



Final Presentation Cal Poly, SLO Advisor: Dr. James Widmann Mentor: Chris Kolbe April 9th, 2021



Team Introductions





Design Objectives



Design Objectives

Vehicle Performance

Improve the previous team's hydraulic system

Manufacture and design a new vehicle frame

Implement an interactive mechatronics system

Safety

Perform race challenges successfully

Innovation

Summary of Midway Revie

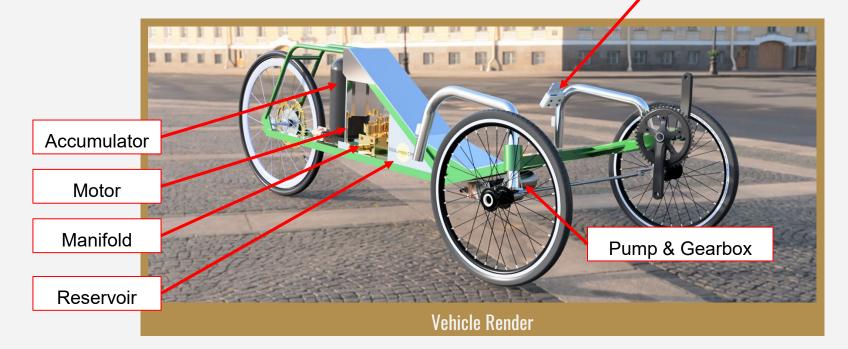


Previous Vehicle Frame



Midway Review Summary & Feedback

Control Interface

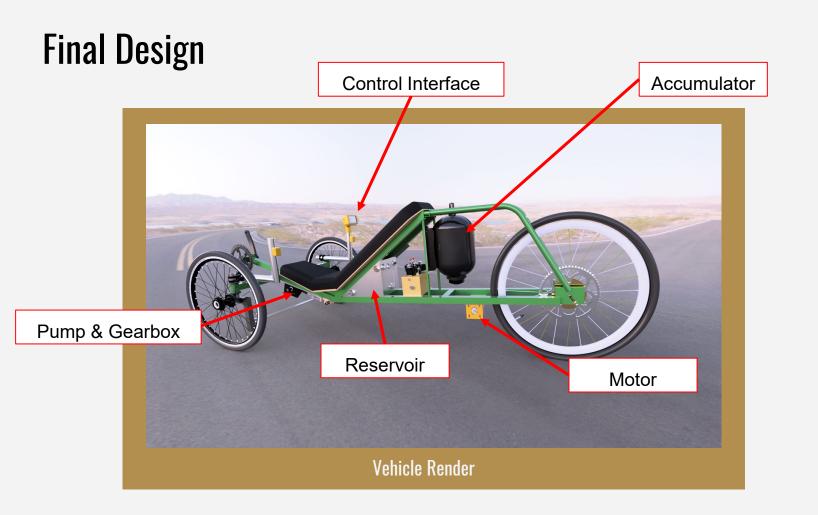


- Consider a way to release accumulator pressure to tank without using the motor
- Pneumatic circuit needs work



Vehicle Frame







Frame Manufacturing









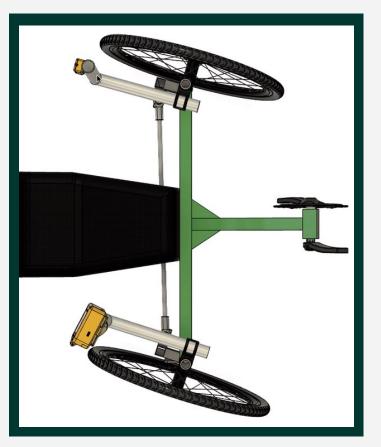


Steering Linkage



Final Steering System Model

- Intuitive To Steer Despite Being Unconventional
- Sturdy and Frgonomic with Ample Feedback
- □ Implements Ackerman Steering Geometry





Sacrifices

Caster Angle



□ Canted Wheels Instead

Centerpoint Steering



Unnecessary Due to Smooth
 Driving Surface and Low Speeds



Linkage Bars





Hydraulics



New Vs. Old Reservoir



- Same capacity of 1.3 gallons
 6061-T6 Aluminum
- New geometry to fit frame





New Reservoir Manufacturing

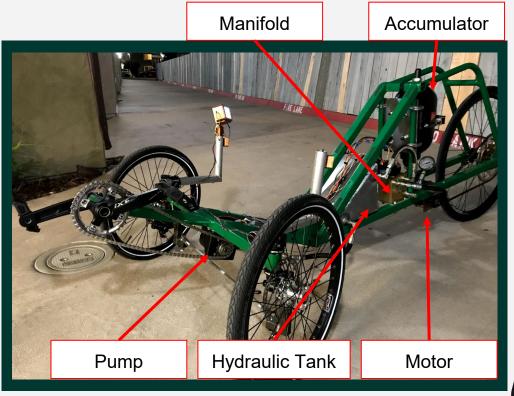


- Used the waterjet to cut the aluminum pieces
- □ Another Cal Poly student, Junnior Rodriguez, and the Cal Poly Machine Shop Professor, Eric Pulse, helped us TIG weld the reservoir



Relocating Hydraulic Components

- Relocating components allowed us to use 2ft less of hydraulic
 - Planned to implement hard lines but ran out of time
- □ Allowed us to mount the accumulator vertically
 - Increased safety & efficiency

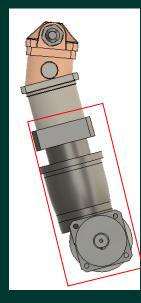




Components

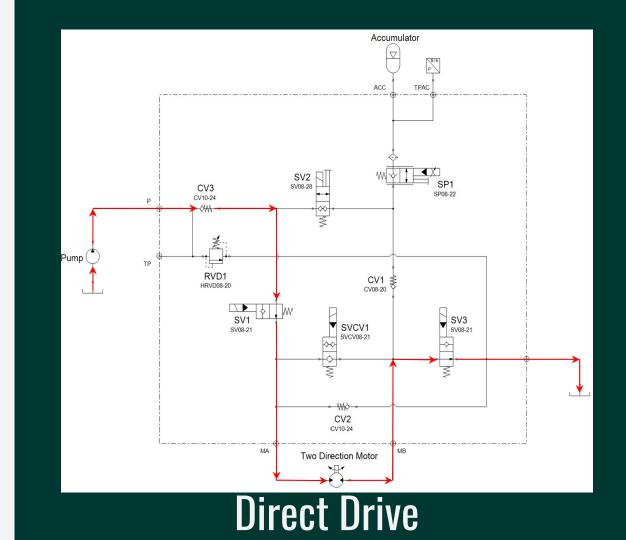
- □ Steelhead Composites Accumulator
 - 1 Gallon Bladder
 - 3000 psi Hydraulic Pressure
 - Light Composite, 10.8 lbs
- □ Hydraforce Hydraulic Manifold
- □ Bosch 5CC Bent Axis Pump and Motor
 - 5 lbs per unit
- Apex Dynamic Hypoid Gearbox
 - 4:1 Ratio (10:1 overall from crank to pump)



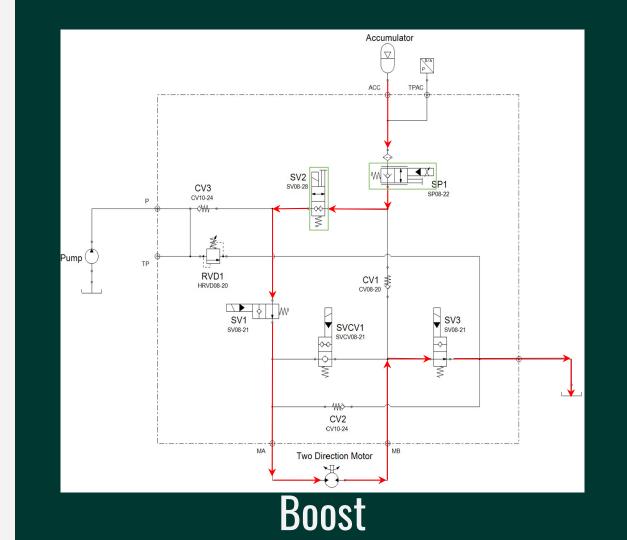




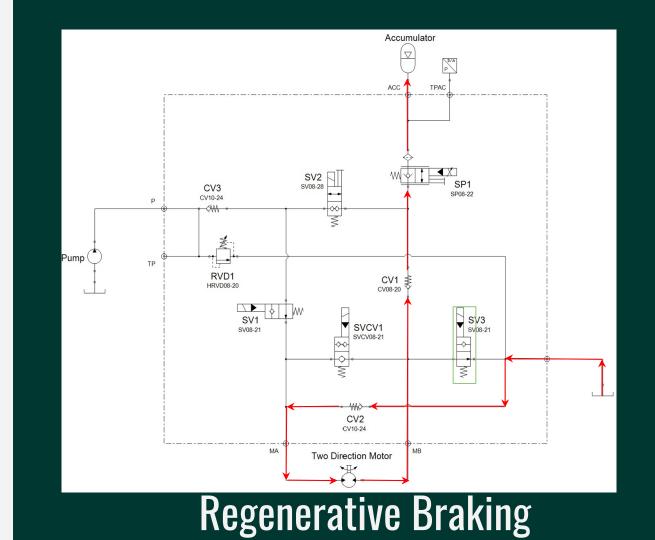




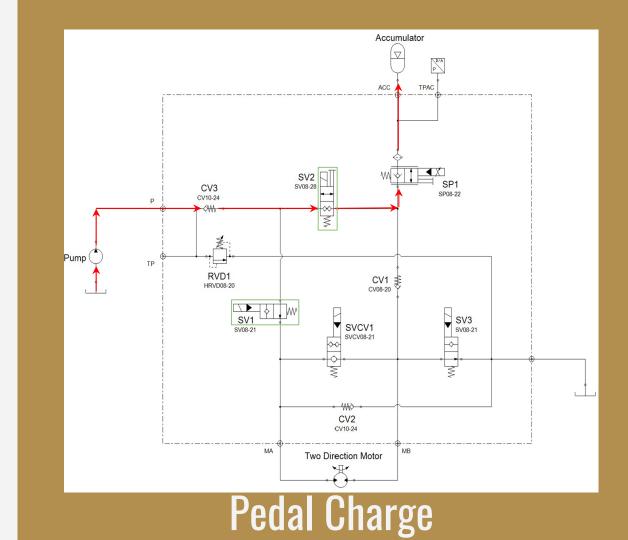














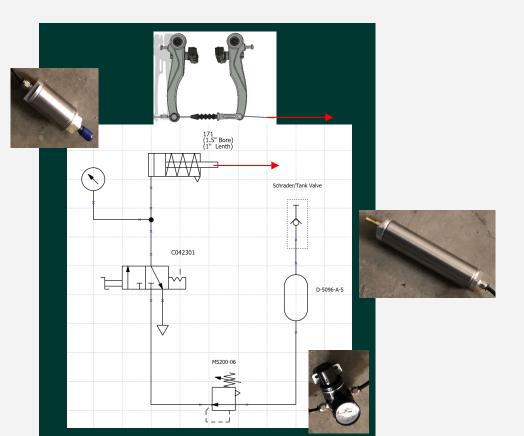
Pneumatics



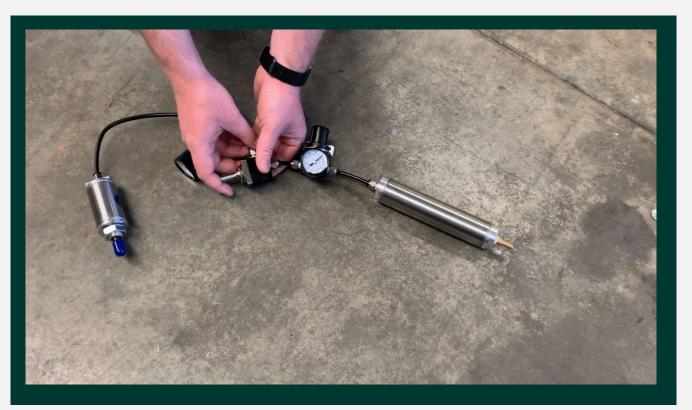
Pneumatic Parking Brake

Simple analog design Single-acting air cylinders Rubber pads to contact rim Sufficient braking force to prevent rotation at full accumulator discharge Calculated braking force of 32.31lbs

 $T_{wheel} = T_{motor} * \frac{wheel \ cog \ size}{motor \ sprocket \ size}$ $F_{Brake} = T_{wheel} * R_{rim}$



Parking Brake Component Test





Mechatronics



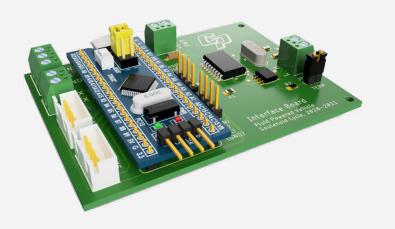
Subsystem Goals

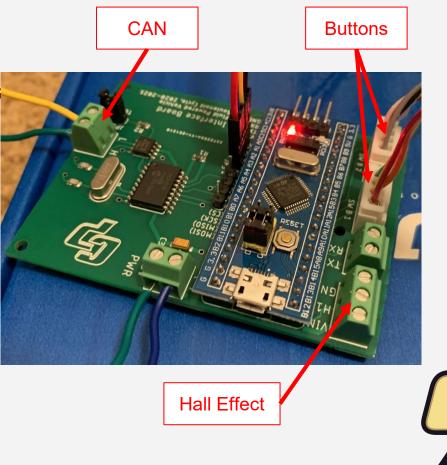
- □ Custom user interface
- Hydraforce PLC valve driver
- Data acquisition
- Network electronics overCANbus



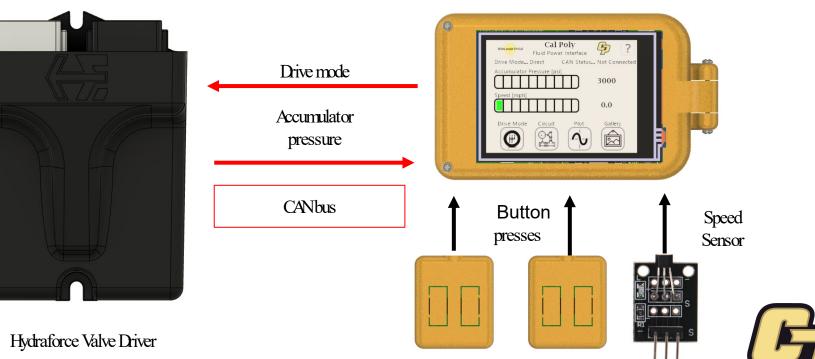
Custom HMI

- Custom circuit board to access CANbus
- □ 72 MHz microcontroller
- \Box 2.8"touch screen





Controller Area Network



Custom Interface

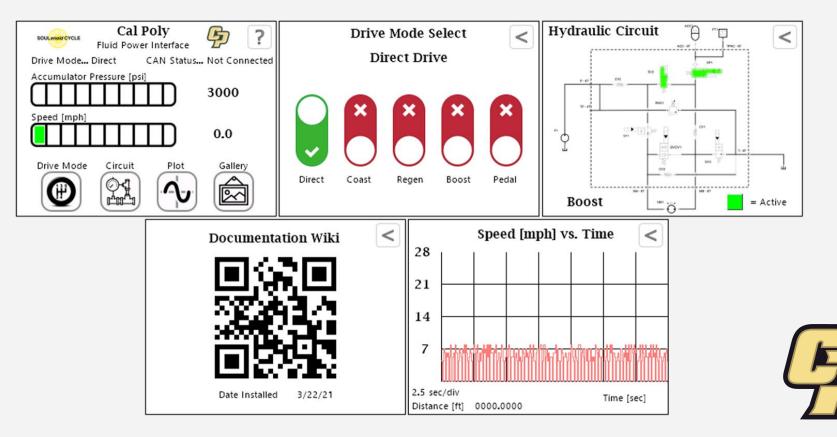
Controller Area Network

- Multipurpose service port:
 - Cbserve CANbus
 - Program the ECDR0506-A





Touch Screen



Published Documentation

Cal Poly NFPA Vehicle Challenge Soulenoid Cycle, 2021.

Support documentation for various mechatronics components on the vehicle.

Cal Poly NFPA Vehicle Challenge Wiki Overview Project Introduction Hardware Design Software Design Enclosure Design Results and Improvements Interface Usage Tutorial Video Total Costs HF Impulse Nextion Editor Controller Area Network (CAN) Printed Circuit Board Schematic Additional Support Files Design Verification and Testing Files

Cal Poly NFPA Vehicle Challenge Documentation

Wiki Overview

Welcome to the official support documentation for Cal Poly's NFPA Fluid Powered Vehicle Challenge team! On this wiki, you will find references and files for various elements of the vehicle's iterate on existing design work. Ownership of the wiki is transferred to the new team; the current team's name and logo are visible on this page as well.



Project Introduction

This report discusses the design and prototyping of a custom CAN node user interface for the electronic control system on a hydraulically-powered vehicle. The vehicle's hydraulic circuit con to achieve different vehicle behaviors. A rider applies human power input to the vehicle using a standard bicycle crankset. The crankset's shaft is coupled with a hydraulic pump that draws flut through a bi-directional hydraulic motor that propels the vehicle. The rider can also release fluid from a pressurized accumulator that applies a "boost" to the vehicle's speed.

Existing hydraulic and electronic components are provided by HydraForce, Inc. Sourcing all components from a single company lends itself to a well-integrated mechatronics system. However, The system's industrial Programmable Logic Controller (PLC) only has one inter-controller communication peripheral: CAN bus, and cannot be programmed using open-source languages, si user interface for this mechatronics system using CAN bus.

Existing Work

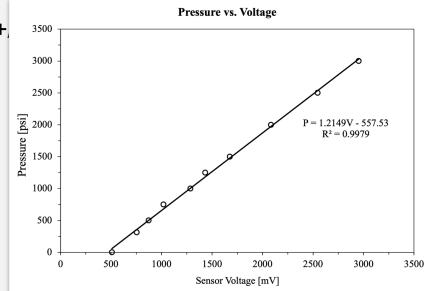
The existing mechatronics system uses a HydraForce ECDR 0506-A electronic valve driver. The vehicle's operator provides input to the system using three push-buttons, which each represe shown in Figure 1, has six inputs, which can be configured to receive an analog voltage or current. With three inputs used for push-buttons, the controller is only capable of reading up to thre button presses to the central controller would allow it to interface with additional sensors and inputs.





Real-Time Measurements

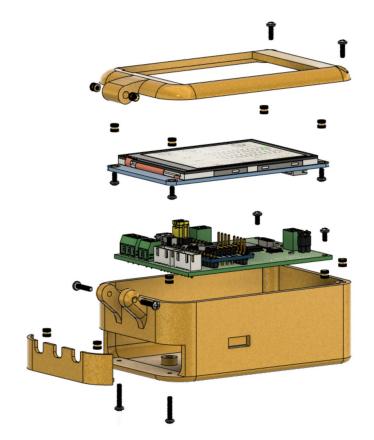
- □ Measure accumulator presst@esto +,
- □ Measure vehicle speed (mph)
- □ Calculate human power input (hp)**
- \Box Calculate distance traveled (ft)**

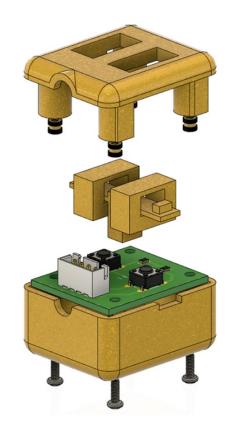






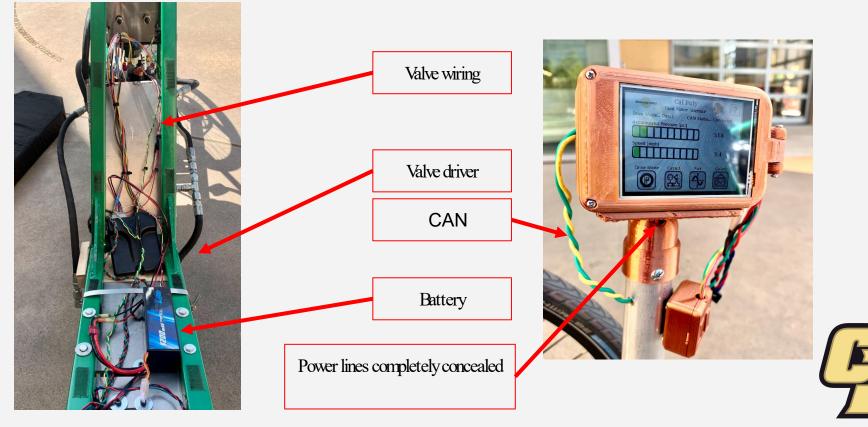
3D Printed Enclosures







Component Placement



Final Vehicle & Race Resu



Vehicle on Race Day



Race Results

Test	Distance (feet)	Result
Efficiency 1	1,200	8%
Efficiency 2	1,300	8%
Sprint 1	500	23.46 seconds
Sprint 2	500	22.75 seconds
Endurance	-	-
Accumulator Charge Time	-	3:45



Lessons Learned



Final Reflection

Biggest Challenges

- COVID Restrictions
- Manufacturing Time
- □ Shipping Times and Lost/Msplaced Packages

Recommendations for Next Year's Team

- Implement Pneumatic System
- Switch to Hard Lines
- Ease Direct Drive by Changing the Gear Ratio or Switching the Pump
- Extend Length of Grankset Arm
- Add Accumulator Dump by replacing CVI

Lessons Learned

- Everything Takes Longer than Anticipated
- Ask for more help



Questions?



Reference Slides

Engineering
Specs

Spec. #	Specification Description	Target Goal	Tolerance	Risk	Compliance
1	External Leakage	None	Max	Н	I, T
2	Bike Weight	120 lbs	Max	L	A, T, S
3	Efficiency Score	18%	±5%	Н	T, S
4	Sprint Time	15 sec	±5 sec	Н	T, S
5	Endurance Time	5 min	±1 min	М	T, S
6	Drive Mode Switch Time	2 sec	±1 sec	М	Α, Τ
7	Internal Leakage	0.5 psi/s	Max	Н	I, T, S
8	Pneumatics Pressure	100 psi	Max	М	I, T, S
9	Pinching Points	0	Max	М	Ι
10	Drag	TBD	TBD	М	A, T, S
11	Accumulator Charge Time	10 Min	Max	Н	A, T, S
12	Presentation Score	100%	Max	Н	T, S
13	NEMA Rating	Type 4	Max	М	I, S
14	Measurement Accuracy	2%	Min	М	Α, Τ
15	Durability	TBD	TBD	Н	A, I, S



FMEA

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurrence	Current Detection Activities	Detection	RPN
Frame / Stability	Bike, components, or rider tip or fall while riding	a) Injure rider b) Break or damage components	10	1) Steering difficulties 2) Rider cannot control the drive mode 3) Unbalanced weight distribution of rider/components	1) Iterate on steering angles 2) Default coast mode 3) Model to confirm overall weight balance	3	Testing done by rider	3	90
Hydraulics / Fluid Movement	Fluid losses or internal leakages	a) Safety concerns for rider. b) Poor performance in challenges	5	1) Too many fittings 2) Broken connections 3) Line length or surface roughness too large	1) Fluid analysis with hand calculations and modeling 2) Performance testing 3) Safety checks before every ride	8	Testing comparison to calculations and models & component checks	4	160
Mechatronic s / Fluid Coordination	No response or late response from electronics system	a) Unable to move or control bike b) Cannot use fluid power system c) Unable to switch drive modes d) Increase in racing	5	1) Damage to electronic circuit 2) Latency issues 3) Sensors unresponsive	1) Electronic components either sheilded beneath seat or in a protective enclosure 2) PCB design analysis	2	Mechatronics circuit design to be checked and tested	2	20

Additional Frame Info



Why design a new frame?



Explored Options



Prone Bike



Elliptical Bike



Upright Standard Bike







Recumbent Vehicle



Frame Concept Selection Decision Matrix

	Weight (1-11)	Frame Concept					
Criteria		Current Frame	New Single Track Frame	Recumbent Frame	Elliptical Frame		
Safety	11		0	11	11		
Cost	1	- Datum -	-1	-1	-1		
Durability	6		6	6	-6		
Weight	10		10	-10	-10		
Manufacturability	9		-9	-9	-9		
Ergonomics	3		0	3	3		
Human-Power Efficiency	8		0	8	-8		
Size/Shipping Ease	2		0	-2	-2		
Steering	5		0	-5	-5		
Aerodynamics	4		0	4	-4		
Creative/New Features	7		0	7	7		
Total			6	12	-24		



Frame Selection - Recumbent Design



Delta Trike (1 front wheel, 2 back wheels)

- Only 1 back wheel is powered unbalanced torque
- Over Seat Steering (OSS)
- **Easier to get into & more familiar for the rider**
- □ More common in the competition

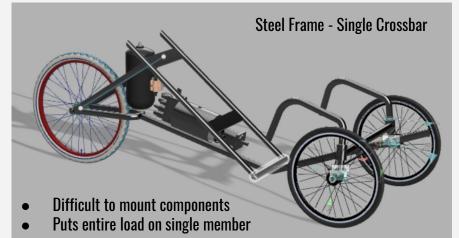
Tadpole Trike (2 front wheels, 1 back wheel)

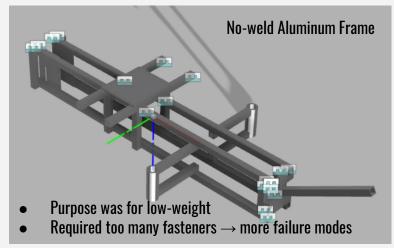
- □ The back wheel is powered
- **G** Front wheels for steering more complex
- **D** Typically faster & lighter than delta trikes
- □ Hydraulic component placement is easier





Recumbent Frame Design







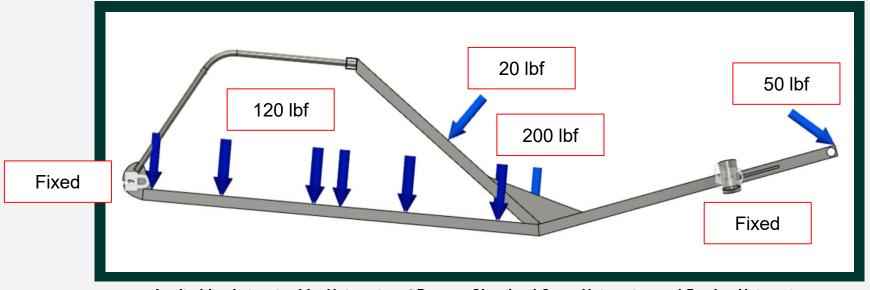


Recumbent Tadpole Tricycle Design





Structural Loading

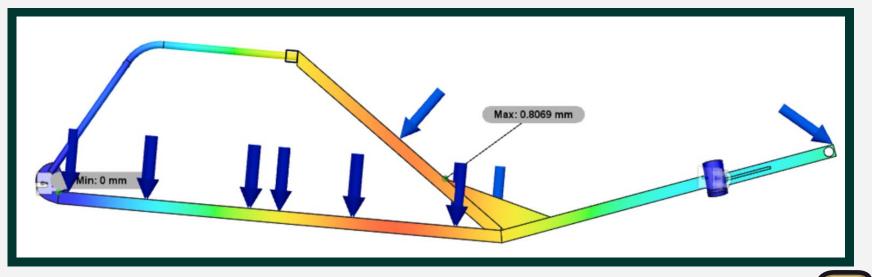


Applied loads inspired by University of Denver, Cleveland State University, and Purdue University



Structural Loading

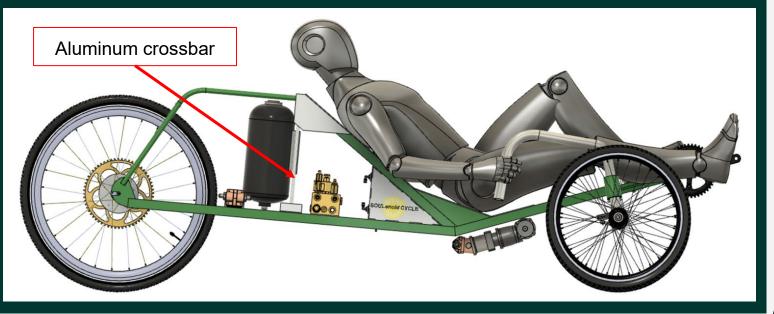
□ Static FOS of 3.0



Static loading FEA results, displaying displacement.

Structural Loading

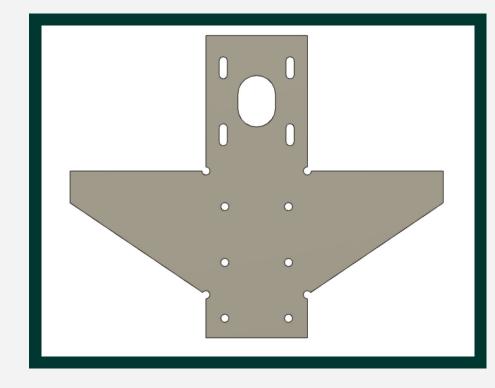
The reservoir, and the aluminum mountings for the accumulator provide additional frame support





Motor Mount

- Sheet metal Aluminum 6061
- 0.08" thickness
- Corner relief





Frame Prototyping



Delta Trike Prototype



Tadpole Steering Mechanism Prototype



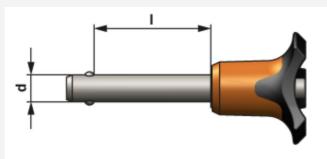


Adjustable Pedal Distance

- Bike is adaptable for people between the heights of 4.5ft and 6.5ft
- Seat is stationary \rightarrow pedal distance should be alterable by 1ft
- A lot of force is put on the pedals \rightarrow extension must be strong with minimal deflection
- Nested tubes with self-locking pins









Ergonomics

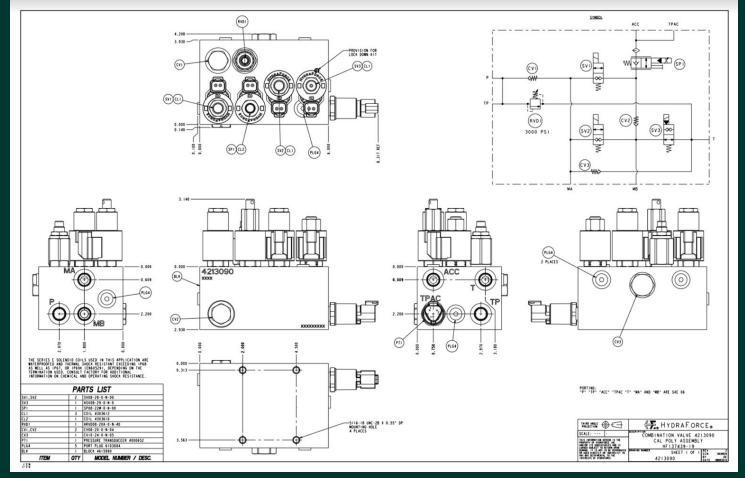
- Height of 4.5' -> Leg Height of 2.25' -> Lower Leg Height of 1.125'
 - At a bend angle of 30, cos(30) = distance/lower leg height(1.125) -> distance ~ 1'
 - Minimum Distance from seat to pedals of 2'
- Height of 6.5' -> Leg Height of 3.25' -> Lower Leg Height of 1.625'
 - At a bend angle of 30, cos(30) = distance/lower leg height(1.625) -> distance ~ 1.4'
 - Maximum Distance from seat to pedals of 2.8'
- 2.8'-2' = 0.8' of adjustable movement ~10 inches



Additional Hydraulics And Pneumatics Info

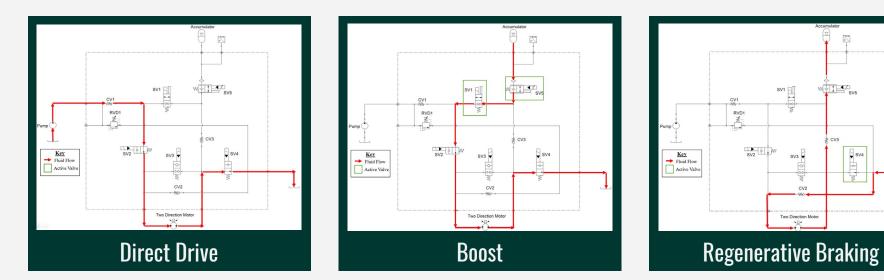


Manifold Drawing



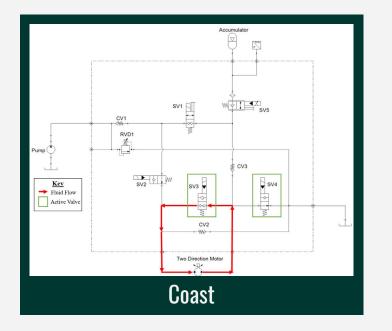


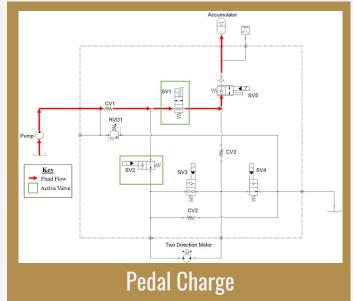
Required Drive Modes





Additional Drive Modes

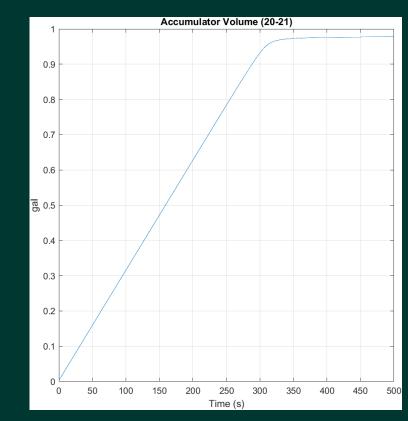






Accumulator Recharge

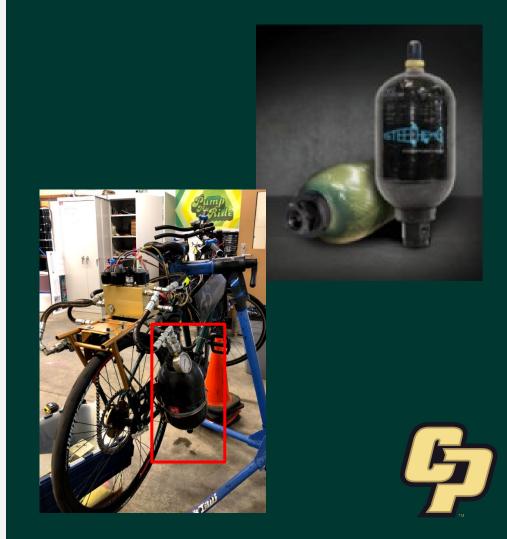
Accumulator Recharge Model
 Model: 5.2 minutes





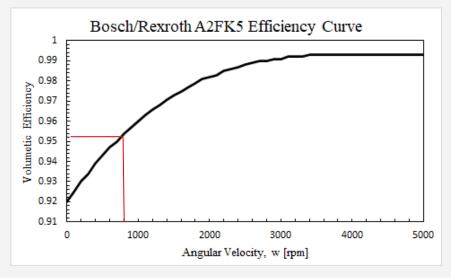
Accumulator

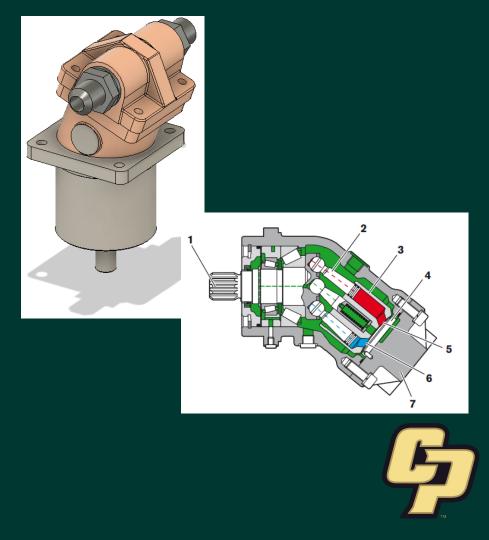
- $\hfill\square$ Steelhead Composites Accumulator
 - 1 Gallon Bladder
 - 3000 psi Hydraulic Pressure
 - 500 psi pre-charge Gas Pressure
 - Light Composite, 10.8 lbs



Pump & Motor

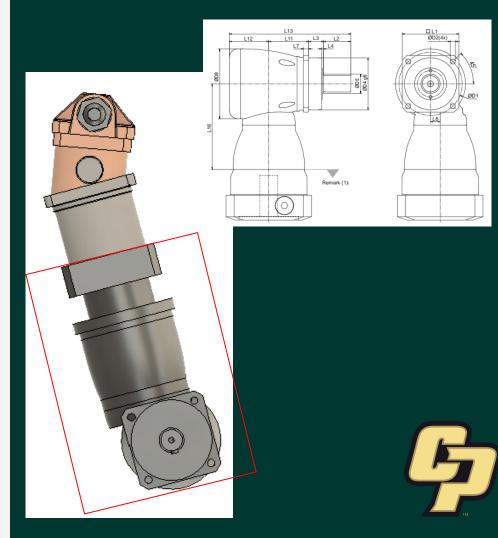
- □ Bosch/Rexroth A2FK5 Bent Axis
 - 5 CC Fixed Displacement
 - 5 pounds Aluminum Body





Front Gearbox

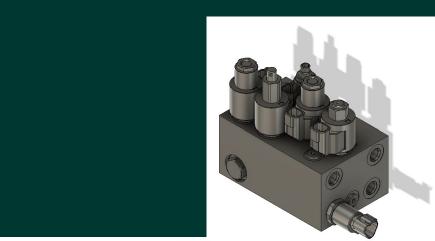
- □ Apex Dynamics KF Series
- □ 4:1 Gearbox attached to Pump
- Total front ratio from crank to pump at 10:1
- Needed to better meet operating range for pump (~800 RPM)

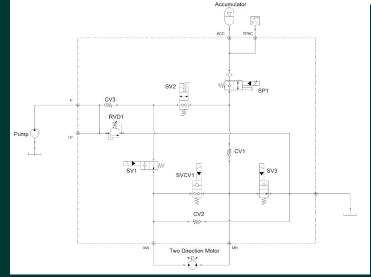


Manifold

Hydraforce Custom Manifold

- Controls hydraulic fluid flow
- Reduces number and lengths of hydraulic lines
- Pressure Losses through valves are flow dependent.





Implementation of Hard Lines, Sizing

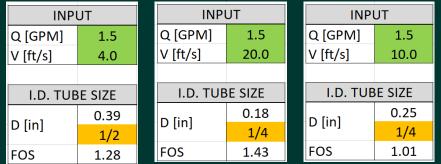
Hardlines are measured by O.D.
 Fluid Speed should not exceed:

 Pump Inlet/Suction: 4 ft/s
 Main Line: 20 ft/s
 Return: 10 ft/s

 Used previous estimates of pump flow rate at 800 rpm:

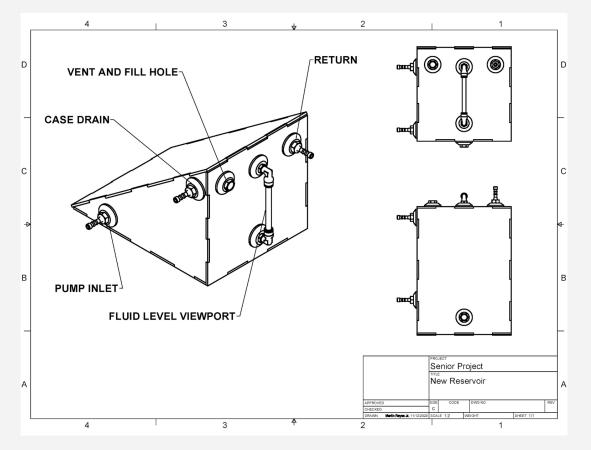
 1.5 gpm

$$D = 0.64 \sqrt{\frac{Q \ [gpm]}{V \ [\frac{ft}{s}]}}$$



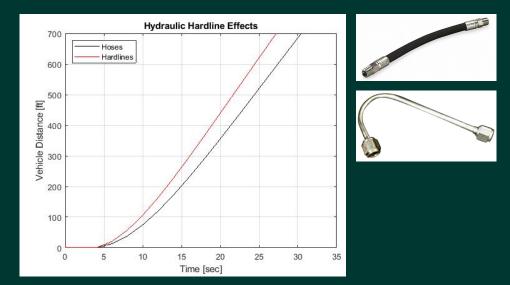


Reservoir Drawing



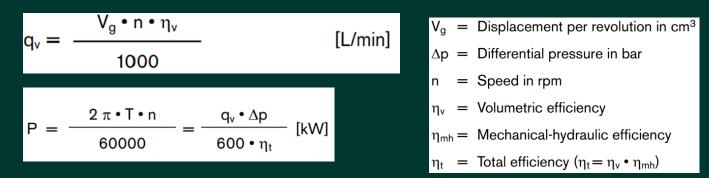
Hydraulic Lines

- Planned implementation of hardlines
 Less Weight, Minimize bends and line length, No cross section line expansion, Require more planning and manufacturing
 - Model Prediction of +11% in sprint time
- With the relocation of components, we reduced the length of hydraulic hoses by 2 feet
 - Recommended improvement for next year's team



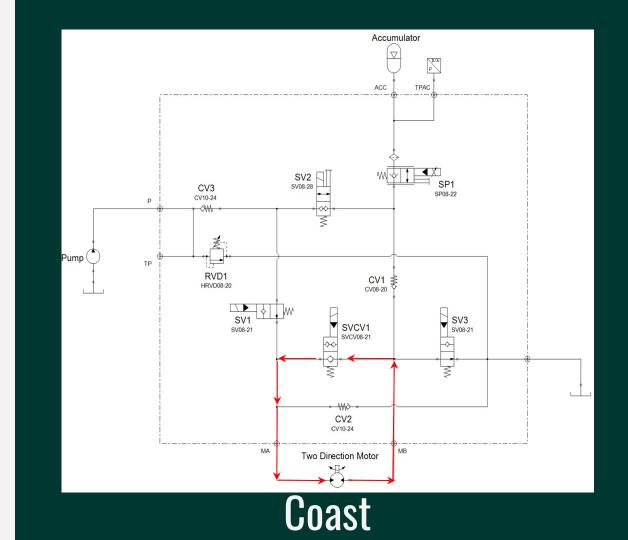


Horsepower Calculation



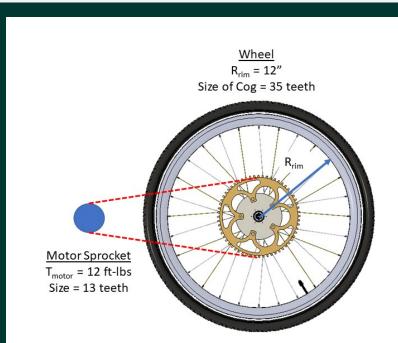
 Function of Flowrate and Pressure.
 Used vehicle speed to get motor speed through tire and cog ratios.







Braking Force Required



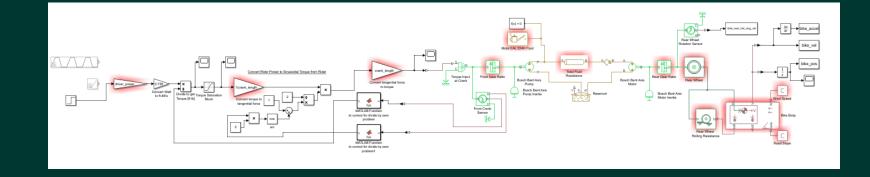
$$T_{wheel} = T_{motor} * \frac{wheel \ cog \ size}{motor \ sprocket \ size}$$

$$T_{wheel} = 12 ft - lb * \frac{35}{13}$$

$$T_{wheel} = 32.31 \, ft - lb$$

 $F_{Brake} = T_{wheel} * R_{rim}$

$$F_{Brake} = (32.31 ft - lb) \left(\frac{12}{12}\right) ft$$
$$F_{Brake} = 32.31 lb$$



Performance Models



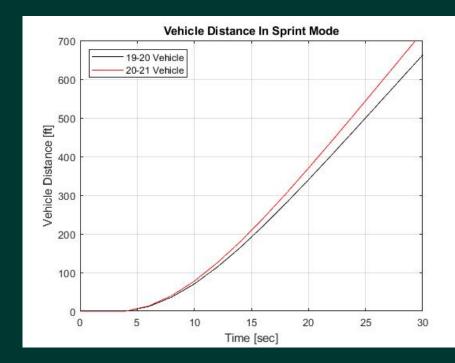
Modeling Parameters

Danamatan	Vehicle			
Parameter	19-20	20-21	% Change	
Tube ineternal Diameter [in]	0.37	0.60	62.2%	
Tube Length [in]	120	70.0	-41.7%	
Tube Roughness [ft]	3.0E-05	5E-06	-83.3%	
Bike Weight [lbf]	103	100	-2.9%	
CG Height [in]	33.0	14.7	-55.5%	
Rolling Resistance Coefficient	0.004	0.005	25.0%	



Sprint Race

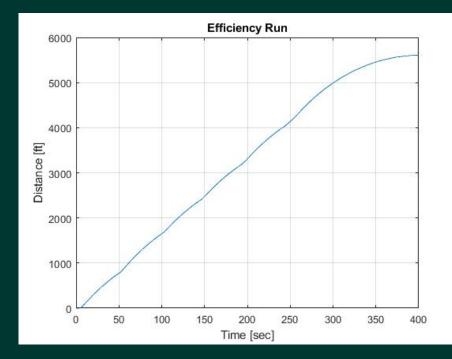
- Sprint Model
- □ Fastest Time to 600 ft
- □ Model: 26.5 seconds
 - ~5% faster than last year's model





Efficiency Score

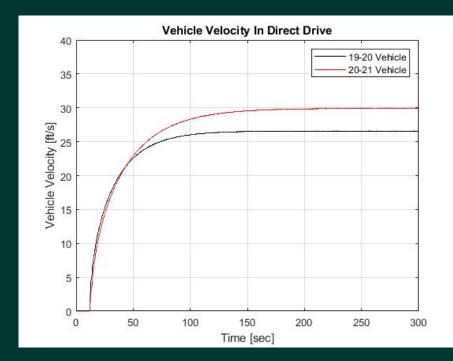
- Efficiency Model + Judging Excel
 Rubric
- $\hfill\square$ How efficiently can the vehicle move
- Function of Accumulator stored energy, vehicle and rider weight, distance traveled
 Model: 5,500 ft
 - From excel rubric, 42%





Endurance Race

- □ Direct Drive Model
- Fastest time to complete 1 mile course.
- □ Model Estimate: 2.9 minutes
 - Average velocity 15% faster than last year's model





Manufacturing & Current B

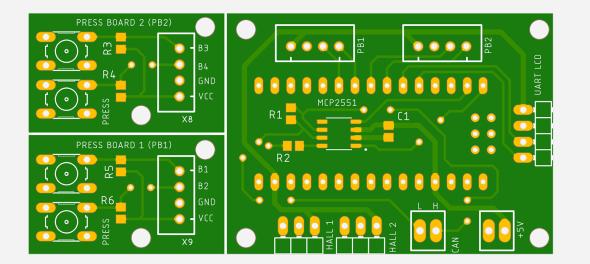


Current Bike Pictures



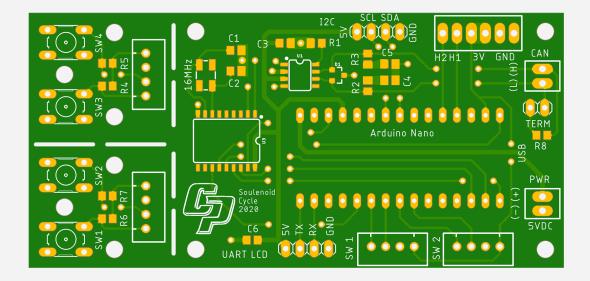


PCB Design 1



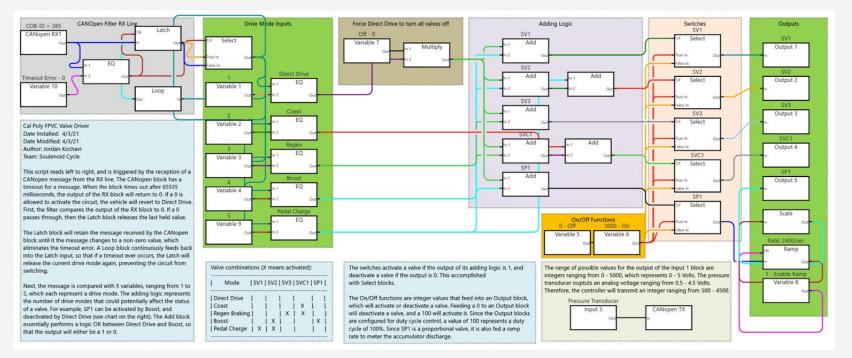


PCB Design 2





HF Impulse Programming





Line Code

OPEN EDITORS	Soule	Cycle > are > @ Interface.cpp >		
UNTITLED (NORICEPACE)		Cycle / arc / 0 (starface.cpp / previousButtenState_CSP = ButtonState; 14 (display.readSater("paps2.veb.es\"(vel)		
- Saulensid Cycle		<pre>if (display,readwater('pape2.val.val')vel) { display,writeStr('pape 2*); }</pre>		
∼ pla > build				
 Bodeps:/genericSTM32F103C8 PrintStream 				
> PrintStream@arc-6e411dcca42bill.				
~ STM32duino FreeRT05		display.writeWes("paged.vsl.vsl",0); previewsHutterSitete_OSP = buttonSitete;		
> github > examples				
y partable				
~ WG		 garaef Taxk which interacts with the Nextion display. garant Taxk address various data as the Nextion, which the nexted tax pressure and the sense of the vehicle. garant A pointer to function parameters which we do 		
~ FreeRTOS > License				
> Source		garan p_parame & pointer to function parameters which we do		
Elinka to dec pages for the d		r tait, diaplay (vite p.jamas)		
E readmentst		<pre>Evoid(p_parame; // Initialise the sizetHeleTime variable with the current time // It will be used to not the task of precise intervals</pre>		
C cmilijos.c C cmilijos.h				
C crostine.h		<pre>// It will be used to run the task at precise intervals TickType_t xiactWebsTime = xTaskGetTickCount[]; // A 1682 serial object used to communicate with the display.</pre>		
C event_groups.h		<pre>// A DAST serial object used to communicate with the display. HardwareSerial MESSerial(PK3, FA2);</pre>		
C PreeRTOS.h C PreeRTOSContig_Detault.h		NECGerial_begin(9648);		
C FreeRTOSConfig.h		// A Nestian class shject used to commuticate with the display. Easyles ephentice(MEEserial);		
C heaps		Explore spiritize(VEEsrial); as A local wardless for straight the accalulator pressure. * The COM task retrieves the accamulator pressure from the TCER MedicA and stress it is an astra-task buffer. * The Glasby task paths to be added from the biffer and stress it is this signed 20-bit strenge. This * wardles is pushed to the display for printing. ***		
C list.h C message_buffer.h				
C repu_prototypes.h		The display task pills the top value from the biffer and stores it is this sized 32-bit isteger. This		
C mpu_wrappers.c				
C portic C porstació.h		10112 - Incalifar accomplatedrammers - At		
C gamen				
C sample.h.		A local variable for strengt the blue typed. • To that writely be calculated the speed of the vehicle of an equilation of the speed of the vehicle of an equilation of the speed		
C stack_reacros.h		 pulls the top value from the buffer and stores it in this signed 32-bit isteger. This variable is pushed to the 		
C STM32FreeRTOS.c C STM33FreeRTOS.h				
C stream_buffer.h		int32_t localWar_bikeSpeed # #;		
C task h		Lot22_1 VecalWar_floatSpeed = 1;		
C timers.h O editocorrig		simole(directiontes, DBUT_Pittip);		
 pitattributes 	480	**************************************		27 Configure buttes pin for input 27 Configure buttes pin for input
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Elbrary.properties		attachInterrupt(digitalPinTcInterrupt(repeakuttor), DBregee, RD		
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> EAGLE FEEL				
5 include		 a biologie, if this satisfies is think, then this tack a series the display to prist an error message to the user. 		
> lib > arc		bool CHArtatum = fallers		
D baseshare.cpp C baseshare.h		for (iii)		
		(Officemented.met/Constatus):		
C cellTriggers.cpd C ces.h		CARcomsected_get(CARstatus); updatedriveNede(nyMextice); if (CARstatus) {		
Ø donygen conf		(
EasyNeotionicIbrary.cpp		<pre>epHoxtion.vriteStrf'papel.t7.tat',"Convectef'); accumulaterPressure.petllocalVar_accumulaterPressure); epHoxtion.vriteHom('papel.rdl.vol', localVar_accumulater)</pre>		
C EasyNextionLibrary.h		mpNextion.vriteNam("papel.rdl.vsl", localVar_accumulater		
C interface.h				
e main.cpp		<pre>{ application.vestbilite("papel, 17, tot", "Not Connected"); </pre>		
F mainpage.dee • mop2515.opp				
C mcp2515.h		bikeSpeed.get(lscalVar_bikeSpeed); floatSpeed.get(lscalVar_floatSpeed);		
 readCustorrCommands.cpp taskpurse.h 		<pre>floatSpeed.get(localWar_floatSpeed); spleatSon_writeWar[poped.sal.vol"_iscalWar_bloatSpeed); spleatSon_writeWar[poped.sal.vol"_localWar_floatSpeed); // Tool type of delay vests writi the given number of 8755</pre>		
C taskshare.h				
C triggeth			revents task to r	
3 STL Fåns		<pre>// inscarracy due to not accounting for how long the task : // winskielug(htil (AdjactWakeTime, 168); }</pre>		
) test) wiki_Support_Files				
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> NE 007 Final				
> NE 507 New Final ~ CAN Receiver Test				
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> .secode		from a different searce.		
> Include > Its		d tank_OW (volde p_params)		
2 m2				
C Adatruit_GEX.cpp		[vaid]p_param; // Door satt // Totalalian the statisticalized and satisfies with the correct time		
C Adatruit_GEX.h © Adatruit_SSD1306.cpp		<pre>twaidig_params; // Does ant // Totitation the signature variable with the current time // Is will be used to run the task at procise intervals TickType_t startWebTime = aTackDetTickTexet[];</pre>		
C Adatruit SSD1306.h		/s A local variable for stories the accamulator pressure.		
C baseshare.cpp		6.4 Lock variable for thrizing the accanulation pressure, * This teak veryiness the accanulation pressure fram. * the TCR 4004-4 and thread 16 in this caput 22-bit. * This tark passes the value to a inserv-task baffer, * which is und by the display task to print in the user.		
C baseshare.h © CAN_test.cpp				
C CAN_test.cpp C CAN_test.h				
C can.h		<pre>x/ ini32_t facalVarPressure = 0; // Local va // An MCP2SIS object used to communicate with the CAN contrall.</pre>		
CANapen.cpp C CANapen.h		<pre>// An Murris's object used to communicate with the DW controlly MC92515 my2515(C5); // Create M</pre>		
C FreeWordRpt7b.h		x102_2 2 [set10/mFreesore #]; // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM control 11 // icol 10 // icol 10 // according dispert und to communicate with the CM		
C gfsfont.h		my2515_eetNoma3Rde(); 2/ Set note		
C gledfont.c				
C main.cpp C mcp2515.cpp		CAN_sendPress(ag2515); // Se		
C mcp2515.h		OWLeastFreen(up2515); // in LocalWarPressure = CMLreadFreenurs(up2515); // in if (LocalWarPressure in CML_SECE) // if the d	staines a	
C splach.h		E of DeceliferPressure in CML010042		



"Ergonomic Testing"





Shop Updates

11/4/2020

- First day working on the bike
- Replaced back tire because it had a leak
- Plugged screw hole in hydraulic reservoir

11/10/2020

- Tested the recharge, coast, and direct drive modes
- Fixed chain tension
- Tightened loose fittings on hydraulic lines

11/17/2020

- Tested regenerative braking and boost modes
- Regenerative braking took 4 minutes and 35 seconds for 3 people to walk the bike to an accumulator pressure of 2800psi
- Took about 23 seconds for a 150lb rider to travel 600ft in boost mode
- Accumulator took approximately 1,000ft to discharge completely for a 150lb rider (approx 35 seconds)



DVP - Frame

- **D** Build welding jig Concept validation
- □ Bend some round steel tubing Concept validation
- □ Laser cut to-scale steering linkage Concept validation
- □ Weigh hydraulic components Design verification



DVP - Hydraulics

Measure losses through manifold - Design verification
 Measure losses through entire hydraulic circuit - Design verification

DVP - Mechatronics

Check controller baud rate compatibility - Design Verification
 Test bench-top CAN transceiver circuit - Design Verification



Purchases & Budgeting



Frame Purchases To-Date

Material	Supplier	Cost
1-1/4 X 1-1/4 X 16GA (.065 wall) A513 Square Steel Tube - 8ft stock	Metals Depot	\$131.60
1 X 1 X 16GA (.065 wall) A513 Square Steel Tube - 2ft stock	Metals Depot	\$5.48
1-1/2 X 1-1/2 X 16GA (.065 wall) A513 Square Steel Tube - 2ft stock	Metals Depot	\$6.94
3/4 OD x 16 GA (.065 wall) A513 HREW Round Steel Tube - 8ft stock	Metals Depot	\$32.48
1 OD x 16 GA (.065 wall) A513 HREW Round Steel Tube - 8ft stock	Metals Depot	\$35.20
.125 (1/8)" thick 6061-T6 Aluminum Sheet - 2 x 4ft stock	Metals Depot	\$131.96
Total		\$343.66





Steering Purchases To-Date

Material	Supplier	Cost
ICE 20" Front Wheel with Disc Hubs (Pair)	Recumbent Trike Store	\$305.00
ICE Standard Steel Front Axles Disc (Pair)	Recumbent Trike Store	\$52.00
FSA The Pig Headset	Amazon	\$23.59
31.8 Stem 45mm Bike Stem Wake Mountain Bike Stem	Amazon	\$9.97
RUJOI Bike Disc Brake Kit	Amazon	\$33.99
SCHWALBE Marathon Racer HS 429 Tires	Amazon	\$85.98
Total		\$510.53



Mechatronics Purchases To-Date

Material	Supplier	Cost
Nextion 2.8" LCD	Amazon	\$32.99
STM32 Blue Pill	Amazon	\$18.99
Buck Voltage Regulator	Amazon	\$13.99
3D Print Threaded Inserts	Amazon	\$7.49
ST-Link Programmer	Amazon	\$6.99
TJA1050 CAN Transceiver	Amazon	\$6.39
Total		\$86.84

