NFPA Fluid Power Vehicle Challenge

PURDUE UNIVERSITY NORTHWEST
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NFPA Education and Technology Foundation

PURDUE UNIVERSITY NORTHWEST

Team Photo

Figure 1. Team Photo. Hammond IN. 2020

Team Members Left to Right. Brian Long, Daniel Kwak, Christian Miller, Sean Slouber, Alireza Alavizadeh

Problem Statement

- Create a vehicle that combines human power and fluid power in order to compete against other schools while promoting/spreading the importance of fluid power in our daily life.

Video 1. Vehicle Turning. Oak Forest IL. 2020

Key Changes Since Midway Review

- Switched from the Quad Design to a Tricycle design
- Traditional peddling rather than elliptical
- Added more to the Electrical Circuit
- Complete redesign on frame and steering system

Midway Review Designs

Figure 2. Midway Review Frame. SolidWorks 2020.

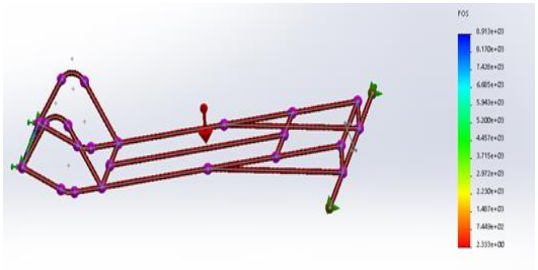


Figure 3. Midway Review FOS. SolidWorks 2020.

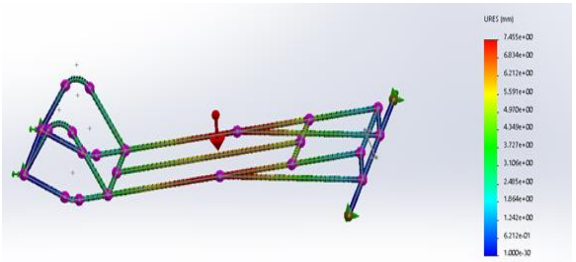


Figure 4. Midway Review Displacement. SolidWorks 2020.

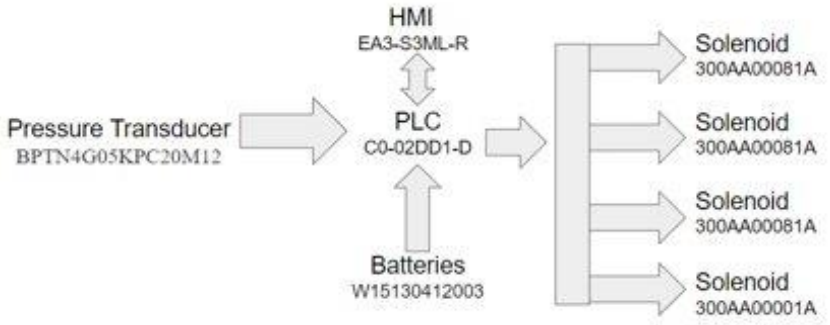


Figure 5. Midway Review Electrical Circuit. SolidWorks 2020.

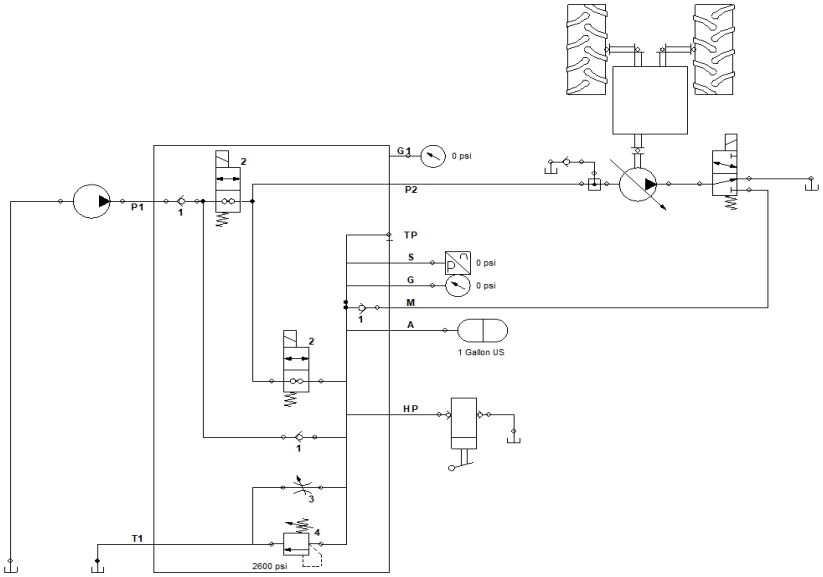


Figure 6. Midway Review Hydraulic Schematic. Automation Studios. 2020

Vehicle Frame BOM & Budget

Budget= $1300

Part name	Link/ distributor	Price
Docol R8 steel	A.E.D	$253.80
Bike rims	Top LowRider	$160.00
Tires	Trek	$50.00
Handlebars	Top LowRider	$39.99
Rear Axle	Top LowRider	$199.99
Front Fork	Top LowRider	$54.99
Front Brake	Top LowRider	$34.99
Brake Levers	Brake Lever	$9.99
Rear Rims	Top Lowrider	$119.98
Fasteners		$200.00
Paint/ Body	Bryan's Auto Rebuilders	$175.00
	Total:	$1,298.73
	Remainder/ over	$1.27

Table 1. Vehicle Frame BOM & Budget. Google Sheets. 2020

Frame Analysis

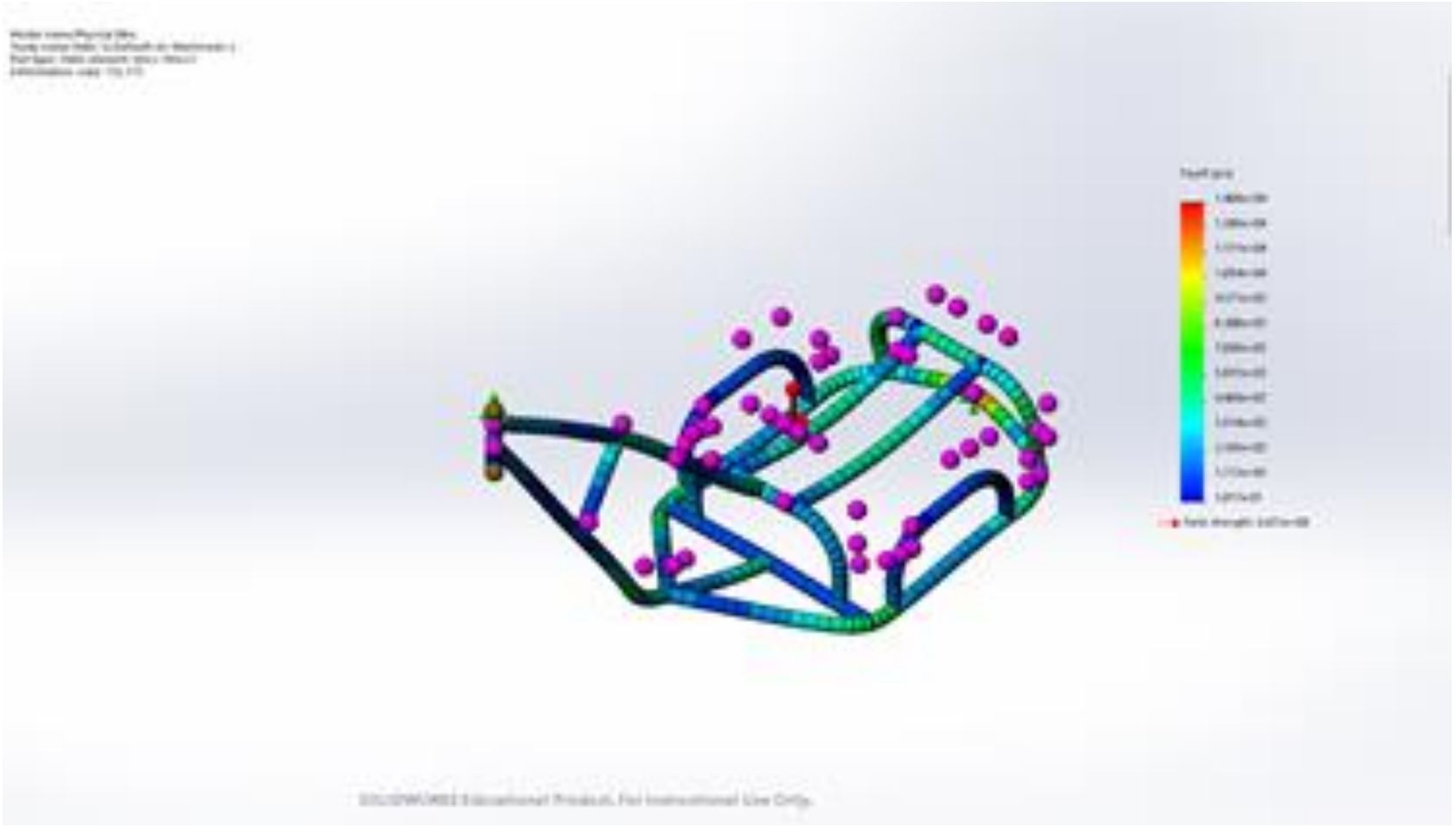


Figure 7. Frame Stress Analysis. Maximum Stress= 14.06 ksi. SolidWorks 2020

Frame Analysis

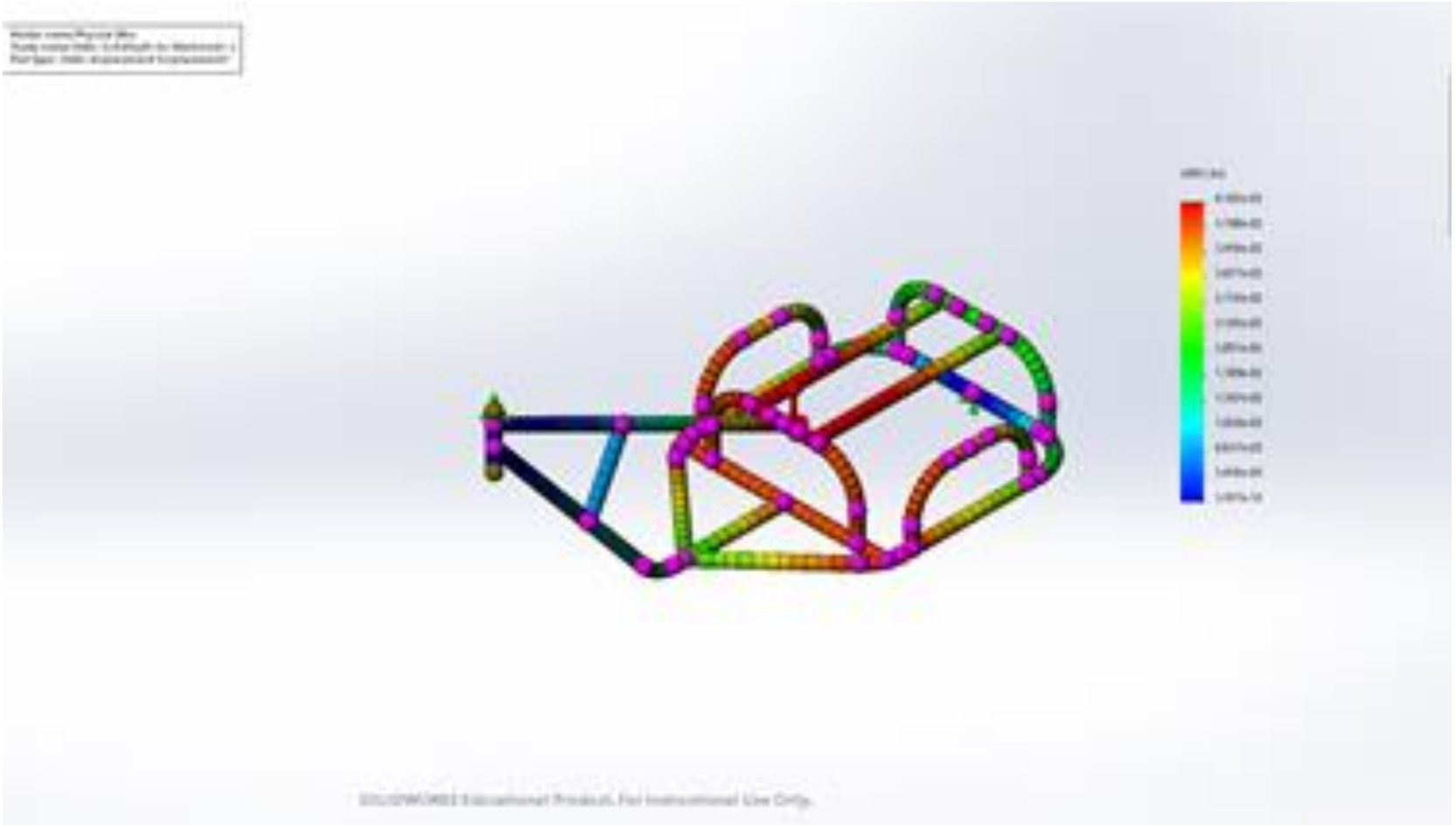


Figure 8. Frame Displacement Analysis. Maximum Deformation= 0.041 in. SolidWorks 2020

Frame Analysis

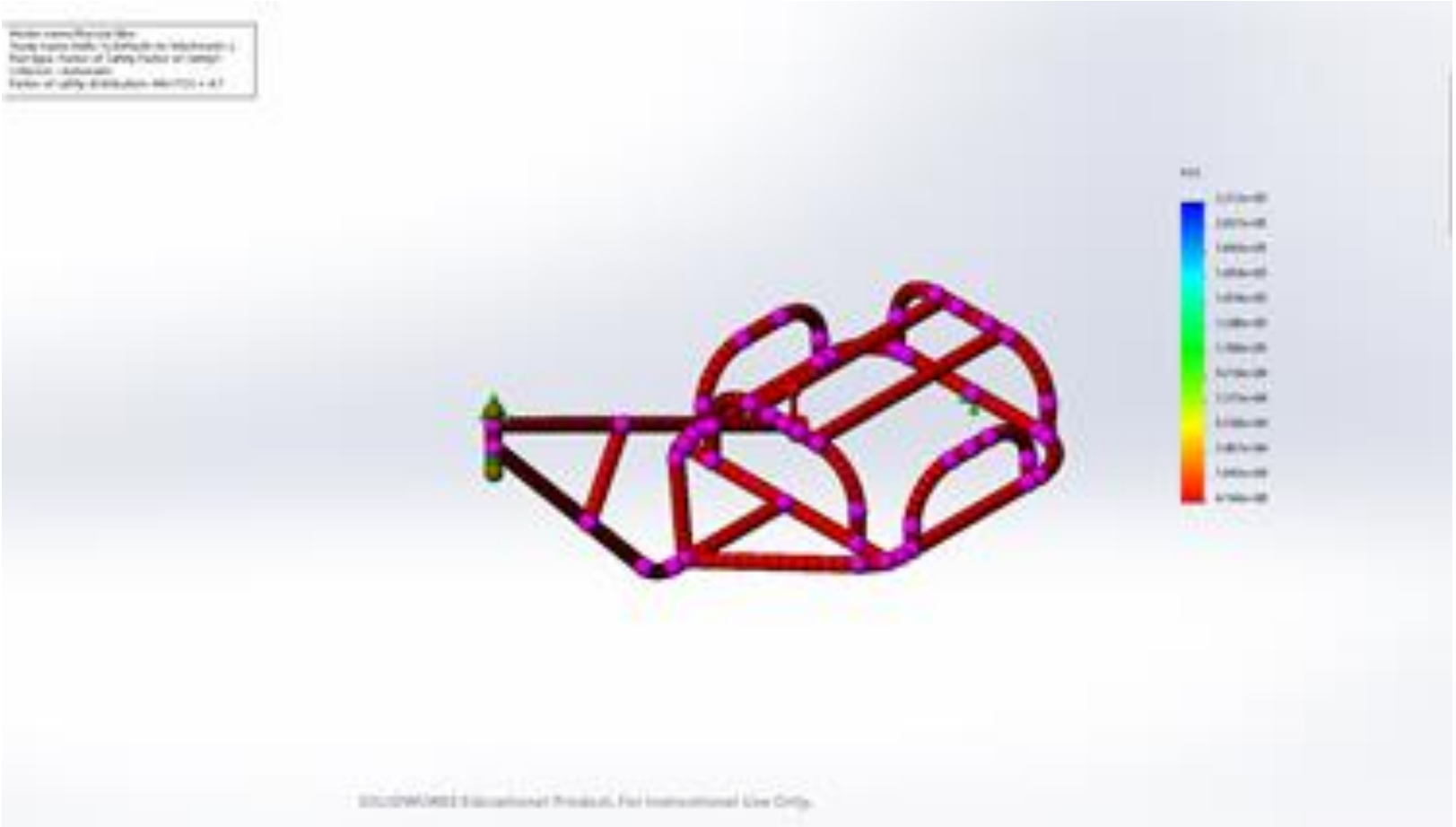


Figure 9. Frame Factor of Safety Analysis. FOS=4.746. SolidWorks 2020

Tubing

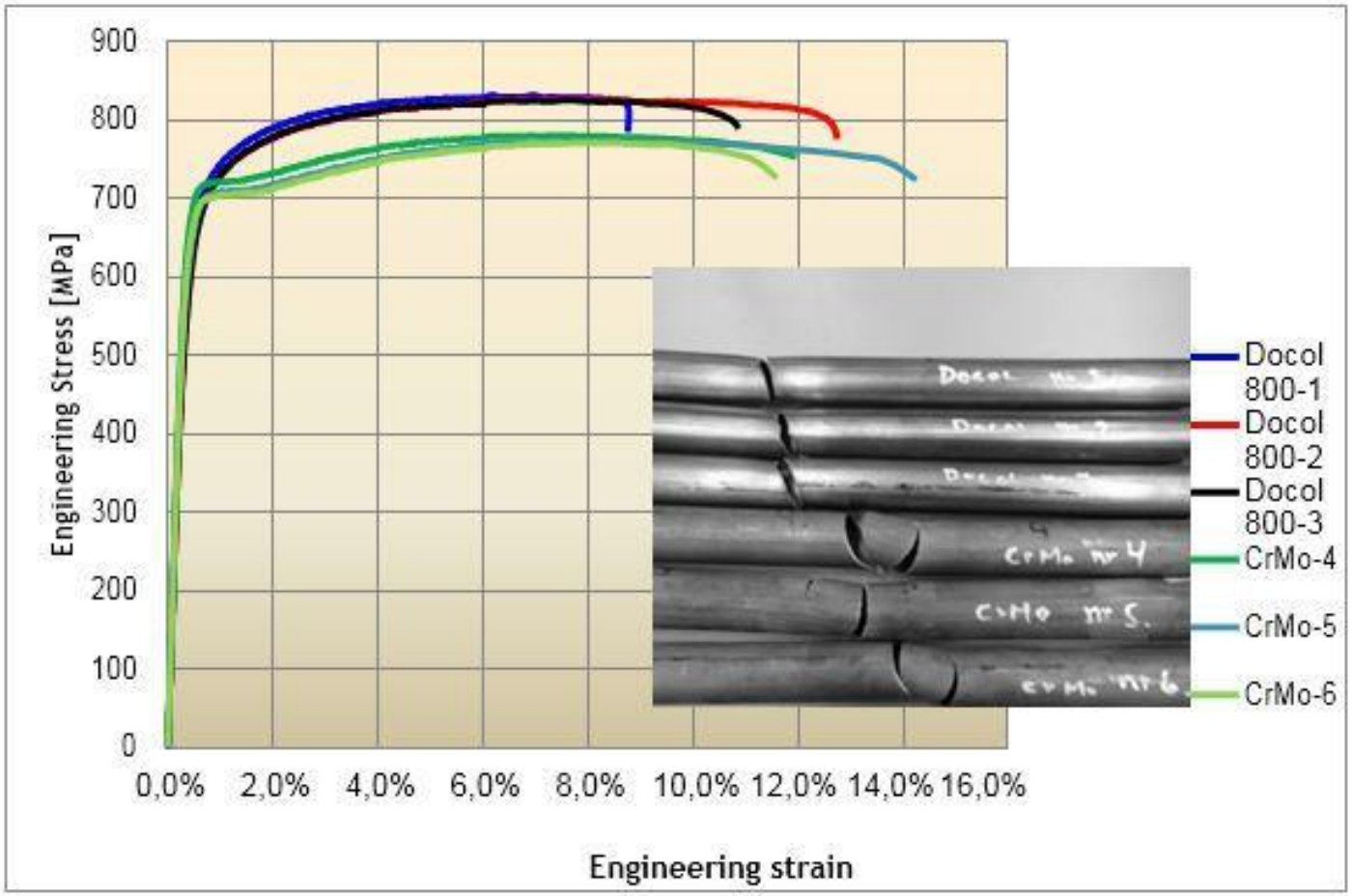


Figure 10. Docol vs. Chrome Moly Graph. Peter Falk. 2020

Vehicle Calculations

Wheel Diameter	24in		Axle Sprocket 1	14 T
Desired Speed	15mph		Axle Sprocket 2	16 T
Pump Displacement	0.763CID		Axle Sprocket 3	18 T
Motor Displacement	0.61CID		Axle Sprocket 4	20 T
Required Torque	100 in*lb		Axle Sprocket 5	22 T
Input RPM	65RPM		Axle Sprocket 6	24 T
Driving Sprocket	42 T		Axle Sprocket 7	28 T
Driven Sprocket	13 T		Motor Sprocket	16 T

Table 3. Givens/ Assumptions for Calculations. Google Sheets. 2020

Vehicle:				Equations
RPM		210.0		(336*MPH)/(Wheel Dia.)

Table 4. Vehicle Calculations. Google Sheets. 2020

Pump:				Equations
Theoretical GPM Pump		0.7		(CIR*RPM)/(231)
Theoretical PSI Pump		823.5		((in*lb)*2pi)/(CID)
Theoretical Pump HP		0.3		(Theoretical GPM*1000)/1714
Theoretical RPM Pump		210.0		(GPM*231)/(CID)

Table 5. Pump Calculations. Google Sheets. 2020

Vehicle Calculations

Motor:		Equations
Theoretical RPM Motor	262.7	(GPM*231)/(CID)
Theoretical Torque Motor	789.1	(CID*PSI)/(2pi)
Theoretical Motor HP	0.4	(Theoretical Torque*Theoretical RPM)/63025

Table 6. Motor Calculations. Google Sheets. 2020

Motor Sprocket Ratios		Equations
Number of Teeth	Gear Ratio	
14	0.9	T2/T1
16	1.0	T2/T1
18	1.1	T2/T1
20	1.3	T2/T1
22	1.4	T2/T1
24	1.5	T2/T1
28	1.8	T2/T1

Table 7. Motor Sprocket Ratios. Google Sheets. 2020

Speed in Different Gears		Equations
Number of Teeth	Actual Speed (MPH)	Desired Speed*Gear Sprocket Gear Ratio
14	13.1	Desired Speed*Gear Sprocket Gear Ratio
16	15.0	Desired Speed*Gear Sprocket Gear Ratio
18	16.9	Desired Speed*Gear Sprocket Gear Ratio
20	18.8	Desired Speed*Gear Sprocket Gear Ratio
22	20.6	Desired Speed*Gear Sprocket Gear Ratio
24	22.5	Desired Speed*Gear Sprocket Gear Ratio
28	26.3	Desired Speed*Gear Sprocket Gear Ratio

Table 8. Speed in Different Gears Calculations. Google Sheets. 2020

Equations from Parker, E (2017)

Hydraulic BOM & Budget

Budget= $2,535.00

Part name	Manufacturer	Part/ model Number	Price	Quantity	Total
2/2 Solenoid	Eaton	SBV1-10-C-0-00	$72.00	3	$216.00
2/3 solenoid	Deltrol	DSV2-100-3B-N	$41.00	1	$41.00
Coil, Series 10	Deltrol	10162-91	$40.00	1	$40.00
Pressure Gauge	Seal fast	118AL25N4P5000	$27.00	1	$27.00
Check Valves (cartridge insert)	Deltrol	DCV-080-PB	$30.00	2	$60.00
Check Valves (in line)	Deltrol	EDC30SS	$30.00	1	$30.00
Pressure Relief Valve	Deltrol	DDRV-080	$45.00	1	$45.00
Hand Pump, .5 CID	Deltrol	DHP-100	$80.00	1	$80.00
Accumulator (1 Gal.)	Steelhead	AB30CN010G0N	$810.00	1	$810.00
Pump	Cassapa	26002-LZG	$310.00	1	$310.00
Motor	Cassapa	26702-DAB	$375.00	1	$375.00
Fittings	Eaton		$200.00	1	$200.00
Hoses	Ryco		$300.00	1	$300.00
			Total:		$2,534.00
			Remainder/ Over:		$1.00

Table 9. Hydraulic BOM & Budget. Google Sheets 2020.

Hydraulic Circuit

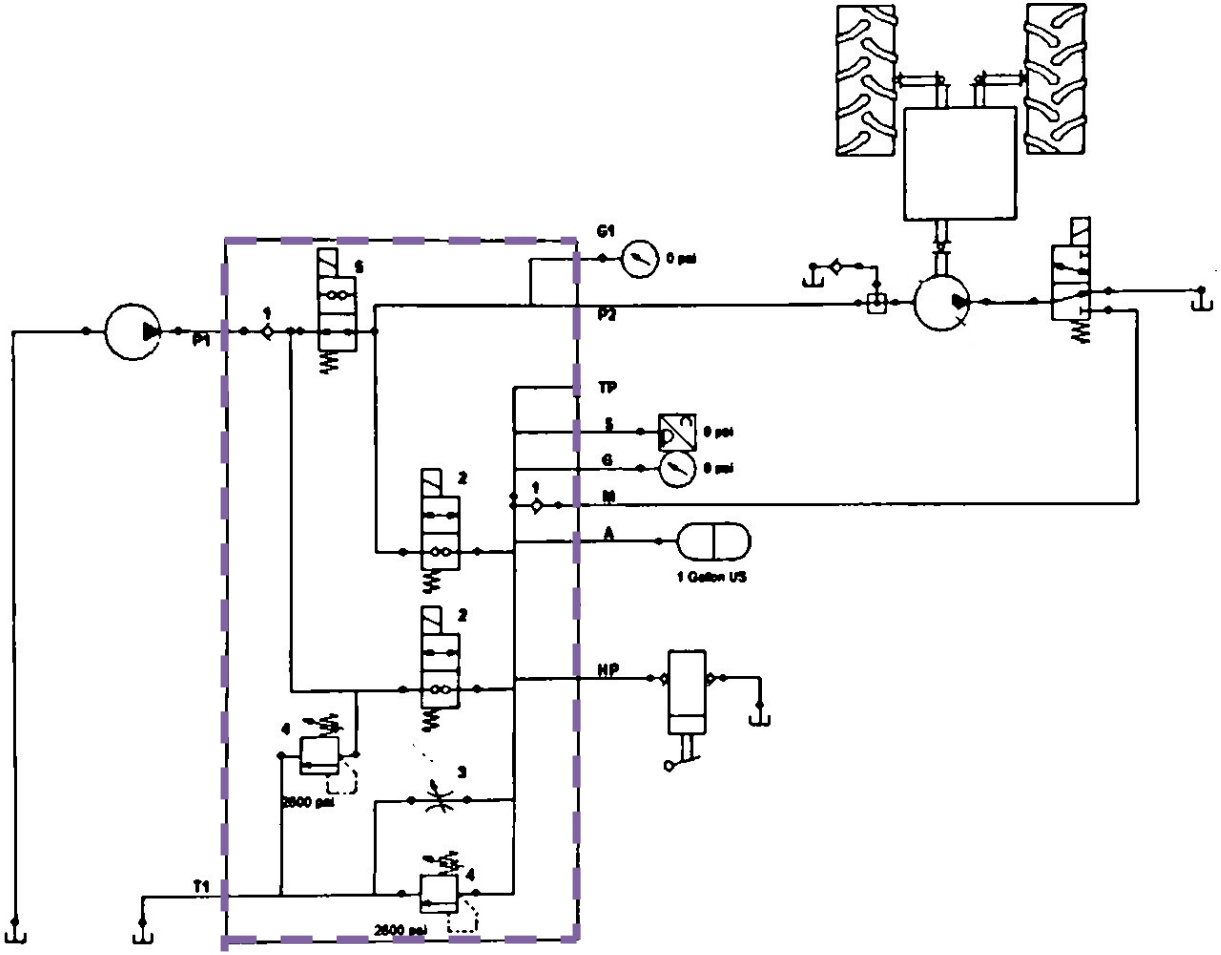


Figure 11. Hydraulic Circuit. Automation Studio. 2020.

Direct Drive Circuit

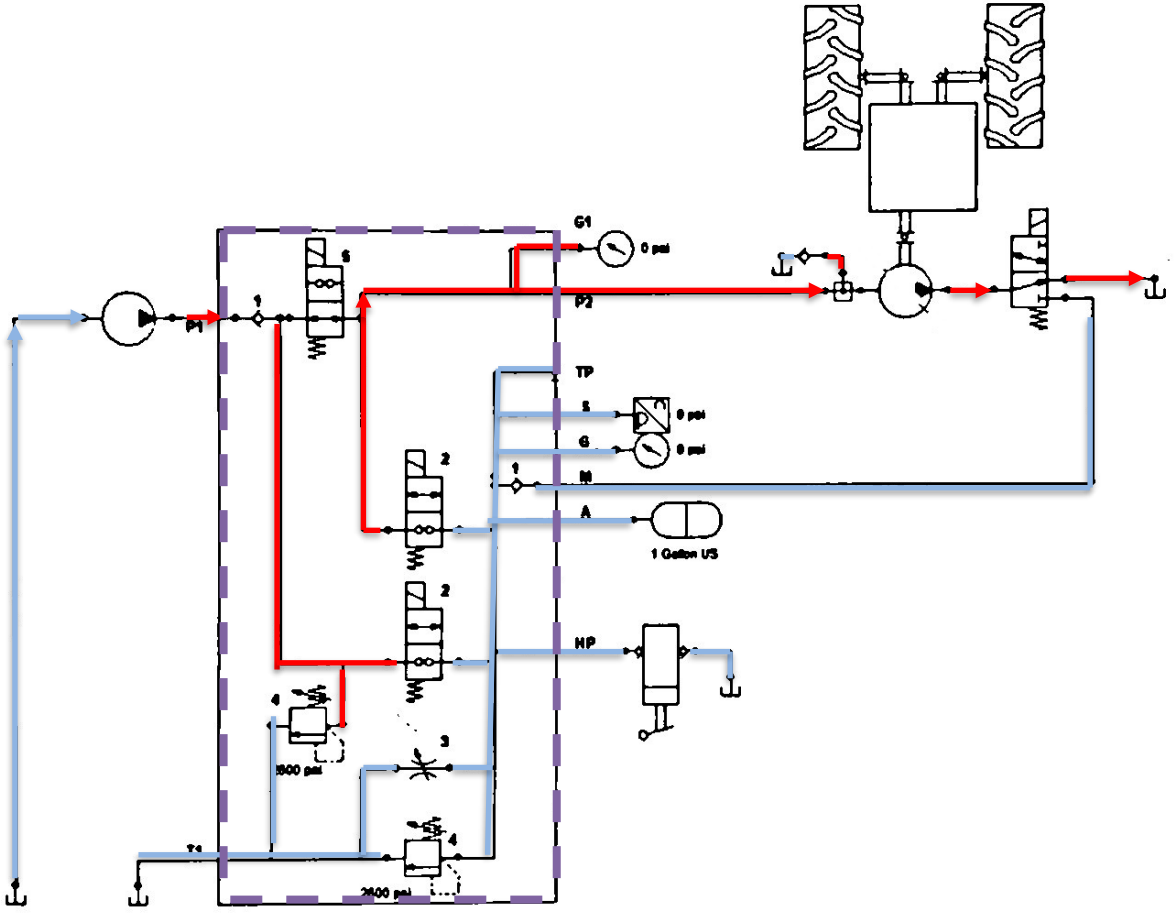


Figure 12. Direct Drive Hydraulic Circuit. Automation Studio. 2020.

Charging Circuit

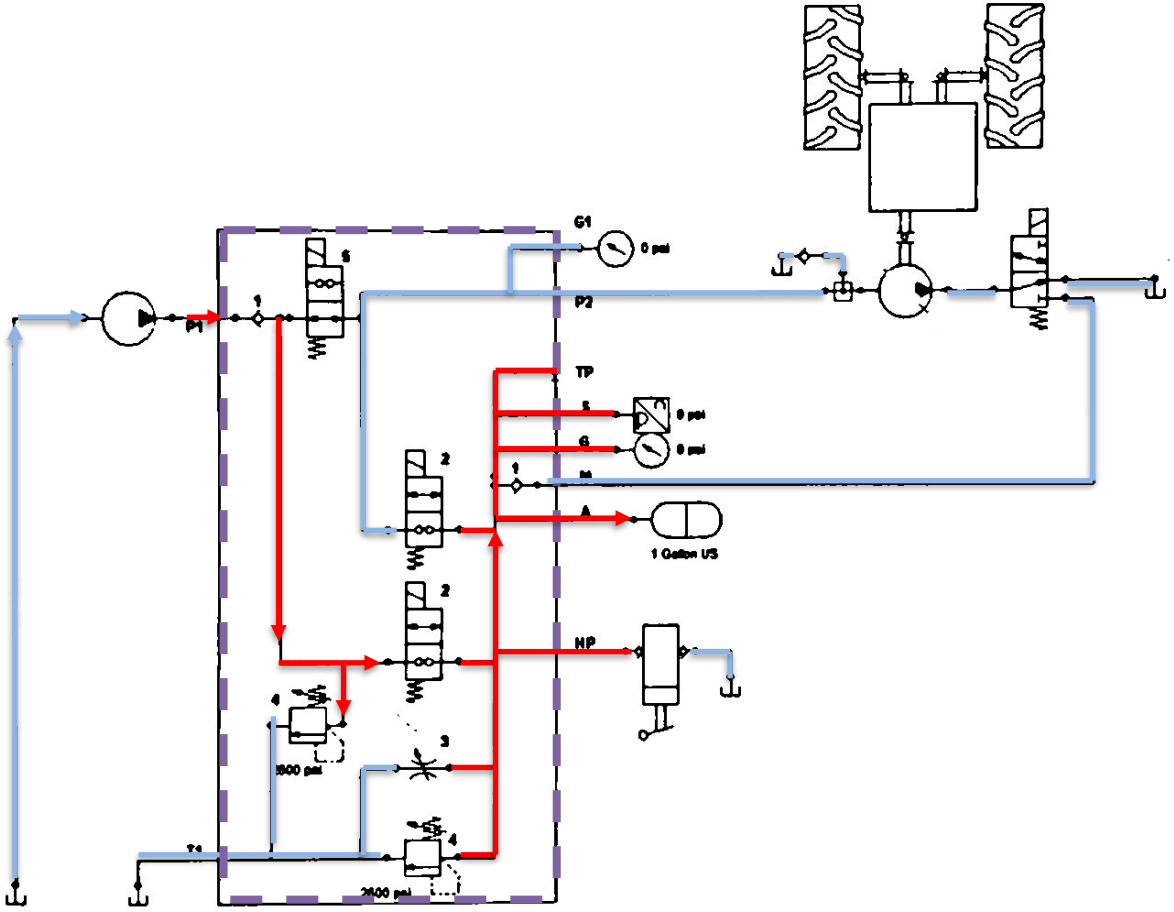


Figure 13. Charging Hydraulic Circuit. Automation Studio. 2020.

Regenerative Braking

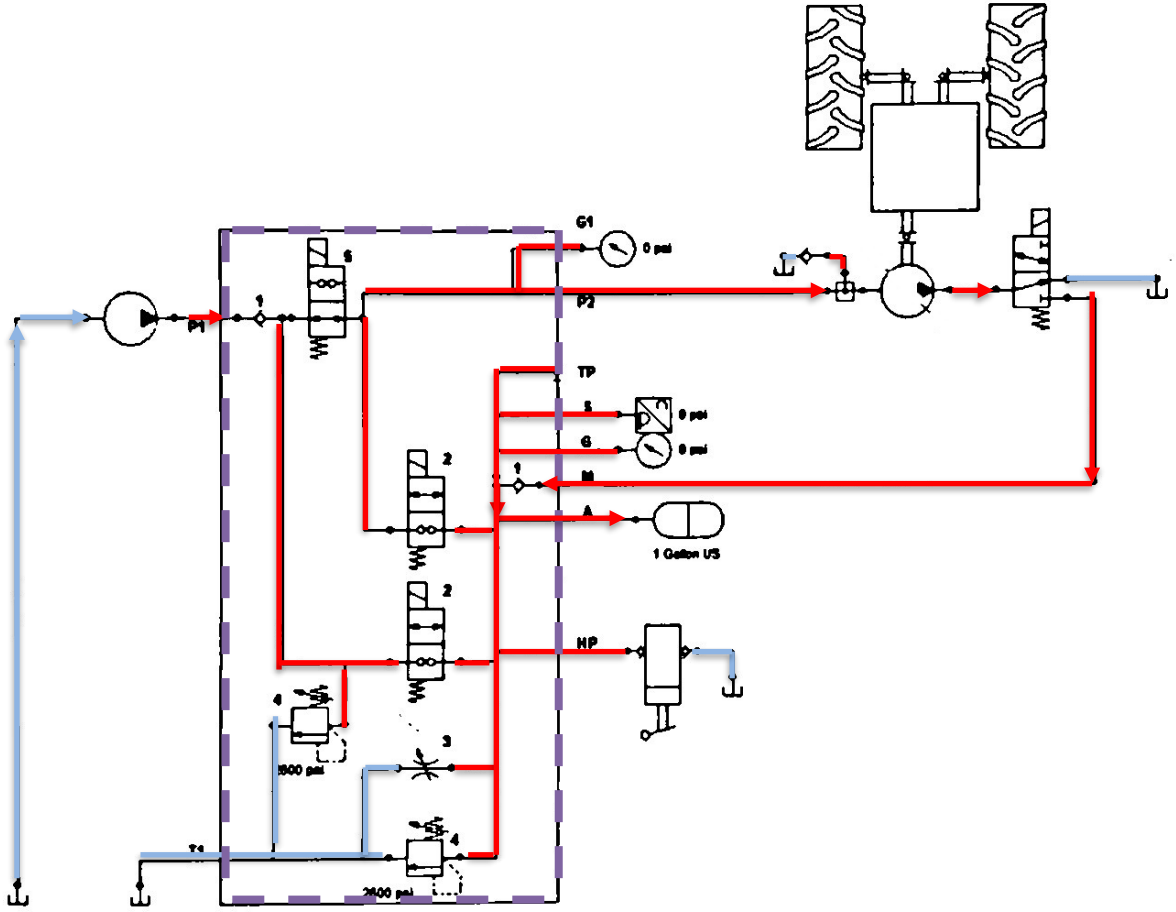


Figure 14. Regenerative Braking Hydraulic Circuit. Automation Studio. 2020.

Discharge Circuit

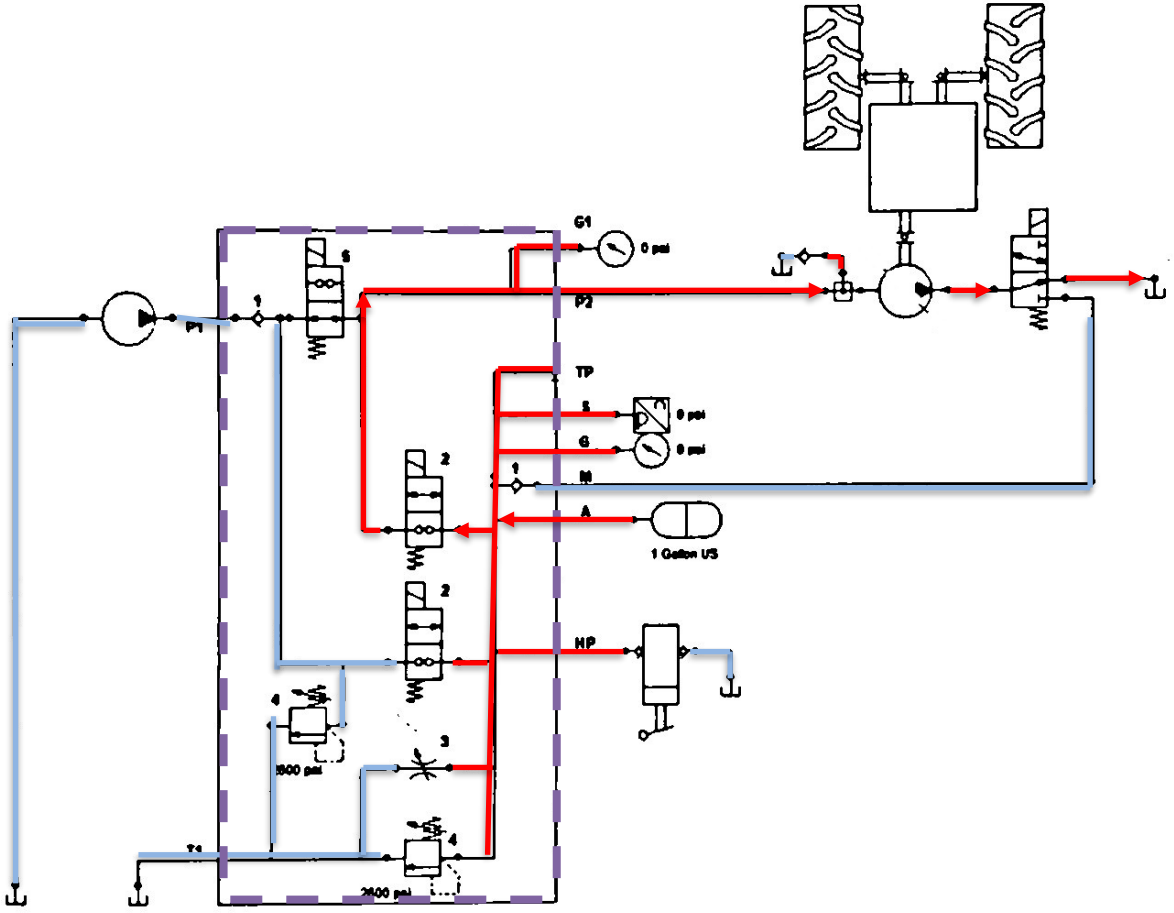


Figure 15. Discharge Hydraulic Circuit. Automation Studio. 2020.

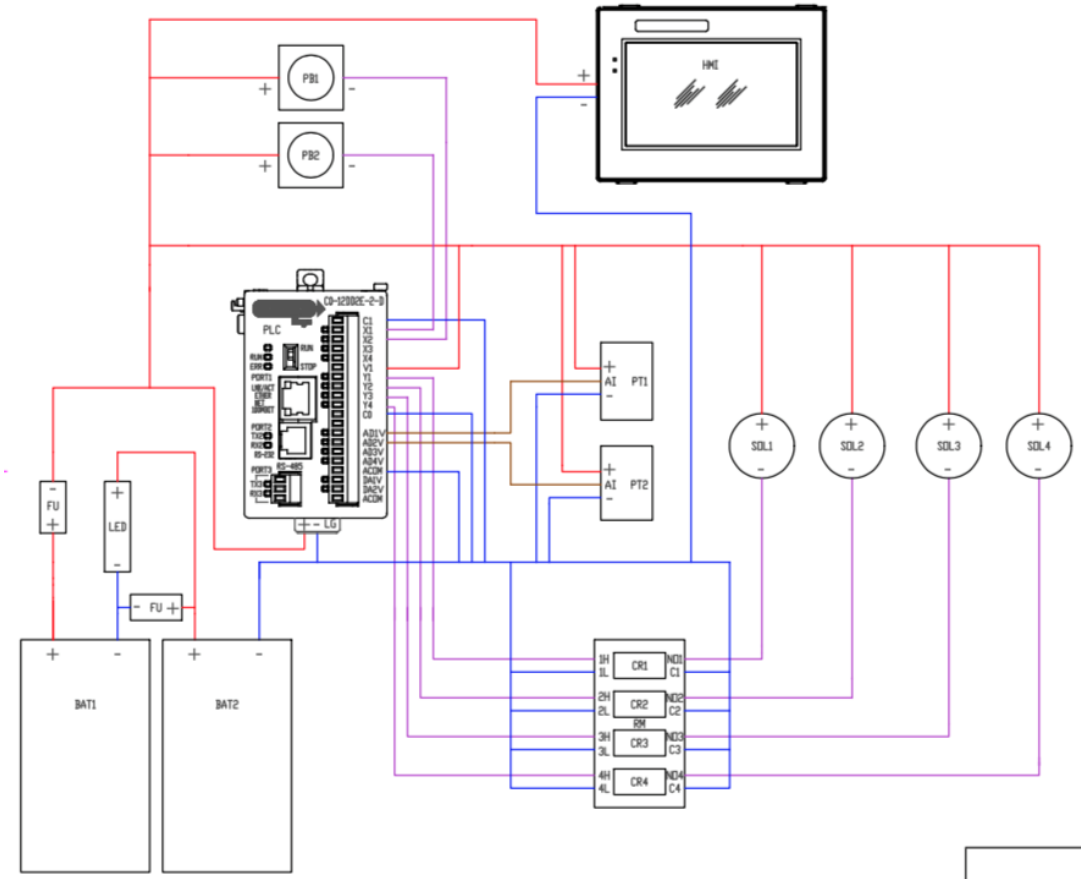
Electrical BOM & Budget

Budget= $565.00

Electrical Budget					
Part name	**Manufacturer**	**Part/ model Number**	**Price**	**Quantity**	**Total**
12V 7Ah Batteries (Set of 2)	Razor	6-DW-7	$85.92	1	$85.92
PLC	Click	CO-12DD2E-2-D	$187.00	1	$187.00
HMI	C-more	EA9-T7CL-R	$282.00	1	$282.00
Pressure Transducer	Cooper	Ptg-402-a-5000-p-3-d-0	$49.99	2	$99.98
24V Solenoid Coil (J-type)	Eaton	300AA00082A	$25.00	2	$50.00
24V Solenoid Coil (H-type)	Eaton	300AA00122A	$32.00	1	$32.00
24V Solenoid Coil	Deltrol	10162-77	$40.00	1	$40
4-Channel Pluggable Power Relay Module w/ 24V Omron G2R-1-E Relays	Electronics-Salon	D-210	$60.00	1	$60.00
DIN Rail	ROHS	D357A11-305	$5.29	1	$5.29
Push Buttons	Keenso	Lqwmutgi-03	$28.19	1	$28.19
Inline Fuse Holders w/ Glass Fuses	Dorman	B07F8RLMPB	$12.00	1	$12.00
12V LED Light Strip	Dainolite	CUTLED_ODRGB	$14.16	1	$14.16
			Total:		**$896.54**
			Budget:		**$565.00**
			Remainder/ Over:		**-$331.54**

Table 9. Electrical BOM & Budget. Google Sheets 2020.

Electrical Circuit



ELECTRICAL COMPONENTS				
Drawing Abbreviation	Manufacturer	Description	Part No.	Qty.
PLC	Click	PLC	CO-12DD2E-2-D	1
HMI	C-more	HMI	EA9-T7CL-R	1
BAT	Razor	12V 7Ah Battery	6-DW-7	2
RM	Electronics-Salon	4-Channel Pluggable Power Relay Module	D-210	1
CR	Omron	24V Industrial Power Relay	G2R-1-E	4
PT	Cooper	Pressure Transducer	PTG-402-A-5000-P-3-D-0	2
SOL1	Eaton	24V Solenoid Coil (H-type)	300AA00122A	1
SOL2, SOL3	Eaton	24V Solenoid Coil (J-type)	300AA00082A	2
SOL4	Deltrol	24V Solenoid Coil	10162-77	1
PB	Keenso	7/8in Handlebar Switch	Lqwmutgi-03	2
FU	Dorman	2A Glass Tube Fuse w/ Inline Fuse Holder	B07F8RLMPB	2
LED	Dainolite	12V LED Light Strip	CUTLED_ODRGB	1

ELECTRICAL CIRCUIT
NFPA FLUID POWER VEHICLE CHALLENGE 2019-2020
PURDUE UNIVERSITY NORTHWEST
HAMMOND, IN

Figure 16. Electrical Schematic & BOM. AutoDesk AutoCAD. 2020

PLC Program

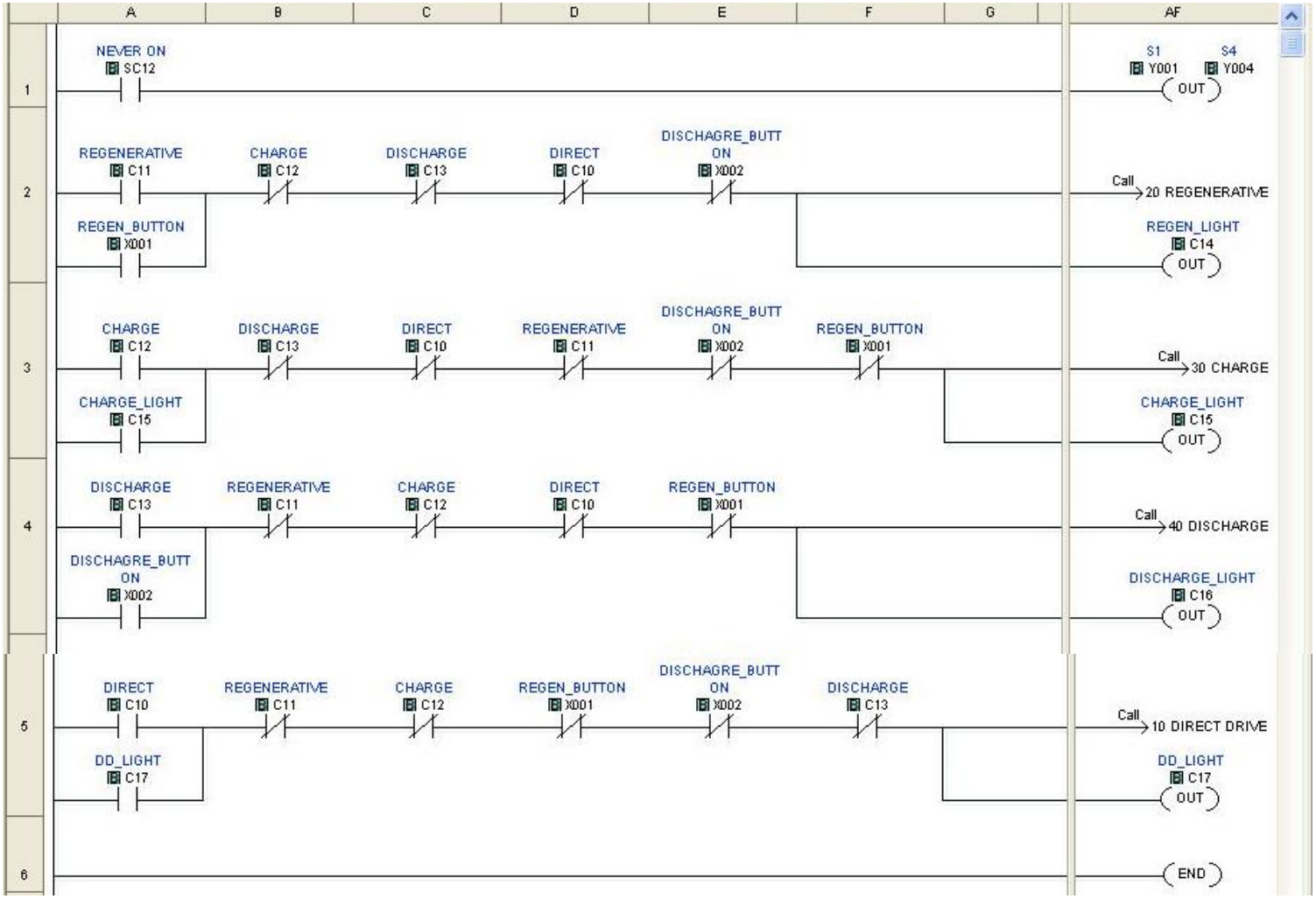


Figure 17. Ladder Logic Program Part 1. Click Programming Software. 2020

PLC Program

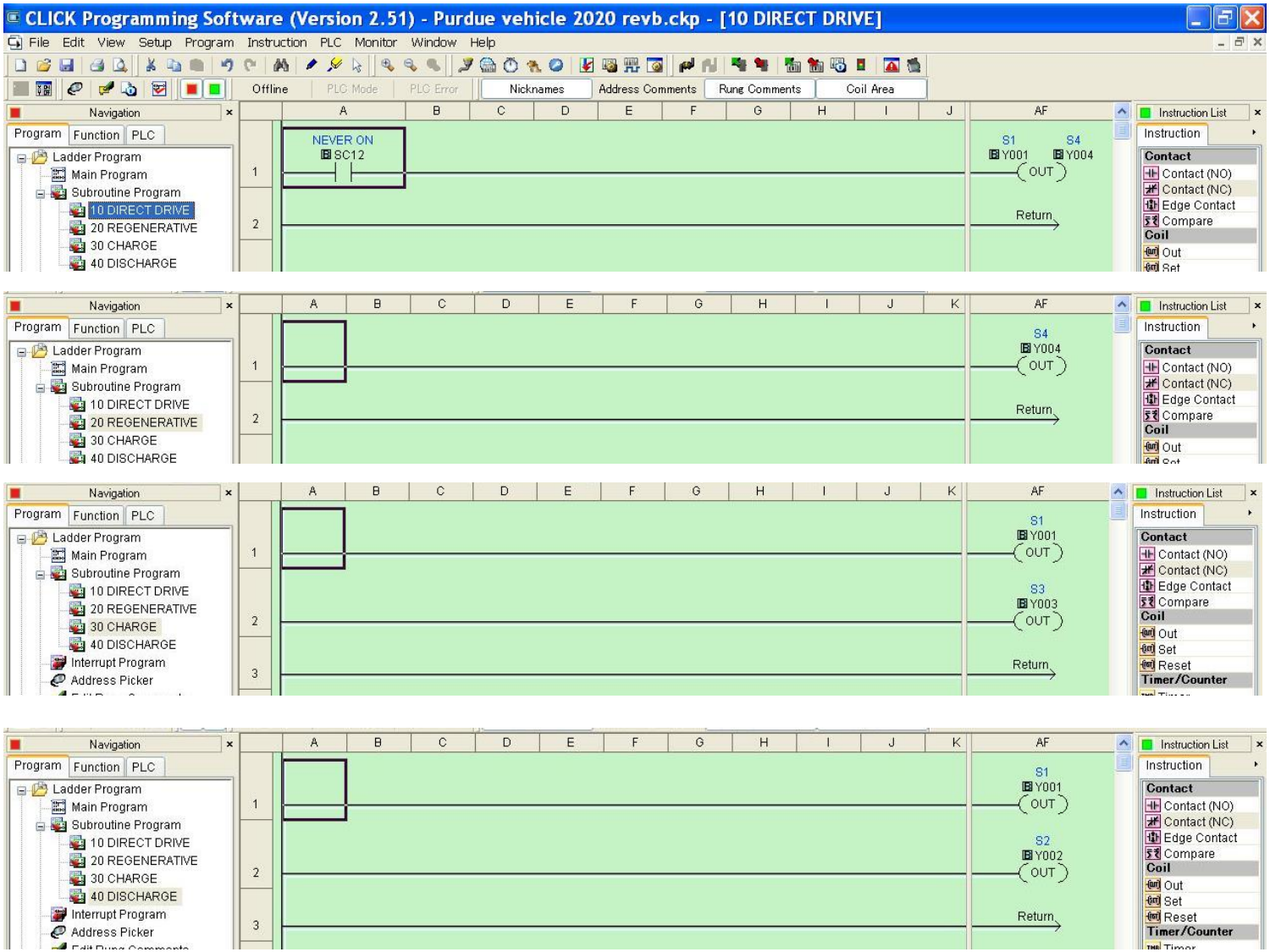


Figure 18. Ladder Logic Program Part 2. Click Programming Software. 2020

HMI Screen

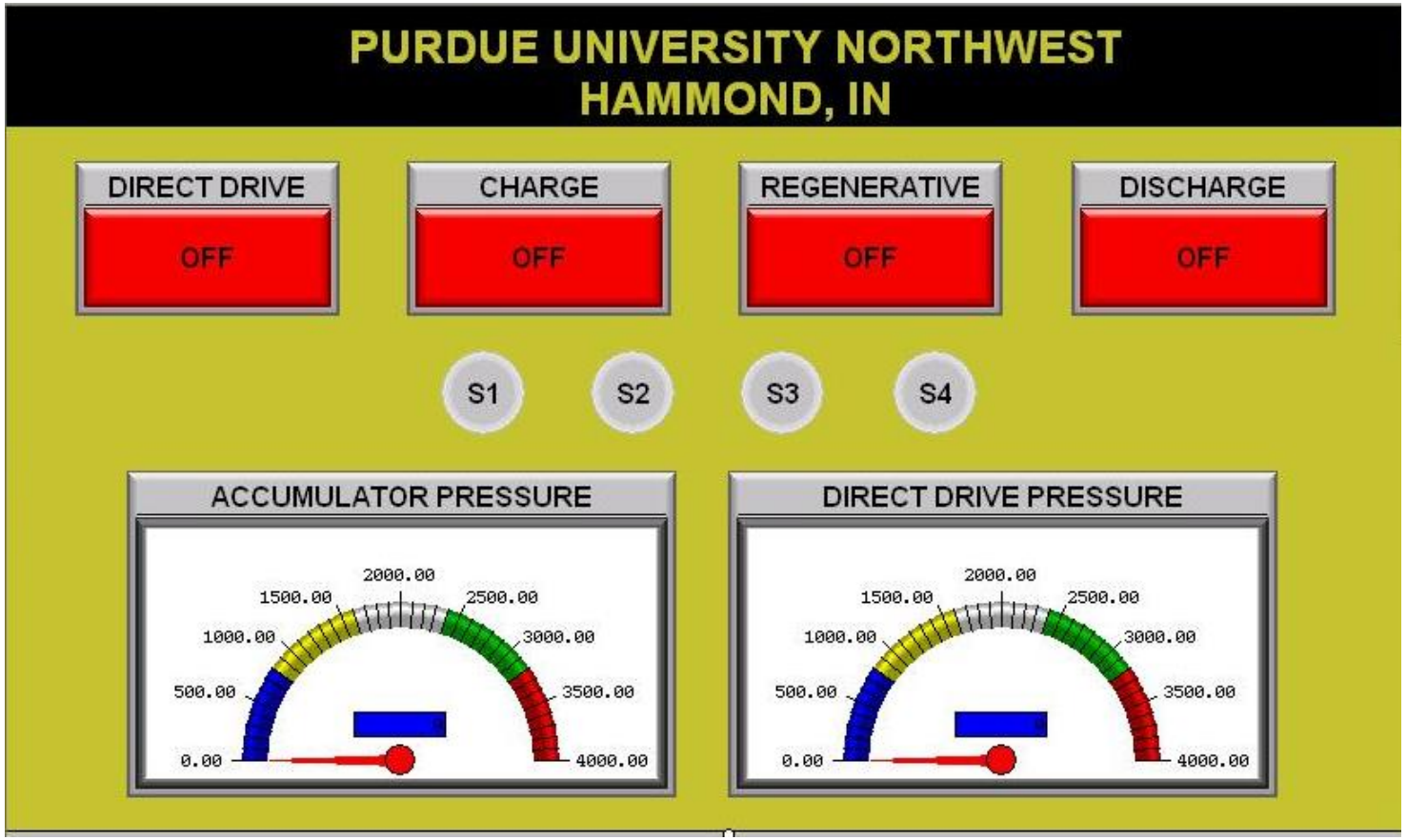


Figure 19. HMI Display Screen. C-more Programming Software. 2020

Build Process

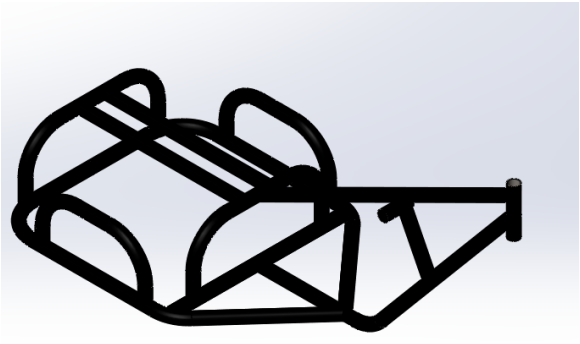


Figure 20. Frame Sketch. SolidWorks 2020

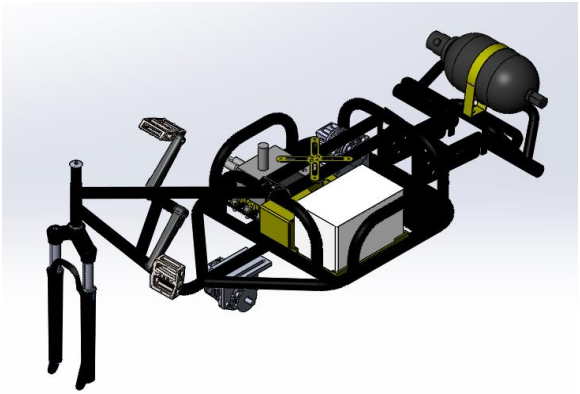


Figure 23. Model Assembly. SolidWorks 2020

Figure 21. Frame Welding. Hammond IN. 2020

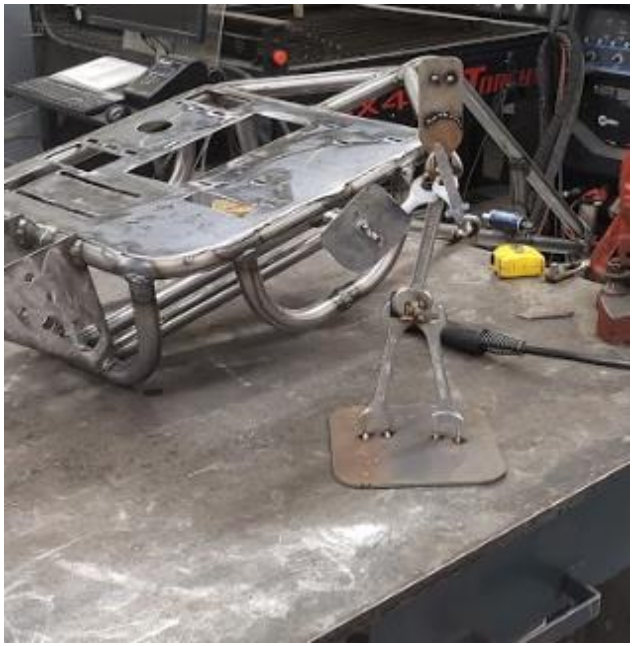


Figure 22. Final Welding. Hammond IN. 2020

Figure 24. Frame Finish Welding. Hammond IN. 2020

Build Process

Figure 25. 3D Printed Parts. Hammond IN. 2020

Figure 28. Tubing for Hydraulic Circuit by Hose Connections. Hammond, IN, 2020

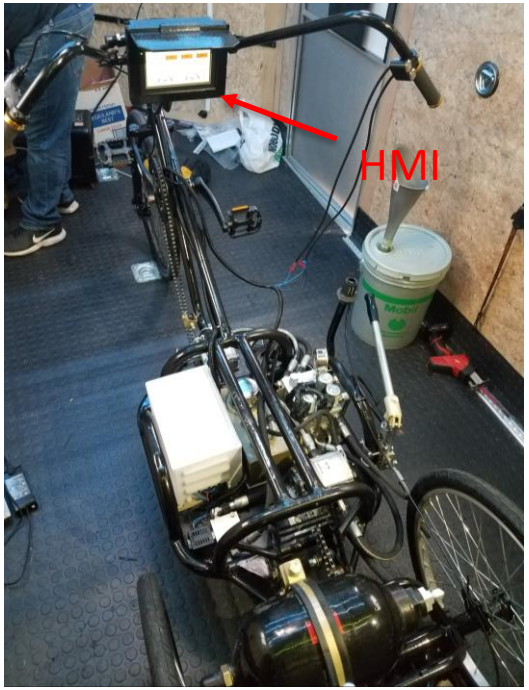


Figure 26. HMI On Bike. Oak Forest IL. 2020

Figure 29. Vehicle in Paint. Chicago Heights. 2020

Figure 27. Finished Vehicle at Night. Oak Forest IL. 2020

Key Features

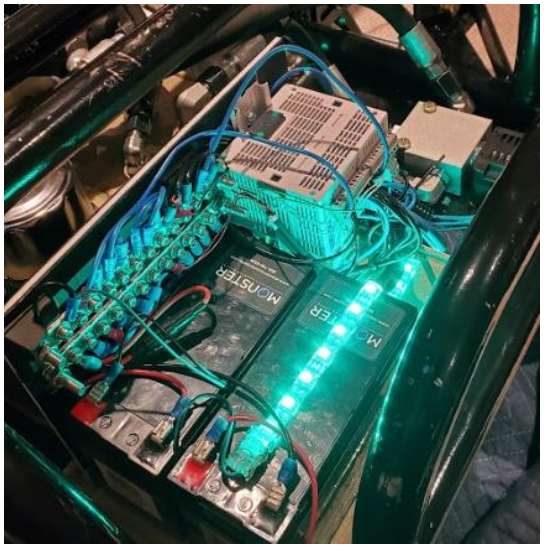


Figure 30. Inside Ebox . Oak Forest IL. 2020

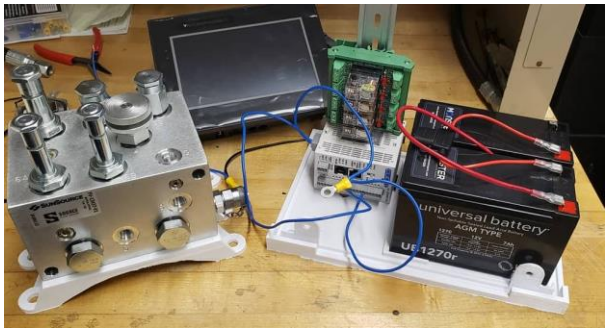


Figure 31. Key Components. Hammond IN. 2020

Figure 32. Frame to axle mounts. Oak Forest IL. 2020

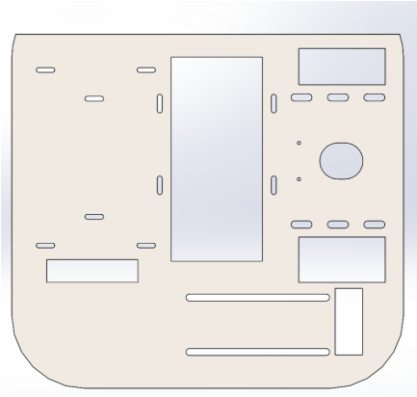


Figure 33. Bottom Mounting Plate. SolidWorks 2020.

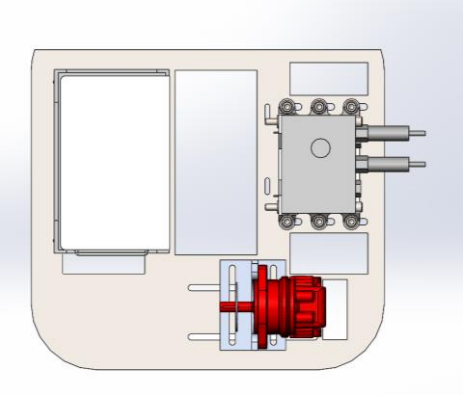


Figure 34. Bottom Mounting Plate Assembly. SolidWorks 2020.

Figure 35. Pump & Motor Mounts. Hammond IN. 2020

Finished Vehicle

Figure 36. Finished Vehicle. Oak Forest IL. 2020

Video 2. Discharge Circuit. Oak Forest IL 2020.

Test Results

- Approx. ¼ mile from 3000psi discharge
- Top speed approx. 17mph
- Final weight is unknown. Approx. 125lbs.

Figure 37. Hose Connections Logo. HoseConnections.com . 2020

Figure 38. PNW BAJA Motorsports. Instagram. 2020

Figure 39. Deltrol Fluid Product Logos. Deltrol.com. 2020

Figure 41. IRG logo. IRG.com. 2020

Figure 40. Bryan's Auto Rebuilder's Logo. Bryansautorebuilders.com. 2020

Lessons Learned

- Contingency plans are necessary
- Outside help is a key to success
- Revisions are important throughout the build process

Bibliography

- Parker, E. (2017). Hydraulic Specialist Certification Review. Bloomington, MN: Hydra Tech Inc.
- Peter Falk, J. L. (2020). *Comparison Report: Docol R8 vs 4130 Chrome Moly*. From AED Metal Products and Supplies: https://www.aedmotorsport.com/resources/comparison-report-docol-r8-vs-4130-chrome-moly