Preliminary Design Review

Team 8: Zotdraulics - Fluid Powered Vehicle Competition

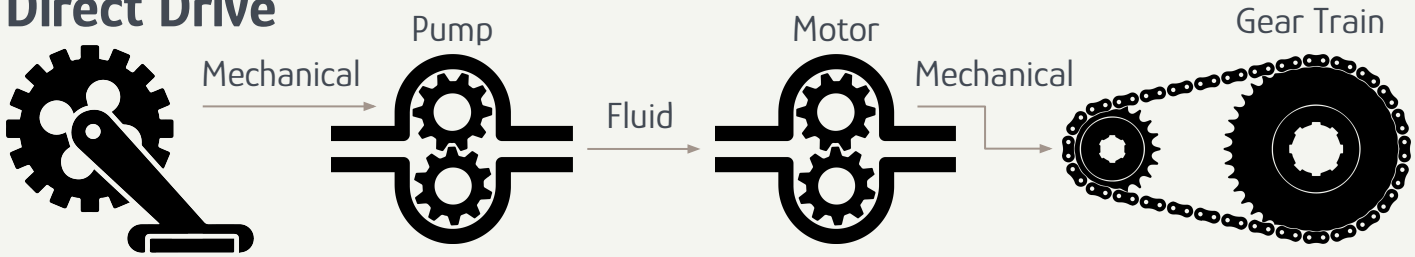
Problem Statement

Northern Illinois University
(2024 Overall Winner)

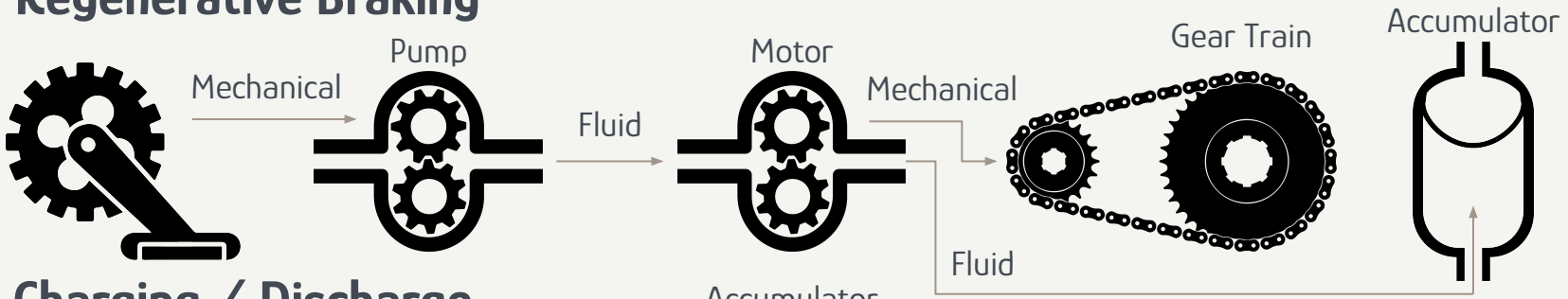
- The Fluid Power Vehicle Challenge is an engineering competition where teams design and **build a vehicle that runs entirely on hydraulic energy converted from human input**
- Competition requires the vehicle to have a **regenerative braking system**
- Sprint Race: Vehicle must **complete a 400-600 ft course as fast as possible**
- Endurance Race: Vehicle must **run for 15 minutes covering at least 2000 ft**
- Build a foundational understanding of fluid power for future teams at UCI to start from

Transmission States

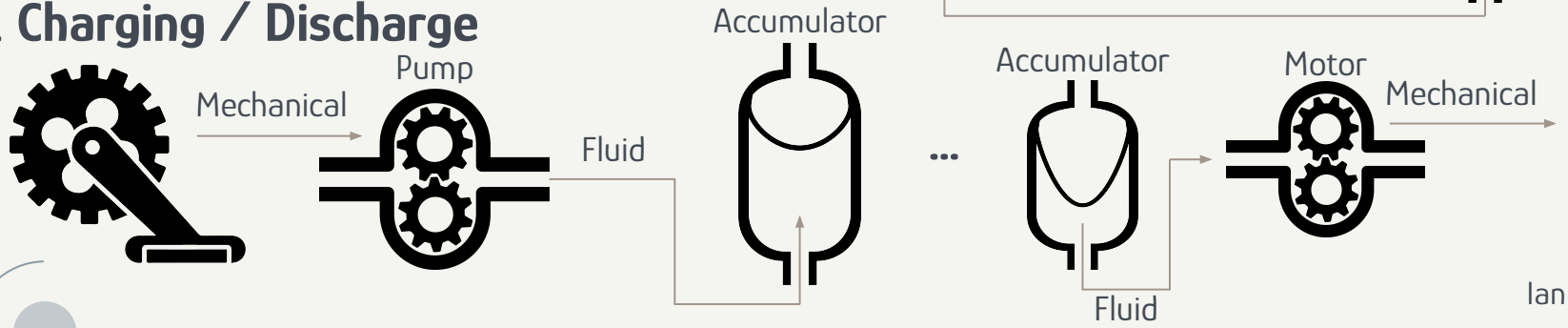
1. Direct Drive



2. Regenerative Braking



3. Charging / Discharge



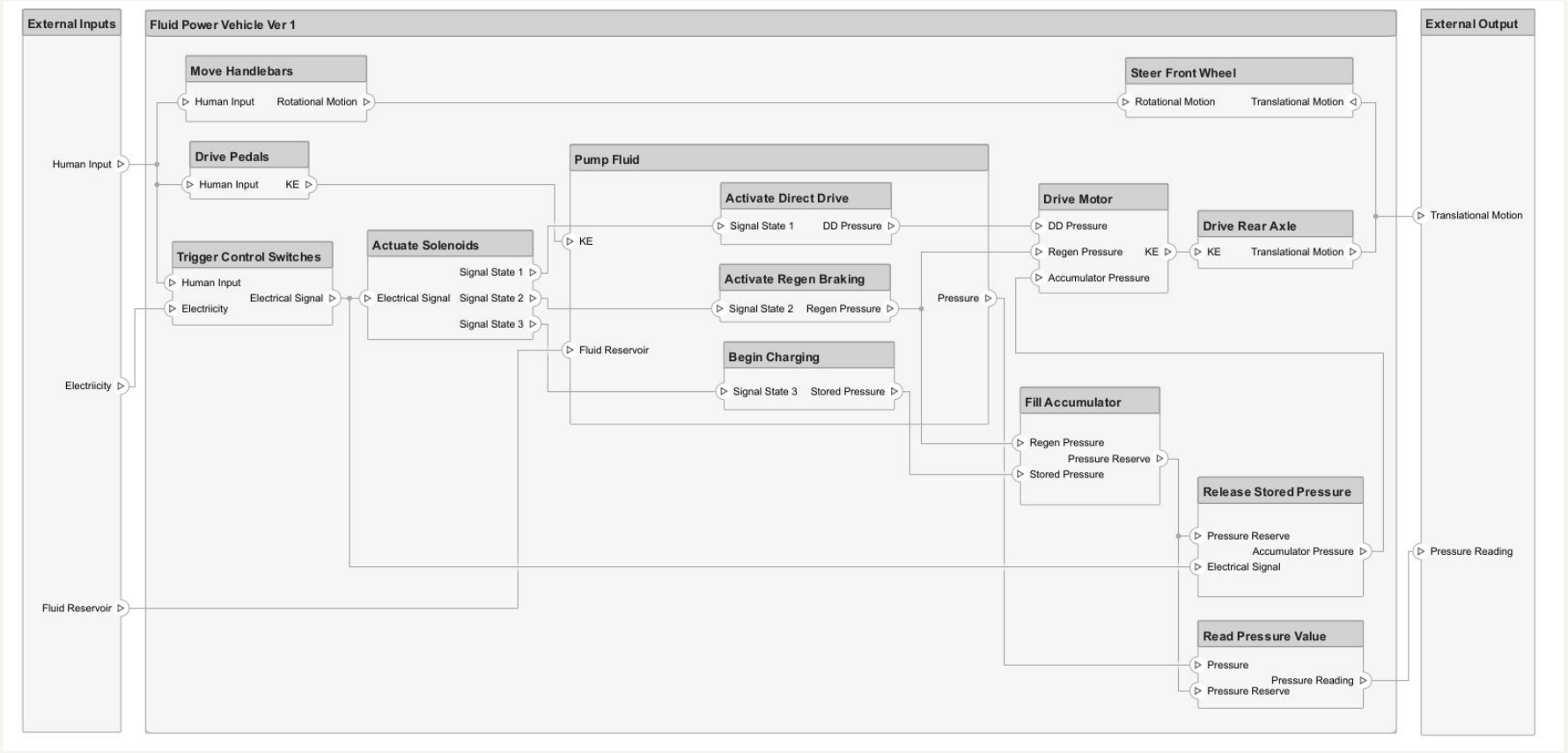
Objectives & Attributes

Key Attributes:

- Regen. Braking System
- Minimum Avg. Speed : 1.5MPH
- Max. Pressure of 3,000 PSI
- Should Weigh < 210 lbs
- Be Durable and Safe to Ride
- ZERO Leak Policy

Attribute	O	C	F	M
Must meet competition requirements		X		
Custom parts should be easy to manufacture	X			
Should cost less than $5700 to build	X			
Must demonstrate a RBS		X	X	
Should be able to travel for at least 2000 ft in 15 minutes	X		X	
Should have sufficient braking capabilities.	X		X	
Must meet safety guidelines of the competition		X		
Must have no leaks		X		
Should provide comfort and ease of use	X			
Display gauge should be easily visible to judges	X			
Should demonstrate high robustness.	X			
Should allow for easy filling/emptying of working fluid	X		X	
Kinetic energy should be stored in the accumulator				X
Maximum pressure must not exceed 3000 psi at any part.		X		
Must weigh less than 210 pounds		X		
Could have an aluminum frame				X
Should be able to traverse up and down hills	X			
Could use heavy duty chain sprockets				X
Could use an off-the-shelf standing trike				X
Should be able to switch between circuits.	X		X	

Grey Box


External Inputs
Fluid Power Vehicle Ver 1
External Output
Human Input
Electriicity
Fluid Reservoir
Move Handlebars
Human Input
Rotational Motion
Steer Front Wheel
Rotational Motion
Translational Motion
Drive Pedals
Human Input
KE
Pump Fluid
KE
Fluid Reservoir
Activate Direct Drive
Signal State 1
DD Pressure
Drive Motor
DD Pressure
Regen Pressure
KE
Accumulator Pressure
Drive Rear Axle
KE
Translational Motion
Translational Motion
Trigger Control Switches
Human Input
Electriicity
Electrical Signal
Actuate Solenoids
Electrical Signal
Signal State 1
Signal State 2
Signal State 3
Activate Regen Braking
Signal State 2
Regen Pressure
Pressure
Begin Charging
Signal State 3
Stored Pressure
Fill Accumulator
Regen Pressure
Pressure Reserve
Stored Pressure
Release Stored Pressure
Pressure Reserve
Accumulator Pressure
Electrical Signal
Pressure Reading
Read Pressure Value
Pressure
Pressure Reading
Pressure Reserve

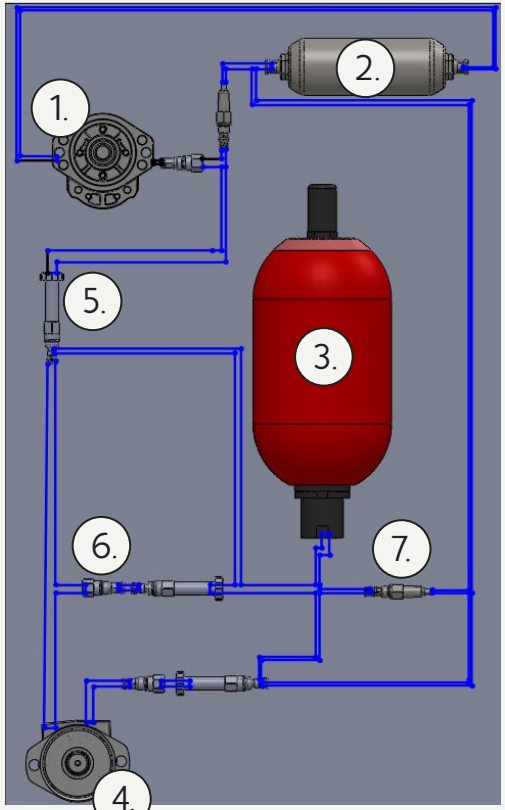
Requirements

#	ID	Description
1	**FR 01**	**The vehicle shall be powered by converting human power to hydraulic power**
2	**FR 02**	**The vehicle shall abide by the safety guidelines of the competition and guidelines set by the manufacturers**
3	**SaR 01**	**The vehicle shall have no leaks of pressure or fluid at anywhere in the system**
4	**SaR 02**	**No part of the system shall exceed 3000 psi**
5	SaR 03	The vehicle shall protect the rider from its own moving components using Chain Guards
6	SaR 04	All components of the vehicle shall remain on the bike during operation.
7	FR 03	Vehicle components shall not be removed between events and demonstrations.
8	SaR 05	The vehicle shall have two independently actuated friction brakes (one brake needed if the vehicle only has one wheel). Each brake must operate on different wheels or axles.
9	**FR 04**	**Brakes shall be able to hold the vehicle at a stop under the full charge of the accumulator**
10	FR 05	The vehicle shall have two pressure indicators, one at the outlet port of the accumulator and one at the supply side of the hydraulic motor.

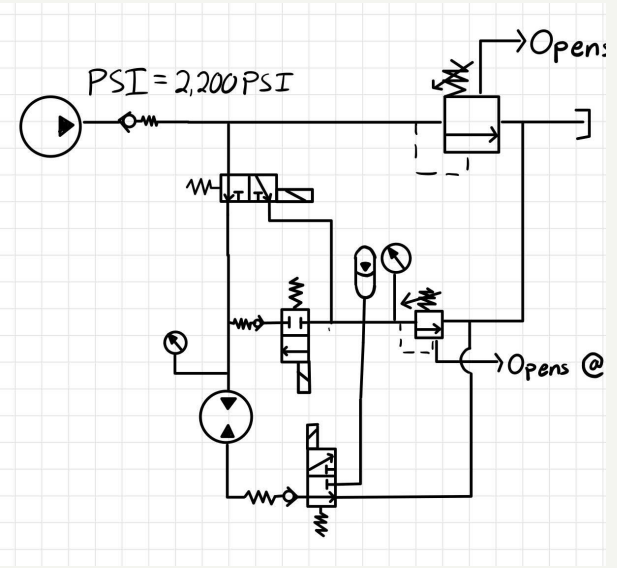
Requirements

#	ID	Description
11	PIR 01	The pressure indicator shall be mounted where the rider can safely read them
12	**FR 06**	**The maximum total volume of oil and nitrogen of all accumulators shall be one gallon or 3.7854 liters.**
13	FR 07	The accumulators shall only be used towards propulsion of the vehicle
14	**FR 08**	**The vehicle shall use only the hydraulic fluid provided by the competition[1]**
15	FR 09	The vehicle shall be designed for a single rider. Rider must be able to enter, exit, and operate the vehicle unassisted.
16	**FR 10**	**The vehicle should weigh no more than 210 pounds[2]**
17	**FR 11**	**The vehicle shall be capable of propulsion through direct drive[3]**
18	**FR 12**	**The vehicle should have a regenerative braking system[4] capable of propelling the vehicle a minimum of 10 feet**
19	EfRR 01	Vehicle should be capable of traveling a minimum of 100 feet
20	EnRR 01	Vehicle should be capable of traveling a minimum of 2000 feet in 15 minutes

Proposed Design - Hydraulic Circuit

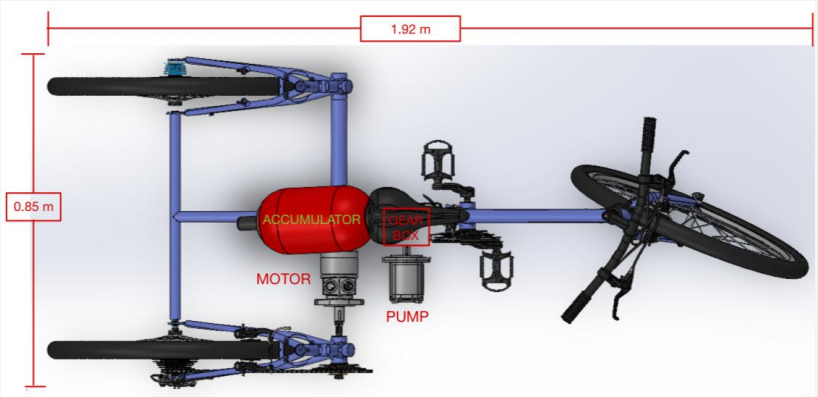


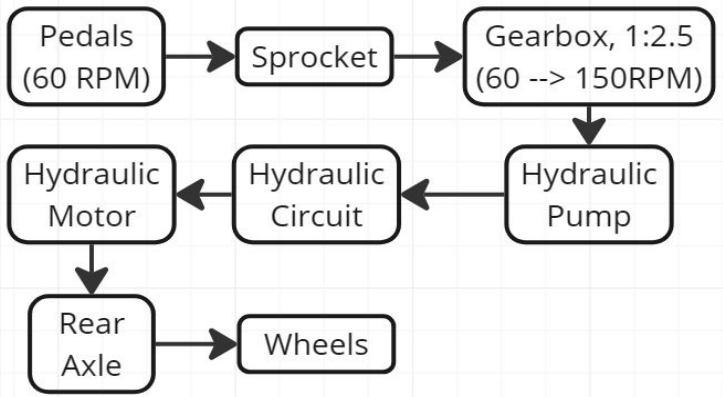
1. **Hydraulic Gear Pump – Pressurizes Fluid**
   a. 4.8″x 4.6″x 5.9″
   b. **Displacement**: 1 inch^3 / rev
2. **Reservoir – Fluid Storage**
   a. L: 9.8″, D: 2.76″
   b. **Volume**: 2 Gallons, Hydraulic Fluid
3. **Accumulator – Energy Storage**
   a. L: 17″, D: 6.7″
   b. **Volume**: 1 Gallon, Nitrogen Gas
4. **Hydraulic Gear Motor – Turns Wheel**
   a. 5″x 4″ x 7.25″
   b. **Displacement**: 0.5 inch^3 / rev
5. **Solenoid Control Valve – Directs Flow**
   a. L: 4.4″, D:0.23″
6. **Check Valve – Prevents Backflow**
   a. L: 2″, D: 0.84″
7. **Pressure Relief Valve – Safety Measure**
   a. L: 3.35″, D:0.7″

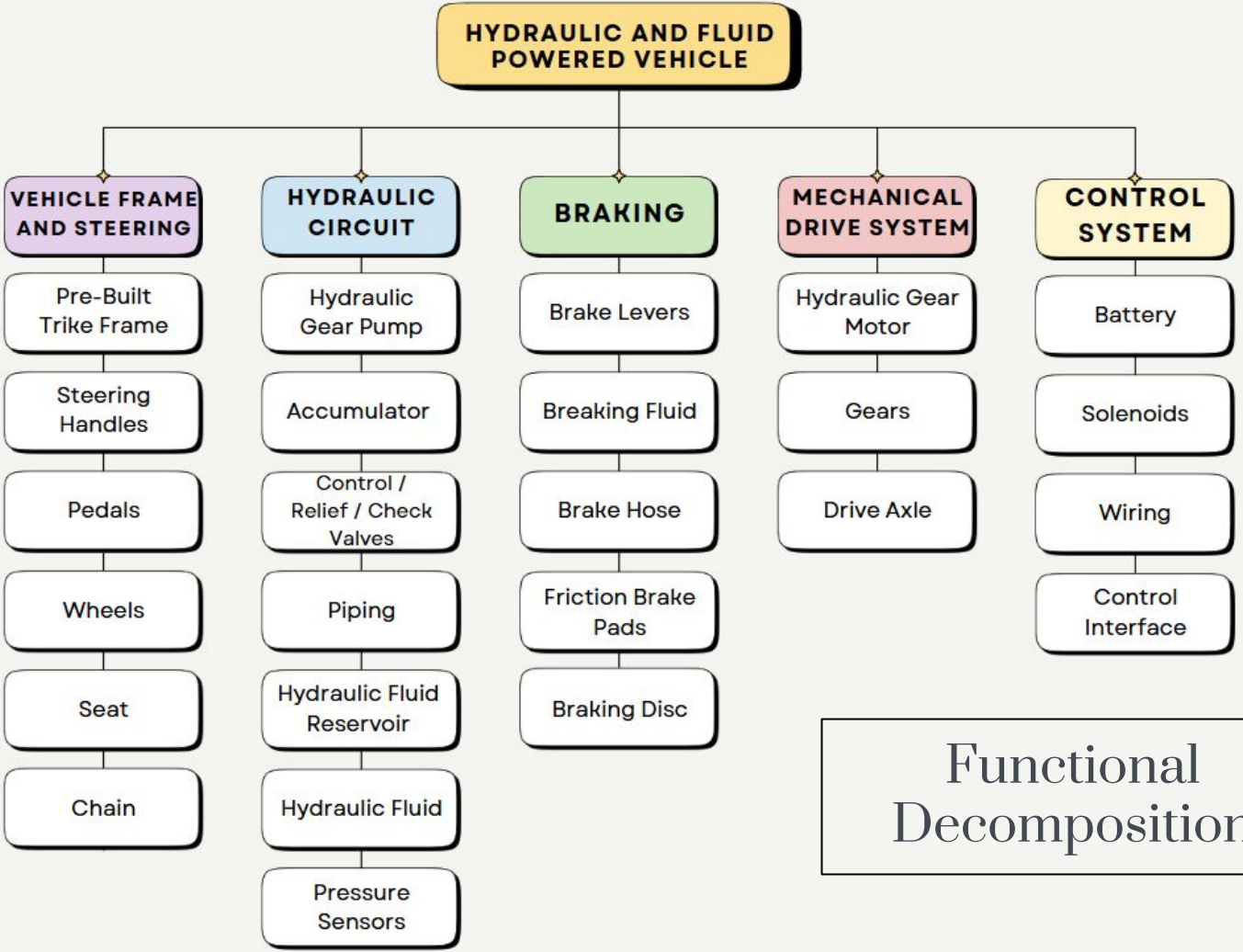


Hydraulic Circuit Diagram

Proposed Design - Drivetrain Representation ◆

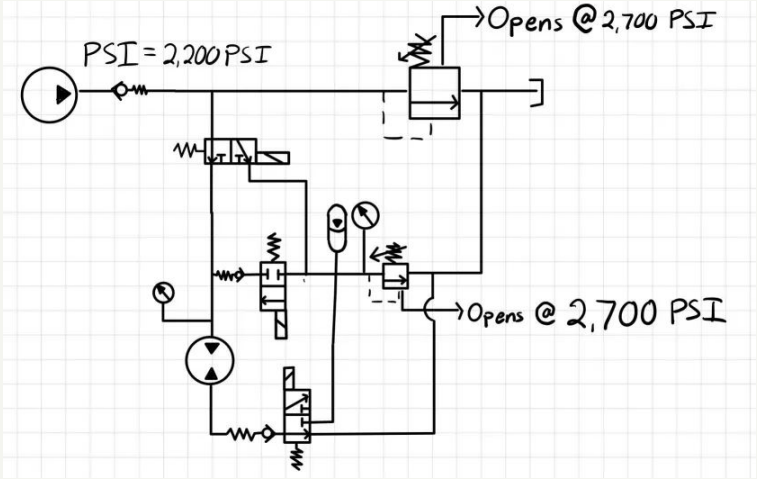






Functional Decomposition

Key Component/Concept Selection



- Key Components
  - Vehicle Frame
    - 3-Wheel Tricycle (Commuter)
  - Actuation Method
    - Solenoid Valve
  - Hydraulic Circuit
    - Three Distinct Stages

		Alternatives		
Criteria	Baseline	Solenoid Valve	Gate Valve	Ball Valve
Response Time	0	+	–	–
On/off Modulating control	0	+	+	+
Actuation Method	0	+	–	–
Pressure capacity within 3000 psi	0	0	+	+
Convenience	0	+	0	0
Cost	0	+	0	–
Control over vehicle distance	0	+	–	–
	0			
	0			
Totals		6	-1	-2
Rank		1	2	3

PUGH Chart Used For Concept Selection

Key Equations & Results

Bike Equations

- Uphill Load = [W * Sin (θ)] + [W * Cos (θ) * RR]
- $Torque_{Min}$ = Uphill Load * r_{Wheel}

Hydraulic Circuit Equations

- $CIR_{Motor} = T_{Min} * 2pi / P_{Working}$ [PSI]
- $CIR_{Pump} = 2 * CIR_{Motor}$
- $GPM_{Pump} = CIR_{Pump} * RPM_{Pump}/231$
- $V_{Piping} = 0{,}25 * pi * D_{hose}^{2} * L_{Piping}$
- $V_{Reservoir} = [CIR_{Pump} * RPM_{Pump}] + V_{Piping}$

Constants

W = 255 lb

Θ = 1.7°

RR = 0.03

r = 14″

$P_{Working}$ = 2,375 PSI

RPM_{Pump} = 150 RPM

D_{Hose} = 0.25″

L_{Piping} = 36″

Key Results

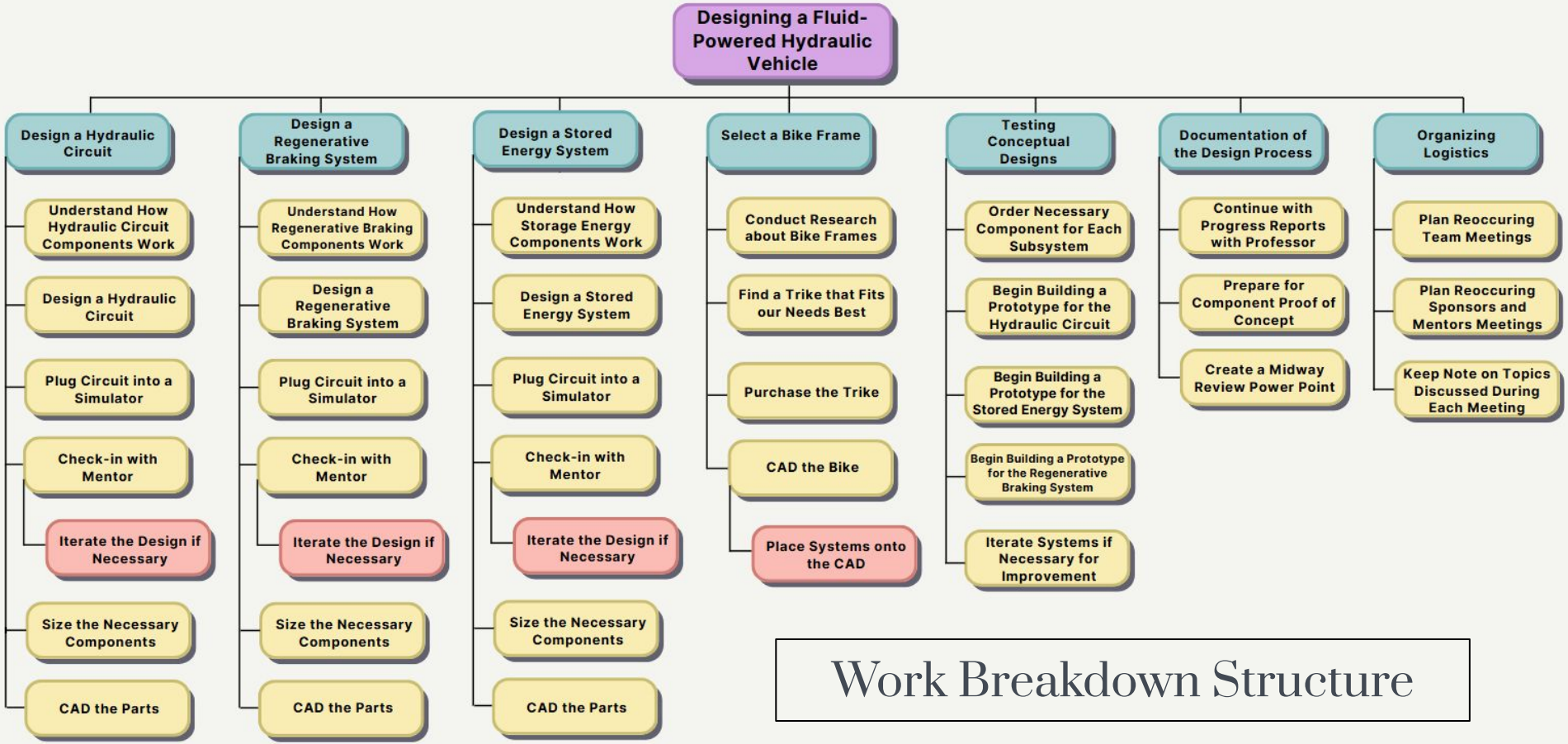
$Load_{Uphill}$ = 13.51 lbs

T_{Min} = 189.19 lb*in

CIR_{Motor} = 0.5 in^3/rev

CIR_{Pump} = 1.0 in^3/rev

$V_{Reservoir}$ = 0.66 gal



Work Breakdown Structure

Timeline

Nov 15	Nov 22	Nov 29	Dec 12	Jan 6	Feb 14	Feb 28	Mar 14	Apr 9
Select concepts for the design of the vehicle	Complete CAD designs, regenerative braking concept, wiring diagram for electronics	Order the trike frame and the first batch of mechanical parts	Verification: Assemble and test proof of concept for hydraulic pump and electronic interface	FPVC Midway Review	Fully assemble vehicle	Validation: Perform testing for vehicle's ability to perform in all four competition events	Submit proof of operational vehicle to competition	Compete in Illinois

Concerns

- Complying with all competition safety standards
- Ensuring our hydraulic system properly functions
- Chain and pedal system withstanding the force input
- Accumulator reliably builds and releases pressure