NAU SAE TOOLBOX

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Engineering 224

Project Description

Department of Mechanical Engineering

- NAU Baja SAE Capstone
- NAU Formula SAE Capstone
- Professor David Willy

Why?

- Yearly SAE collegiate competitions
- Ongoing need for mobile tools and equipment at competition
- Incremental increase from current wagon storage

Figure 1: 2025 Baja SAE Pit Setup

Figure 2: Projected End Goal [1]

Subsystem Checklist

Table 1: Modeling Check and Requirements

Subsystem	Physical	Virtual	Client/ER Requirement
Brakes	-		Needs to brake quickly and safely
Steering		-	Needs to be able to be driven by one person
Toolbox/Cabinets	-	-	Needs to store required tools/equipment/extras
Casters		-	Needs to have a minimum of 8” casters for terrain
Power System		-	Needs to power battery chargers/phones/extras
Base Frame		-	Needs to be durable and as small as possible for trailer storage
Tire Storage	-	-	Needs to carry both Baja and Formula sized tires

Physical Prototype

"Backwards Bike" braking system

Question

Can we create a simple, effective self-braking system that engages automatically when the user lets go of the handle?

Prototype Images

Figure 3: Front View

Figure 4: Rear View

Figure 5: Spring

Brake Prototype Calculations

Required bike braking force:

$$\frac{\frac{\frac{1}{2}(110\ kg)\left(2\frac{m}{s}\right)^2}{3\ m}}{.3937\ m} = \frac{.4552F_b}{0.08255\ m} \rightarrow F_b = 33.78\ Nm \approx 25\ ft\ lbs \qquad (1)$$

Required tool cart braking force:

$$\frac{\frac{\frac{1}{2}(227\ kg)\left(2\frac{m}{s}\right)^2}{3\ m}}{.127\ m} = \frac{.4552F_b}{0.08255\ m} \rightarrow F_b = 216.1\ Nm \approx 160\ ft\ lbs \qquad (2)$$

Estimated brake system braking force:

$$16.9\ MPa\ (0.1^2 m)(.4552) = 773\ Nm \approx 570\ ft\ lbs \qquad (3)$$

Answer

Yes — flipping the bike handle and adding a spring successfully keeps the brakes engaged until the handle is pulled.

Informed Design

- Proved the concept works with minimal components
- Next step: refine spring tension and mount location for smoother operation and ergonomic use

Virtual Prototype

- Model of the front steering/ caster subsystem
- Physical prototype not needed to answer questions
- Designs based on existing framed tool carts and go carts

Figure 6: Miller Custom Fab Benchmark [2]

Question

What are we trying to answer?

- Overall function
- Motion study
- Length of tie rods
- General setup/sizes
- Where bracing is needed
- Bolt sizes
- Steering angles

Will the tie rod and handle steering system provide sufficient turning radius and mechanical advantage for off-road maneuverability?

Initial CAD Parts

Figure 7: Top View

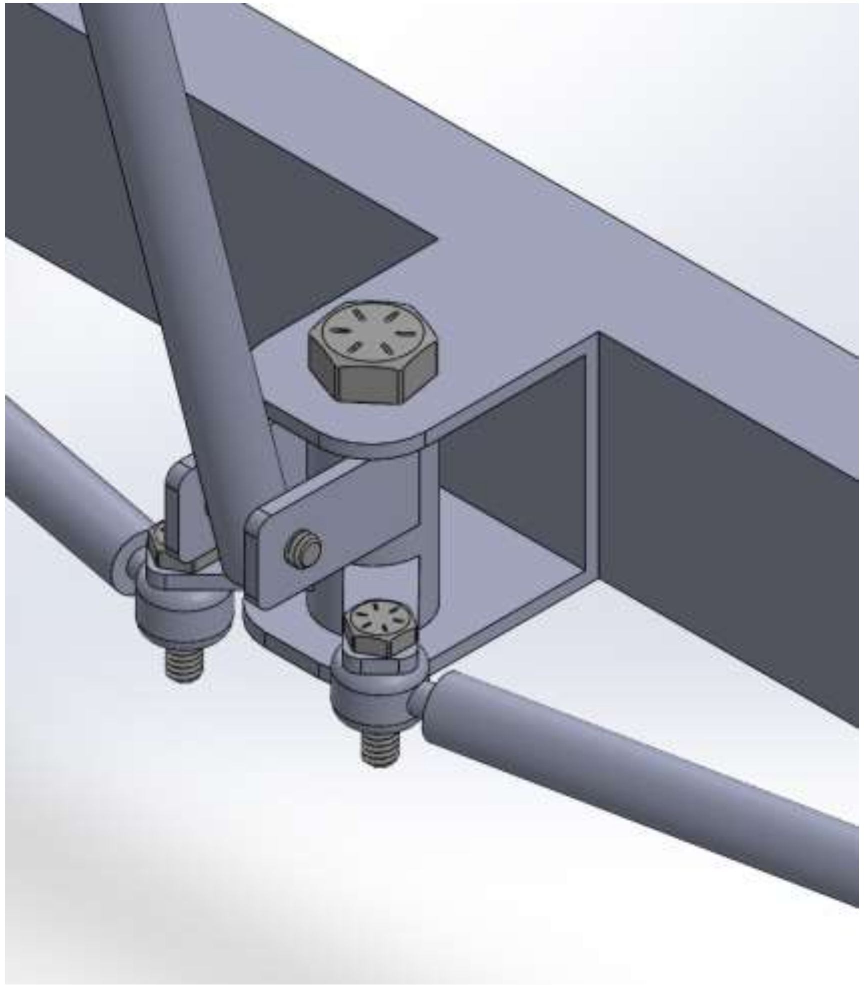

Figure 8: Center Handle Component

Initial CAD Parts

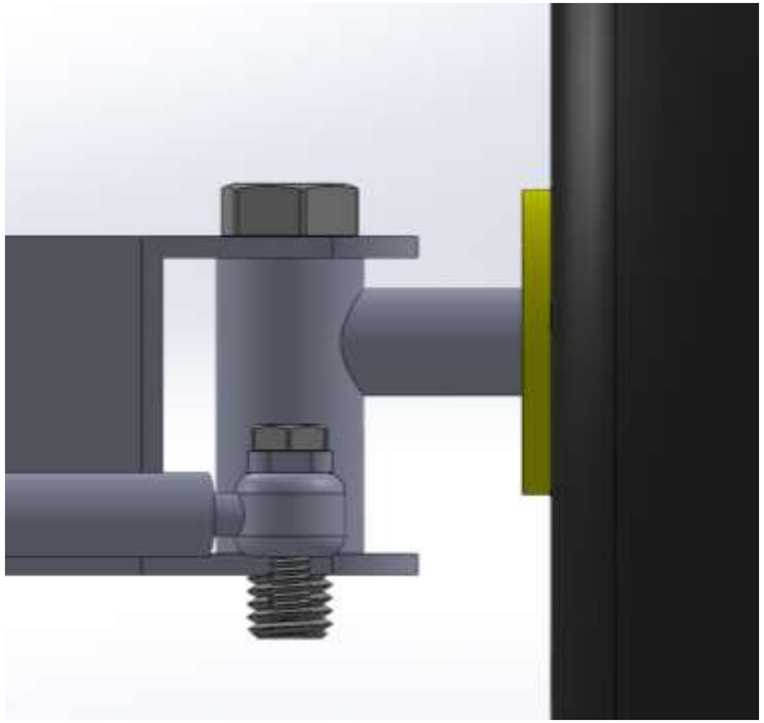

Figure 9: Left Axle Hub

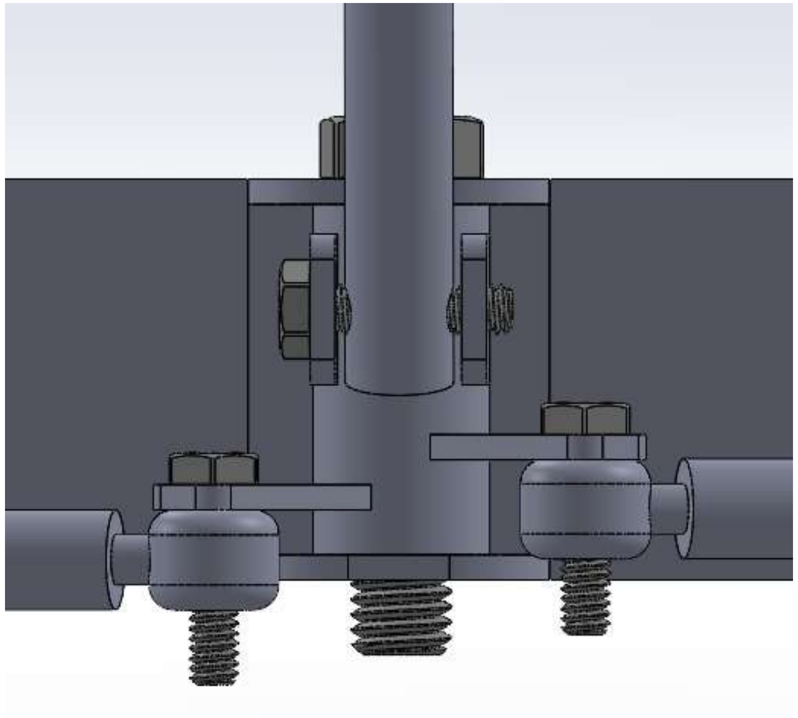

Figure 10: Center Steering Hub View

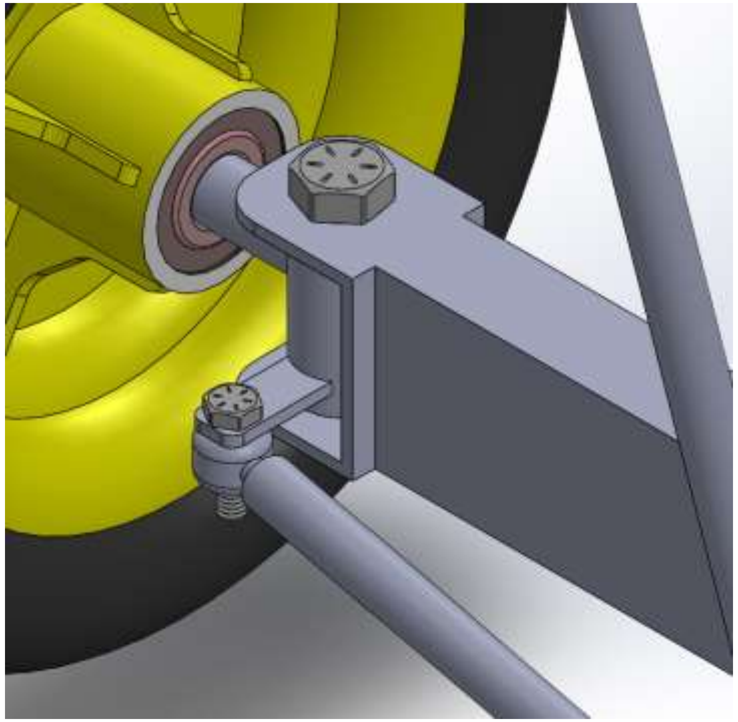

Figure 11: Right Axle Tie-Rod Setup

CAD Part Changes

Figure 12: Updated Top View

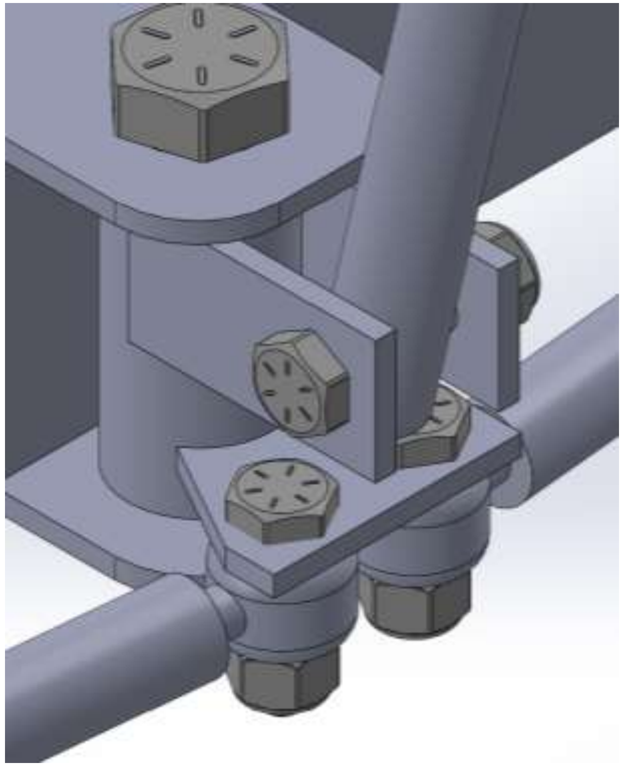

Figure 13: Updated Center Steering Hub

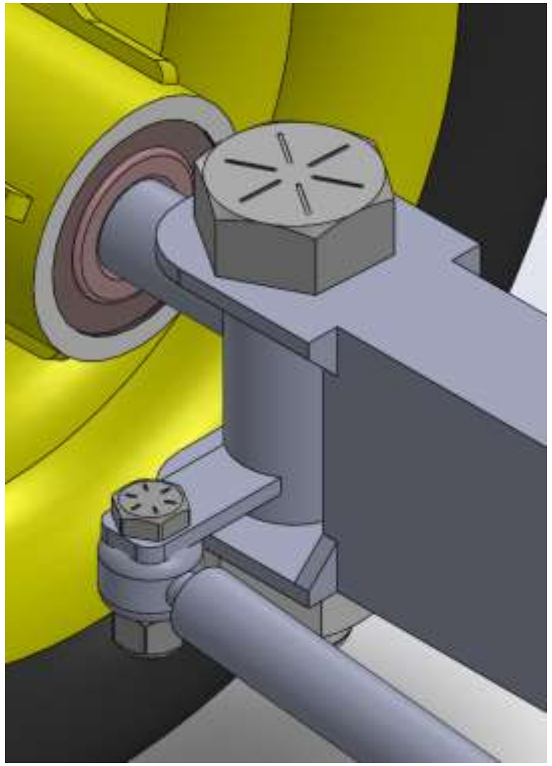

Figure 14: Updated Cut Frame

Motion Study

- Integrated collision detection test
- Stops when wheel hubs touch the frame
- Turning radius increased visually after geometry changes
- General go-cart steering design [3]
- Hardware rated for weight loads

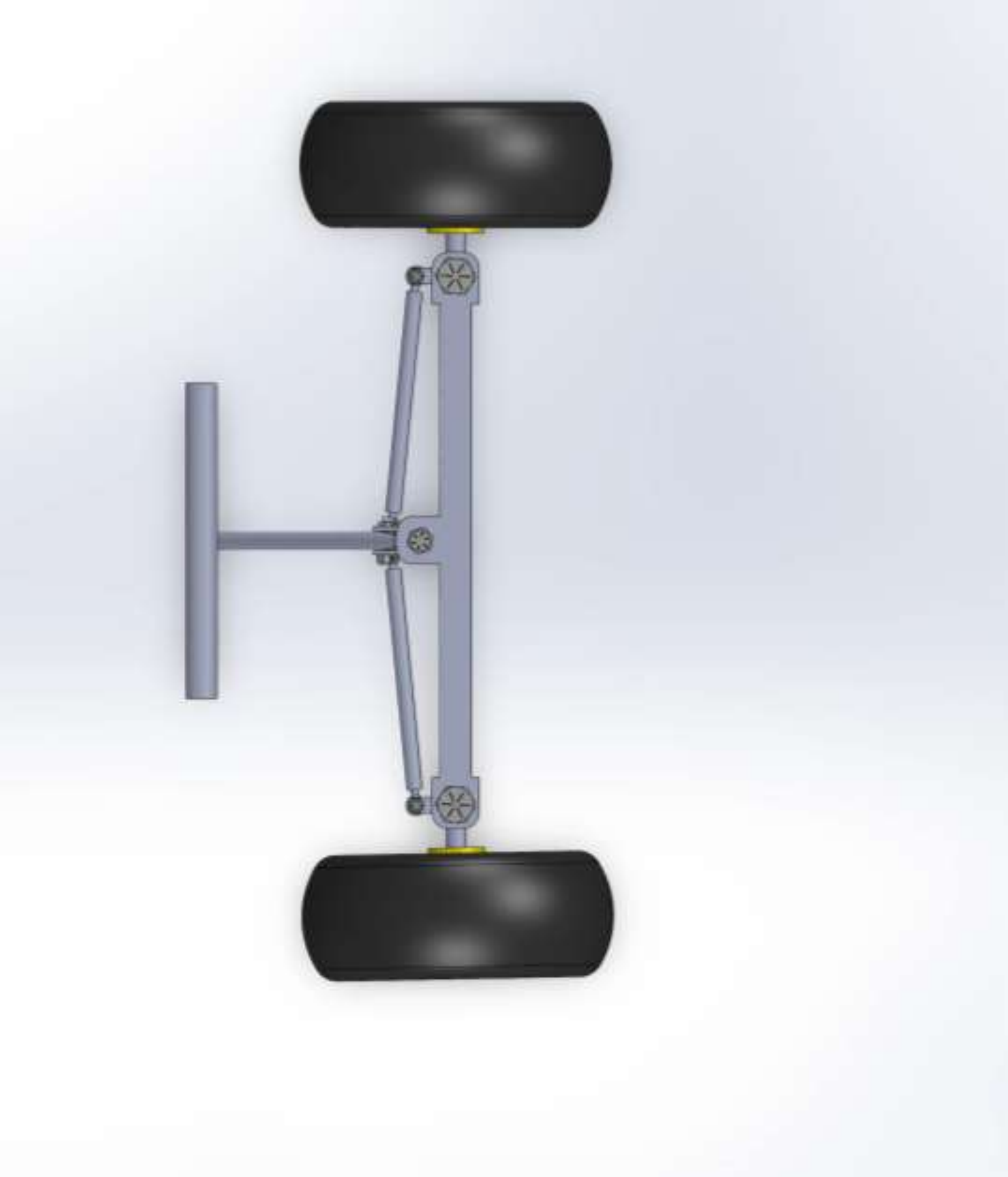

Figure 15: Simple Steering Motion Study

Answer

The virtual motion study confirmed smooth steering articulation with a turning radius of ~27.4° on one wheel and 39.4° on the other because of Ackermann. [5]

- Typical car steering angle is ~33°. [6]
- ~39” turning radius from 24.75” wheelbase

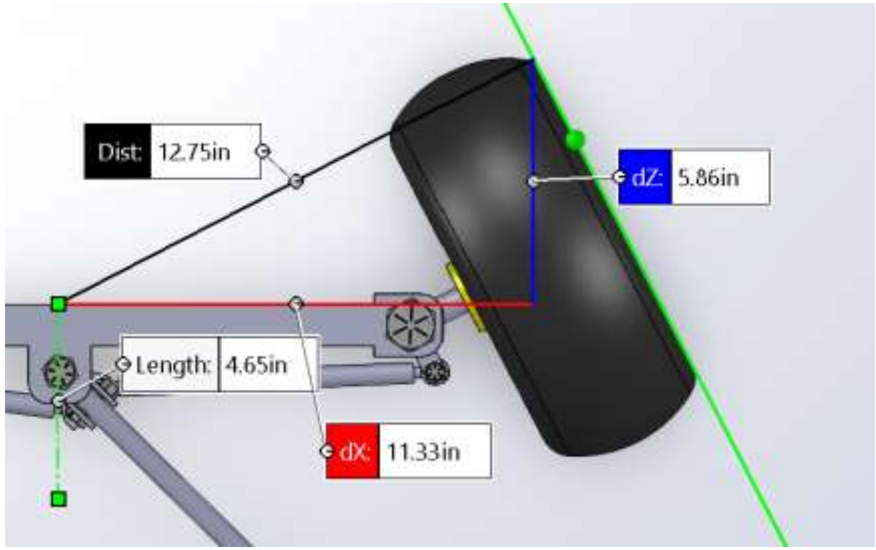

Figure 16: 27.4 Degree Measured Steering Angle

Informing the Design

- Validated geometry and component placement
- Plan to reinforce steering knuckle mounts and test alternative rod-end bearings to reduce physical play

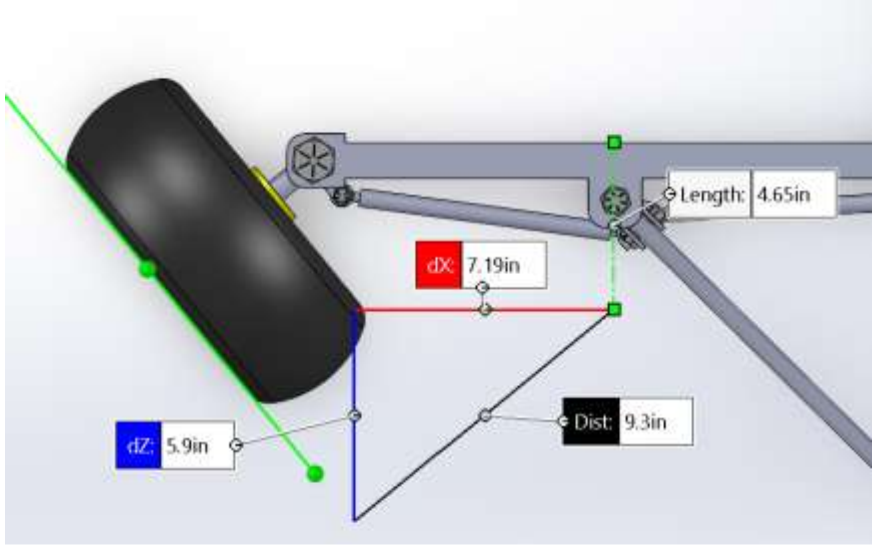

Figure 17: 39.4 Degree Measured Steering Angle

Rough Integrated CAD

Figure 18: Integrated Steering Subsystem

Figure 19: Rough Assembly Isometric

Next Steps

- Model the shell of the frame
  - Get a scaled version to calculate outer aluminum needs
  - Optional build material (popsicle sticks, 3D print, Legos)
- General setup/layout:
  - Shelves, tabletop, shade mounting, vice, etc.
- Inner cabinet volume calculations from fractional model
- Tire carrier integration placement

References

[1] Rockin' Toolboxes, "Extreme Tools® Professional 70″ 7 Drawers and 2 Compartments Pit Box," *RockinToolboxes.com*. [Online]. Available: https://rockintoolboxes.com/shop/carts-road-boxes/extreme-tools-professional-70-7-drawers-and-2-compartments-pit-box/?attribute_pa_color=blue. [Accessed: Jul. 24, 2025].

[2] Miller Custom Fabrication, "Roller Pit Cart Frame," *MillerCustomFabrication.com*. [Online]. Available: https://www.millercustomfabrication.com/store/p/roller-pit-cart-frame. [Accessed: Jul. 24, 2025].

[3] GR Pro Tooling, "Extreme Tools Roller Pit Cart Frame Build." *YouTube*, Jul. 18, 2025. [Online]. Available: https://www.youtube.com/watch?v=g1hxAQg6_XY. [Accessed: Jul. 24, 2025].

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[6] J. Hocking, "Typical maximum steering angle of a real car," *Game Development Stack Exchange*, Dec. 10, 2012. [Online]. Available: https://gamedev.stackexchange.com/questions/50022/typical-maximum-steering-angle-of-a-real-car. [Accessed: Jul. 24, 2025].

Thank You

Questions?