NFPA

Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
Team 0 Chainz
Advisor: Dr. Jim Widmann
April 20, 2017

0 Chainz

Mechanical Engineering
CAL POLY

Team Introduction

Advisors: Dr. James Widmann, George Leone

Agenda

- ✔ Team Introductions
- Problem Statement
- Project Objectives
- Final Design
- Testing Results
- Cost Analysis
- Lessons Learned
- Conclusions

Problem Statement

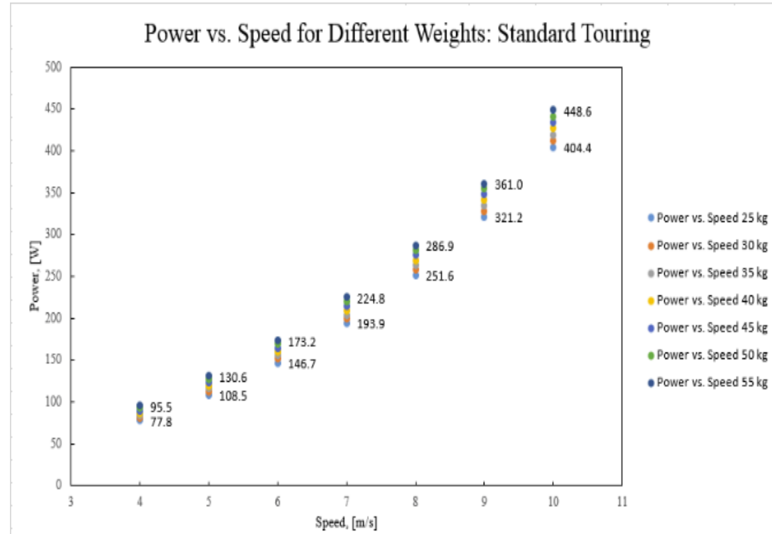
- *The purpose of our project is to design and manufacture a human-powered, hydraulically driven vehicle and outperform the previous Cal Poly entries in all sub-competitions.*

Project Objectives

- Low Cost – limit spending to below $7,500
- Quickness – sub 29 second sprint time
- Efficiency – at least 10% more efficient compared to previous year’s entry
- Aesthetic – streamlined hydraulic components, circuit, and finish
- UI / UX – implement an electromechanical control system for innovation and improved ergonomics, control

Final Design- Geometry

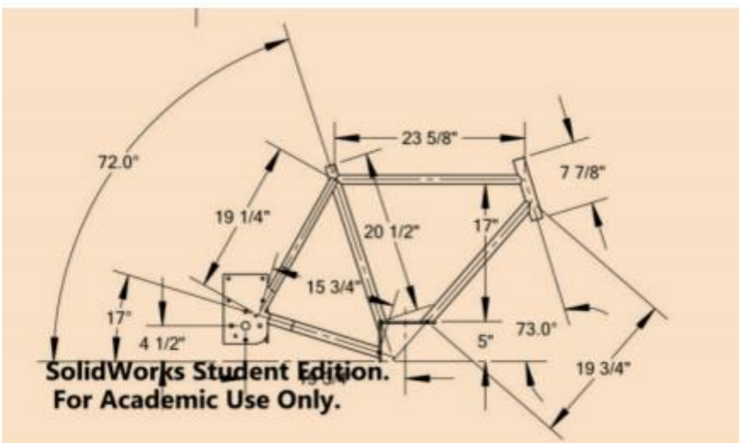
- Upright design selected
- Weight not as important as first thought



Concept	Criteria / Weight/100	Rideability	Manufacturability	Aesthetics	Weight	Aerodynamics	Production Time	Production Costs	Drivetrain Efficiency	Overall Satisfaction
		20	10	5	15	15	10	5	20	100
Current	Raw Score/100	70	70	50	70	50	70	70	70	66
	Weighted Score	14	7	2.5	10.5	7.5	7	3.5	14	
Recumbent	Raw Score/100	50	40	50	60	90	50	70	60	59.5
	Weighted Score	10	4	2.5	9	13.5	5	3.5	12	
Tricycle	Raw Score/100	90	40	50	50	90	50	60	60	65.5
	Weighted Score	18	4	2.5	7.5	13.5	5	3	12	
Standard Touring	Raw Score/100	80	70	70	70	70	70	70	75	73
	Weighted Score	16	7	3.5	10.5	10.5	7	3.5	15	
Aero/HPV	Raw Score/100	40	40	80	50	100	40	40	60	56.5
	Weighted Score	8	4	4	7.5	15	4	2	12	
TT	Raw Score/100	60	70	80	65	90	65	65	70	70
	Weighted Score	12	7	4	9.75	13.5	6.5	3.25	14	

Final Design- Geometry

- Updated and cleaned up last year’s frame



Final Design- Geometry

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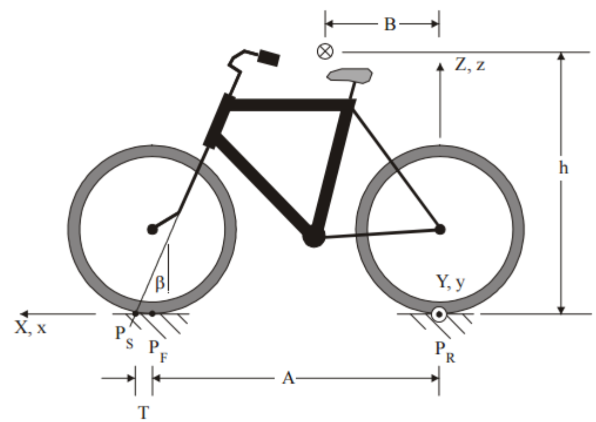
- Matched handling characteristics using PCM
- Use Trek FX7.3 as reference

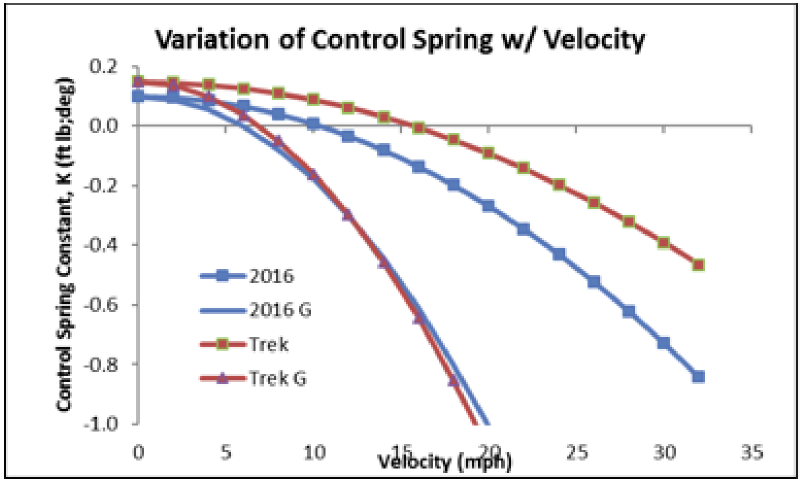
Patterson Control Model (PCM)

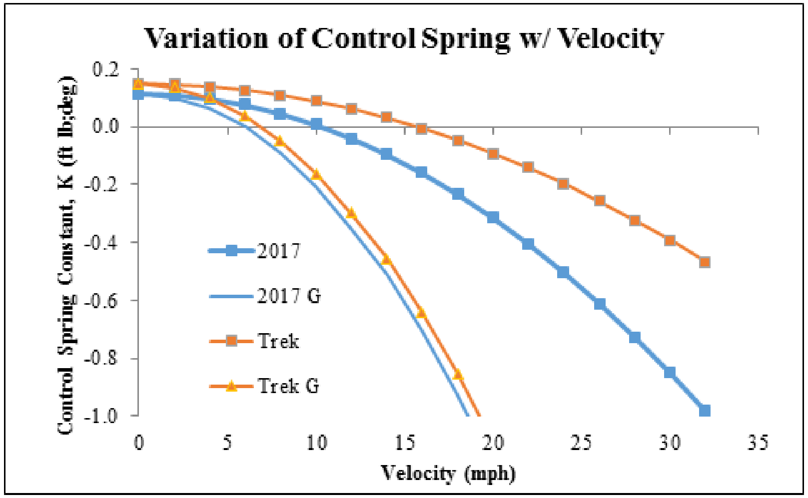
Inputs					
A	1.080	m	T	0.066	m
h	1.037	m	K1	8.852	
Rh	0.305	m	K2	0.416	1.247
kx	0.420	m	K3	0.000667	m/N
m	130	kg	K4	0.374	
B	0.438	m	g	9.81	m/s2
β	17.0	deg.	Iw	0.179784	kg m2
R	0.346	m	mw	1.5	kg
e	0.038	m		1%	

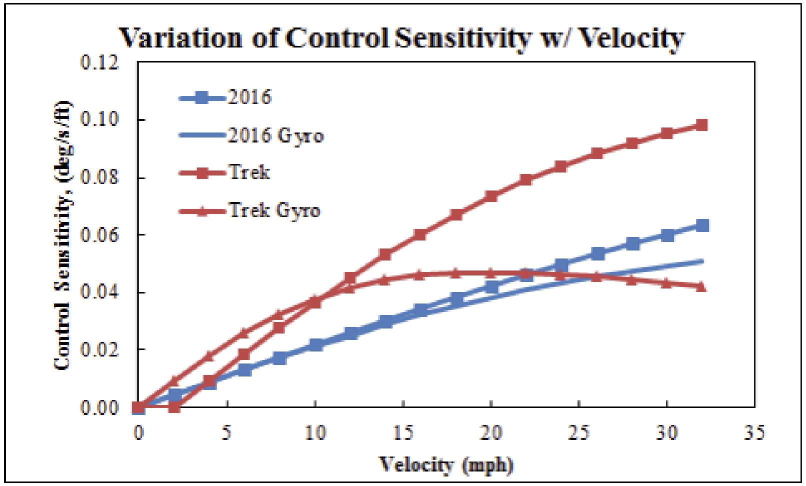
Figure 1 shows the geometry of the bicycle with important parameters indicated.

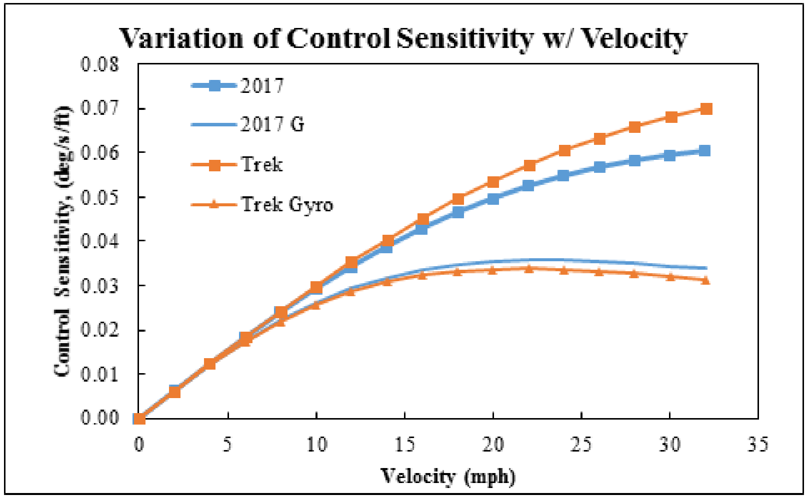


Final Design- Geometry







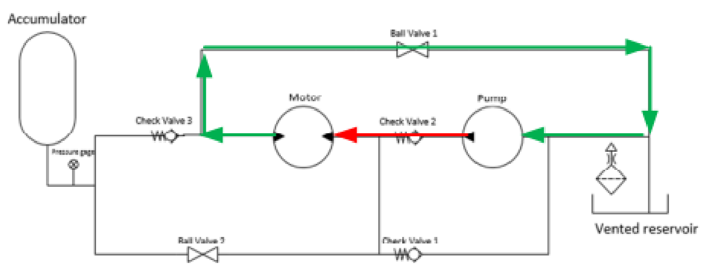


Final Design- Geometry

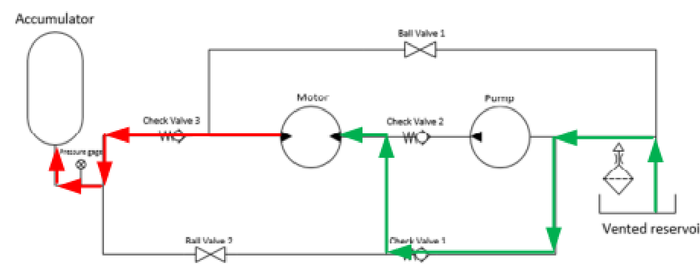
Bicycle BOM							
1	Bicycle tire	Schwalbe	11600593	730	$75.00	2	$150.00
2	Bicycle tube	Bontrager	411836	215	$7.99	2	$15.98
3	Front brake	Tektro	R540	164	$79.99	1	$79.99
4	Rear brake	Tektro	R540	164	$0.00	1	$0.00
5	Stem	Bontrager	512322	144	$64.99	1	$64.99
6	Handle bar	Bontrager	427218	240	$89.99	1	$89.99
7	Brake Levers	Tektro	RL520	272	$29.99	1	$29.99
8	Seat	-	-	-	$24.99	1	$24.99
9	Fork	Sunlite			$60.00	1	$60.00
10	Grips / bar tape	Bontrager	534785	50	$19.99	1	$19.99
11	Brake cable	Shimano	SPTFE-P	180	$20.99	1	$20.99
12	Cranks	Kalloy			$19.99	2	$39.98
13	Spring Preload Bolt	3D Motorsports	-		$1.25	7	$8.75
14	PTO Shaft Screw	3D Motorsports	-		$1.25	1	$1.25
15	1/4" Bearing Ball	3D Motorsports	-		$0.99	3	$2.97
16	Drive Key	3D Motorsports	-		$1.25	1	$1.25
Subtotal:							**$611.11**

Final Design- Hydraulics

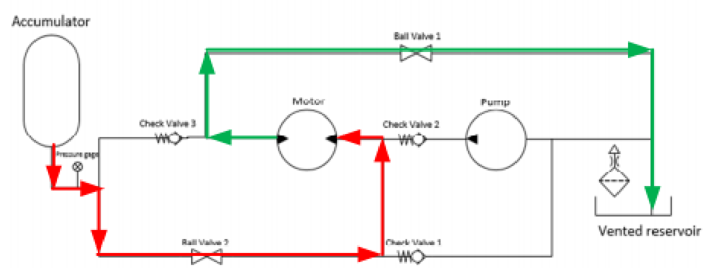
Direct drive



Regen braking

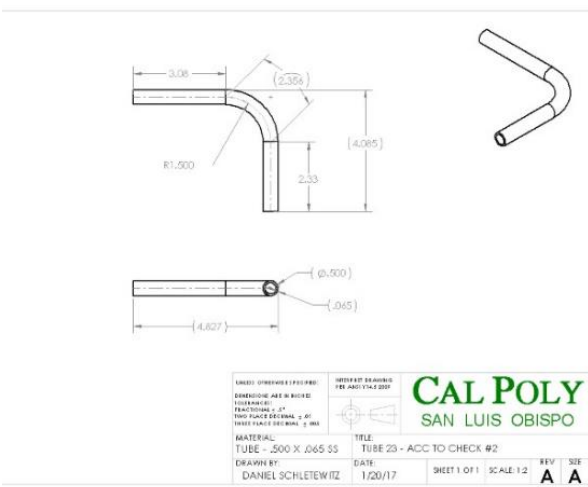


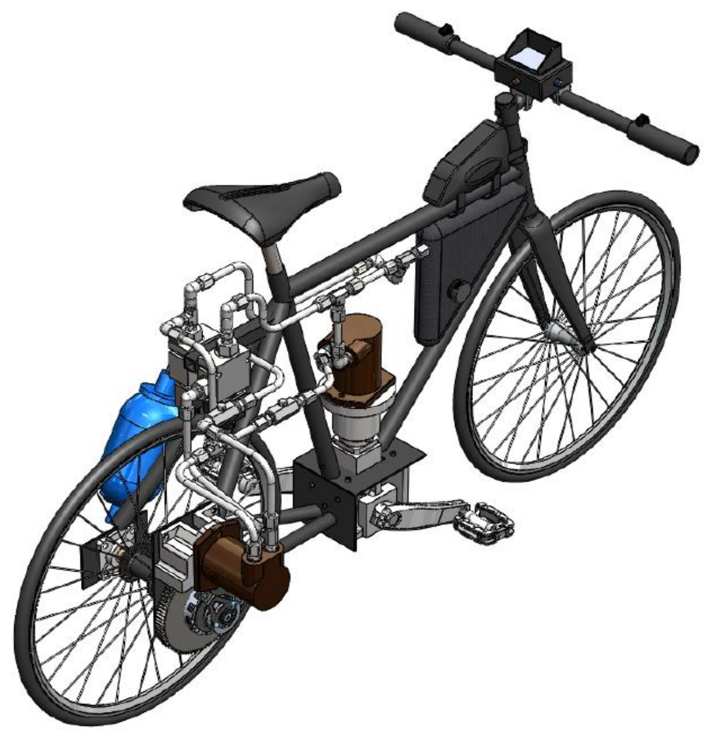
Accumulator discharge



Final Design - Hydraulics

- Used Solidworks model as guide for construction





Final Design- Hydraulics

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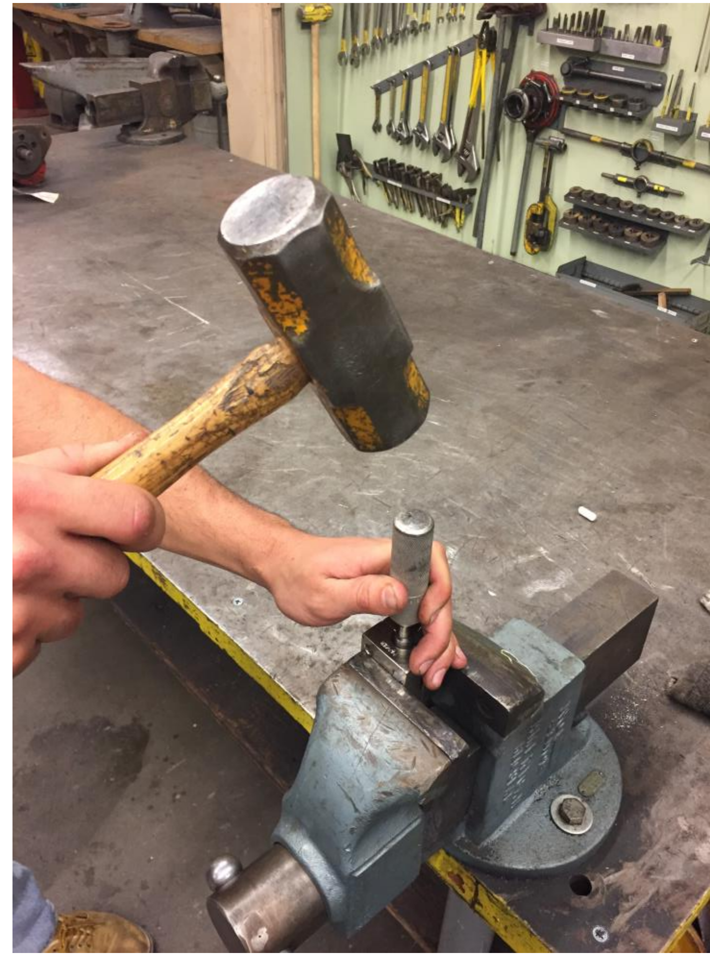
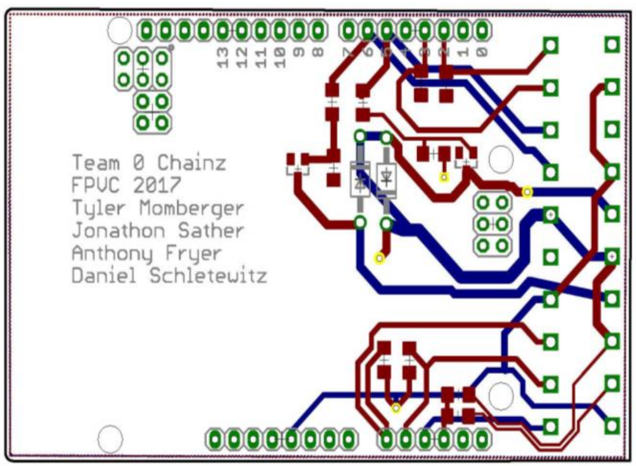
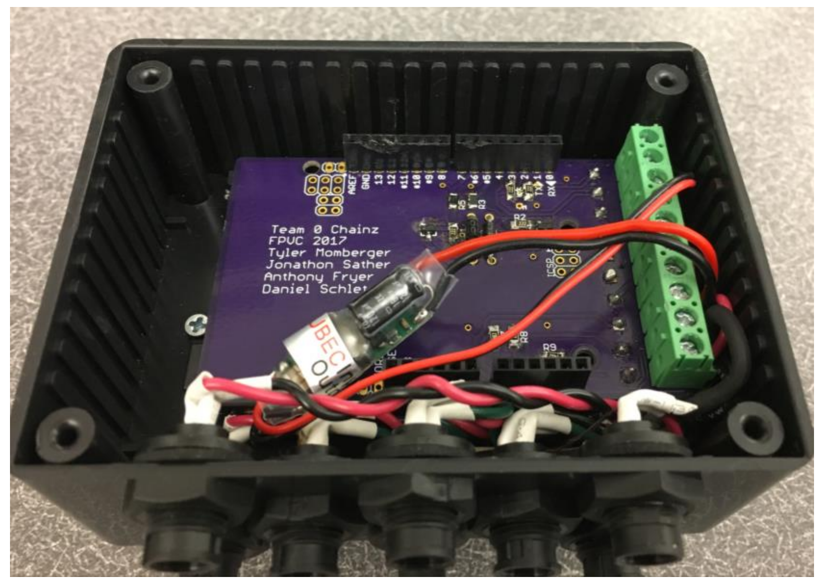


Final Design- Hydraulics

Final Design- Mechatronics

- Custom PCB designed using Eagle



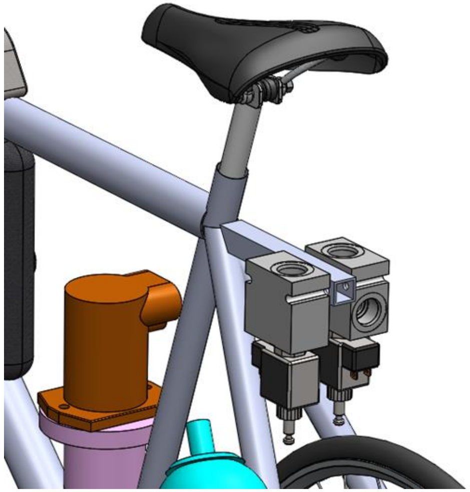


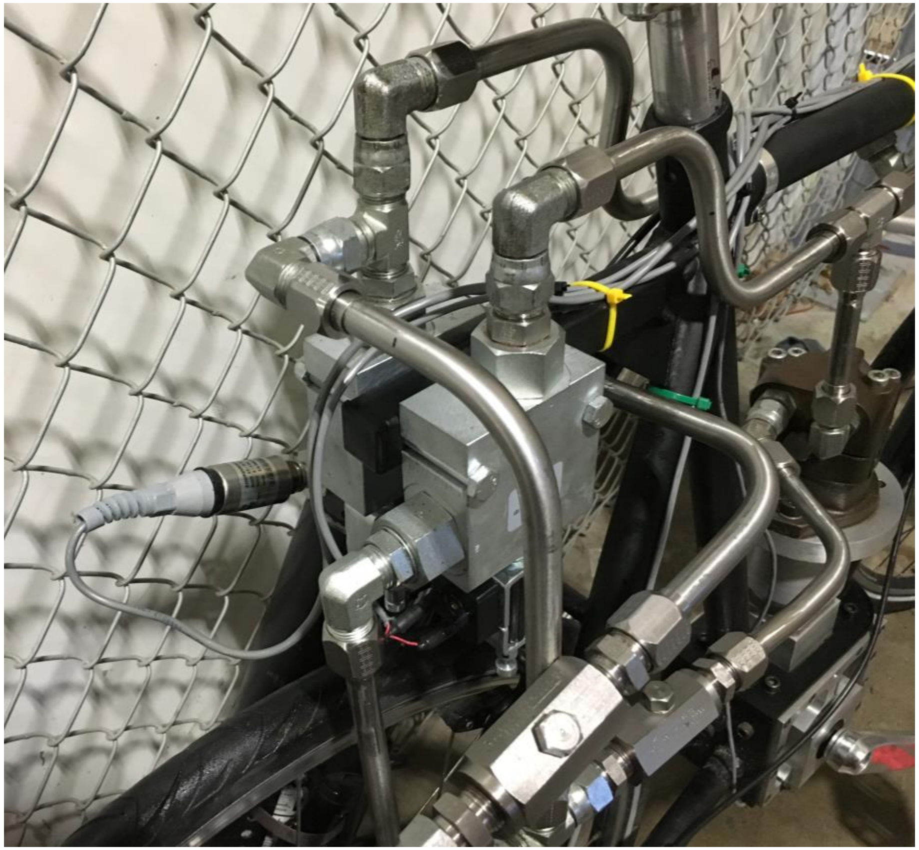
Final Design- Mechatronics

- Designed to be “water resistant”
- Includes 3D printed sunlight shield

Final Design- Mechatronics

- Solenoids mounted on frame extension





Final Design- Mechatronics

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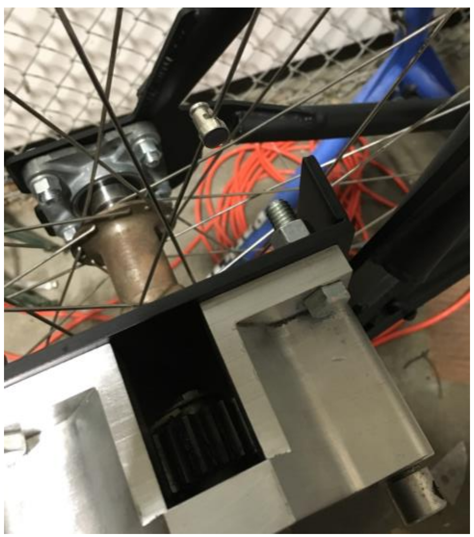
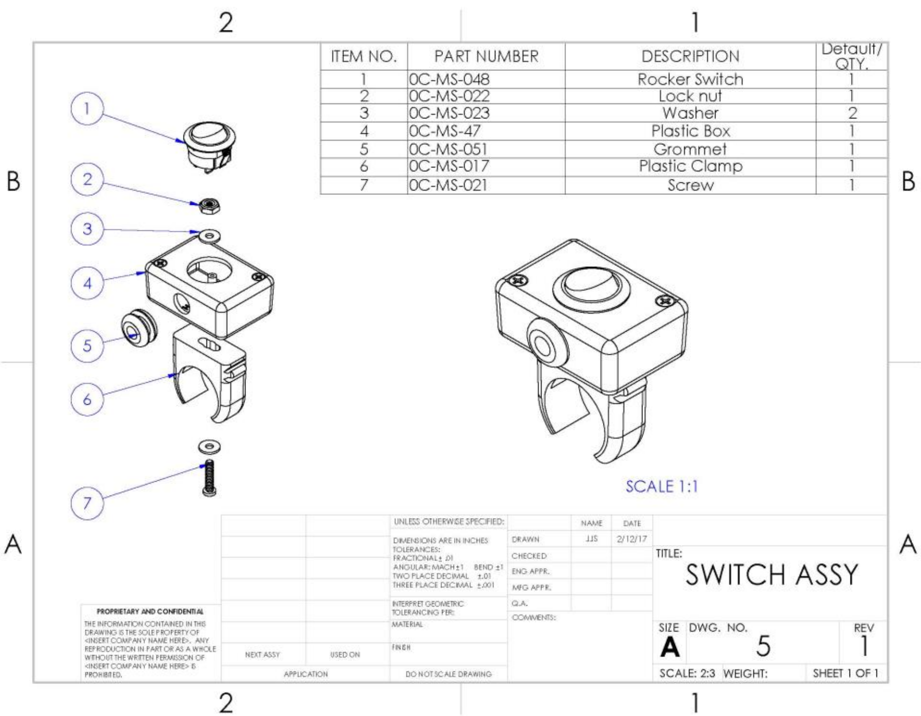
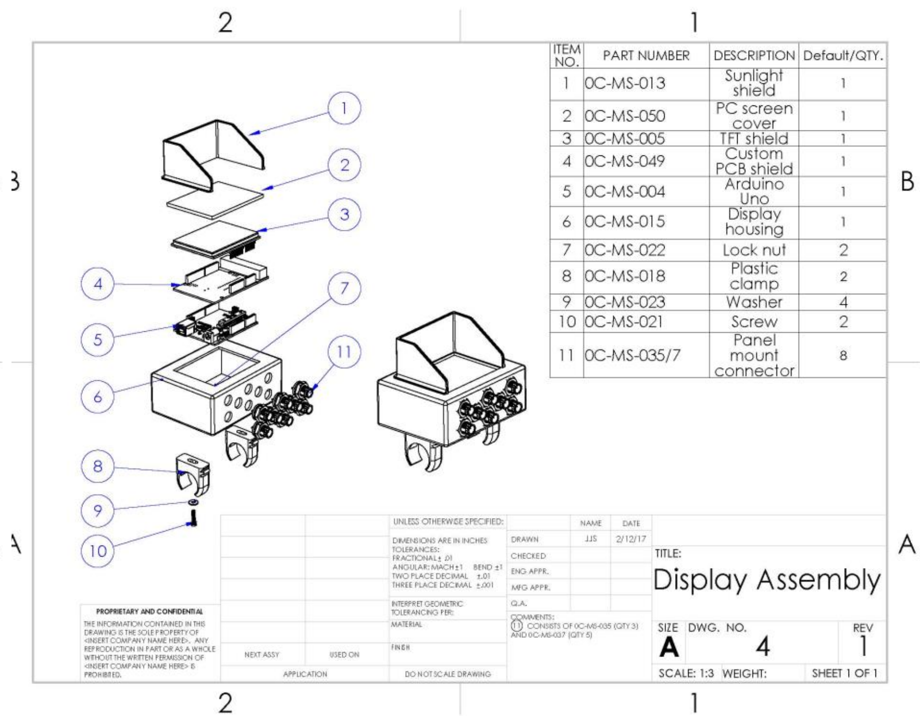
- Hall effect sensor mounts take advantage of existing geometry

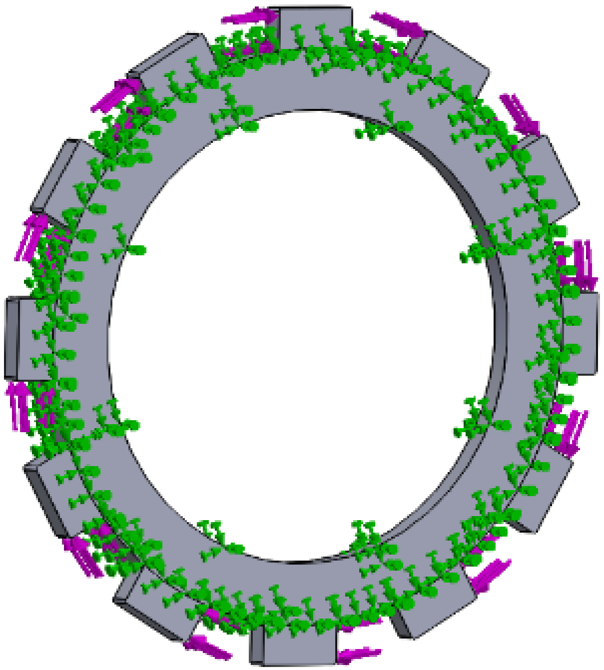


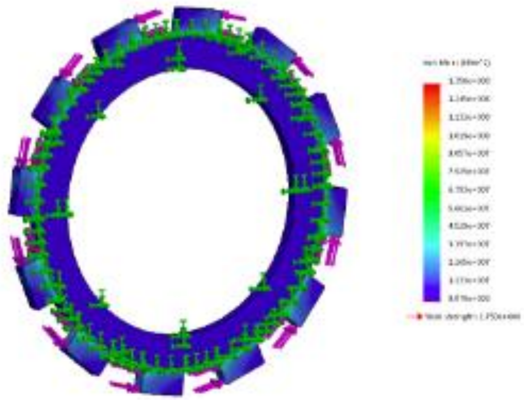
Final Design- Mechatronics

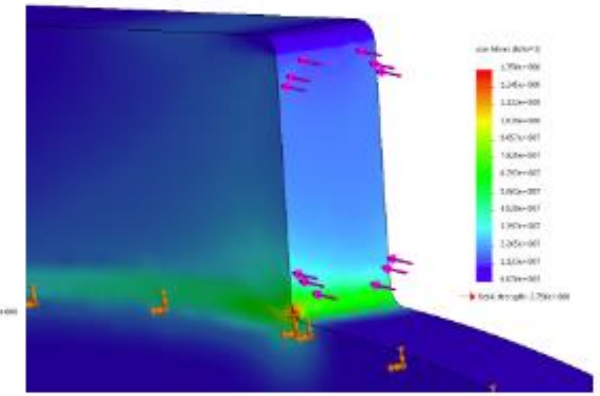


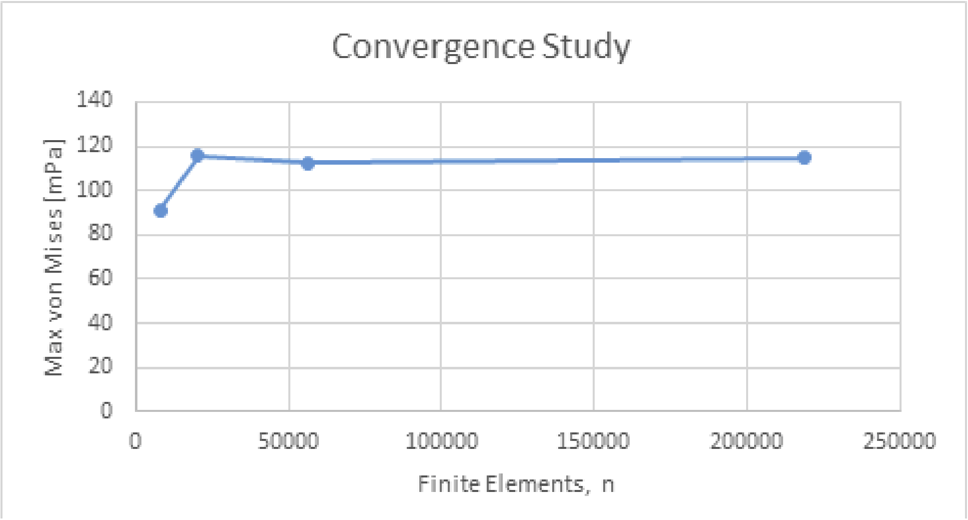


Final Design- Clutch

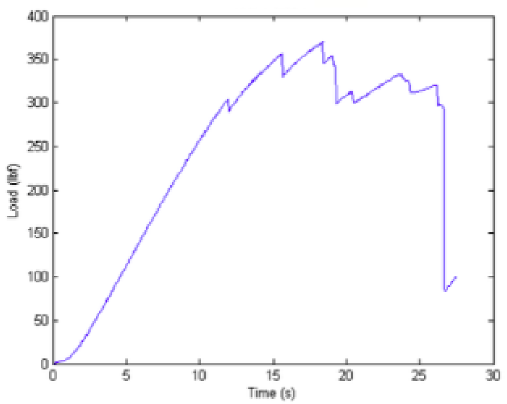




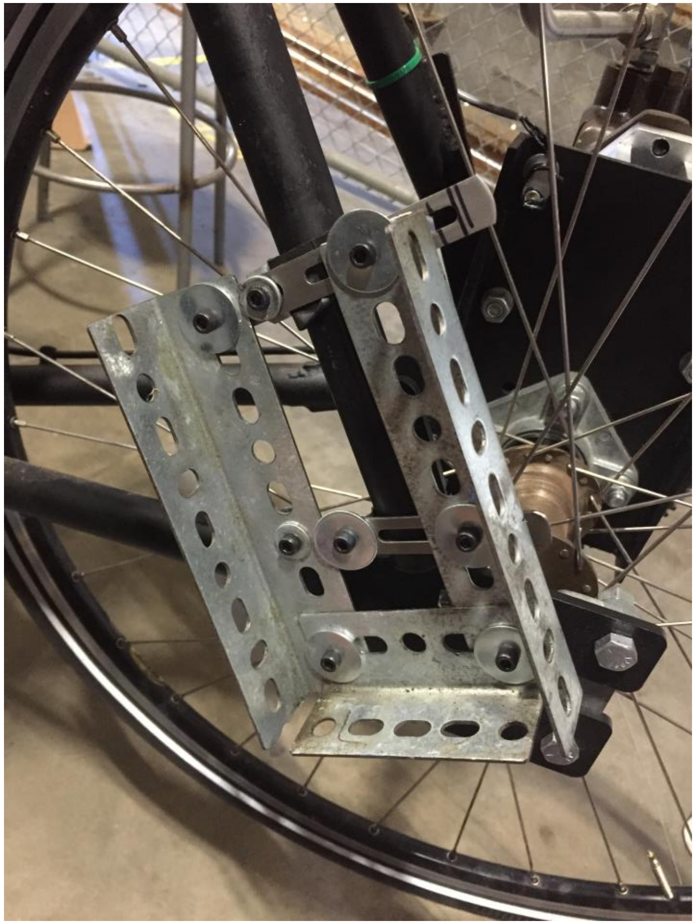




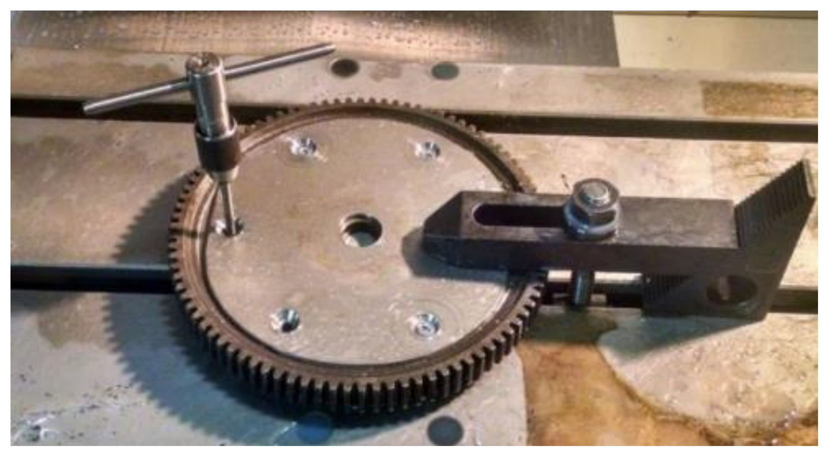
Final Design- Clutch



Final Design-
Accumulator



Final Design- Other Components



Testing Results- Power Draw

- Runs 8hr+ under "normal" operation
- Small brownout when actuating solenoid

Solenoid power supply		
Voltage	12	*V*
Expected Current	0.683	*A*
Max Current	4.66	*A*
Power	8.196	*W*
Ideal continuous operating time	8	*hrs*
Power needed	5.464	*Ah*

Everything else power supply		
Voltage	7	*V*
Current	0.177	*A*
Power	0.782	*W*
Ideal continuous operating time	48	*hrs*
Power needed	5.36	*Ah*

Calculated Values		
Wire cross-sectional area	0.000698	ft^2
Voltage drop	0.001579	*V*

Testing Results-Performance

Max Speed (Continuous discharge)

Trial	Max Speed (mph)	Max Pressure (psi)
1	16.5	4000
2	16.3	4000
3	16.5	4200

Max Speed (Rider pedaling only)

Trial	Max Speed (mph)	Rider
1	18.5	Tyler
2	20.54	Jon
3	17.5	Tyler

Sprint Test

Trial	Distance	Time (s)	Rider	Notes
1	200m	31.63	Anthony	Slight downhill
2	200m	43.76	Anthony	Slight uphill. Fumble at start
3	200m	29.8s	Anthony	Slight downhill.
4	200m	n/a	Jonathon	Leak while regenerative braking. Conclude testing.

Testing Results- Performance

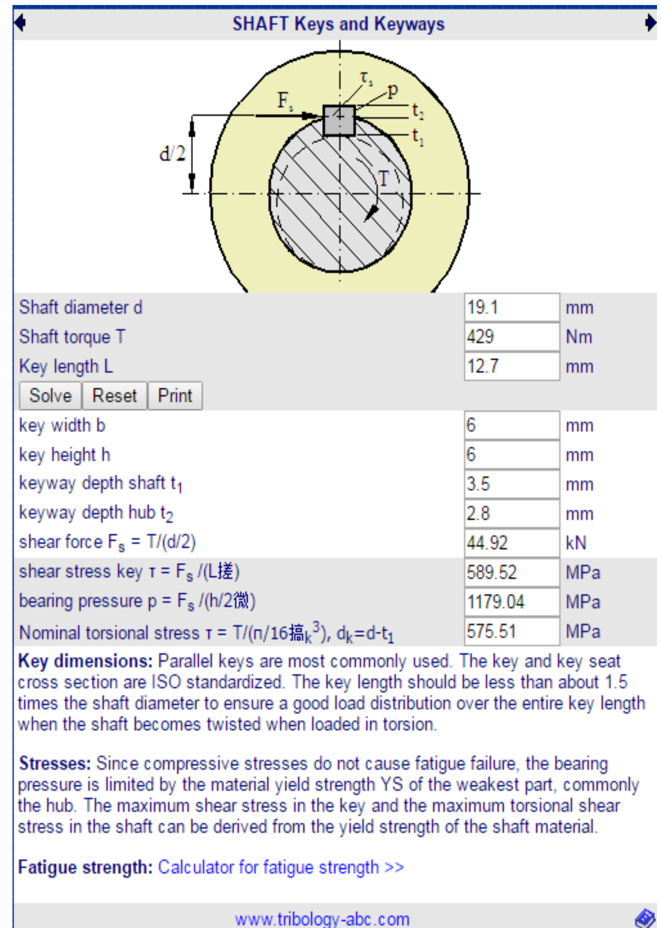
- Approx. 100% improvement in efficiency from 2016

Discharge Distance + Efficiency

Trial	Distance (in)	Pressure (psi)	Method	Efficiency	Notes
1	4330.711	3950	All at once	43.30711	Slight downhill
2	4921.2625	4200	All at once	49.212625	Slight downhill
3	n/a	4000	All at once	n/a	Leak in reservoir tubing mid-run.
4	3543.309	4000	All at once	35.43309	Slight uphill
5	7795.2798	4000	Bursts	77.952798	
6	8425.2014	4100	Bursts	84.252014	
7	7677.1695	4000	Bursts	76.771695	

Testing Results- Endurance

- 15 miles ridden
- Keyway holding up



Cost Analysis

Bicycle Components Subtotal:	$611.11
Mechatronics Subtotal (with labor/R&D):	$4,695.80
New Hydraulic Fittings Subtotal:	$242.94
Cost of This Year's Bicycle:	$5,549.85
Inherited Parts Subtotal:	$15,349.17
Cost of Complete/Updated Bicycle:	$20,899.02

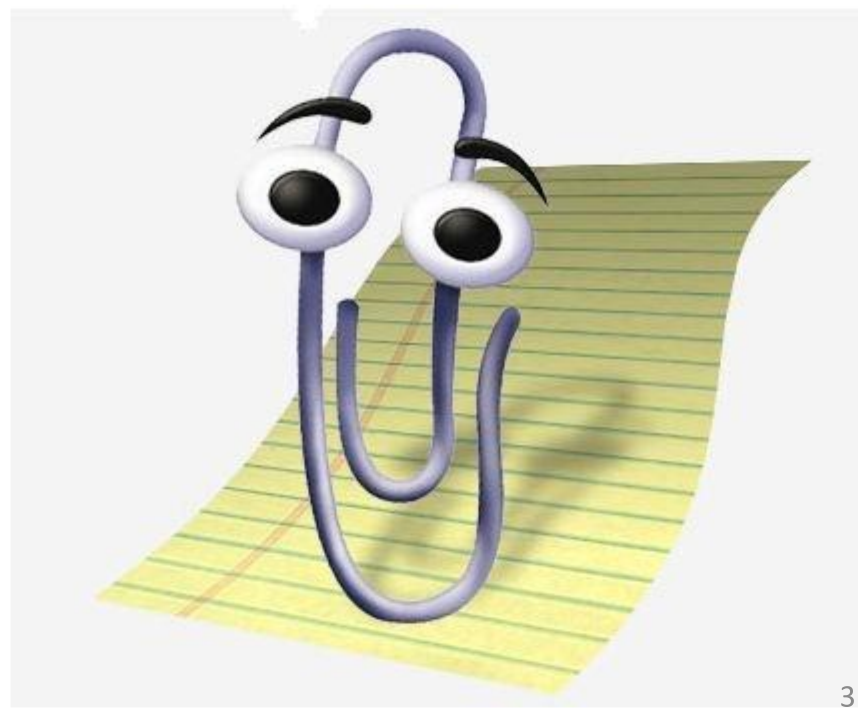
Lessons Learned

- Lead time estimation – always pad your schedule with extra time, and front load most of the work.
- “Rule of pi”

π

Lessons Learned pt2

- Along with the lead times, always give yourself more time for troubleshooting and final assembly before testing.



Lessons Learned pt3

- Don’t be afraid to consult other departments or other sources of information – oftentimes it is beneficial for your success, and develops good relationships.

Lessons Learned pt4

- Inheriting others' work includes inheriting the problems associated with it. While original designs are more costly and time intensive, it allows for unobscured vision of the design problem and solutions.

Conclusions

- We all agreed that this project was both fulfilling and invaluable to our experience and knowledge as engineers. It challenged our problem solving abilities while incorporating elements of controls, vehicle dynamics, fluid dynamics, and manufacturing. We look forward to competing in this year's NFPA Fluid Power Vehicle Challenge.

Q & A

NFPA Fluid Power VEHICLE Challenge