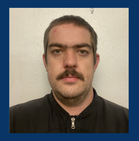
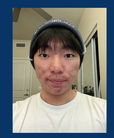
NAU SAE TOOLBOX

Derek Griffith  , Hailey Hein  , Haoran Li  , Yanbo Wang 

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Abstract

The SAE Toolbox Capstone Project addresses the need for a mobile, durable, and multifunctional toolbox cart to support Northern Arizona University's SAE Formula and Baja teams in both competition pits and shop environments. Current pit operations are hindered by unorganized tool storage, limited maneuverability on uneven terrain, and lack of integrated power. Our team set out to design a solution that improves efficiency, safety, and reliability under race conditions.

The cart measures 60"L × 32"W × 33.5"H and is constructed from welded A36 steel square tubing, chosen for its strength and manufacturability. It rides on four 13-inch off-road casters to ensure mobility across gravel and grass. A steering handle with a tie rod system achieves the requirement for tight maneuverability in the trailer and pit spaces. Storage is provided by a four-drawer lockable toolbox and additional compartments, offering 21.6 ft³ of organized space, nearly triple the required minimum. Onboard power is supported by a 2500W inverter generator, ensuring charging capabilities for power tools and equipment during long events.

Requirements

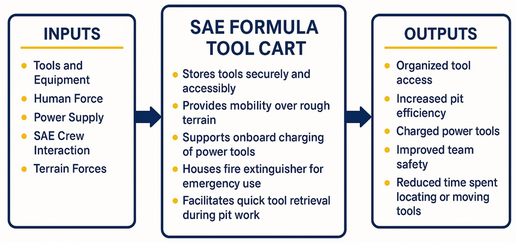


Figure 1: Requirement Black-Box Model

Table 1: Customer and Engineering Requirements

Category	Client Requirements	Engineering Requirements	Solution
Mobility	Terrain capable tires	Rubber casters >8" OD, 6" Minimum	13" D x 5.5 W" Casters
	Steering system	Human operated steering system	Tie-rod steering
	Brake system	Human operated foot brake system	Exterior push-latch
	Trailer footprint	Fits and can maneuver in the travel trailer	60" L x 32 W" Frame
Storage &	General tool storage	Secure drawers with latch systems	3D Printed spring latches
Tooling	Ancillary equipment	Space to store required equipment	5 cabinet doors
	Driver gear storage	3'x2'x1' Internal cabinet volume minimum	
	Fire extinguisher	External quick-acces mount	Exterior un-latchable extinguisher mount
	Tire carrier	Storage for Baja or Formula SAE car tires	30Lx25W" Tire carrier
Power &	Integrated power	Stand alone system that can handle charging loads	2500W Inverter generator
Electrical	Charging capabilities	Extension cord with power bank	25 ft extension cord
	Powered tools	Capacity for power tools to charge	13-outlet 120V strip
Work Features	Mounted vice	Top mounted vice big enough for work	6" Table-mounted vice
	Tabletop work area	Top panel doubles as the workspace	60 x 32" Top panel
Durability	Strong materials	2x1" and 1x1" steel frame construction	A36 welded steel
	Construction	Sufficient welds and mechanical fastening's	MIG welded corner connections
Identity	Visual Branding	NAU, SAE and Sponsor logo display	Sponsored vinyl wrap

Results

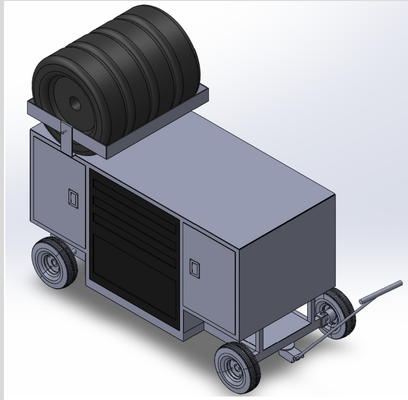


Figure 2: Toolcart CAD Design Front View

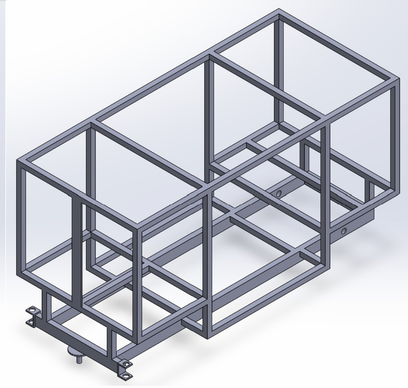


Figure 3: Raw Frame CAD Design

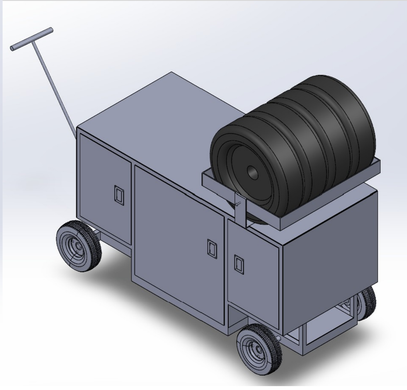


Figure 4: Toolcart CAD Design Back View

Figure 5: Physical Toolcart Front View

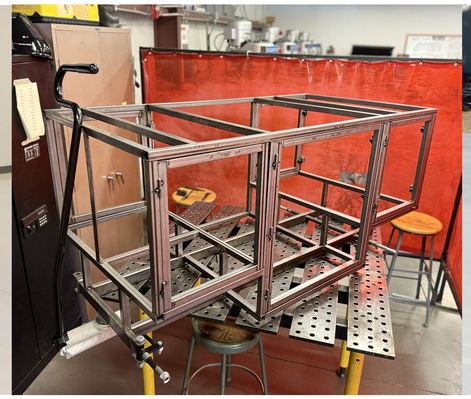


Figure 6: Physical Raw Frame

Figure 7: Physical Toolcart Back View

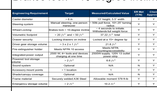
Figure 8: Loaded Tire Carrier

Figure 9: Interior Cabinet Storage

Table 2: Testing Plan Summary

Testing Procedure	Requirement Met	Equipment Needed
Brake application	Safety, fast brake response	Completed cart, slanted hill
Power Supply	Tool charging, supplied power	Inverter generator, gas, 10W-30 oil
Turning Radius	Able to maneuver swiftly/easily	Completed cart, travel trailer, masking tape
Weight capacity	Able to withstand loads	Various heavy objects, all tooling
Equipment fitment	Able to store tools, tires, equipment	Completed cart, driver gear, tools, tires
Correct tools	SAE teams can efficiently go through tech with the provided tools	Tools and toolbox, SAE tech sheet
Drawers/door latches	Able to stay locked/closed on inclines	Drawer latches and magnets

Table 3: Testing Results Summary

Engineering Requirement	Target	Measured/Calculated Value	ER Met (Y/N)	Client Approved
Caster diameter	> 6 in	13" height, 5.5" width	Y	Y
Steering system	Manual steering, one-person maneuver	~ 50lb pull force, 101.25" turning radius	Y	Y
Wheel Locking	Brakes lock > 10-degree incline	~ 4 seconds to initiate. Withstands full weight force	Y	Y
Volumetric footprint			Y	Y
Drawer security	Locking drawers on incline	Locked at a 15+ degree tip	Y	Y
Driver gear storage volume			Y	Y
Fire extinguisher holder	Meets NFPA 10 access	Meets NFPA mounting/accessibility	Y	Y
Integrated power output	2500 W, 4+ tools and devices charging at one time	2500W supply, 120V 13 outlet power-strip	Y	Y
Powered tool storage volume			Y	Y

Methods

Structured Design and Validation Process:

- Define key criteria (stability, storage capacity, maneuverability)
- Initial CAD model parts design, assemblies and sketches
- FEA validation on various components (frame, tire carrier)
- Moving component motion studies (steering, doors, drawers)
- Stay below the allocated budget from NAU SAE and fundraising

Table 4: Purchasing Plan

Location	Parts	Price	Status	Method
Amazon	Extinguisher mount, 25 ft cord, safety wire pliers, power strip, brake bleed kit, inverter generator, magnet door latches	$ 430.02	Delivered	Budget
Walmart	Four drawer/cubby latching toolbox with 238 tools in foam	$ 284.39	Delivered	Budget
Summit	Formula jacking-push rod	$ 290.84	Delivered	Budget
McMaster-Carr	1x1" 6' long steel bars, 0.065" thick aluminum panels	$ 1,056.29	Delivered	Budget
Lane Auto	Base frame, wheels, tie rods, center hub mount, kingpin axles, 38" handle	$ 403.87	Delivered	Discounted
Home Depot	3x3' Diamond plate aluminum panels	$ 100.48	In-Person	Budget
Harbor Freight	6" vice, super glue, assorted bungees, safety wire roll, assorted rivets	$ 86.33	In-Person	Budget
Grainger	Exterior mount brakes, spring-loaded exterior handles	$ 180.34	Delivered	Sponsored
Home Depot	Handle mounting hardware	$ 12.36	In-Person	Sponsored
McMaster-Carr	Drawer latch inner springs	$ 10.07	Delivered	Sponsored
Total Spent / $2,475.95		$ 2,534.97	Over by:	-$59.02

- Validate all integrated components through various calculations

Table 5: Subsystem Calculation Summary

Subsystem	Initial Values	Intermediate Values	Values to Date	Improved?	Customer Need Met
Brake Force	320 *lbf*	34 *lbf*	*1530 lbf*	Yes	Safety/quick response
Frame			7500 in/lbf bending moment	Yes	Stability/strength
Caster Resistance	9 *N*	9 *N*	-	No	Different Terrain
Steering	-	2.46 *lbf* pulling	101.25" Radius	Yes	Maneuverability
Power Supply	-	46.4 *Ah*	2500 W	Yes	Power supply
Storage Volume				Yes	Equipment storage

4. Paint all components using spray paint for rust prevention
5. Install all wheels, steering and brake hardware
6. Insert toolbox to frame and fasten with bolts
7. Cut and fasten all aluminum panels to steel frame using rivets
8. Vinyl wrap outer panels and clean all components
9. Insert all required tools in designated spaces - completion

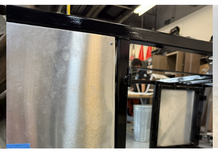


Figure 10 & 11: Close-up Weld and Rivet Fastening

Figure 12: Brake Application

Conclusion

The finalized SAE Toolbox cart meets all functional and safety requirements set by the client and the engineering team. The design offers reliable mobility, ample tool storage, and integrated electrical power in a compact and durable platform. By combining ergonomic steering, effective braking, and robust construction, the cart improves NAU SAE's team efficiency during SAE competition and shop use.

References

[1] A. Supardjo, A. D. Anggono, and T. Riyadi, "Finite element analysis of truck frame by using CATIA V5," *AIP Conference Proceedings*, vol. 1977, no. 1, p. 030029, 2018. Available: https://doi.org/10.1063/1.5042949

[2] Extreme offroad tool cart build part 1, YouTube video, 2015. Available: https://www.youtube.com/watch?v=crmGOD5fnts

[3] ANSI/AWS Z49.1, *Safety in Welding, Cutting, and Allied Processes*, American Welding Society / ANSI, 2021.

[4] ISO 12100:2010, *Safety of Machinery — General Principles for Design — Risk Assessment and Risk Reduction*, International Organization for Standardization, Geneva, Switzerland, 2010.

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