HPV Child Size Exhibition

TEAM #21SPR06 – ASME HPV

ABEL ALDAPE

PRESTON BERCHTOLD

MARTIN DORANTES

TRENT TODD

Project Description

Figure 1: Client - Perry Wood

1. Project based on ASME Human Powered Vehicle
    - Project transitioned to Child Size HPV
2. New Goals and Criteria for Child Size HPV
    - To inspire
    - To educate
    - Lower Speeds
    - Higher Safety Factor

Figure 2 - NAU 2014 HPV [1]

Figure 3 - Queensland Recumbent Gekko FXS [2]

Prototype

- PVC frame
- Applied heat to bend frame for roll cage/spine
- Going Forward

Figure 4 - HPV Prototype

Design Description

- Tadpole Trike
- 6061 Aluminum
- Adjustable Seat Bracket
- Ackerman Steering
- 4-point roll cage
- Chain Drive System
- 3-wheel braking system

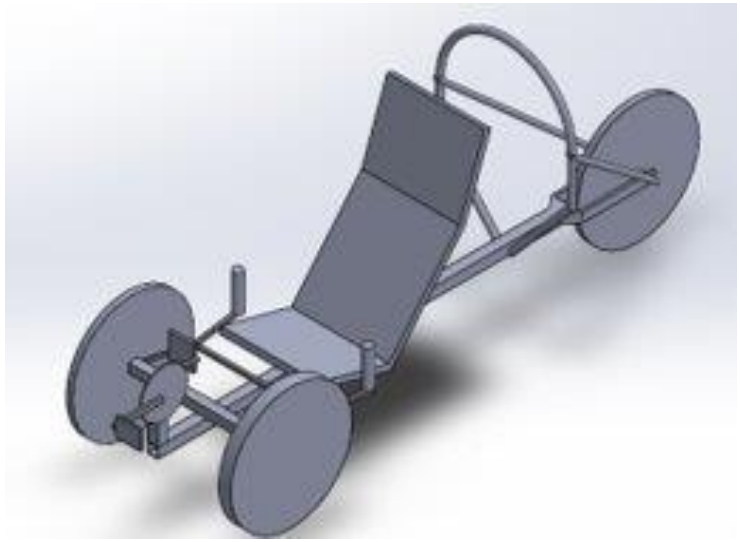


Figure 5 – First CAD Design

Figure 6 - Current Steering CAD [5]

Design Description

Functionality

- Roll Cage
  - Safety
- Seat Bracket
  - Adjustability
- Drive Train
  - Provides motion
- Steering
  - Control over motion

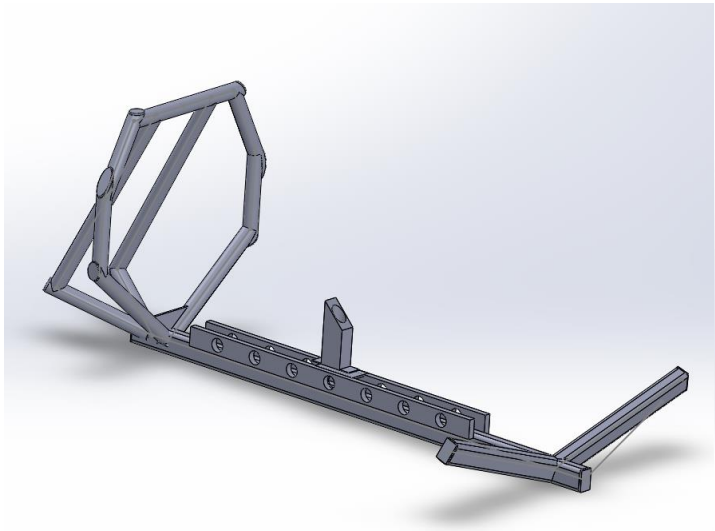


Figure 7 – Current Seat Brack Design

Figure 8 - Current Steering Cad [5]

Design Requirements

Table 1 - Customer requirements

1	Safety
2	Stability
3	Operation age (5-13 years of age)
4	Educational
5	Ease of operation
6	Transportable
7	Rollover protection
8	Manufacturability

Roll cage & seat belt implementation

Recumbent & tadpole design

Fits for average heights of various children

Traits to educate children of engineering concepts

Limited actuating systems to optimize operation ability

Ideal volume to fit in bed of truck

4-point roll cage with double bent spine

Material selection for ease of manufacturability

Design Requirements

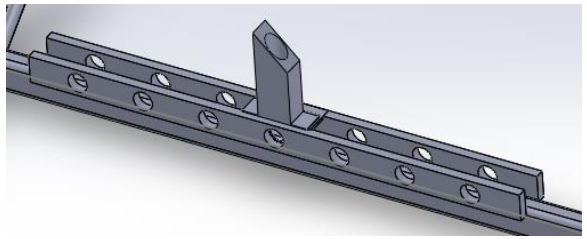


Figure 9- Adjustable Seat Bracket

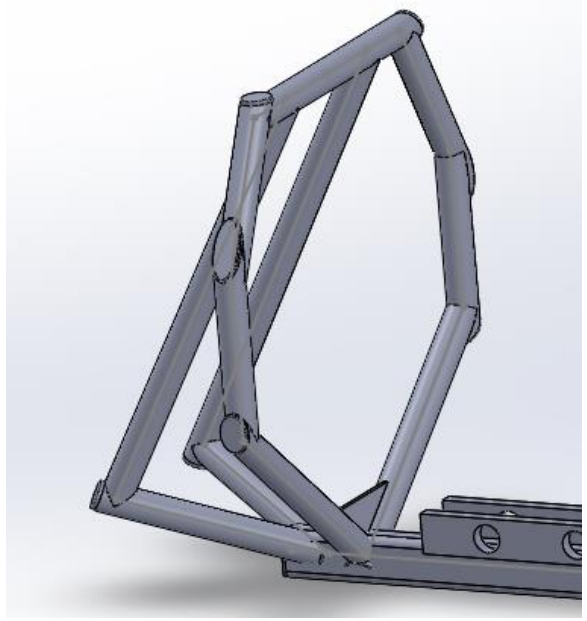


Figure 10 - Roll Cage

Figure 11 - Current Steering CAD [5]

Design Requirements

Bending Calculations

Moment Diagram

$$\sigma_{max} = \frac{Mc}{I}$$

$$I = \frac{bd^3 - hk^3}{12}$$

Braking Calculations

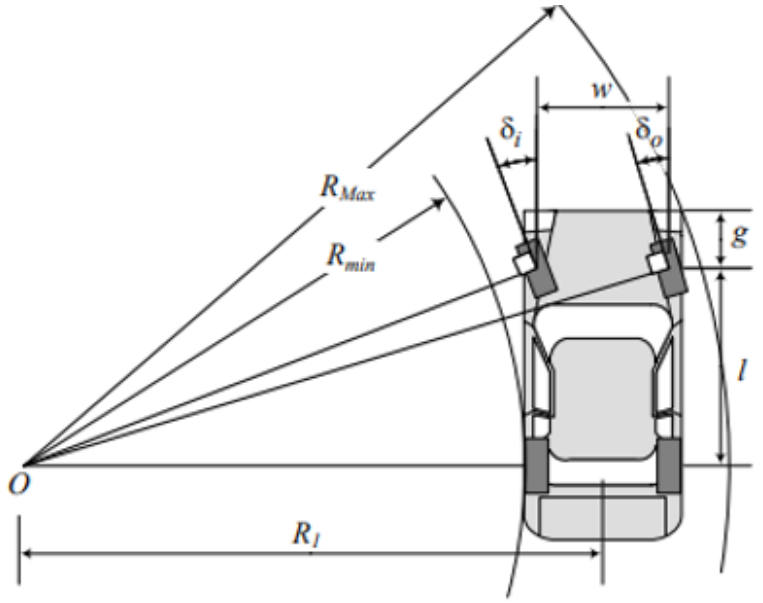
$$v_f^2 = v_i^2 + 2ad$$

$$a = \frac{-v_i^2}{2d}$$

$$F_{bi} = m_{total}a$$

$$F_{br} = F_{bi}\frac{r_{wheel}}{r_{rotor}}$$

Ackerman Steering Calculations



$$R_{Max} = \sqrt{(R_{min} + w)^2 + (l + g)^2}$$

$$R_{min} = R_1 - (w/2) = (l/\tan\delta_i) = (l/\tan\delta_o) - w$$

Figure 12 – Turning radius [3]

Table 2 - Design Requirements

Allowable Bending Stress (MPA)	Actual Bending Stress (MPA)	Acceleration, a (m/s^2)	Net Stopping Force, F_{bi} (N)	Brake Force, F_{br} (N)	Min. Turning Radius (m)	Max. Turning radius (m
110	51.8	-1.929	210	828.8	1.6	2.64

Design Validation - FMEA

Table 3 – Potential Failures/Mitigation

Critical Potential Failures	Mitigation
Handlebar/stem failure when loaded by steering	Reinforcement along joints
Joint cracks	Joint reinforcement (fillets)
Snapped chain	Maintain oil, keep spare on HPV, keep derailleurs aligned
Wear on brake pads	Maintain brake pads and control cables regularly
Brake levers	Tadpole design = brake levers are behind wheels
Head tube	Fillet reinforcement
Pedals/crank arm	Recumbent design = not all weight loaded on pedals Hip angle implementation Material properties/finishes on material to expand cycle life
Seat/seat post	Recumbent design = no seat post
Fork leg	Material properties/finishes

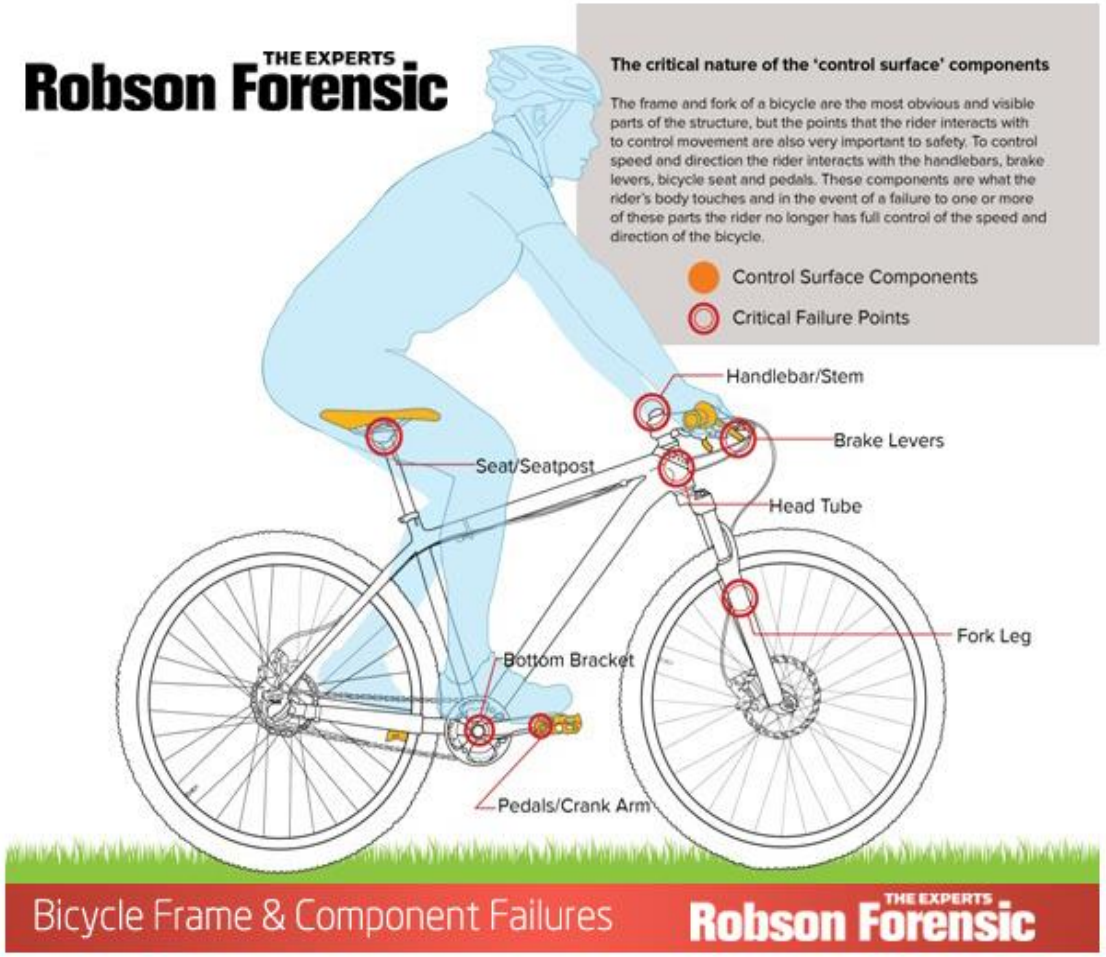


Figure 13 - Common bike frame failures [6]

Design Validation ctd.

Testing procedures to follow for 486C

- Test braking distance from various speeds to ensure 8m safe & steady stop is completed
- Ensure different sized children can fit in HPV
- Tip-over angle test
- Trials & steering course to test maneuverability
- Intentionally try to roll HPV to test roll cage durability

Equipment & resources needed

- Orange cones for maneuverability
- Machine shop parking lot/south commuter
- Perry Wood to supervise all tests
- Test on sunny, windy, rainy, and/or snowy days
- Helmet and body pads

Table 4 - Engineering Requirements

BRAKING DISTANCE (WITHIN 8 m)	Center of mass (within 1 m from ground)
LIMIT ACTUATING SYSTEMS	Gear ratio (3:1 or 4:1 typically seen in bicycles)
MINIMUM OF 3 WHEELS	Turn radius (within 8 m)
SEAT-TO-PEDAL DISTANCE (50 cm ADJUSTABILITY RANGE)	Tensile strength (250-560MPa)
VOLUME (NO MORE THAN 5.2 m^3)	Weight (no more than 45 kg)

Table 5 – Budget estimation

Subsection	Estimated cost
Frame	$400.00
Drivetrain	$600.00
Wheels	$300.00
Brakes	$100.00
Seat	$125.00
Steering	$500.00
Additional hardware	$300.00
Misc.	$500.00
Total =	**$2,825**

Budget

- The team has currently spent $42.06
- Budget is based off estimated bill of materials and previous HPVC teams
- Exact budget has not been given

Future Schedule

Table 6 – Future schedule for 486C

TASK	START	END
Capstone 1		
Final Presentation	19-Mar-21	2-April-21
Final Proposal	25-Mar-21	2-Apr-21
Individual Analytical Assignment	2-Apr-21	16-Apr-21
Final Bill of Materials/CAD	2-Apr-21	9-Apr-21
Final Prototype	2-Apr-21	26-Apr-21
Team Goals		
Frame Finalized	6-Sep-21	15-Sep-21
Functional Braking System	15-Sep-21	20-Sep-21
Functional Drive Train	15-Sep-21	27-Sep-21
Functional Steering	15-Sep-21	3-Oct-21
Capstone 2		
Post Mortem	16-Aug-21	22-Aug-21
Machine Shop Training	23-Aug-21	29-Aug-21
Finalize CAD and Begin Manufacturing	30-Aug-21	5-Sep-21
Finalize Manufacturing	6-Sep-21	3-Oct-21
Midpoint Presentation	4-Oct-21	10-Oct-21
Testing Procedures Outline	11-Oct-21	17-Oct-21
Device Summaries and Reports	18-Oct-21	24-Oct-21
Testing Device	24-Oct-21	7-Nov-21
Manual Report	8-Nov-21	14-Nov-21
Final Presentation, Report, and CAD	15-Nov-21	28-Nov-21

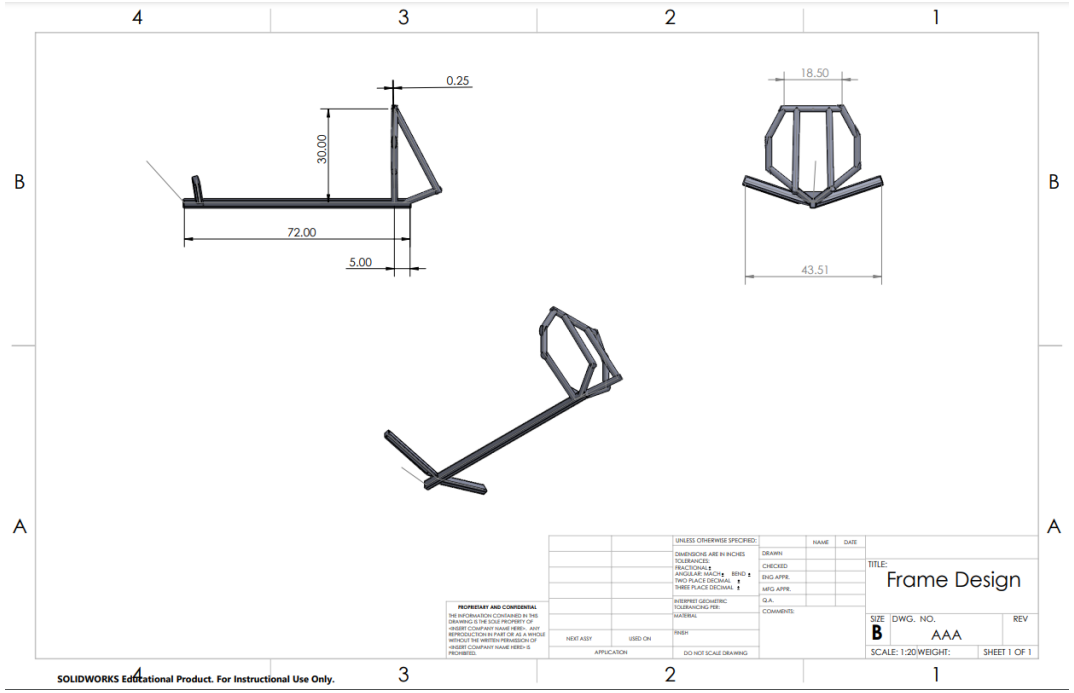
- Summer schedule is unknown
- Teams is mostly on track, slightly behind on CAD design and analyses

Table 7 – Roles for each team member

Member	Roles
Abel	Team manager and design
Trent	Manufacturing and design lead
Preston	Financial and scheduling lead
Martin	Communication, testing, and website lead

Conclusion

- Quickly rebuild CAD models
- Purchasing Materials and Parts
- Training machining and Assembly



Questions?

References

[1]	A. Hawley, M. Gerlich, P. Kinsley, H. Kutz, and K. Montoya, *NAU HPVC*, 2014. [Online]. Available: https://www.ceias.nau.edu/capstone/projects/ME/2014/HumanPoweredVehicle/capstone.html. [Accessed: 21-Feb-2021].
[2]	Q. Recumbent, "Recumbent Trikes Perfect for Kids," *Recumbent Co*, 2020. [Online]. Available: https://recumbent.co/recumbent-trikes-perfect-for-kids/. [Accessed: 21-Feb-2021].
[3]	Reza N. Jazar Vehicle Dynamics: Theory and Applications Springer 2008
[4]	R. Hibbeler, Mechanics of Materials, Upper Saddle RIver: PEARSON, 2012.
[5]	Endeshaw, M. (2018). Free CAD Designs, files & 3D models: THE GrabCAD community library. Retrieved March 24, 2021, from https://grabcad.com/library/20-inch-bicycle-wheel-2
[6]	Person, "Bicycle Frame & Component Failures – Expert Article," *Robson Forensic*, 26-Feb-2020. [Online]. Available: https://www.robsonforensic.com/articles/bicycle-frame-component-failures-expert-article/. [Accessed: 20-Mar-2021].

Appendix

Table 8 – Parts & Expenses

Part List			sum =	$2,760.27	
art / Expense	comments	Cost Per un	qauntit	Projected	source
75" OD Aluminum Round Tube 6061-T6-	8ft sticks (.29lb/ ft)	11.28	3	$33.84	https://wv
" x 1.5" x 0.125" Aluminum Rectangle	8ft sticks (.67lb/ ft)	31.93	1	$31.93	https://wv
Wheels + Tires		$100	3	$300.00	
Pieces Bike Brakes Calipers	2 front brakes (incluc	$22.99	1	$22.99	https://wv
ke Disc Brake Kit, Aluminum Front and Re	2 rear brake	$36.99	1	$36.99	https://wv
x 2' 0.1' 6061 T6 plate	2.84 lb		1	$34.52	https://wv
eering system + spindles				$500.00	
eat		$125.00	1	$125.00	https://wv
erailleur		100	1	$100.00	
roupset (Rear Der, Trigger Shifter W Clam	needs additional par	375	1	$375.00	https://wv
isc drive train		200	1	$200.00	

Part List			sum =	$2,760.27	
Part / Expense	**comments**	**Cost Per un**	**qauntit**	**Projected**	**source**
0.75" OD Aluminum Round Tube 6061-T6-	8ft sticks (.29lb/ ft)	11.28	3	$33.84	https://wv
1" x 1.5" x 0.125" Aluminum Rectangle	8ft sticks (.67lb/ ft)	31.93	1	$31.93	https://wv
Wheels + Tires		$100	3	$300.00	
6 Pieces Bike Brakes Calipers	2 front brakes (incluc	$22.99	1	$22.99	https://wv
Bike Disc Brake Kit, Aluminum Front and Re	2 rear brake	$36.99	1	$36.99	https://wv
1' x 2' 0.1' 6061 T6 plate	2.84 lb		1	$34.52	https://wv
Steering system + spindles				$500.00	
Seat		$125.00	1	$125.00	https://wv
Derailleur		100	1	$100.00	
Groupset (Rear Der, Trigger Shifter W Clam	needs additional par	375	1	$375.00	https://wv
Misc drive train		200	1	$200.00	
Misc harware/ parts/ 3d printing		500	1	$500.00	
Misc labor/ shipping/ prototyping/ testing		500	1	$500.00	