NFPA Fluid Power VEHICLE Challenge

FINAL PRESENTATION & DESIGN REVIEW
The University of Alabama at Birmingham
Mentor: Dr. Littlefield
4/10/2025

NATIONAL FLUID POWER ASSOCIATION · NFPA ·

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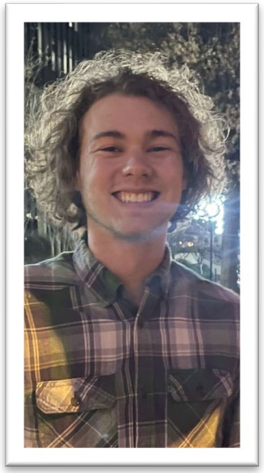
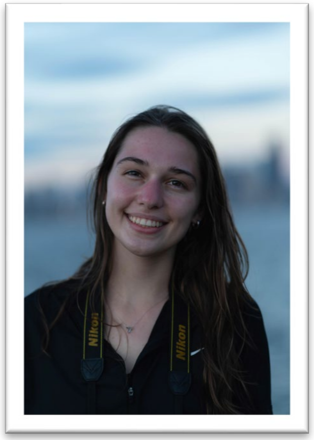
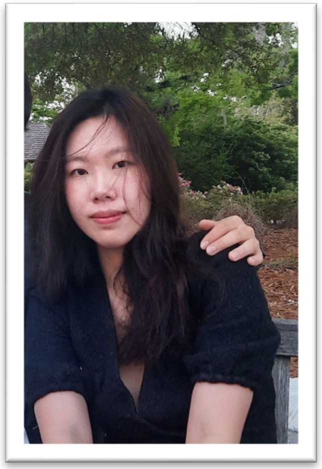
Meet the Team



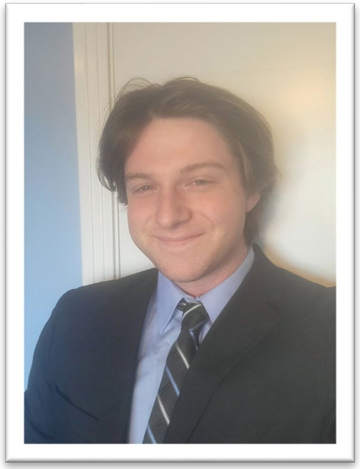
Jonah Libby



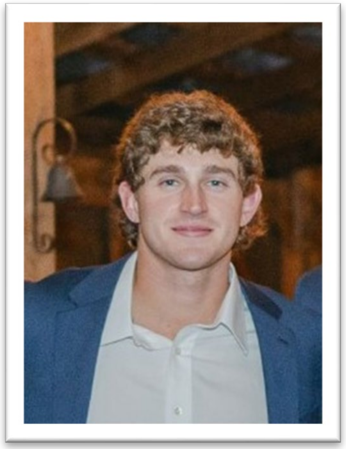
Madeline Richardson



Haley Ha

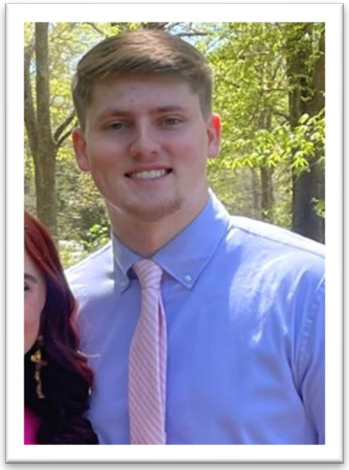


Shane Prunty



Zac Durham

Evan Van Beek



Cannon Taylor

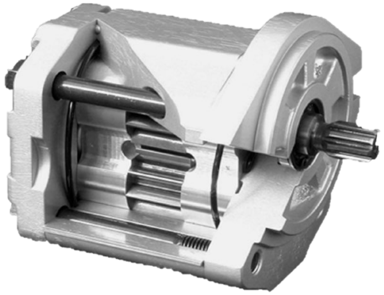
Coleman Oliver

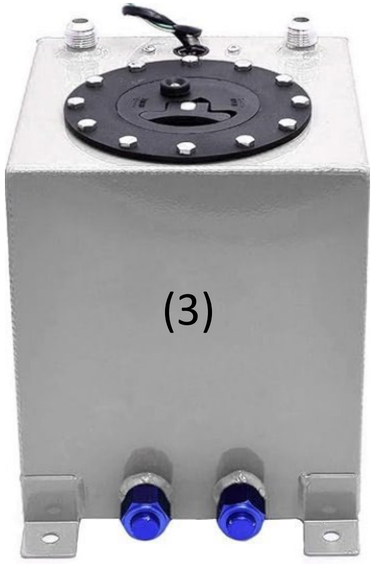
Midway Review Summary

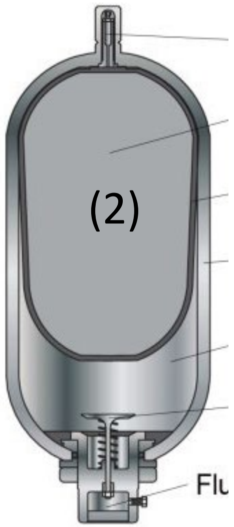
- Major Components
  1. SunSeeker Eco Tad SX Tadpole Recumbent Trike
  2. Steelhead Composites Micromax Series Accumulator
  3. 2.5 Gallon Aluminum Fuel Cell
  4. *Danfoss SKU2NN (16.8cc motor)*
  5. *DANFOSS111.20.370.00 (6.4cc pump)*
  6. *DANFOSS 111.20.372.00 (8.4cc pump)*
  7. Exor ex705
  8. HY-TTC 32 Micro-Controller
- Feedback:

You need to verify if the Nuvinci drive can be used as a ""speed-up"" gearbox. If you connect your pedal to what is normally the hub's output, torque will be moving opposite of that hub's normal application.

(4,5, and 6)







Gantt Chart

TASK	ASSIGNED TO	PROGRESS	START	END
Initiation & Management				
Project Charter/ Design Empathy	All Team Members	100%	9/17/24	9/26/24
NFPA & Mentor Meetings	All Team Members	100%	9/23/24	4/3/25
Research and Developments	All Team Members	100%	9/17/24	10/3/24
Considerations	All Team Members	100%	9/23/24	10/3/24
Design Ideation	All Team Members	100%	9/26/24	10/21/24
Design & Specifications				
Overall Design Choices	All Team Members	100%	9/17/24	10/21/24
Frame Design	Frame Design Team	100%	9/17/24	2/28/25
Hydraulic Design	Power Train Team	100%	9/26/24	2/28/25
Electronics Design	Frame Design Team	100%	10/3/24	2/28/25
Ordering Components	Madeline Richardson	100%	10/24/24	3/30/25
Build & Test				
Fabrication	All Team Members	100%	10/21/24	2/14/25
Construction	All Team Members	100%	11/15/24	3/6/25
Feedbacks and Improvements	All Team Members	100%	1/21/25	2/22/25
Testing	All Team Members	100%	2/22/25	4/3/25
Final Considerations	All Team Members	100%	2/22/25	4/7/25
Competition				
Travel	All Team Members	100%	1/21/25	3/31/25
Competition	All Team Members	0%	4/8/25	4/12/25

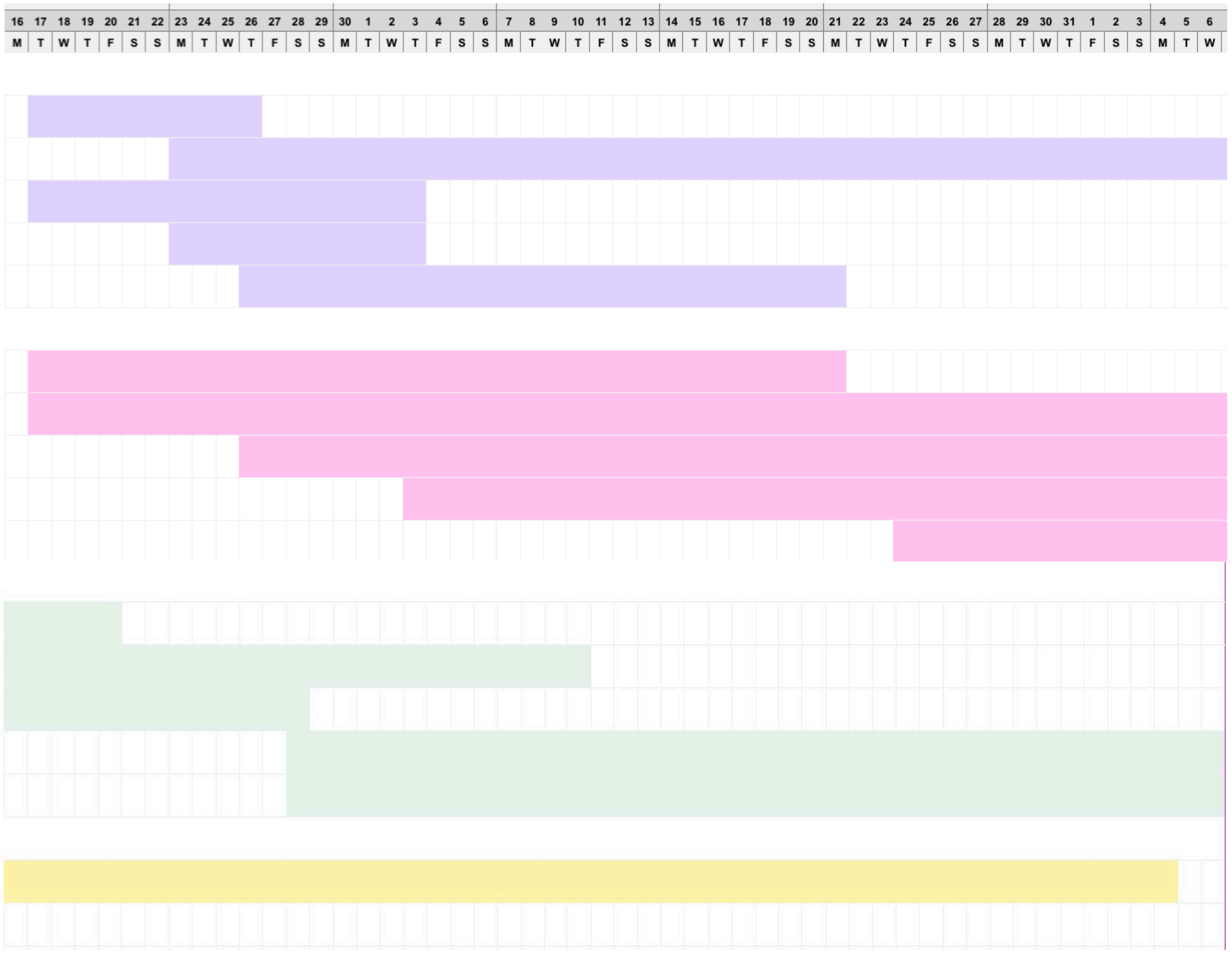
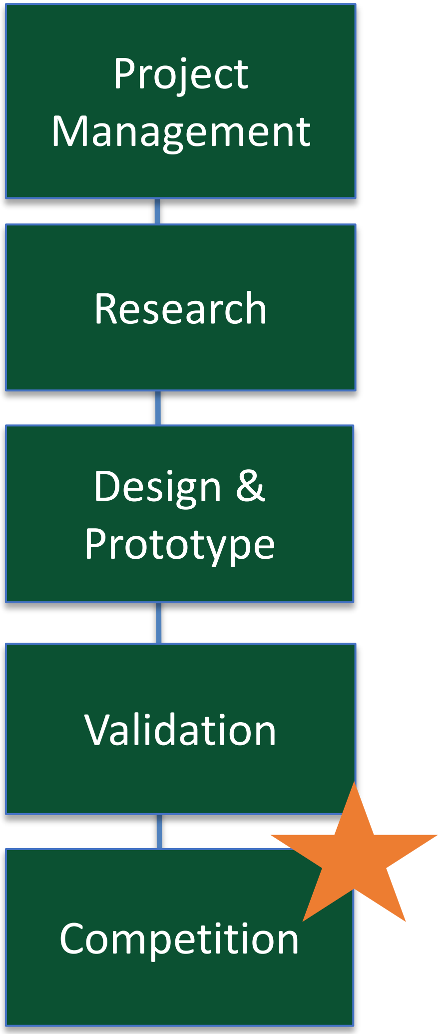


Figure 1. Gantt Chart



Design Objectives

Constructing a reliable, safe, and high-quality vehicle on schedule, incorporating regenerative braking, optimizing performance through testing-driven improvements, enhancing operator safety and ergonomics, and integrating innovative design advancements.

- Improvements from last year:
  - Lower center of gravity and disperse weight along bike frame to avoid a moment on the back
  - Reduced frame weight for safety
  - Utilized multiple motors that we can swap between to match driving conditions
  - Utilized a CVT and gearing system to help with startup and get pump up to high speeds
  - Utilized data from exercise bikes while selecting components in hopes of making the bike easier to ride
  - Utilized a magic arm for more ergonomic and user-friendly use of electronics

Figure 2. 2023-2024 Vehicle

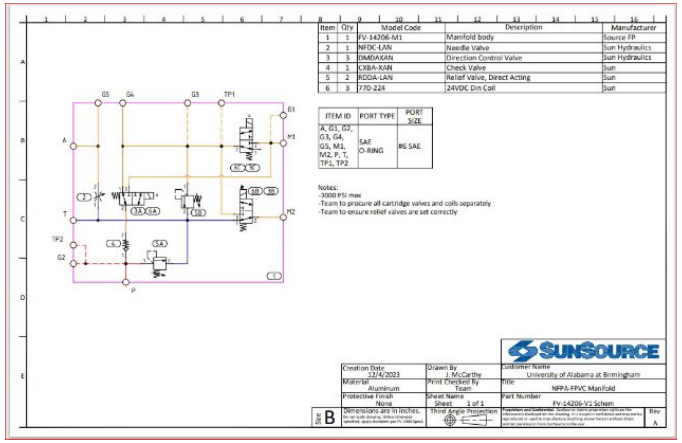


Figure 3. 2023-2024 Hydraulic Circuit

Hydraulic Circuit

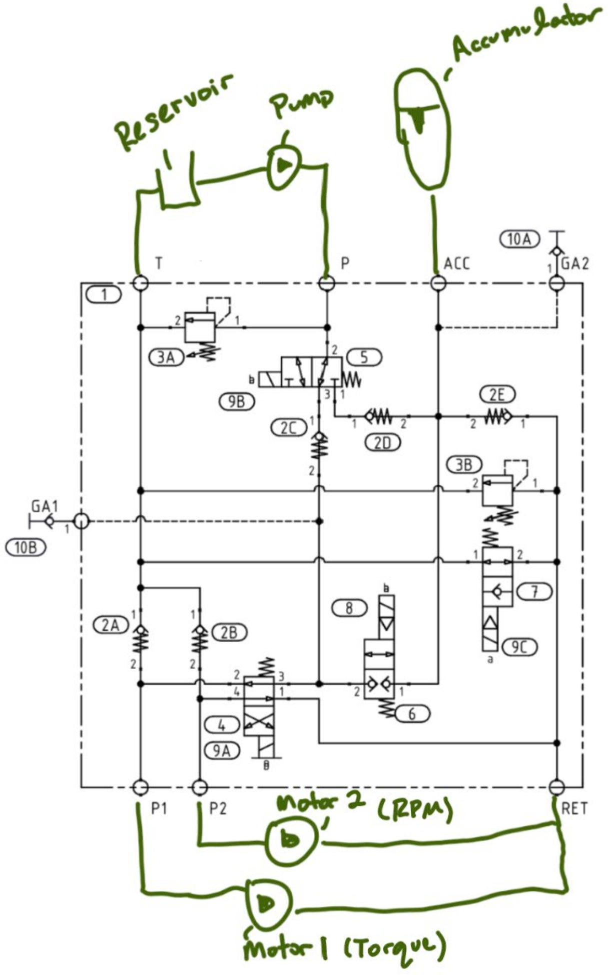


Figure 4. Hydraulic Circuit

- 5 modes
  - Direct Drive High Torque
  - Direct Drive High RPM
  - Charge Accumulator
  - Launch Accumulator
  - Regenerative Braking
- 4 Solenoids

Regenerative Braking

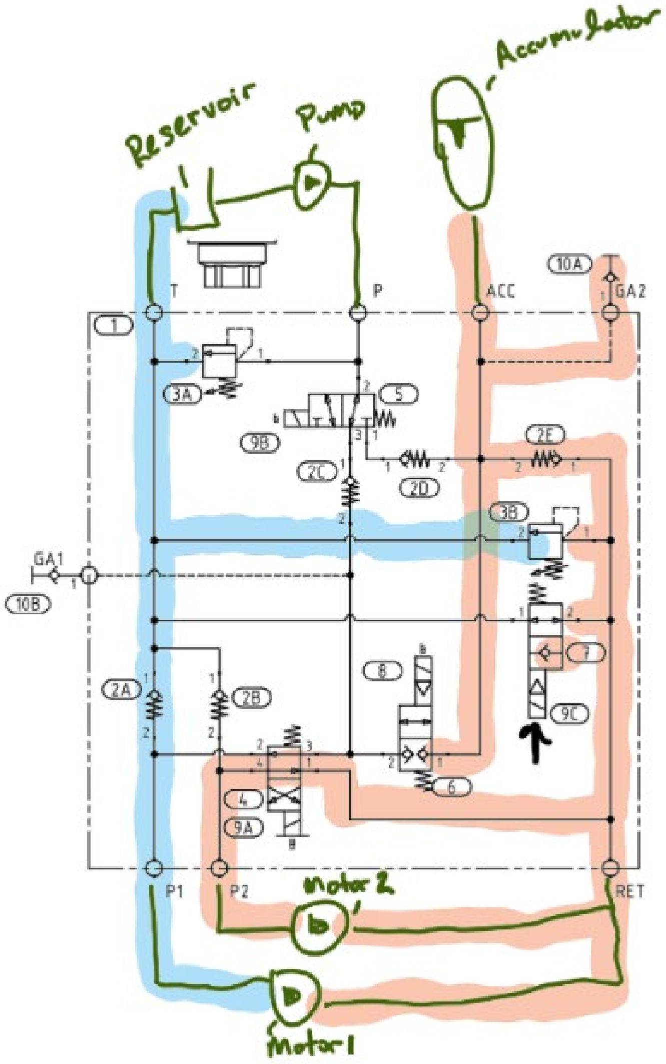


Figure 5. Regenerative Braking Schematics

- For this mode we aim to use the motion of the wheel to pressurized the fluid by swapping the low side and high side pressure to make the motor act as a pump
- Since the wheel and the motor are locked, we allow the low-pressure fluid to fall from the reservoir to the motor and the motor then pumps the fluid to the accumulator
- Since the motor is using the work from the wheel to pump the fluid you will slow down

Design Choices

Taking more considerations on how design choices contribute to vehicle performance,

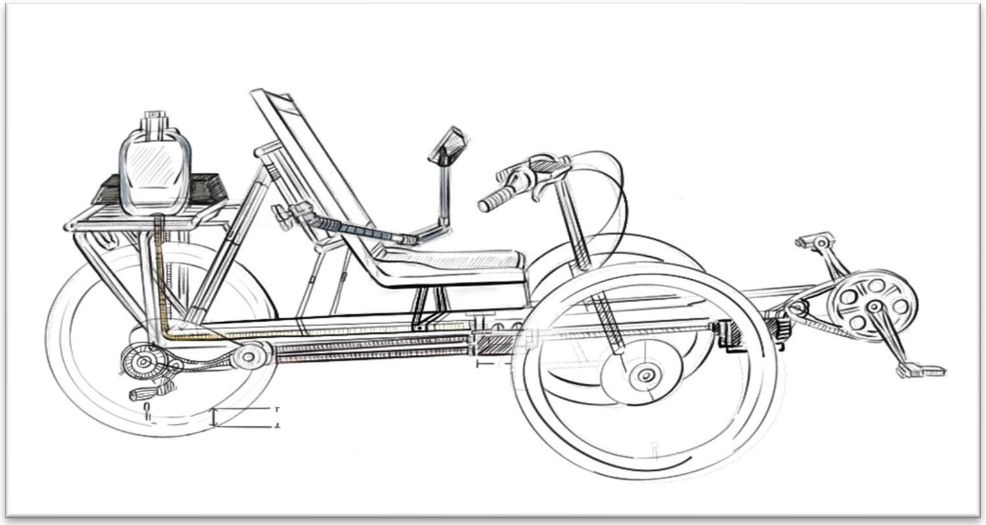


Figure 6. Initial Design Choice

- Addition of two separate platforms
- Addition of bracket and relocation of CVT
- Relocation of magic arm
- Addition of safety factors

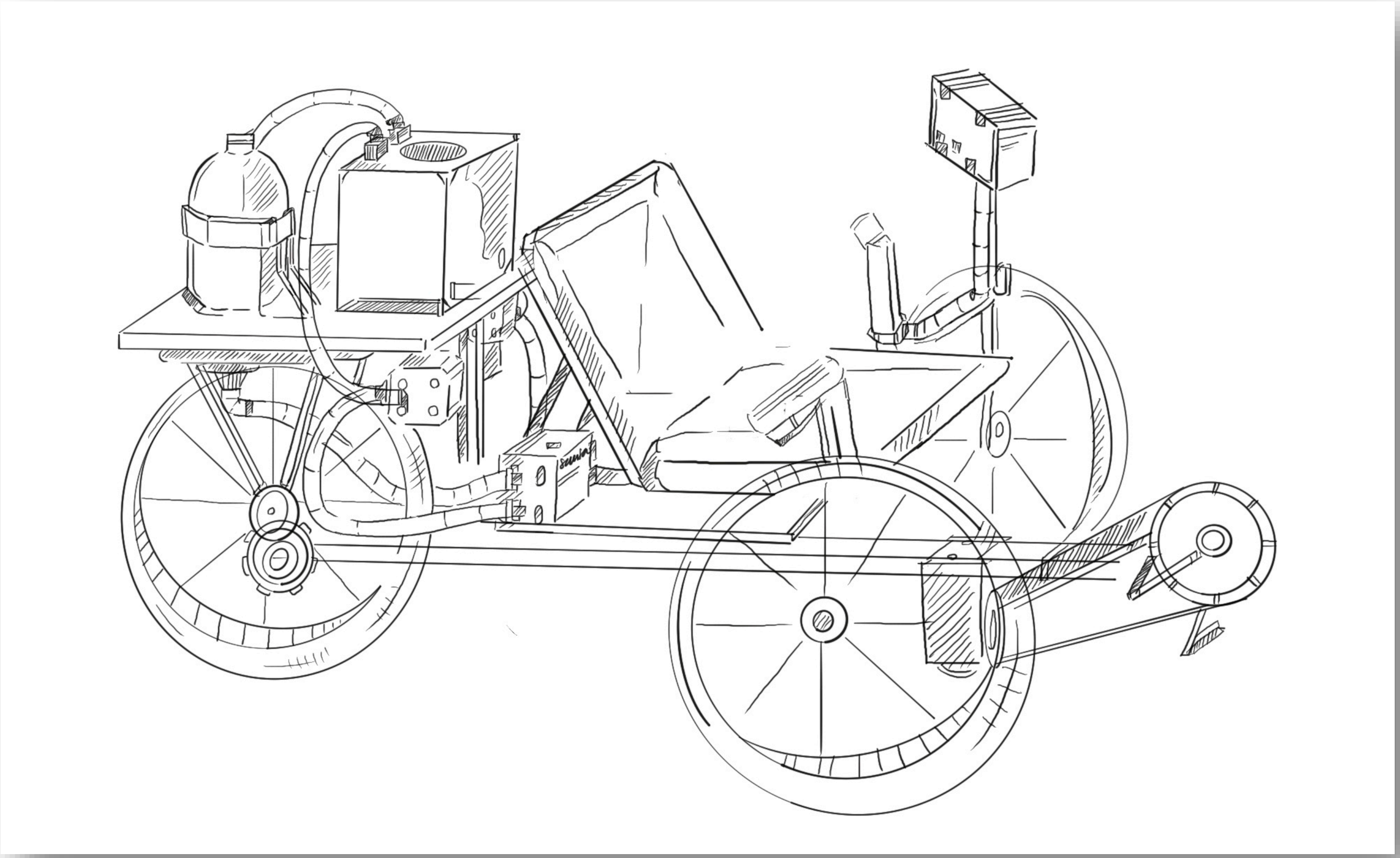


Figure 7. Final Design Choice

Vehicle Construction

Frame Assembly → Mounting provisions → Pumps, Motors and CVT

Figure 8. SunSeeker Eco Tad SX Tadpole Recumbent Trike

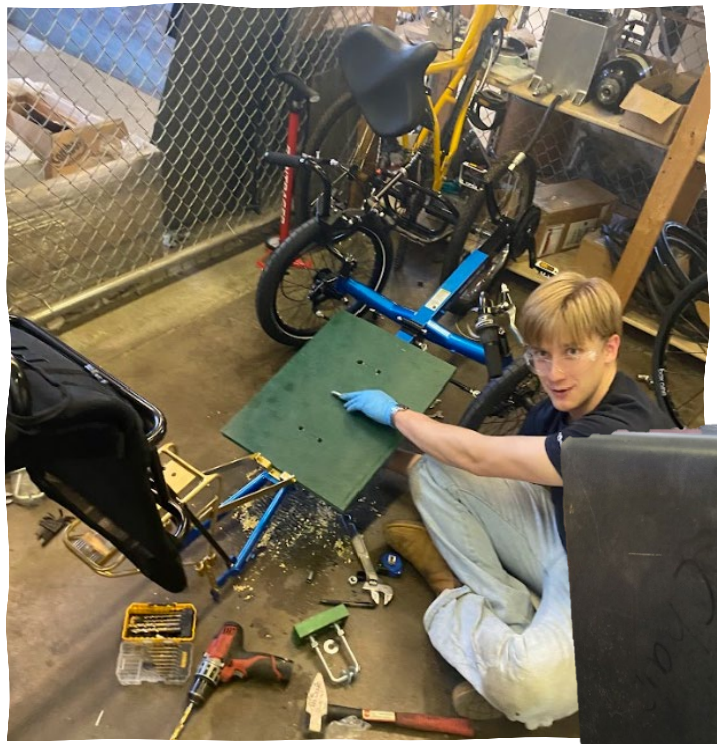


Figure 9. U-bracket Mounting

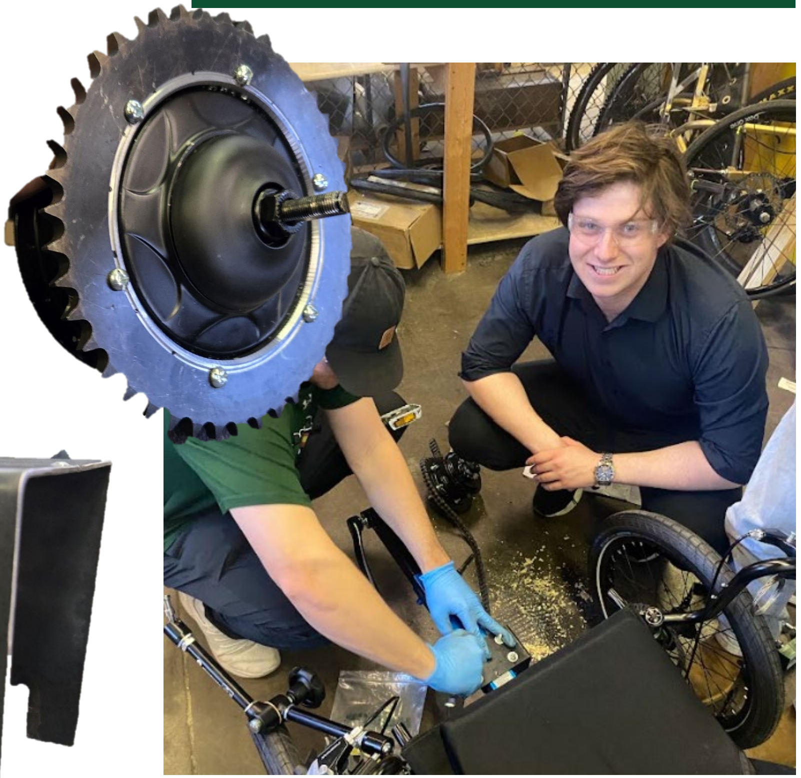


Figure 10. Pumps, motors, and CVT installation

Vehicle Construction

Manifold, Hosing, and Gauges

HMI and Control System

Figure 11. Hosing and Gauges

Figure 12. Various Prototypes for HMI Enclosure and Control System Wiring

Vehicle Construction

Bike Completion and Adjustments

Figure 13. Progress photos

Tests and Tune Up

Figure 14. Rider Test

Final Vehicle

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Figure 15. Final Vehicle

Vehicle Testing

We have been able to run tests improve on our design the past 3 weeks. Based on our tests, we believe that we can get an output of roughly 4.32 inches of forward motion per psi stored in our accumulator.

- Test 1 (3/19)
  - Bike worked in accumulator charge and drive mode. Had issues with our components as well as problems with our true/false statements in our code causing solenoids to misfire.
- Test 2 (3/20)
  - After working with Motion Industries, we were able to get our direct drive mode to work and test. This led to a change from the original pump-motor shaft design for the output to a motor-motor shaft design for output. We still had issues with solenoids misfiring and our regenerative braking was not as effective as we had hoped.
- Test 3 (3/21)
  - We worked with IFP to get our solenoids and code straightened out. We were finally able to get all modes working properly. We tested which output motor would be best to use for regen. We were able to charge up a decent amount of fluid when traveling downhill.

Figure 16. Test 2 (3/20/25)

Vehicle Testing cont.

- Test 4 (3/27)
  - Filled up accumulator to 2800 PSI. Had concerns about the chains and gears holding up under higher pressure but they did fine.
- Test 5 (4/1)
  - After tightening the brakes, adjusting chains, and adding stability features, we tested the bike again at 2800 PSI and everything functioned the way we wanted.
- Test 6 (4/3)
  - Timed ourselves charging the bike to 2600 PSI and tested with a lighter rider to see if there was any major differences.
- Test 7 (4/5)
  - Adjusted the CVT range and CVT mount. Was able to get a much smoother ride and reduce risk of chains slipping. Performed finals tests for each mode and events and was satisfied by the results.

Considerations and Improvements

- Had concerns with our original mounting provisions breaking since they were made of coosa board which is a foam composite. We fixed this by replacing them with a balsa wood and fiber glass composite.
- During our first test we had issues getting our direct drive mode to work. We worked with Motion Industries and determined that we could not use a pump as an output like we originally hoped. We replaced the pump with a motor from a previous year.
- Had issues with chains slipping due to the CVT mount twisting. We fixed this by improving on our mount design to make it more rigid.

Figure 17. Bracket Considerations

Lessons Learned

Project Management

- Effective teamwork required clear communication and collaboration to align on shared design goals. Planning ahead helped avoid delays and ensured that components fit and functioned as intended. We also learned to stay adaptable and respond quickly to unexpected challenges—such as compatibility or fitment issues—to keep the project moving forward. Another thing we learned was to always be prepared for something to go wrong and have a backup plan if things do not work out.

3D printing with CAD

- Designing 3D-printed components taught us to pay close attention to clearances and tolerances in the model to ensure proper fitment and ease of assembly. We learned to account for material properties and print orientation to minimize weak points and prevent warping. Accessibility was also key—designing enclosures to allow for easy installation, wiring, and maintenance of HMI components. Early prototype testing was essential to catch design flaws before committing to a final version. Coordination with the electrical and mechanical components ensured that the enclosure met all mounting, ventilation, and protection requirements.

Hydraulic systems

- Throughout this project, we gained extensive knowledge of various hydraulic components and their applications in real-world systems. We learned how to design an effective and efficient hydraulic circuit, taking into account factors like flow, pressure, and component compatibility. We also became familiar with industry standards related to hydraulic tubing and safety, ensuring our design met professional expectations.

Control Systems

- We were introduced to both the hardware and software used in control systems for hydraulics. This experience gave us practical insights into how electronic control can enhance system functionality and precision to coordinate direction of flow.

Machine Shop

- Hands-on experience in the machine shop allowed us to learn how to safely and effectively use tools such as press brakes, punches, and saws. These skills were essential for fabricating key components and understanding the limitations and capabilities of manufacturing processes.

Prototyping and Testing

- Trying to combine all our components together to make a final product while still attempting to improve out individual parts of the project allowed us to better understand how to coordinate our design changes and better implement them in respect to the other parts of the project to minimize the disrupting to the overall testing procedure

Design Engineering

- This project sharpened our design skills, including the importance of clearances and tolerances in mechanical systems. We performed calculations to ensure system feasibility and reliability, and designed mechanisms involving chains and sprockets to transmit power effectively. We also learned how to design components to withstand mechanical loading, considering forces, stresses, and material limitations to ensure durability and safety under real-world operating conditions.

Communicating with Professionals

- Working with mentors from UAB, the NFPA, and various vendors helped us develop our professional communication skills. Their feedback was invaluable in refining our design and aligning it with real-world expectations and constraints. Additionally, working with industry professionals taught us to be respectful of their time and availability even if it contradicts ours.

Acknowledgements

NFPA Fluid Power Vehicle Challenge

- N.F.P.A.
- Hubbell
- SunSource & IFP
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- Dr. David Littlefield
- Dr. Selvum Pillay
- Jordan Barre
- Alex Murray

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+ LUBRIZOL
+ PARKER HANNIFIN
+ SOURCE FLUID POWER

+ APPLIED FLUID POWER
+ BRENNAN INDUSTRIES
+ DANFOSS POWER SOLUTIONS
+ HELIOS TECHNOLOGIES
+ HYDAC

Thank you!
Questions?