NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

FINAL PRESENTATION
West Virginia University
Institute of Technology
Dr. Yogendra Panta
4/21/2022

WVU TECH

Agenda

- Team Introductions
- Objectives
- Midway Review
- Vehicle Design
  - Preliminary work
  - Selection of Hardware
  - Hydraulics System
  - Pneumatics System
- Vehicle Construction
- Results and Analysis
- Final Vehicle & Testing
- Lessons Learned
- Acknowledgments

Meet the Team

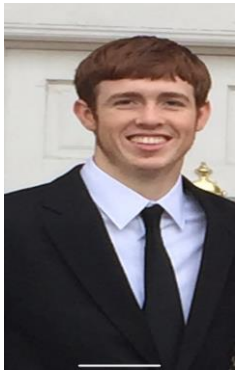
Advisor: Yogen Panta

Antonio Fernández Castaño

Jacob Cross

Matthew Lanzer

Gregory Panther



Kerry Smith

Charles White

Design Objectives

- Operating pressure: 1000 psi
- Vehicle Weight: 110 lbs.
- Drag Coefficient: 0.6
- Maximum Velocity: 15 mph
- Sprint Challenge: 600 ft in 30 sec
- Endurance Challenge: 5280 ft in 6 min
- Efficiency Challenge: 500 ft

Midway Review

- 3.6/5.0 on midway presentation

  highest rating compared to prior years

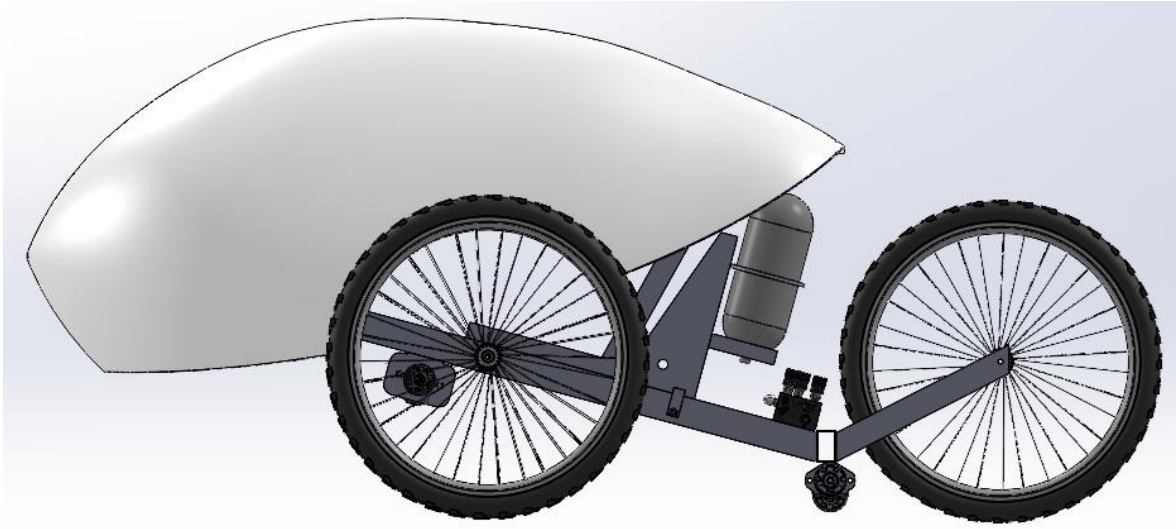
  records

- Changes after midway review
  - Added an external check valve to the motor inlet
  - Added a 4-way valve for the Pneumatic System

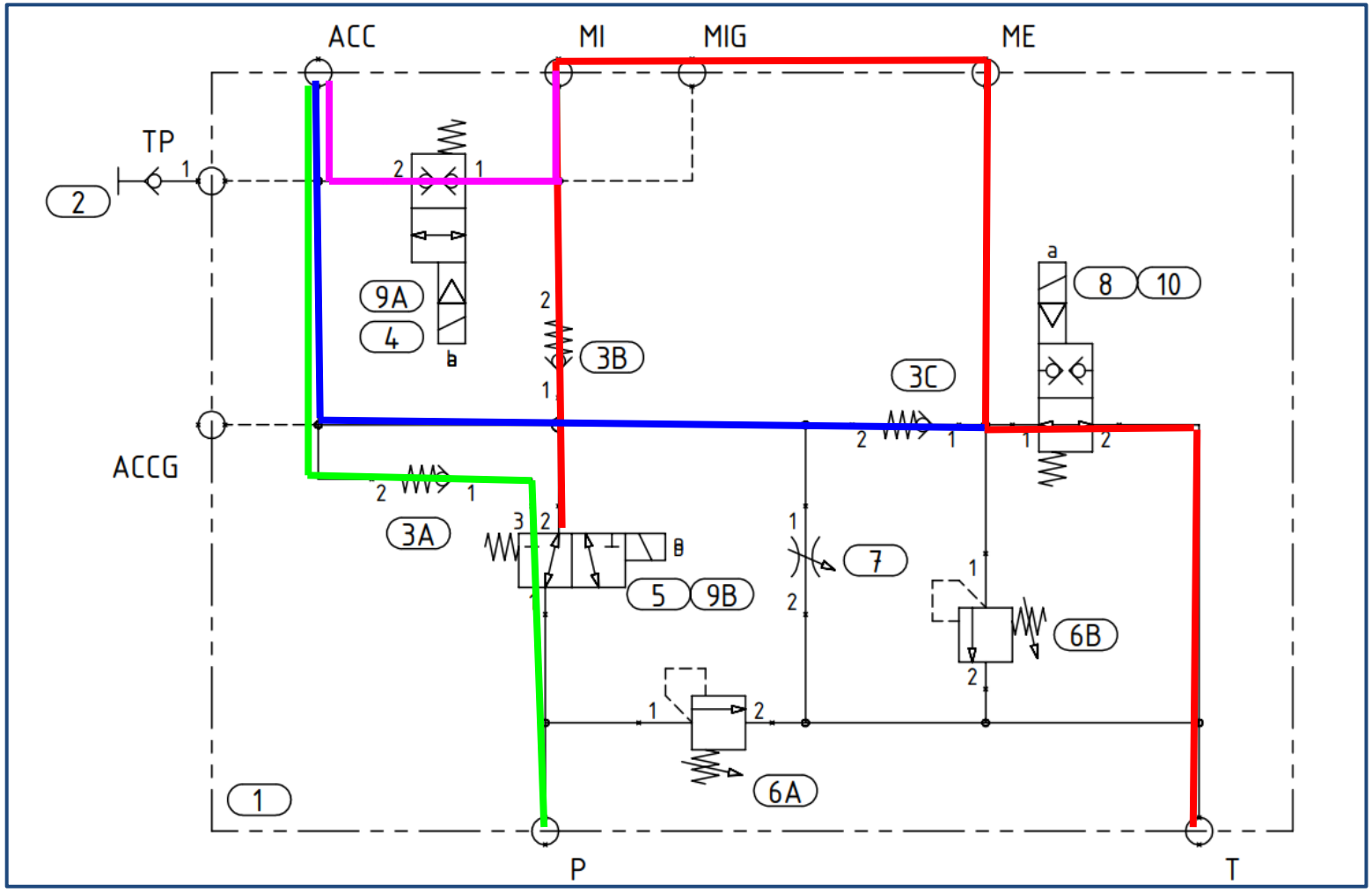
Midway Review Cont...

Vehicle Design Components (Hardware)

- Frame
- Steering
- Brakes
- Drivetrain
- Hydraulics
- Pneumatics
- Windshield
- Electronics



Hydraulic Circuit Design



Mode colors

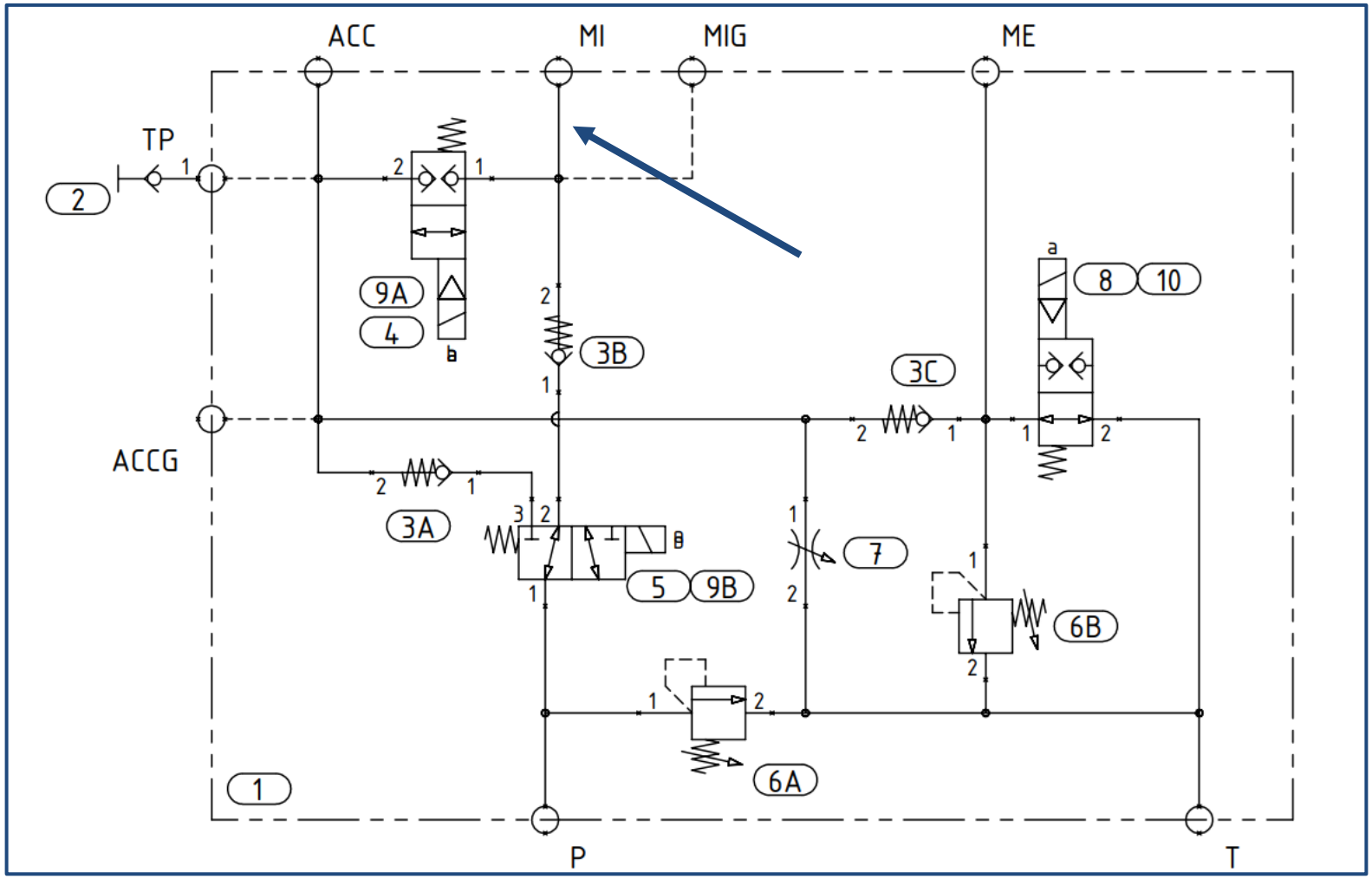
Green: Charge

Red: Drive

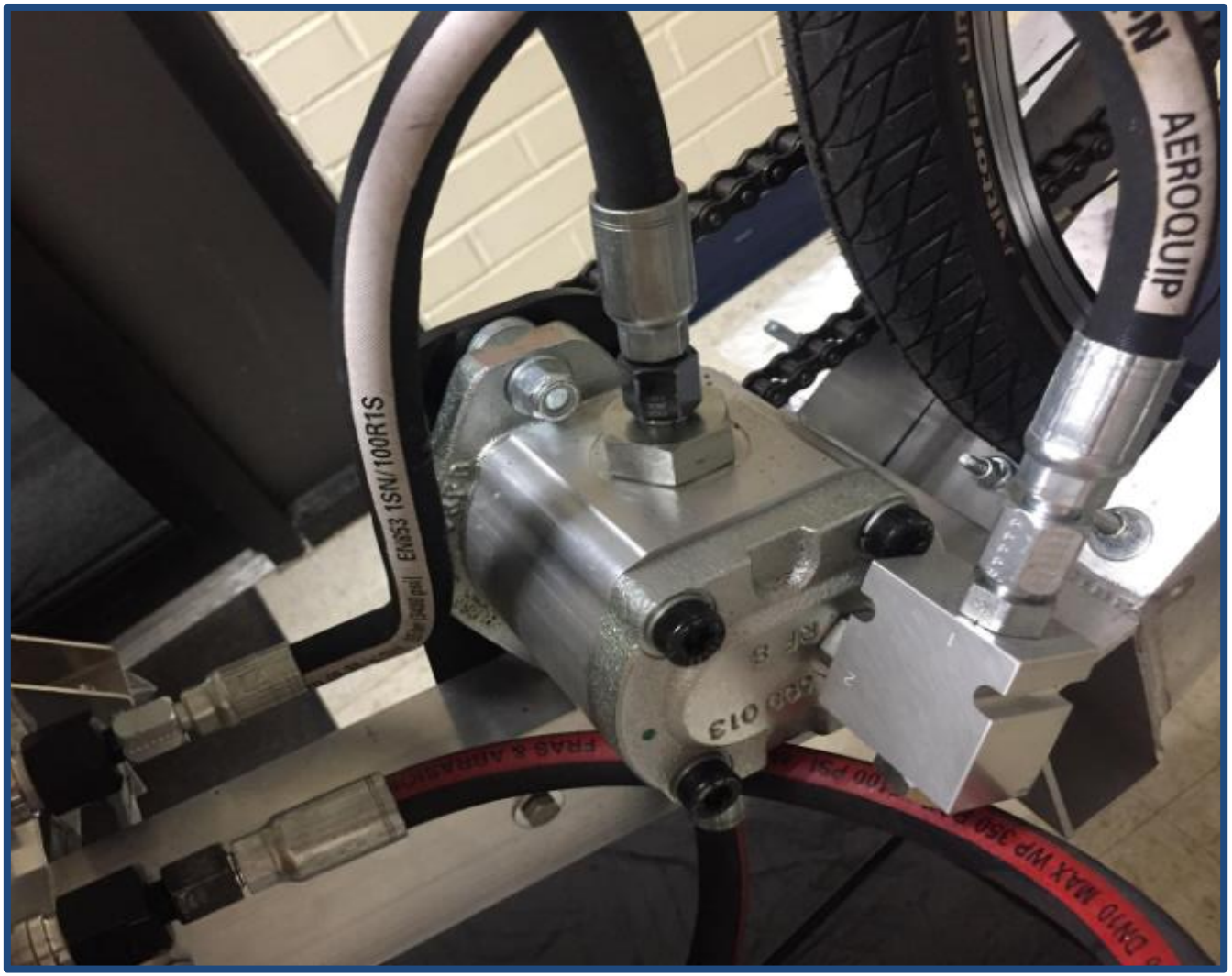
Blue: Regen

Magenta:Boost

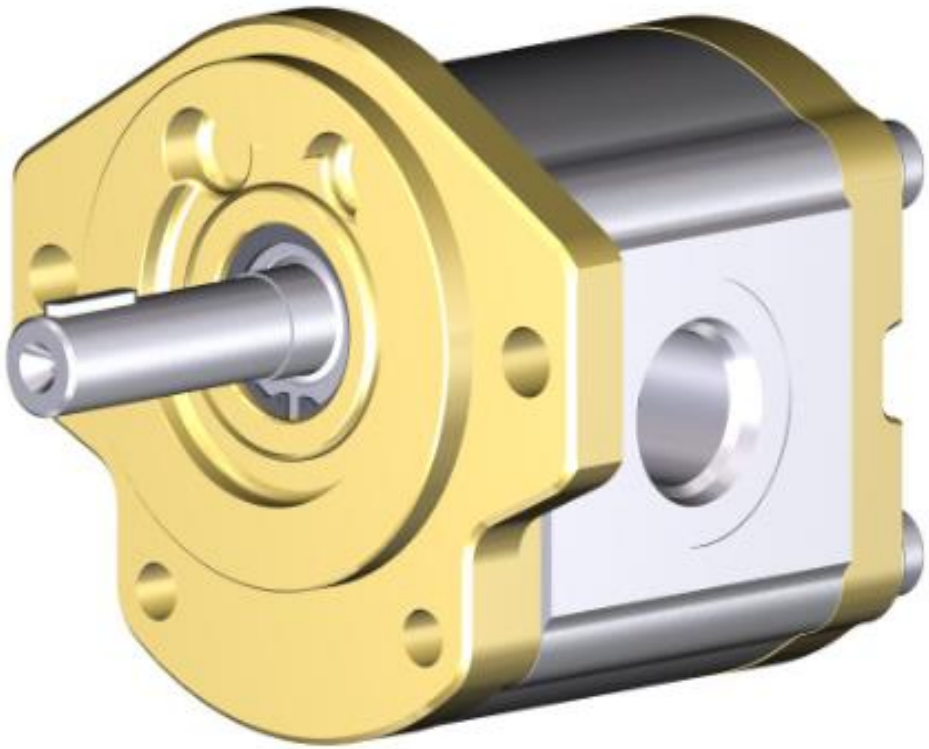
Hydraulic modifications



External Check valve



Selection of Hydraulic Components -1/2 (Motor)



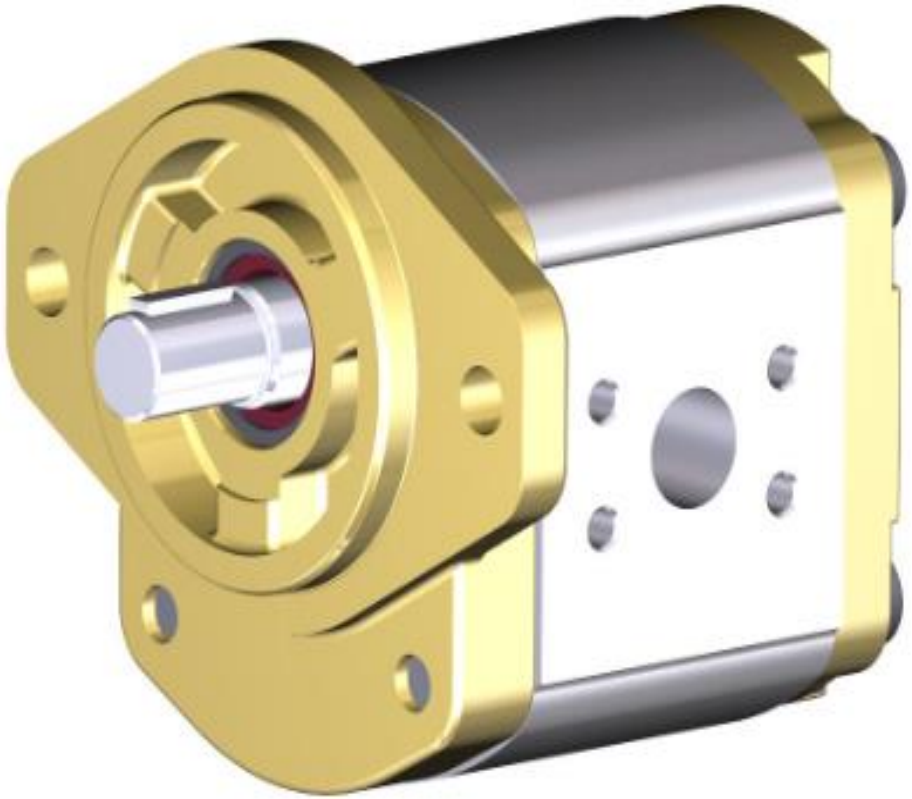
Bosch rexroth

Gear type

1.159 In^3/rev

Bi directional

Selection of Hydraulic Components -2/2 (Pump)



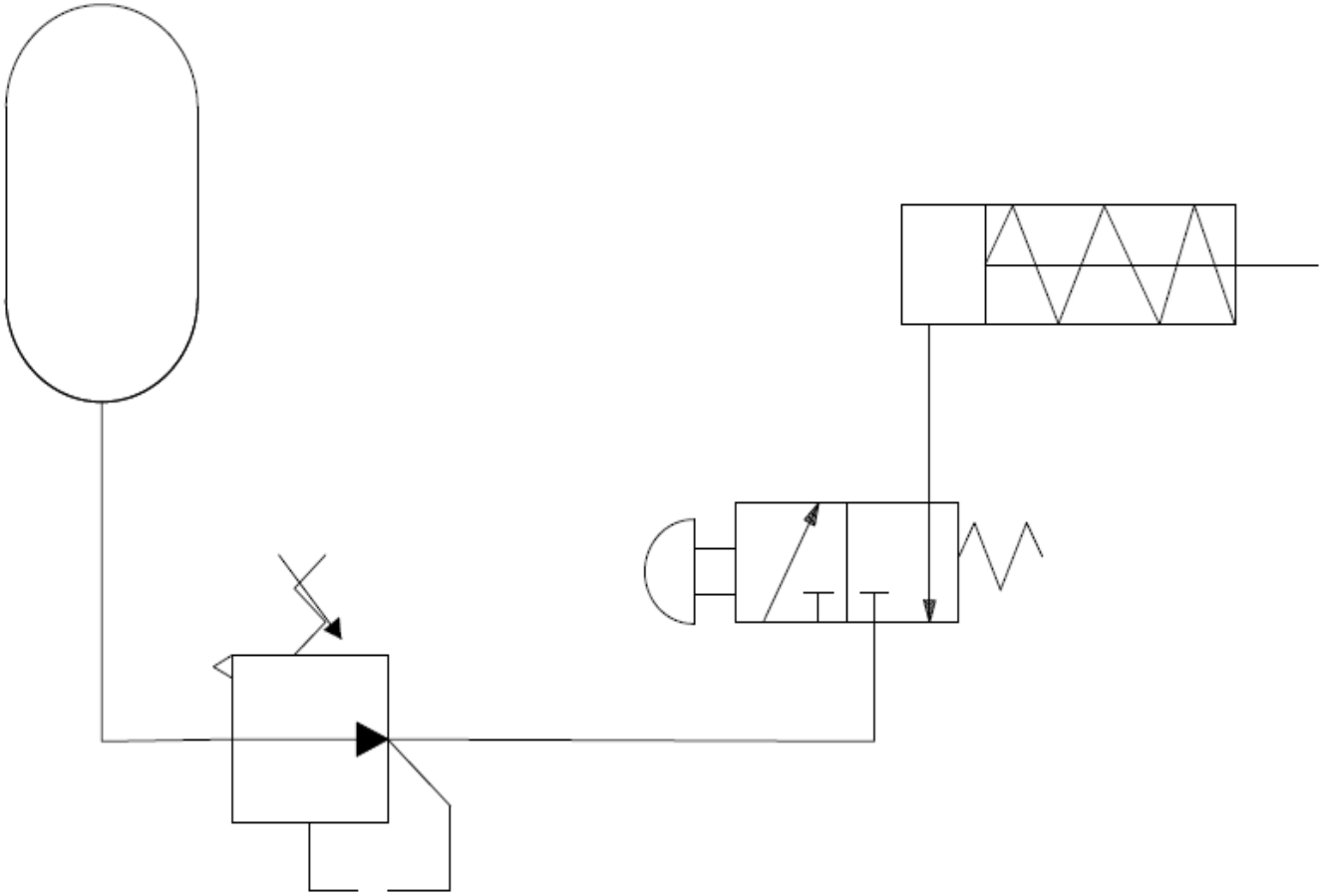
Bosch rexroth

Gear type

2.441 In^3/rev

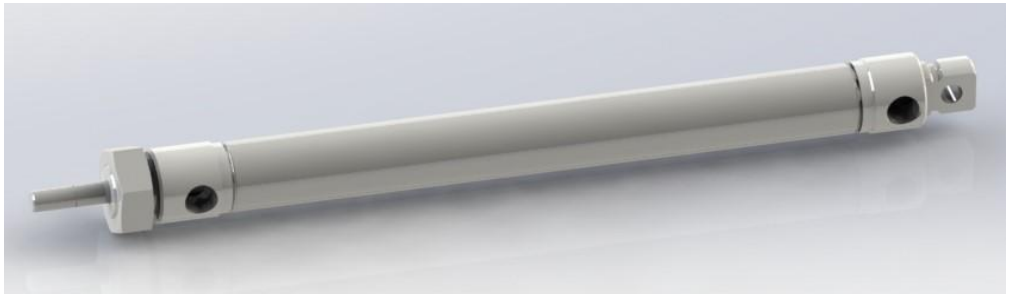
Clockwise rotation

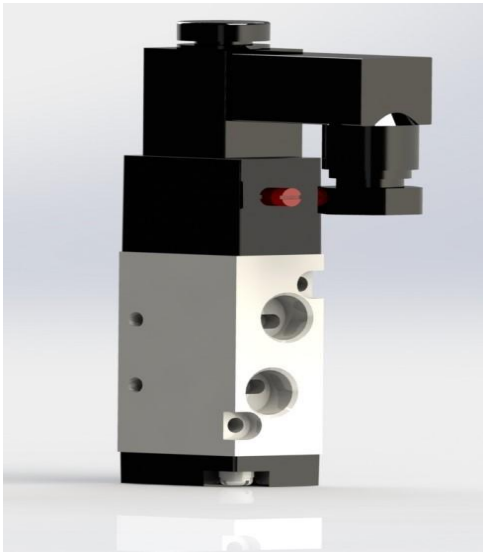
Pneumatic Circuit Design

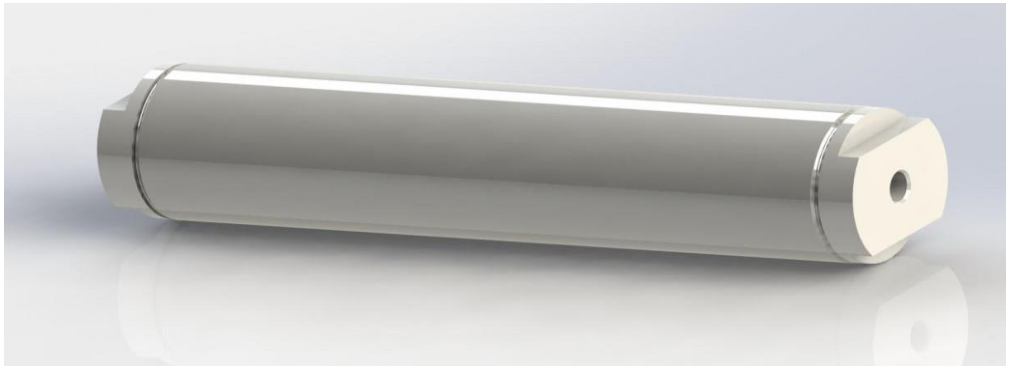


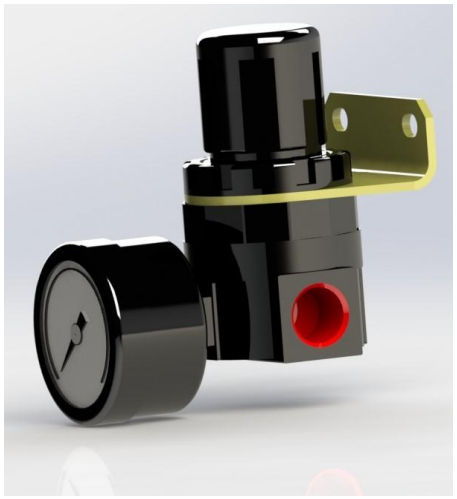
Selection of Pneumatic Components w/specifications

Cylinder: Double acting, ¾” bore, 6” stroke
Reservoir: 2.5” bore x 8” length
Valve: 5 port- 2 position, 12V Double Solenoid
Regulator: ¼” NPT ports



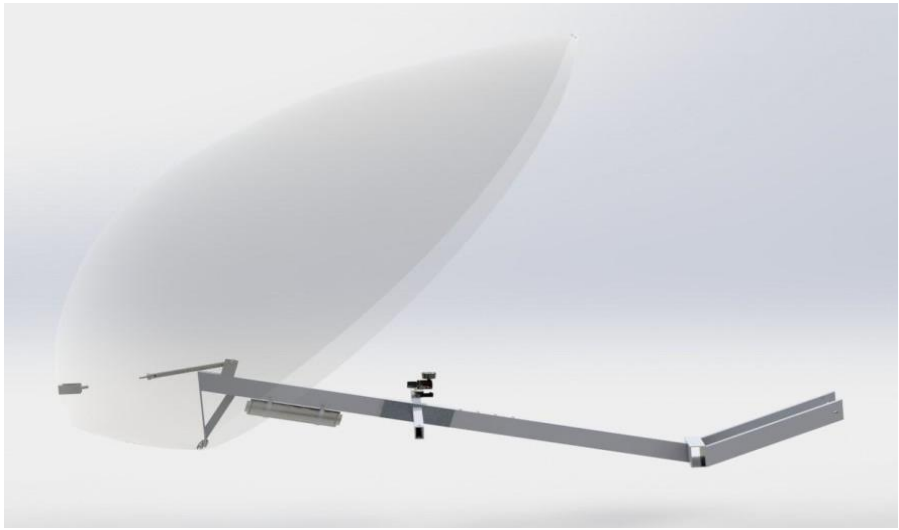




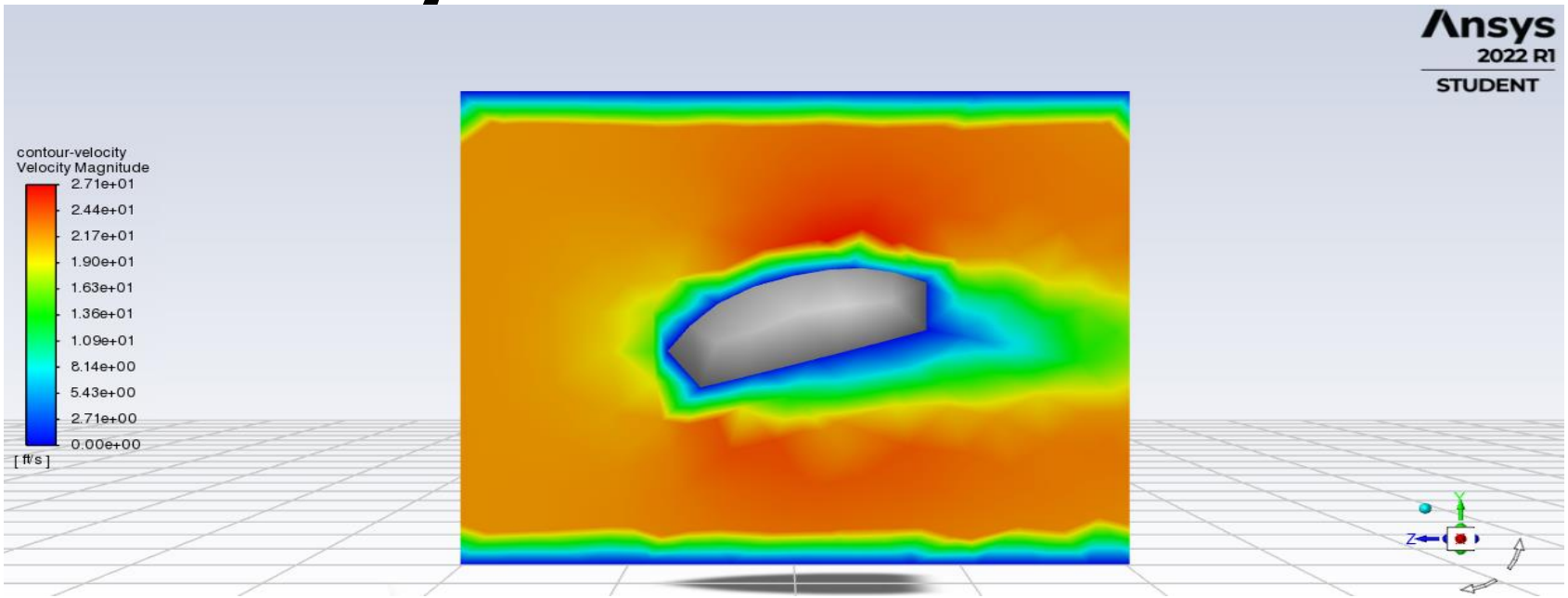


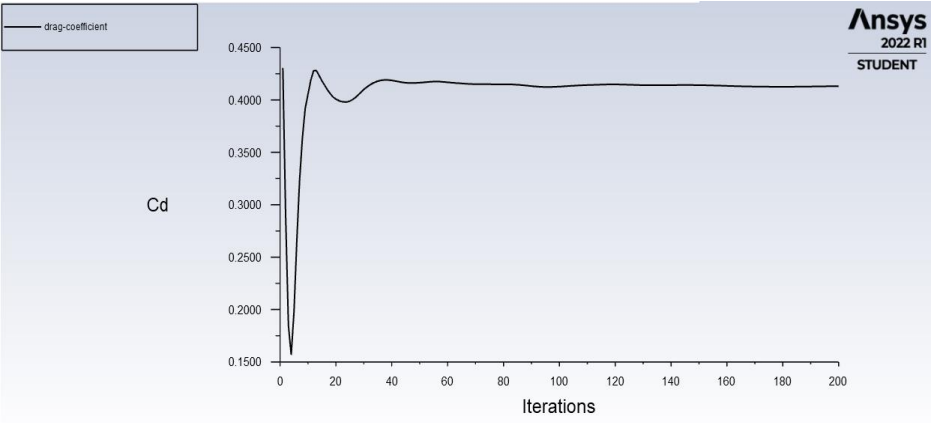
Application of Pneumatics

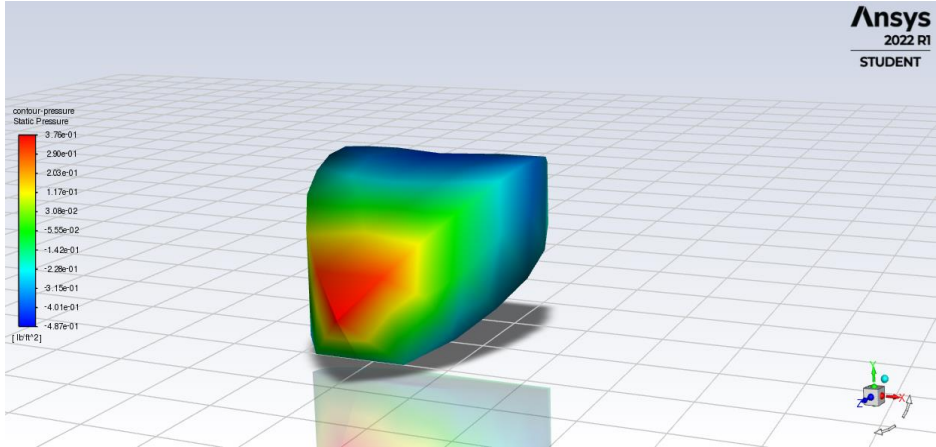
- System is capable of lifting the designed load of 10 lbf.



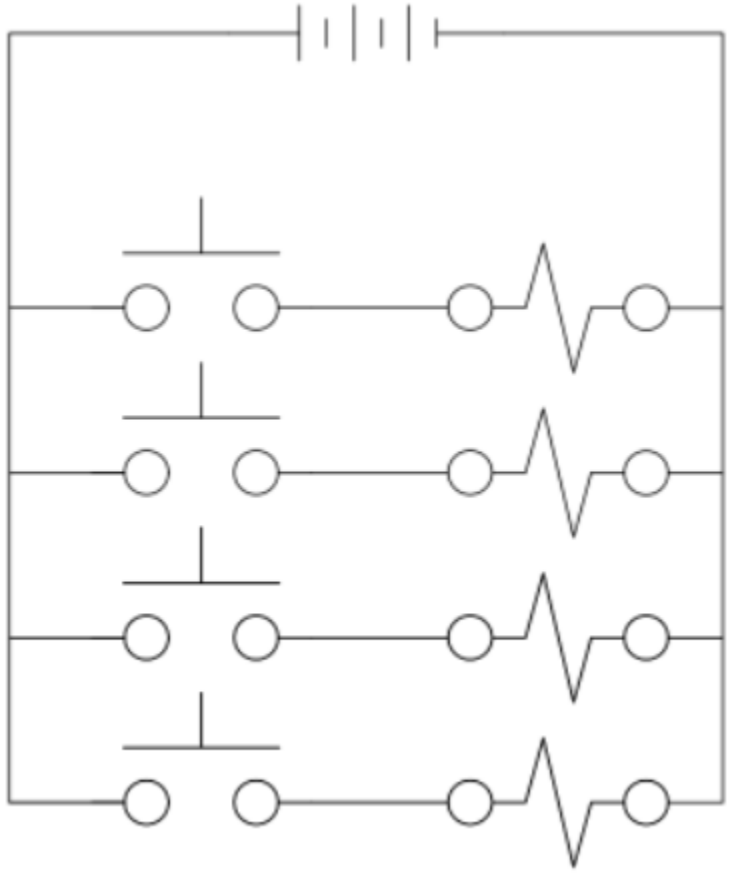
Design of Windshield w/ CFD Analysis







Electronics Circuit Design



Regeneration

Boost

Drive/Charge

Pneumatic

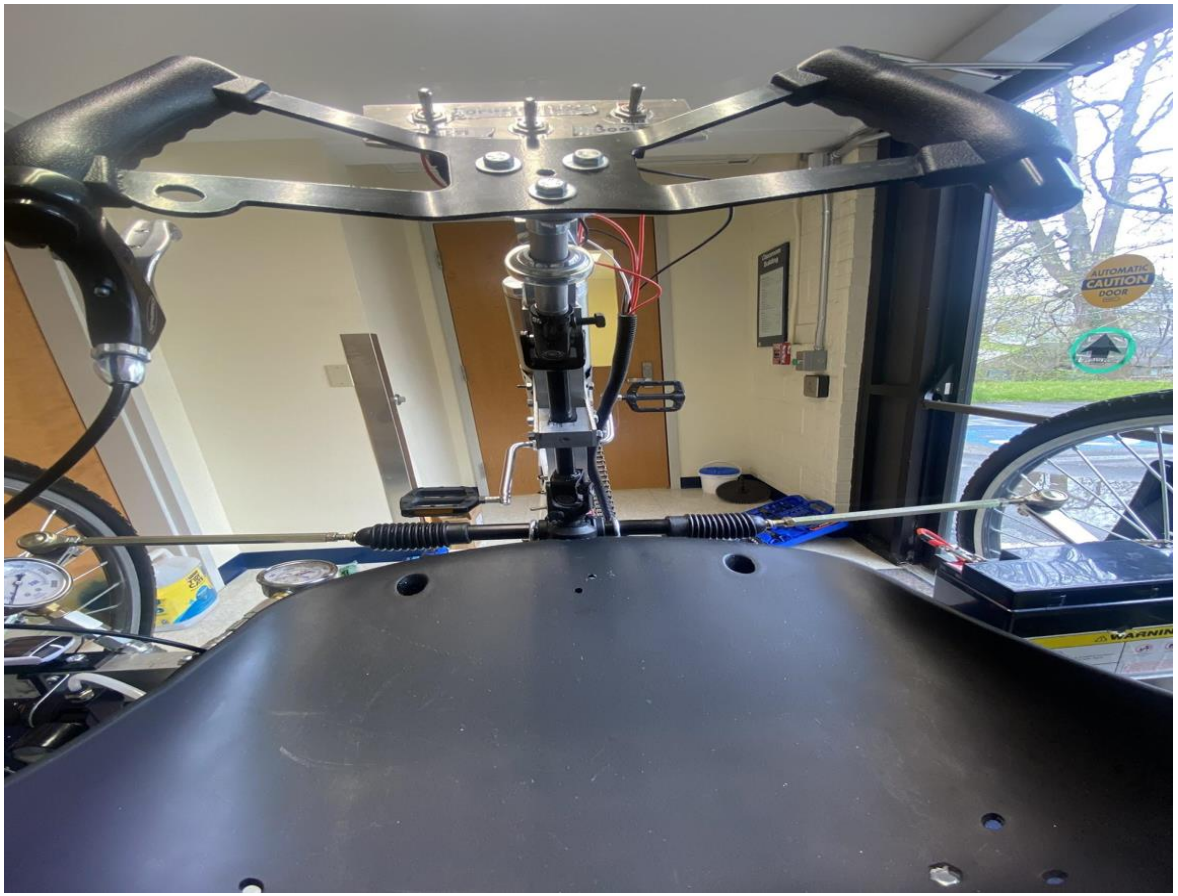
Selection of Electronics Components

Battery: 12V 18Ah Sealed Lead Acid (SLA), Rechargeable.

Switches: Heavy Duty Rocker Toggle 20A 12V

Wires: Copper. AWG 10,18, and 30. High temperature resistance 200 degree C, Low temperature resistance,in extreme cold -60 degree C.Rated Voltage: 600 volts

Steering Design

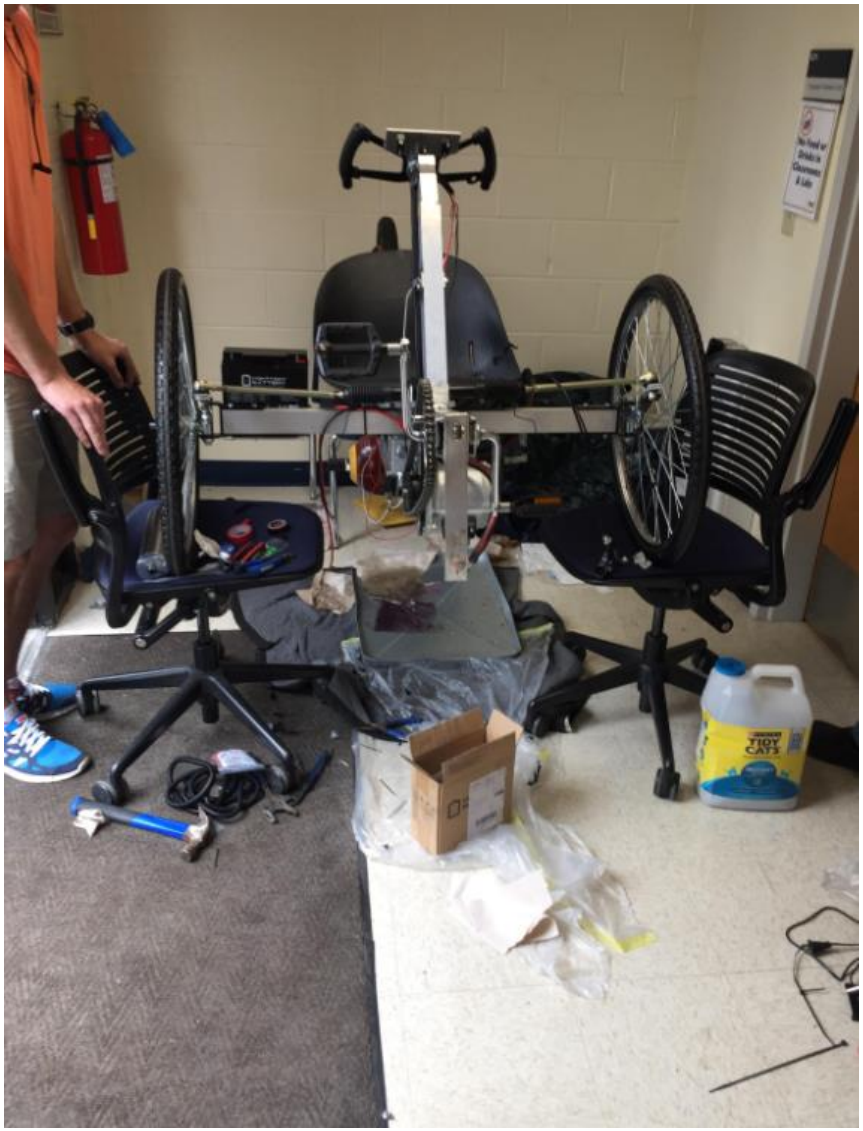


Gear and Brake design

Vehicle Construction 1/3

Vehicle Construction 2/3

Vehicle Construction 3/3



Expense Report

Pump/Motor	$ 1,308.00
Valves/fittings/Pressure Gauges	$ 993.51
Frame Materials/Manufacturing	$ 1,904.00
Wheels/Steering	$ 543.13
Electronics	$ 253.19
Pneumatics	$ 53.18
Windshield Materials/Manufacturing	$ 81.63
Total Cost	$ 5,136.64

Vehicle Testing Clip

Final Vehicle and Future Improvement

The vehicle is fully -constructed and is operational. All systems including hydraulic, pneumatic, and electronic components are interconnected and all circuits work properly.

Improvements to make:

- Ergonomics
- weight reduction
- component selection
- tighter turning radius

Lessons Learned

- Learning experience in fluid power education and its application to the construction of fluid vehicle
- Opportunity to meet industry professionals
- Adaptability and first-hand machining experience
- The value of time management and troubleshooting
- Always have a team member double check work
- Check for Component compatibility and Harmonization
- Fabrication/Construction without a proper access to workshop

Acknowledgements

National Fluid Power Association
Dr. Yogen Panta (WVUIT Team Advisor)
Dr. Winnie Fu (WVUIT Academic Advisor)
Dr. Bernhard Bettig (WVUIT Academic Advisor)
Dr. Kenan Hatipoglu (WVUIT Academic Advisor)
Dr. Guillermo Hahn (WVUIT Academic Advisor)
WVUIT Student Government Association
Karen Skaggs (WVUIT Engineering Secretary)
Kevin Simmons (Janitor at Classroom Building)
Ernie Parker (NFPA Mentor)
Kevin Lingenfelter (Industry Mentor)
Stephanie Scaccianoce (NFPA Contact)
Jeff McCarthy (SunSource)
Pam Wieczorek (SunSource)
Kent Sowatzke (Bimba)
Cameron Stevens (Tiefenbach Representative)
Jason Justice (Fabrication Consultant/Welder)
Zach Lockhart (Fabrication Consultant/Welder)

Questions?

Pneumatics Analysis

CYLINDER SELECTION

Operating Pressure (psi)	Bore Size (in)	Area (in^2)	Stoke Length (in)	Lift Force Applied (lb)	Volume of Cylinder (in^3)	Volume per Stroke @ Operating Pressure (in^3)
50	0.75	0.4417864669	6	22.08932335	2.650718801	9.01850436
60	0.75	0.4417864669	6	26.50718801	2.650718801	10.82220523
70	0.75	0.4417864669	6	30.92505268	2.650718801	12.6259061
80	0.75	0.4417864669	6	35.34291735	2.650718801	14.42960698
90	0.75	0.4417864669	6	39.76078202	2.650718801	16.23330785
100	0.75	0.4417864669	6	44.17864669	2.650718801	18.03700872
50	1.0625	0.8866408954	6	44.33204477	5.319845372	18.09963722
60	1.0625	0.8866408954	6	53.19845372	5.319845372	21.71956467
70	1.0625	0.8866408954	6	62.06486268	5.319845372	25.33949211
80	1.0625	0.8866408954	6	70.93127163	5.319845372	28.95941956
90	1.0625	0.8866408954	6	79.79768059	5.319845372	32.579347
100	1.0625	0.8866408954	6	88.66408954	5.319845372	36.19927444
50	1.25	1.22718463	6	61.35923152	7.363107782	25.051401
60	1.25	1.22718463	6	73.63107782	7.363107782	30.0616812
70	1.25	1.22718463	6	85.90292412	7.363107782	35.0719614
80	1.25	1.22718463	6	98.17477042	7.363107782	40.0822416
90	1.25	1.22718463	6	110.4466167	7.363107782	45.0925218
100	1.25	1.22718463	6	122.718463	7.363107782	50.102802
50	1.5	1.767145868	6	88.35729338	10.60287521	36.07401744
60	1.5	1.767145868	6	106.0287521	10.60287521	43.28882093
70	1.5	1.767145868	6	123.7002107	10.60287521	50.50362442
80	1.5	1.767145868	6	141.3716694	10.60287521	57.7184279
90	1.5	1.767145868	6	159.0431281	10.60287521	64.93323139
100	1.5	1.767145868	6	176.7145868	10.60287521	72.14803488

Pneumatics Analysis

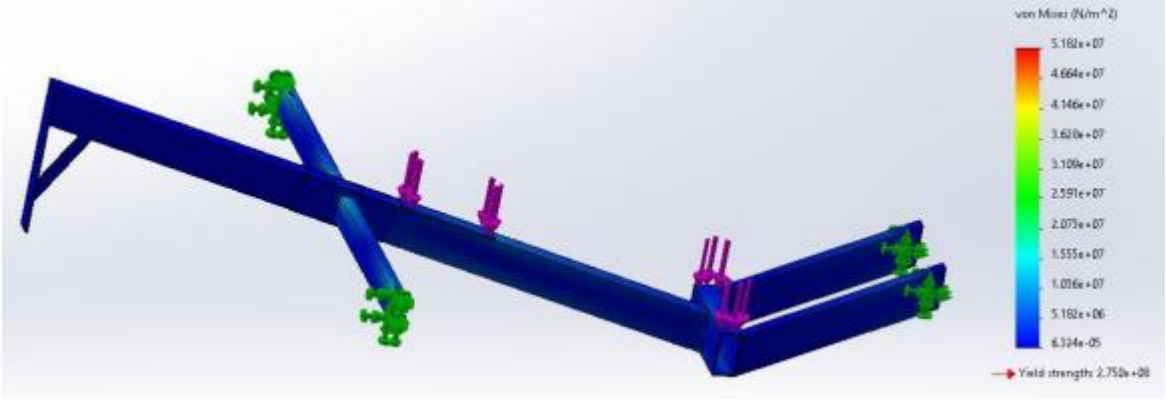
TANK SELECTION

Operating Pressure (psi)	Bore Size (in)	Area (in^2)	Stroke (in)	Volume of Tank (in^3)	Total Volume @ Operating Pressure (in^3)
100	2.5	4.908738521	6	29.45243113	58.90486225
95	2.5	4.908738521	6	29.45243113	55.95961914
90	2.5	4.908738521	6	29.45243113	53.01437603
100	2.5	4.908738521	8	39.26990817	78.53981634
95	2.5	4.908738521	8	39.26990817	74.61282552
90	2.5	4.908738521	8	39.26990817	70.68583471
100	2.5	4.908738521	10	49.08738521	98.17477042
95	2.5	4.908738521	10	49.08738521	93.2660319
90	2.5	4.908738521	10	49.08738521	88.35729338
100	2.5	4.908738521	12	58.90486225	117.8097245
95	2.5	4.908738521	12	58.90486225	111.9192383
90	2.5	4.908738521	12	58.90486225	106.0287521
100	3	7.068583471	6	42.41150082	42.41150082
95	3	7.068583471	6	42.41150082	40.29092578
90	3	7.068583471	6	42.41150082	38.17035074
100	3	7.068583471	8	56.54866776	56.54866776
95	3	7.068583471	8	56.54866776	53.72123438
90	3	7.068583471	8	56.54866776	50.89380099
100	3	7.068583471	10	70.68583471	70.68583471
95	3	7.068583471	10	70.68583471	67.15154297
90	3	7.068583471	10	70.68583471	63.61725124

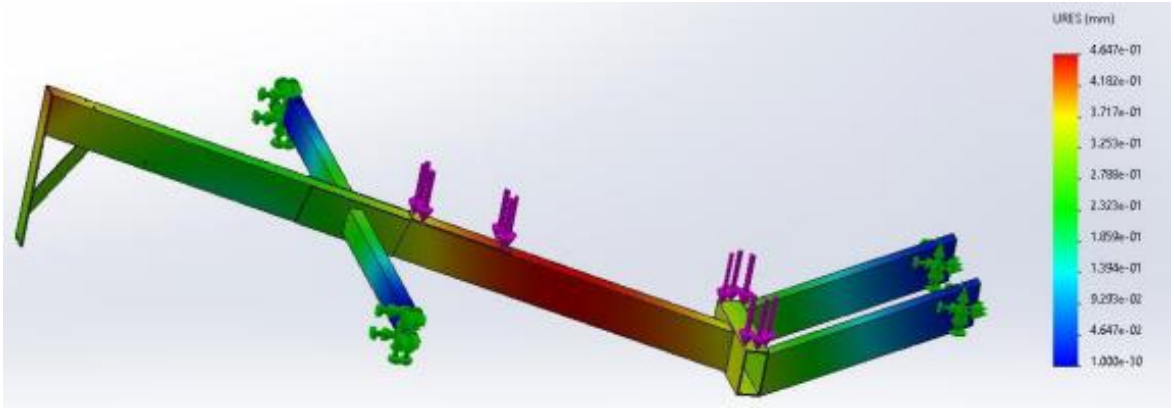
Pneumatics Analysis

Actuations of Selected Components @ Different Operating Pressures							
50 PSI Cylinder Operation							
Number of Actuations	Tank Pressure (psi)	Cylinder Pressure (psi)	Tank Volume (in^3)	Tank Volume @ Operating Pressure (in^3)	Volume of Cylinder (in^3)	Volume of Cylinder @ Operating Pressure (in^3)	Cylinder Force (lb)
0	100	50	39.26990817	78.53981634	2.650718801	9.018504358	22.08932335
1	88.51728362	50	39.26990817	69.52131198	2.650718801	9.018504358	22.08932335
2	77.03456723	50	39.26990817	60.50280762	2.650718801	9.018504358	22.08932335
3	65.55185085	50	39.26990817	51.48430327	2.650718801	9.018504358	22.08932335
4	54.06913447	50	39.26990817	42.46579891	2.650718801	9.018504358	22.08932335
5	42.58641808	42.58641808	39.26990817	33.44729455	2.650718801	7.681315942	18.81410318
6	27.94202453	27.94202453	39.26990817	25.76597861	2.650718801	5.0399054	12.34440829
7	14.74738478	14.74738478	39.26990817	20.72607321	2.650718801	2.659987078	6.515195016
8	6.784521176	6.784521176	39.26990817	18.06608613	2.650718801	1.223724676	2.99730964
40 PSI Cylinder Operation							
Number of Actuations	Tank Pressure (psi)	Cylinder Pressure (psi)	Tank Volume (in^3)	Tank Volume @ Operating Pressure (in^3)	Volume of Cylinder (in^3)	Volume of Cylinder @ Operating Pressure (in^3)	Cylinder Force (lb)
0	100	40	39.26990817	98.17477043	2.650718801	7.214803487	17.67145868
1	92.65106151	40	39.26990817	90.95996694	2.650718801	7.214803487	17.67145868
2	85.30212303	40	39.26990817	83.74516345	2.650718801	7.214803487	17.67145868
3	77.95318454	40	39.26990817	76.53035997	2.650718801	7.214803487	17.67145868
4	70.60424606	40	39.26990817	69.31555648	2.650718801	7.214803487	17.67145868
5	63.25530757	40	39.26990817	62.10075299	2.650718801	7.214803487	17.67145868
6	55.90636909	40	39.26990817	54.88594951	2.650718801	7.214803487	17.67145868
7	48.5574306	40	39.26990817	47.67114602	2.650718801	7.214803487	17.67145868
8	41.20849212	40	39.26990817	40.45634253	2.650718801	7.214803487	17.67145868
9	33.85955363	40	39.26990817	33.24153905	2.650718801	7.214803487	17.67145868
10	26.51061515	26.51061515	39.26990817	26.02673556	2.650718801	4.781721965	11.712031
11	14.34223825	14.34223825	39.26990817	21.24501359	2.650718801	2.586910764	6.336206766
12	6.814351462	6.814351462	39.26990817	18.65810283	2.650718801	1.229105167	3.010488257

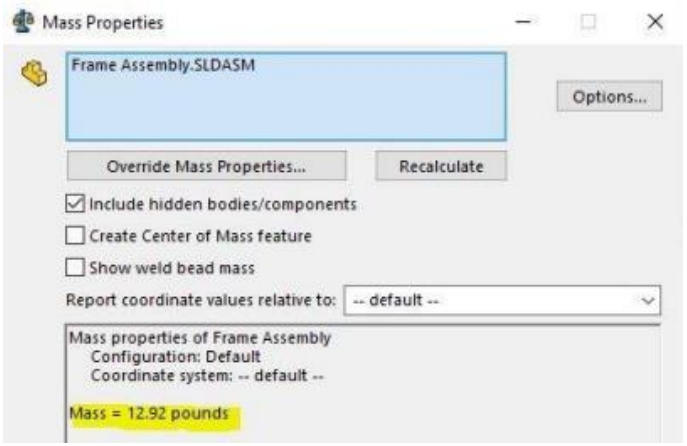
Frame Analysis



Stress



Displacement

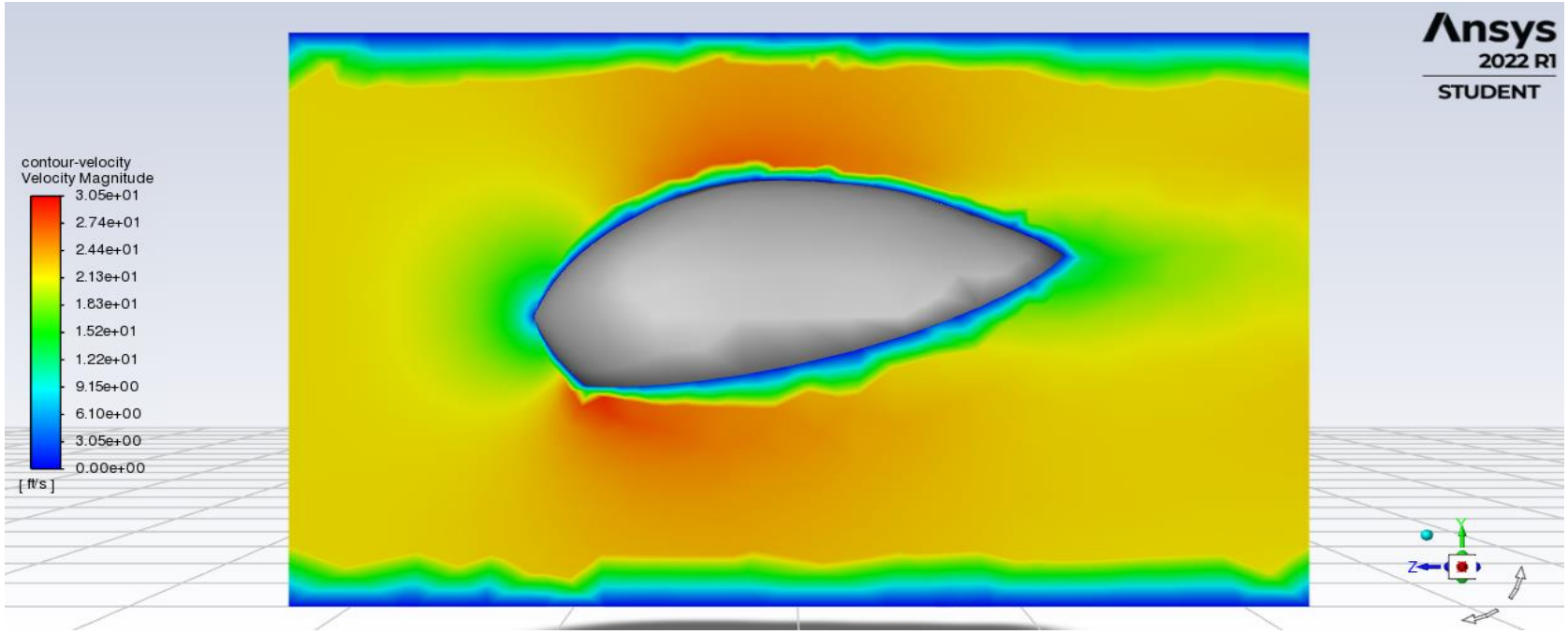


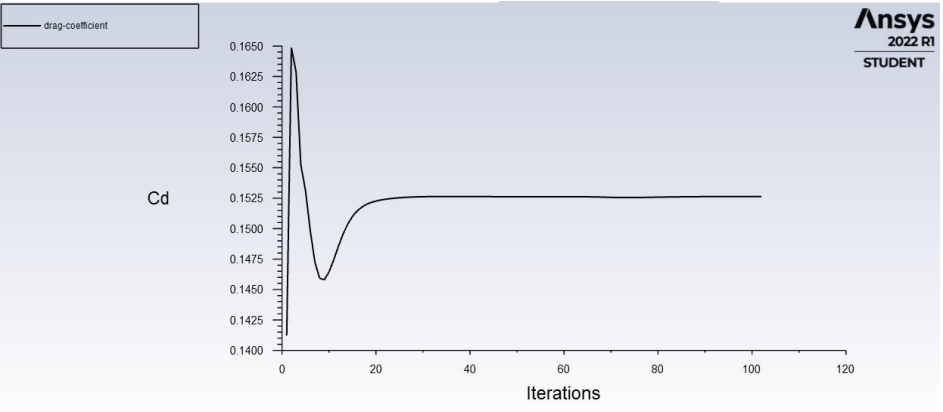
Weight

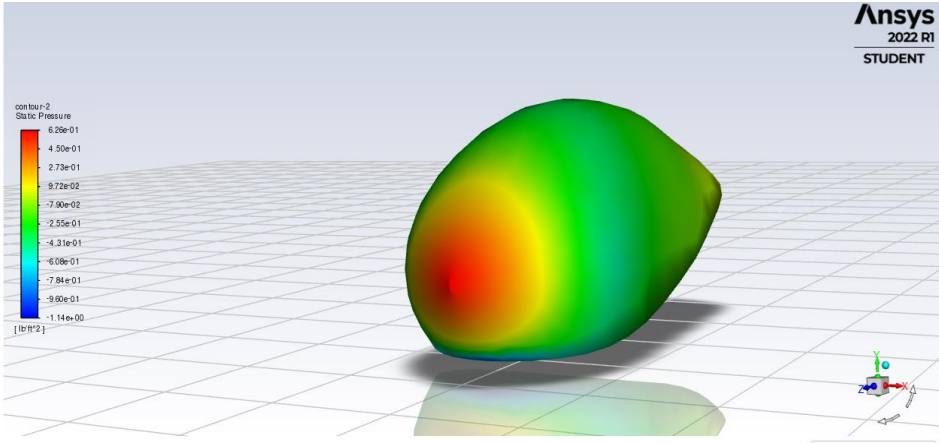
Frame Analysis

	Wall Thickness	Outside Dimentions	Length Base_outer (in)	Length Base_inner (in)	Length Height_outer (in)	Length Height_inner (in)	Area (in^2)	MOI (in^4)	Max Stress (psi)	Safety Factor	Aspect Ratio
Cross Beam	1/8 inch (cross beam)	2x1	1	0.75	2	1.75	0.6875	0.331706	4100.02	4.390223	2
	1/8 inch	2x1.5	1.5	1.25	2	1.75	0.8125	0.441732	3078.791	5.84645	1.333333
	1/8 inch (rear arms)	2.5x1.25	1.25	1	2.5	2.25	0.875	0.678385	2505.95	7.182904	2
	1/8 inch	2.5x1.5	1.5	1.25	2.5	2.25	0.9375	0.766602	2217.58	8.116958	1.666667
	1/8 inch	3x1.5	1.5	1.25	3	2.75	1.0625	1.208659	1687.821	10.66464	2
	1/8 inch	3x2	2	1.75	3	2.75	1.1875	1.467122	1390.477	12.9452	1.5
	3/16 inch	3x1.5	1.5	1.125	3	2.625	1.54688	1.67926	1214.821	14.817	2
	1/8 inch	2x1.5	1.5	1.25	2	1.75	0.8125	0.441732	7074.429	2.544375	1.333333
Main Beam	1/8 inch (main beam)	3x1.5	1.5	1.25	3	2.75	1.0625	1.208659	3878.266	4.64125	2
	1/8 inch	3x2	2	1.75	3	2.75	1.1875	1.467122	3195.03	5.63375	1.5
	3/16 inch	3x1.5	1.5	1.125	3	2.625	1.54688	1.67926	2791.408	6.448359	2
connector	1/8 inch (connector)	3.5x1.75	1.75	1.5	3.5	3.25	1.25	1.961589	2787.919	6.456429	2
	1/8 inch	4x2	2	1.75	4	3.75	1.4375	2.976237	2099.967	8.571563	2
	3/16 inch	4x2	2	1.625	4	3.625	2.10938	4.216125	1482.404	12.14244	2
	Beam A (cross bar)			Beam B (main beam)							
	Length	34	inch	Length	50	inch					
	Load	160	pound	Load	250	pound					
	Bending Moment (point load, max stress)	1360	pound-inch	Bending Moment (point load, max stress)	3125	pound-inch					

Windshield


Ansys
2022 R1
STUDENT
contour-velocity
Velocity Magnitude
3.05e+01
2.74e+01
2.44e+01
2.13e+01
1.83e+01
1.52e+01
1.22e+01
9.15e+00
6.10e+00
3.05e+00
0.00e+00
[ft/s]


drag-coefficient
Ansys
2022 R1
STUDENT
Cd
0.1650
0.1625
0.1600
0.1575
0.1550
0.1525
0.1500
0.1475
0.1450
0.1425
0.1400
0
20
40
60
80
100
120
Iterations


Ansys
2022 R1
STUDENT
contour-2
Static Pressure
6.26e-01
4.50e-01
2.73e-01
9.72e-02
-7.90e-02
-2.55e-01
-4.31e-01
-6.08e-01
-7.84e-01
-9.60e-01
-1.14e+00
[lbf/ft^2]