	11
	Development in meters							
24	2.0	2.3	2.8	3.2	3.7	4.3	5.1	6.0
34	2.9	3.3	3.9	4.4	5.2	6.2	7.1	8.5
42	3.5	4.1	4.8	5.4	6.3	7.6	8.9	10.4

Speed @ max development and 100 RPM = *38.9 mph*

Presentor(s): David Lozano

BRAKING SYSTEM: MECHANICAL DISC BRAKES

	Power Rating	Durability	Brake Calipers	Disc Brake Rotor	Total Price (minus rotors)
B-type (Wide, Resin): **B03S** ($16)	4/5	5/5	BR-M375 ($25.98)	180 mm (M) 160 mm (S)	**$41.98**
			BR-TX805 ($18.99)	180 mm (M) 160 mm (S)	**$34.99**
G-type (Narrow, Resin): **G03S** ($18.99)	4/5	5/5	BR-TX805 ($66)	160 mm (S) 140 mm (SS)	**$84.99**
K-type (Narrow, Resin): **K03S** ($12)	4/5	5/5	BR-RS305 ($65)	160 mm (S) 140 mm (SS)	**$77**

Presentor(s): Anisha Jayasekara

STEERING MECHANISM SELECTION

Track Rod Steering

- Less variables to control
- Cost-effective
- Stable, but potential avenues of bump steer

Six-bar Steering Mechanism

- Five variables to control
- Potential budget sink
- Greater stability and range of motion

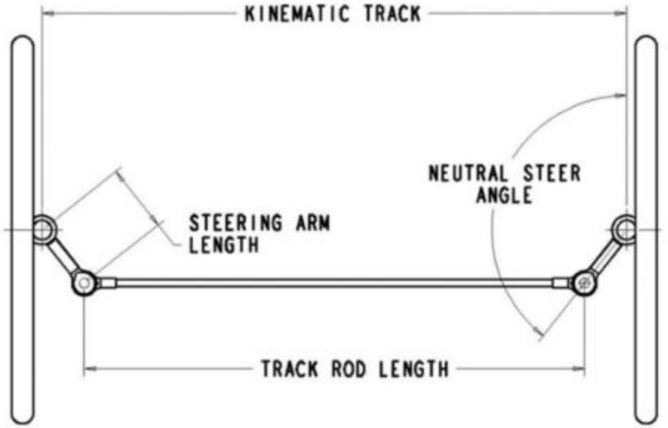


Figure 11-5 Track rod steering parameters

Courtesy of Mark Archibald. *Design of Human Powered Vehicles*

Presentor(s): Daniel Jang

DIRECT VS. INDIRECT STEERING

Direct Steering

Indirect Steering

Direct	Indirect
"Grounded"	"Weightless"
Similar effort as bike steering	Noticeably less effort to steer
Handlebars attached to wheels	Tie rods attached to wheels
Horizontal or vertical handlebars	Vertical handlebars

Courtesy of Laid Back Cycles

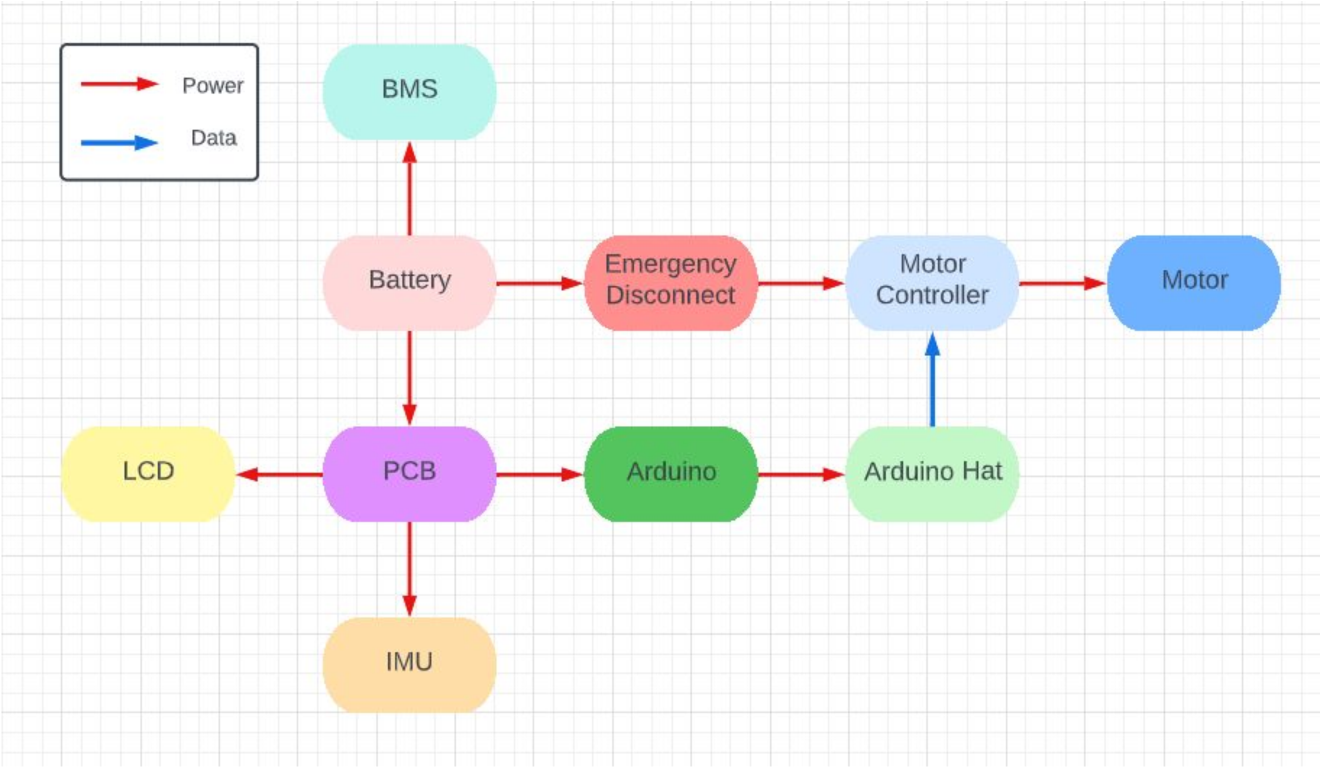
Presentor(s): Daniel Jang

WHEEL ANGLES

	Cost	Stability
(-) Camber		
(+) Castor		
Kingpin	Necessary	Necessary

Presentor(s): Daniel Jang

Electrical System Breakdown



Concerns

Bike Frame Design:
Continue FEA to determine the best tube size for the frame, apply mounts for seat & harness

Drivetrain:
Optimize mounting point for the motor to avoid interference with the seat, determine front derailleur mounting solution (braze-on or clamp)

Brakes:
Finalize the rotor selection and determine whether to use one brake lever versus two independent levers

Steering:
Find optimal placement of tie rods and connection points

Presentor(s): Daniel Jang, Anisha Jayasekara, David Lozano, and Sophia Shannon

Future Recommendations

- Utilize flow chart to improve workflow
- Keep better documentation of project additions and changes

Winter Quarter Outlook

- Optimize design
- Finalize hardware choices
- Assemble bike

Presentor(s): David Lozano

THANK YOU

Questions?

References

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https://grabcad.com/library/hpvc-2021-design-with-fairing-1

ASME Human Powered Vehicle Competition 2023 Rulebook

Design of Human Powered Vehicle by Mark Archibald