NFPA

Fluid Power Vehicle Challenge

NFPA
Education and Technology Foundation

Final Presentation
Colorado State University
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Presentation Overview

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Meet the Team

Left to right: Riley Abbott, Jake Griffin, Patrick Brown, Drew Perry, Erik Kaminen

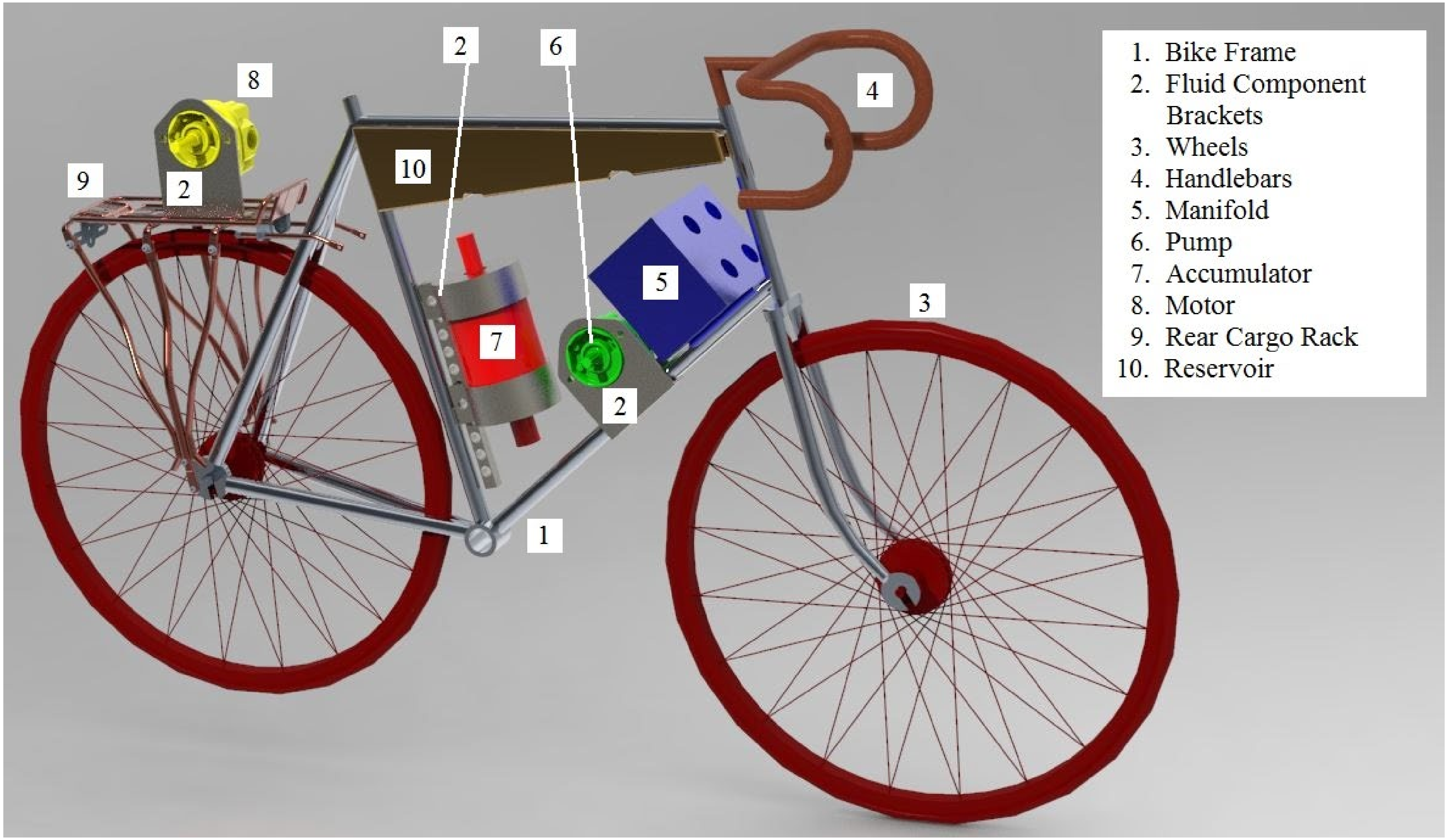
Problem Statement

Design a human-driven vehicle that incorporates a fluid link between the human power input and mechanical output, while making the vehicle follow industry standards and function safely.

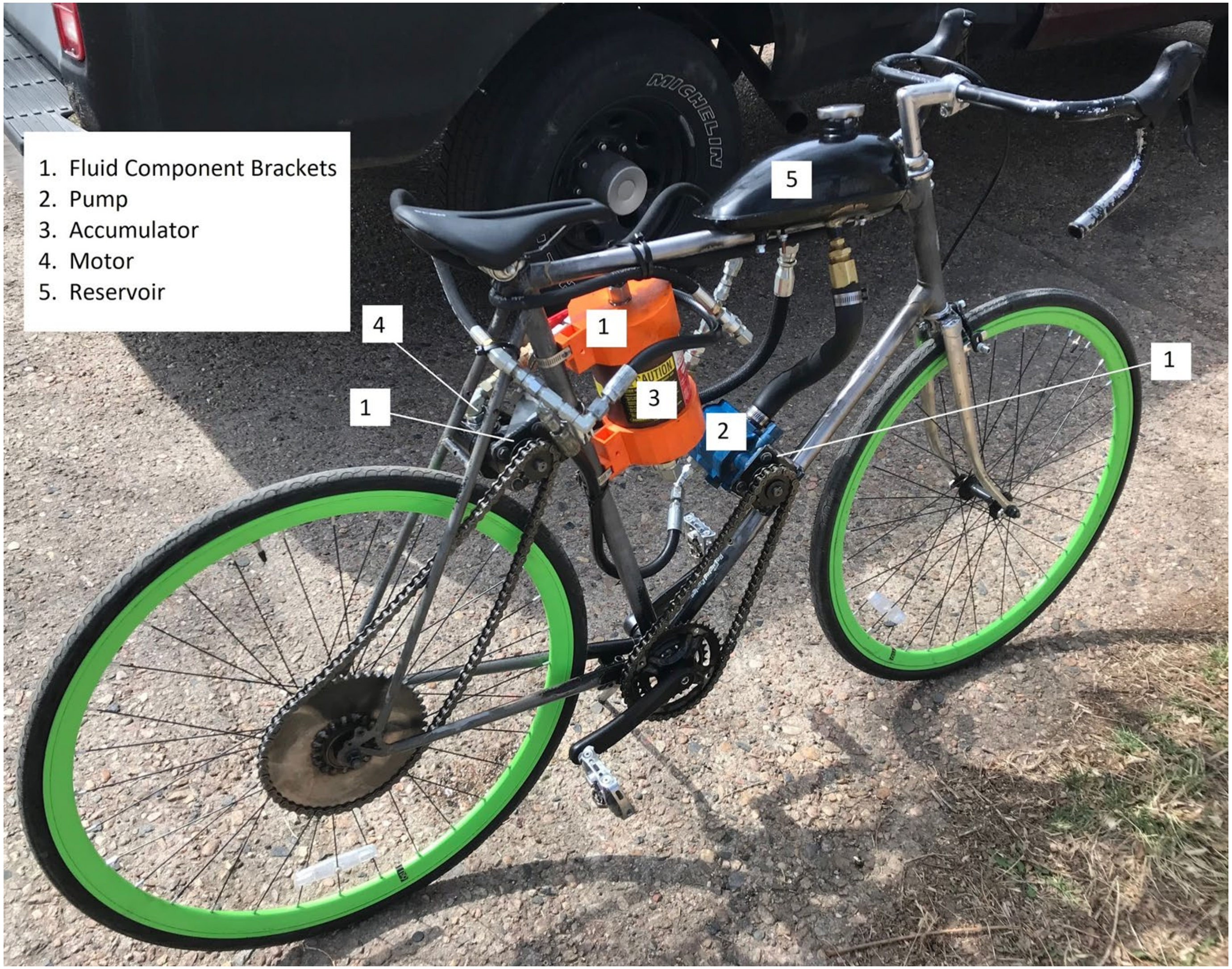
Design Objectives

Name	Priority Rating	Measurement Method	Objective Direction	Target
Speed	5	mph	Increase	20 mph
Weight (with rider)	4	lb	Decrease	250 lb
Fluid Power Circuits	4	Wheel torque (lb* in), output flow rate to motor GPM	Increase	250 lb*in 0.644 GPM
Reliability	3	Experimental Trials	Increase	50 trials
Efficiency	3	Efficiency (%), distance traveled (ft) by a full accumulator charge	Increase	80% ~185 ft w/ 1 qt accumulator

Proposed Component Placement



Final Component Placement



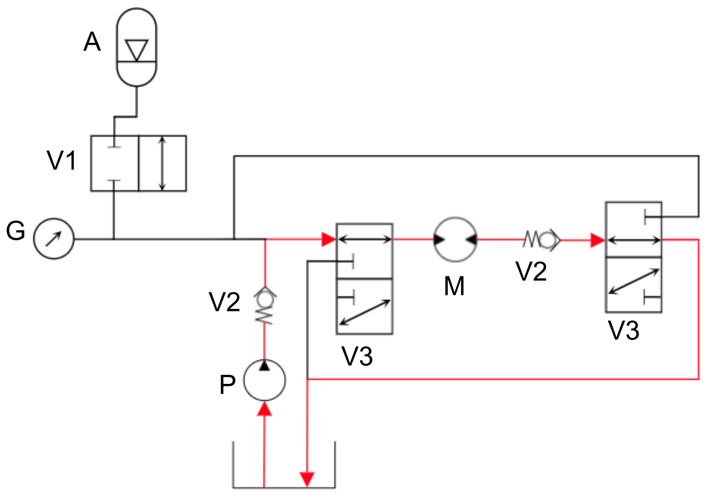
Fluid Power Circuit

- Neglected manifold and electronic control system
  - Determined it added too much weight
  - Created additional flow restriction
  - Electrical problems in hardwiring solenoids; not behaving as needed

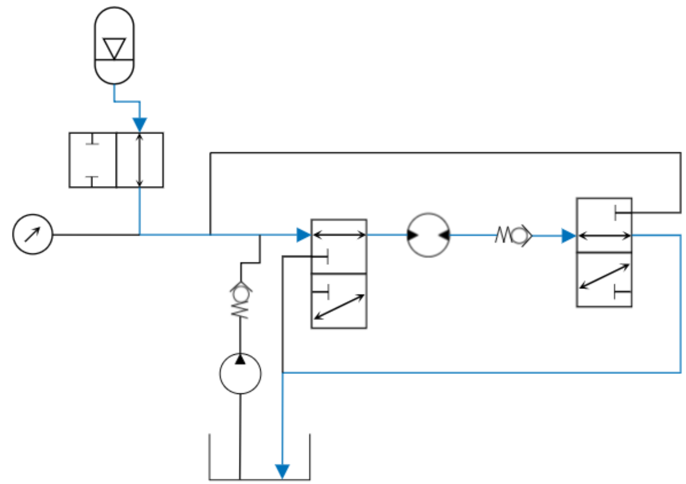
- Manual Valves
  - Fewer valves overall, lower weight, less flow restriction

Fluid Power Circuit

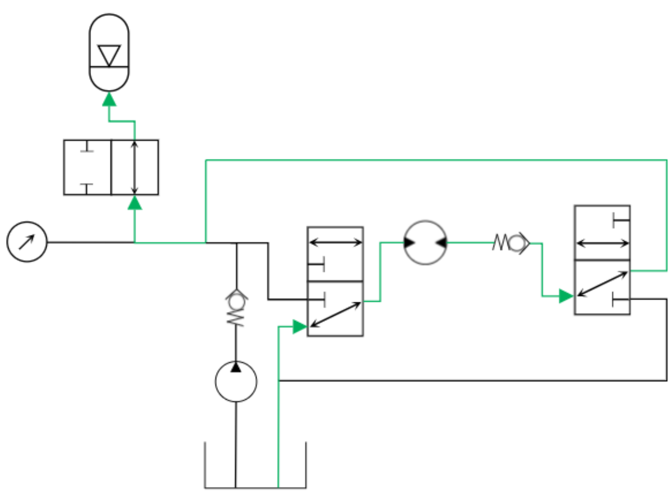
Direct Drive



Efficiency



Regeneration



A	Accumulator
G	Pressure Gauge
P	Pump
M	Motor
V1	2 Pos, 2 Way Valve
V2	Check Valve
V3	2 Pos, 3 Way Valve

Hardware Selection

- 0.58 CID 26 Series gear pump (Eaton)
  - Largest pump on donation list
  - Require mechanical advantage

- 0.129 CID GC Series concentric gear pump/motor (Grainger)

- 1 quart bladder accumulator (Accumulators Inc.)
  - Also from donation list

Performance Analysis

Speed/RPM

Pedal RPM ~ 40 (measured)
Pedal to pump gear ratio: 2.117

Pump RPM = 84.705
Pump output flow rate = 0.213 GPM

Motor RPM = 380.848
Motor to back wheel gear ratio = 0.333 (using 36-tooth cog)

Back wheel RPM = 126.948

Speed = 10.3 mph

Torque/HP

Pressure out of pump ~ 1100 psi (measured)
Pump torque = 8.46 ft*lb
Pump HP = 0.1365
Pump efficiency = 99%

Motor Torque = 1.883 ft*lb

Torque at back wheel = 5.65 ft*lb

~ 13 lb of pull

Vehicle Testing

- **4 Pumps tested**
  - 0.06 CID, not enough flow for pedal RPM
  - 0.127 CID, not enough flow
  - 2 stage concentric, higher flow but incredibly difficult to pedal uphill
  - 0.58 CID best overall, higher top speed, more displacement for same energy input, usable torque at all RPM

- **Rear cog combinations**
  - 30 tooth: hardest to pedal, not much higher speed ~ 15 mph
  - 36 tooth: harder to pedal, higher speed ~ 14 mph
  - 48 tooth: easiest to pedal, moderate speed ~ 10 mph

- **Elliptical pedal cog**
  - Found stall points in pedals near 12 and 6 o'clock
  - Extended cog with a 45 degree offset to overcome stall points
  - Allows for a more consistent pedal stroke

Vehicle Testing

- **Accumulator**
  - Supplied back pressure against pump, needed check valves for direct and regeneration circuits
  - Found equilibrium pressure to be around 500 psi, needed to be above for useful work

Lessons Learned

- Keep things within the scope of the project
  - Ex: electronics require precision and theoretically can be implemented well, but added complexity, flow restriction, and unneeded weight; manual just as functional

- Trust failures will occur the first time, prototype quickly for most trial and errors during the test phase

- Stick to principles and adjust for nuances
  - Ex: light weight components, mass centralization, gearing, and plumbing

Thank You

We want to thank the sponsors for funding the challenge and providing personnel to make this event possible.

We also want to thank IMI Precision Engineering and the Bimba Manufacturing Company for hosting the challenge.

Questions?

NFPA Fluid Power VEHICLE Challenge