

# THE ETUG PROJECT

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## MOTIVATION

Air and noise pollution at and around airports is a serious problem with no current solutions.

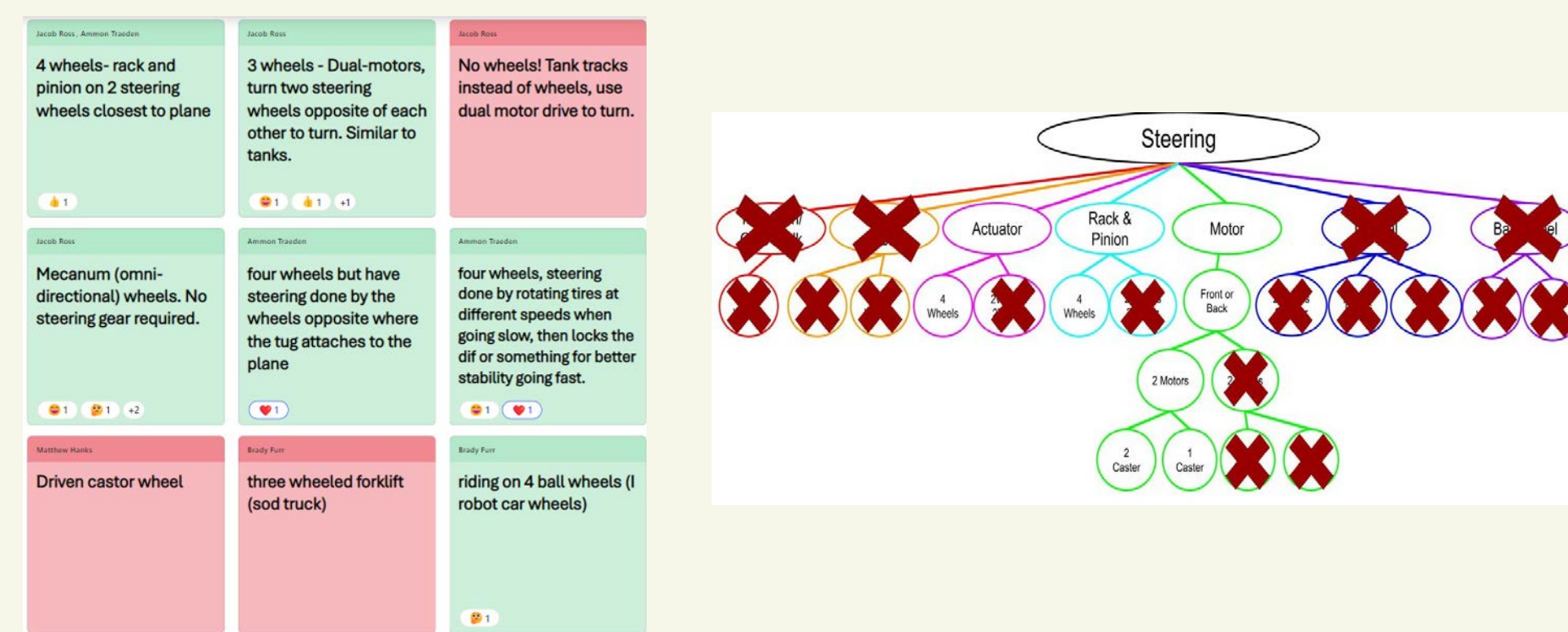
## OBJECTIVE

Create a better environment for airport staff and the surrounding population by reducing carbon emissions and noise pollution through the design of a proof of concept for an autonomous electric tug.

## IDEA GENERATION

### Brainstorming methods:

- Sticky notes with voting system
- Tree diagram



The top ideas moved on to the next step

## ANALYSIS

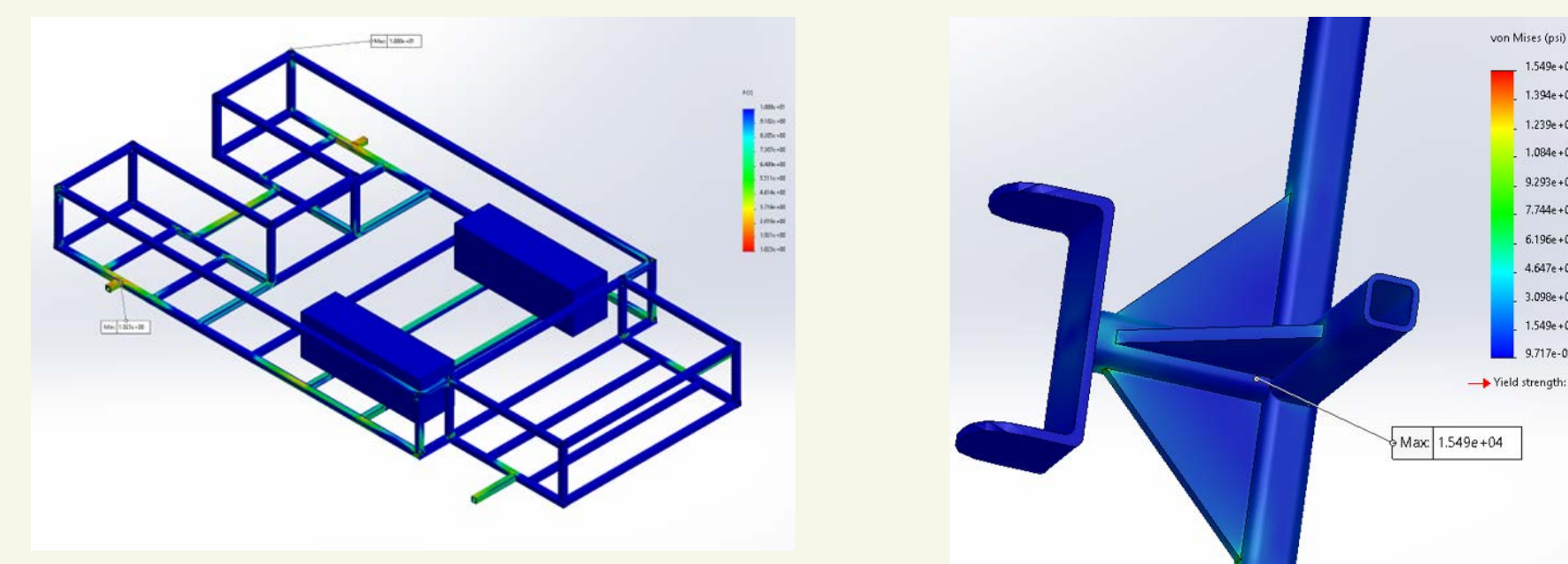
Excel calculators were built to ensure the parts ordered would be able to power and stop the tug

Variable	Value	Unit
Weight of plane (lb)	1000	lb
Weight of Tug (lb)	1000	lb
Braking Resistance (lb)	1000	lb
Mass of Tug	545.45 kg	kg
Mass of Plane	1792.27 kg	kg
Mass Combined	1744.64 kg	kg
Radius	0.4572 m	m
Stopping Distance	0.0001 m	m
Traveling Velocity	2.24 m/s	m/s
Minimum Deceleration	-0.83626667 m/s <sup>2</sup>	m/s <sup>2</sup>

Variable	Value	Unit
Deceleration under normal conditions	0.3 Gs	Gs
Deceleration under normal conditions	-0.988 m/s <sup>2</sup>	m/s <sup>2</sup>
Normal Braking Force Required	171.538613 N	N
Desired Braking Force Required	1659.92421 N	N
Avg Braking Power	1936.923242 W	W
Required Braking Torque for normal stop	893.197722 N-m	N-m
Required Braking Torque for Desired Stop	893.939309 N-m	N-m

Simple FEA was used to show weak points in structural designs and areas for improvement



## TESTING & REFINEMENT

Functional tests were performed at the Provo airport using a Diamond DA-40.



These tests highlighted weak points to redesign for the final build

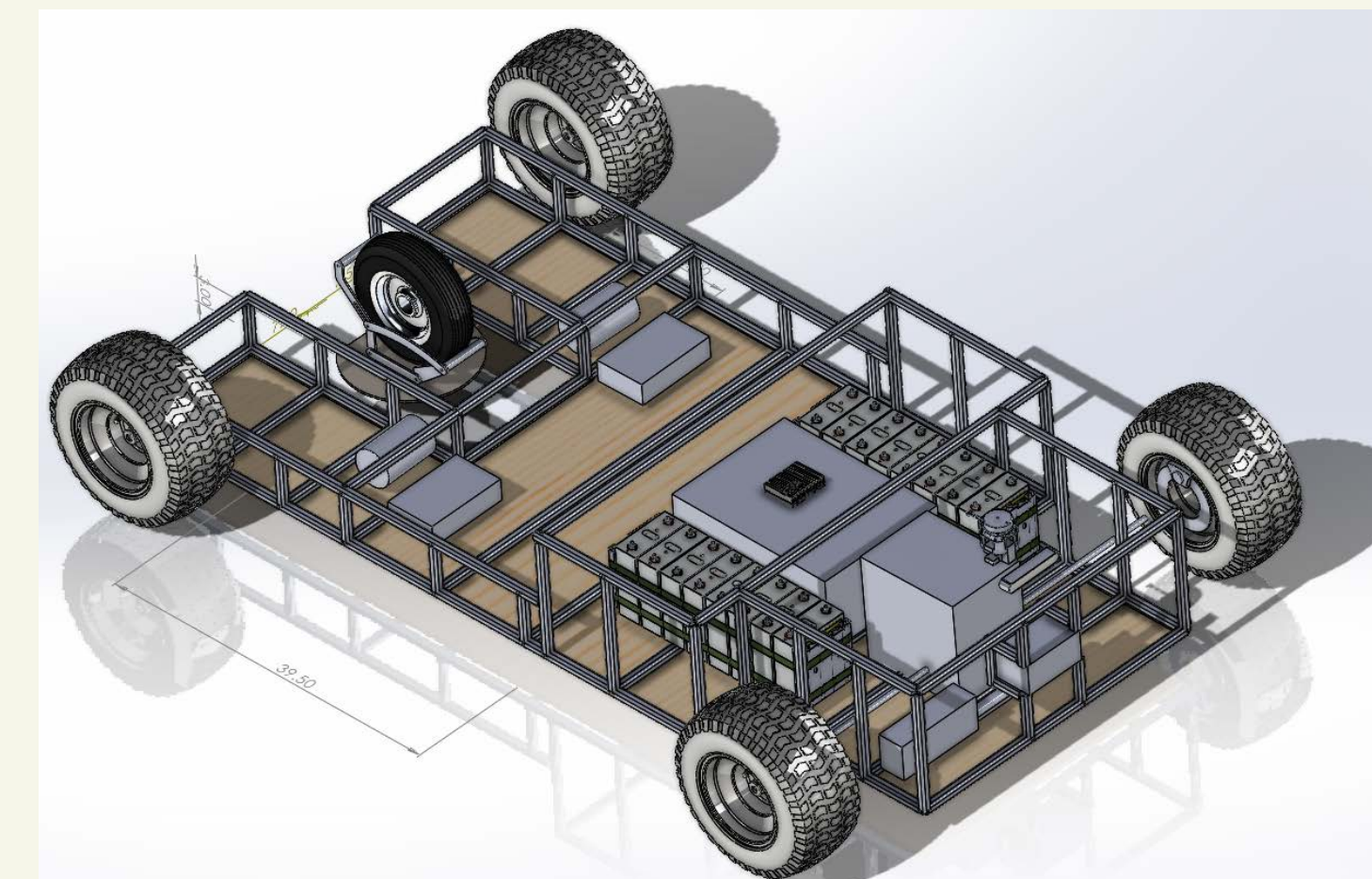


## DESIGN SELECTION

Decision matrices were used to initially rank ideas for each system

Criteria	Weight	4 wheels - rack and pinion steering	3 wheels - Dual motor, turn left steering wheels opposite of each other to turn. Similar to tanks.	No wheelie Tank tracks instead of wheels, use dual motor drive to turn.	4 wheels - steering done by rotating tires at different speeds when going left. This locks the diff or something for better stability going fast.	4 wheels - steering done by rotating tires at different speeds when going left. This locks the diff or something for better stability going fast.
Cost	0.15	3.75	4.20	3.75	3.75	3.75
Mechanical Complexity	0.15	3.00	3.00	3.00	3.00	3.00
Range of Design	0.15	3.00	3.00	3.00	3.00	3.00
Time to Build	0.15	3.00	3.00	3.00	3.00	3.00
Manufacturability	0.15	3.00	3.00	3.00	3.00	3.00
Production/Manufacturing	0.15	3.00	3.00	3.00	3.00	3.00
Maintainability	0.15	3.00	3.00	3.00	3.00	3.00
Stability	0.15	3.00	3.00	3.00	3.00	3.00
Overall Score	0.15	3.00	3.00	3.00	3.00	3.00
Stability	0.15	3.00	3.00	3.00	3.00	3.00
Total	0.15	3.00	3.00	3.00	3.00	3.00

After combining, the teams collaborated to combine ideas to reach a final design.



## DESIGN REQUIREMENTS

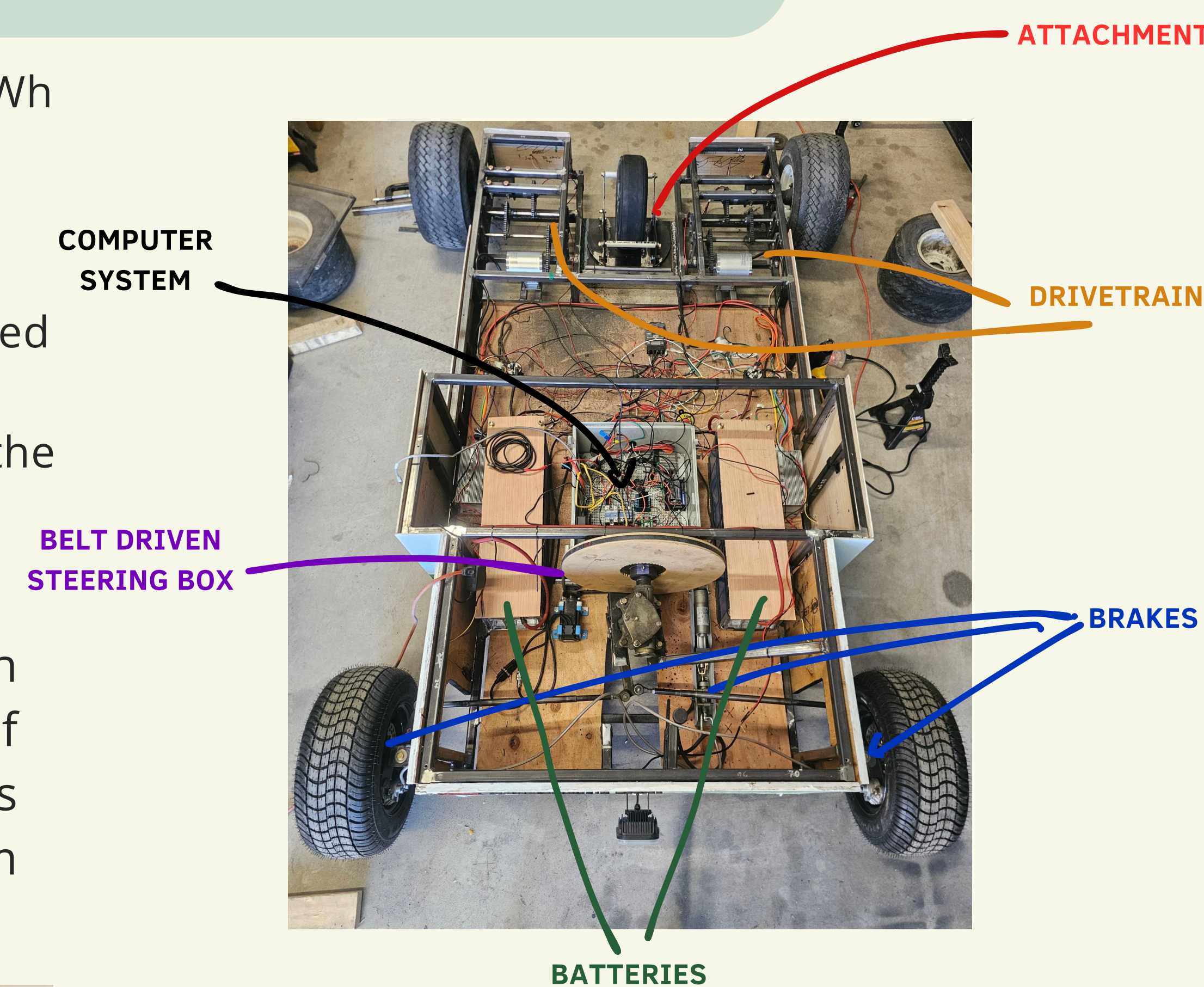
- Multiple Control Options
  - (Remote, Partial Autonomy)
- Automatic Plane Attachment
- Fully Electric Vehicle
- Enough power and range to pull a small aircraft to the runway and then return multiple times
- Ability to monitor the tug remotely

## FINAL BUILD

- Batteries are lithium-ion from Lion Energy with 14.3 kWh
- The computer controls the entire system
- A hydraulic disk brake system was used
- A stepper motor controls the steering
- The attachment was completely designed and fabricated by the team
- A gearing system was designed and implemented for the dual motor drivetrain

### Project Goals Review:

At end of semester, tug is partially autonomous, with features in place to implement a further level of autonomy in the future. The tug's physical systems establish a solid proof of concept of a scalable system that would improve emissions and noise pollution.



### Next Steps:

This project succeeded in its goal of being a proof of concept, the next steps for this project are to:

- Refine the autonomous system
- Improve tolerances and functionality of the attachment feature
- Implement lazy susan attachment feature
- Incorporate steering system that is capable of 90 degree steering angles



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## PROTOTYPING

Prototypes were used to test complicated designs and check tight tolerances

