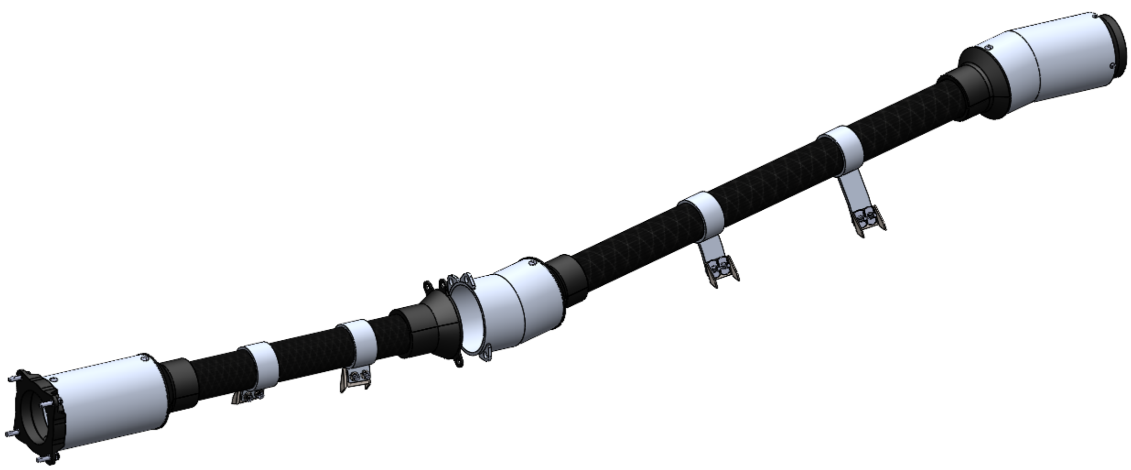
Cornell Baja Racing

Spring 2025

Technical Report



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Project:
4WD Guarding

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Contents

1 4WD Guarding

1.1 Abstract

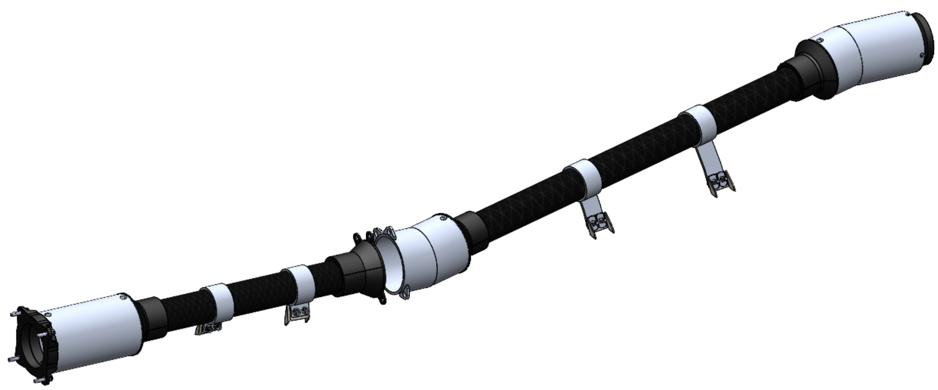

Figure 1: TG21 4WD guarding full assembly

The four-wheel drive (4WD) guarding follows and encases the propshaft along its route from the bevel box to the front gearbox. Its primary functions are to protect the driver from hazardous release of energy (HROE) from propshaft components, provide pinch point and entanglement (PPAE) protection, contain any lubricating oil released from the gearboxes, and shield the propshaft from environmental elements to maintain 4WD efficiency. The guarding system consists primarily of aluminum HROE universal joint guards, carbon fiber PPAE guards, four frame-mounted aluminum hoops and tabs, and 3D-printed joining components.

1.2 Design Requirements

All powertrain, driveshaft, and universal joint guarding requirements are outlined in the 2025 Baja SAE Rules.

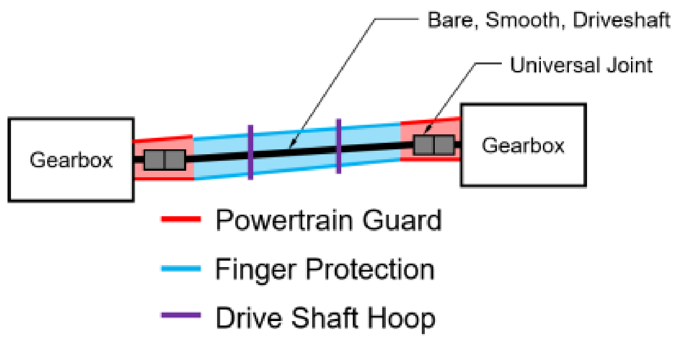

Figure 2: Driveshaft guarding requiremets per 2025 Baja SAE Rules

Constraints:

- All driveshafts shall be constrained from failure via two drive shaft hoops within 2.0 in. of the 1/3 length point and the 2/3 length point
- The driveshaft hoops shall be a minimum of 1.0 in. wide, have no more than 1.0 in clearance to the driveshaft, and shall be mounted by welding or threaded fasteners.
- Hazardous release of energy (HROE) guards shall be durable and mounted with sound engineering practices. HROE guards shall extend around the entire periphery of the guarded components.
- HROE guarding must be constructed of either 1.5 mm thick steel that meets or exceeds the strength of AISI 1010 steel, or of 3.0 mm thick aluminum that meets or exceeds the strength of 6061-T6 aluminum.
- Pinch Points and Entanglement (PPAE) guarding must be made of rigid, resilient materials and must prevent clothing and fingers from contacting rotating parts.

Objectives:

- The HROE guarding shall be designed to provide easy access to the propshaft and universal joints for installation and servicing
- The 4WD guarding will be designed to minimize weight
- The 4WD guarding will be designed such that bolts are easily accessible to maximize serviceability

1.3 Initial Research

1.3.1 Last Year's Car

I spoke to many team members about what changes they would like to see for TG21's four-wheel drive guarding. The primary concern was maximizing propshaft serviceability. Minimizing weight was also desired.

Project ownership of TGXX's 4WD guarding transferred hands midway through the design cycle, meaning critical time and effort was lost. As a result, TGXX's 4WD guarding was problematic. In practice, it was incredibly difficult to service the propshaft. The aluminum HROE guarding was difficult to remove, and most of the part's hardware was difficult to access.

Additionally, the PPAE guarding was made using a carbon fiber tube that was hand-cut lengthwise and mounted over top of the aluminum hoops via tape and steel cable ties. Team members expressed that, when taking the propshaft out, it was almost inevitable that your hand would get cut. Also, since the propshaft was not sufficiently sealed, dirt and debris constantly entered the system, which potentially hindered 4WD performance. The cable ties were often very difficult to remove further hurting serviceability.

Finally, on TGXX, one of the frame-mounted aluminum hoops was struck while installing another component, causing it to bend and rub against the propshaft. While accidents like this are difficult to avoid due to the nature of the aluminum tabs, caution and/or removal of the aluminum tabs is advised, particularly when servicing heavy components like the engine.

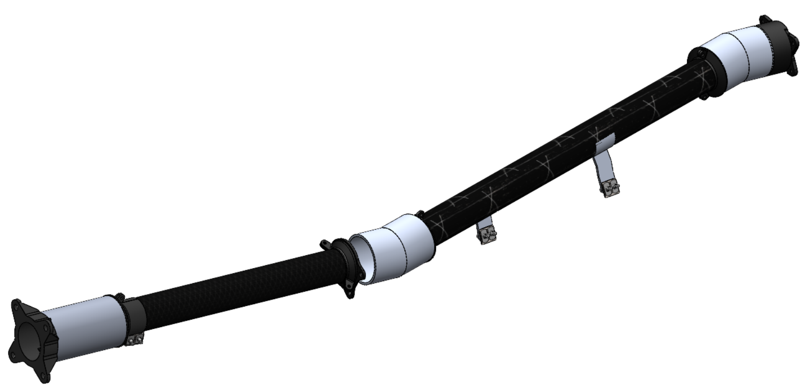

Figure 3: TGXX 4WD guarding full assembly

1.4 High Level Description

The 4WD guarding consists of HROE guarding tube, frame-mounted hoops and tabs, 3D printed connectors, and carbon fiber PPAE guarding.

Figure 4: 4WD guarding on propshaft prior to first drive

1.4.1 HROE Guarding

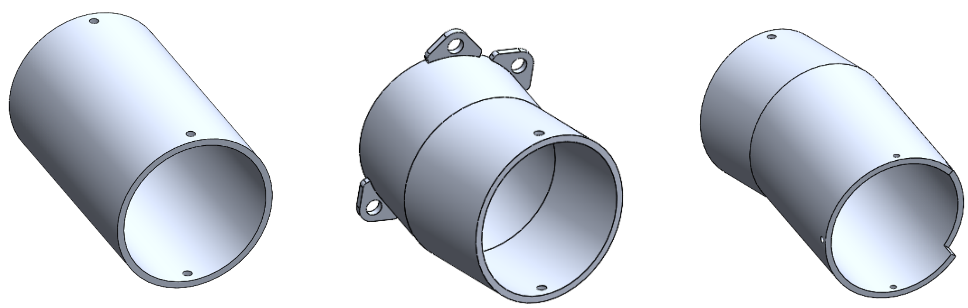

Figure 5: (Right to left) Rear, middle, and front U-Joint HROE guarding

The HROE guarding is made from 0.125" thick, 3" OD 6061-T6 aluminum tubing—an increase in diameter from last year's design. This change was made to accommodate both the sprag yoke and a new interface with the front gearbox. All HROE feature drilled holes to connect to 3D printed components.

The front U-Joint HROE is secured to the 3D-printed gearbox interface using three 4-40 bolts through holes in the HROE. Initially, only two bolts were planned, but a third was added to improve rigidity, as the driver's foot frequently rests on this section of the guarding. Additionally, the front HROE features a slot cut into its side to allow connection to a tab on the side of the front gearbox.

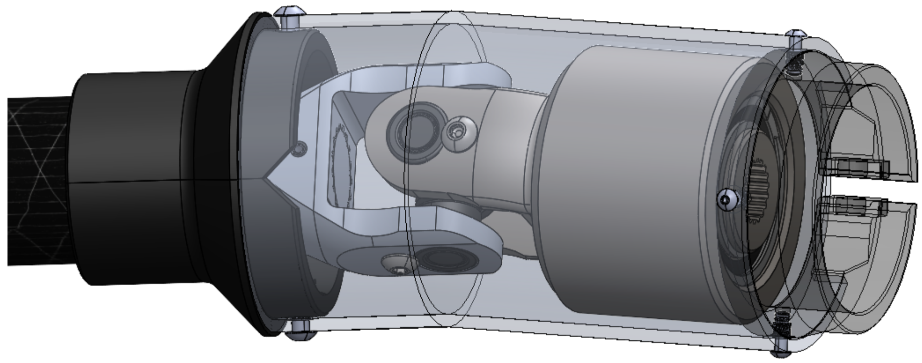

Figure 6: Front HROE transparent view with sprag yoke

The middle HROE interfaces with the propshaft bearing casing via welded aluminum tabs. Tab locations were selected for ease of access during installation and maintenance. The first set of guarding used three individual tabs; however, welding these on proved difficult, and the limited weld width resulted in weak connections. To address this, the top two tabs were consolidated into a single wider tab on the two subsequent spare middle HROE. This revision significantly improved strength and ease of fabrication, and the revised design was used for competition. Two small slots had to be mitered out of the tube due to interference with the propshaft bearing casing frame mounting tabs.

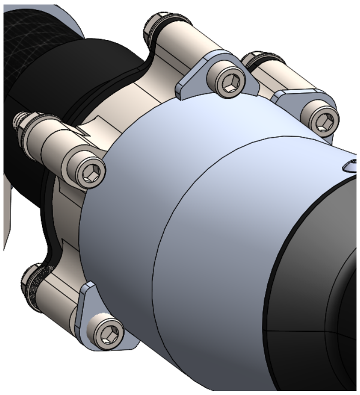

Figure 7: Bearing casing interface

Figure 8: Updated tab design

1.4.2 PPAE Guarding

The propshaft PPAE guarding consists of two woven carbon fiber tubes of 1.5" ID and 0.04" thickness. Continuous tubes were desired due to issues with TGXX's PPAE as described previously. The tubes are sit within the aluminum hoops, and are constrained axially by a lip within 3D-printed connectors. Clearance from the driveshaft to the inner wall of the PPAE is 0.2in radially.

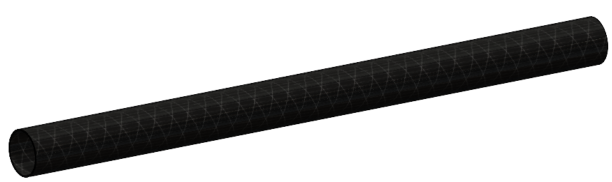

Figure 9: Front carbon fiber PPAE guarding

1.4.3 3D Printed Interfaces

Custom 3D-printed components are used to bridge the gaps between the HROE guarding and the PPAE guarding, the front gearbox, the bevel box, and to link the PPAE to the bearing casing.

HROE to PPAE connectors join the rear HROE to the rear PPAE tube, and the middle and front HROEs to the front PPAE tube. Each connector is composed of two pieces with a beveled rear edge, allowing for easy removal by angling them upwards. Additionally, they feature notches and slots along both sides of the smaller-diameter section, enabling them to snap together securely when properly aligned, and 8-32 threaded heat-set inserts for connection to HROE via 8-32 nylon patch button hex bolts. An internal lip within the smaller-diameter section prevents axial movement of the PPAE tube once assembled.

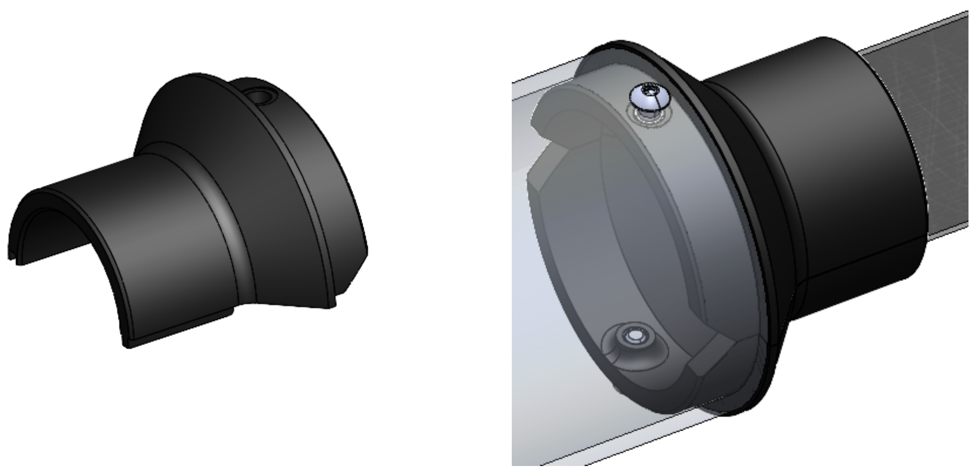

Figure 10: HROE to PPAE connector

Similarly, two custom 3D-printed components connect the rear PPAE tube to the propshaft bearing casing. Each features integrated tabs with bolt holes that align and attach to the existing bolts on the bearing casing.

Figure 11: Bearing casing interface with rear PPAE exploded view

The bevel box interface at the rear of the guarding connects the bevel box to the rear HROE. The interface is secured to the bevel box using four 3/4” 10-24 socket head nylon patch bolts, which pass through unthreaded inserts and thread into crush sleeves housed within the bevel box casing. Additionally, two 8-32 button head hex nylon patch bolts fasten the rear HROE to the 3D-printed interface through two vertically aligned holes, using heat-set inserts embedded in the print.

An entirely new connection to the front gearbox casing was designed for TG21 to accommodate the new cover plate and the sprag yoke. This 3D-printed interface includes three 4-40 heat-set inserts, which allow the front HROE to bolt securely into the print. The 3D-printed part itself is attached to the gearbox via a tab on its side using a 10-24 socket head nylon patch bolt and a nylon locknut. Unthreaded inserts were also used on this tab to increase the durability of the 3D print at the bolt holes.

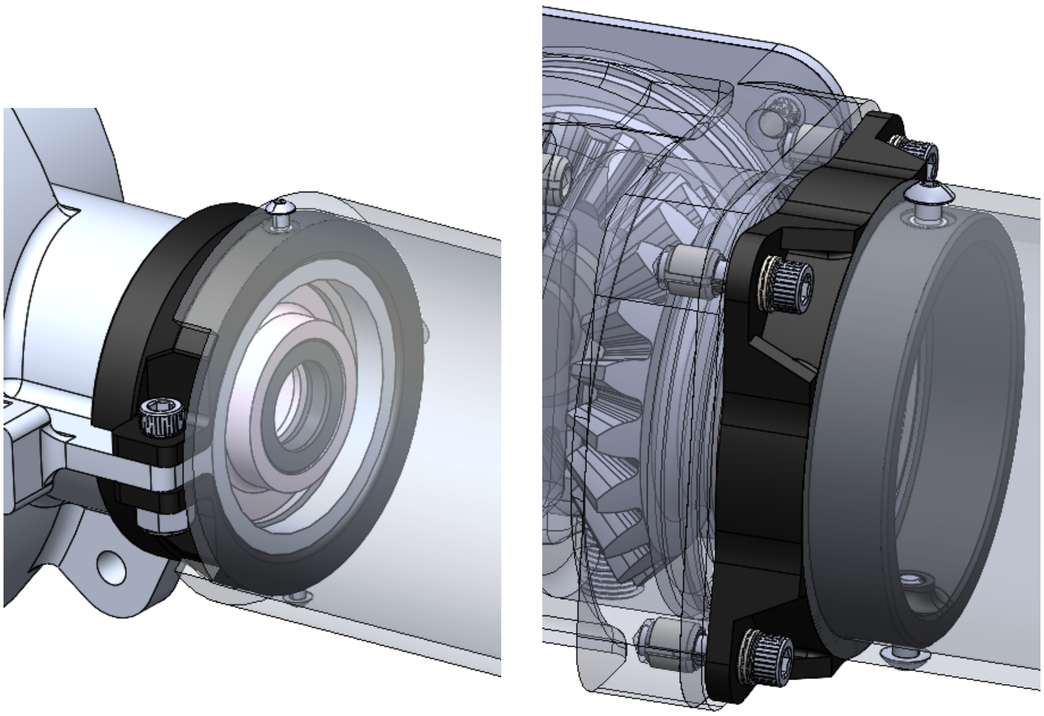

Figure 12: Front gearbox (left) and bevel box (right) interfaces

1.4.4 Aluminum Hoops and Tabs

Four aluminum hoops and tabs are made of 0.125" thick 6061-T6 aluminum in compliance with the rules. 1" length of aluminum tube of 1.625" ID is welded to the aluminum tab which is then bolted to the frame via welded steel frame tabs. 8-32 nylon patch bolts thread into weld nuts welded to the frame tabs to secure the aluminum tabs to the frame. These hoops locate the PPAE tube to ensure the propshafts is concentric within it.

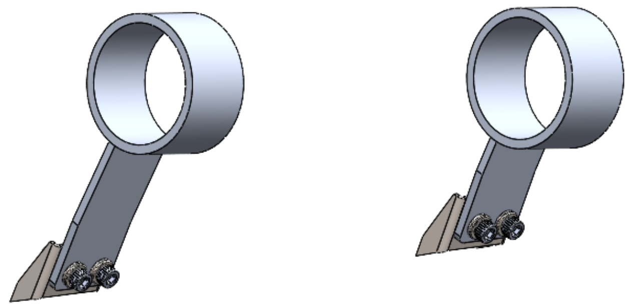

Figure 13: Front aluminum hoops and tabs

1.5 Manufacturing

The HROE tubes were cut to length by hand and finished using a belt sander. Because the middle and front HROEs require precise angular orientations, custom 3D-printed guides and fixtures were used to maintain accurate positioning prior to welding and to locate bolt holes for the connectors. The middle HROE tabs were made by hand as well. Another 3D-printed fixture was used to locate the aluminum tabs on the middle HROE for welding.

The PPAE guarding, made from carbon fiber tubing, was cut to size using a hand saw. All 3D printed components were printed through the RPL. Markforged Onyx was used for two sets and PETG for one set. Heat-set threaded and unthreaded inserts were installed using a soldering iron.

The aluminum tabs were cut using a waterjet, and the hoops were brought down to 0.125” thickness and parted to 1” on a manual lathe in the shop. Hoops were then welded to the tabs tangential to the surface of the hoop. The steel frame tabs were fit and welded directly to the frame with the propshaft installed, prior to first drive.

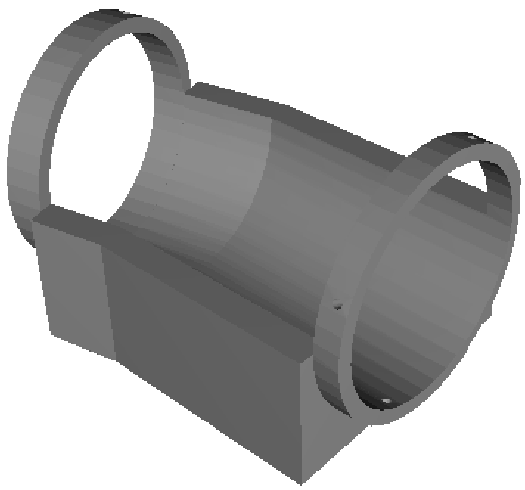

Figure 14: Custom 3D printed fixture for front HROE

1.6 Current Status

The design process has been completed, all components and spares have been manufactured and assembled, and the 4WD guarding has been installed on the car. The guarding made it through the first competition of the year with no issues in technical insepction or during any dynamic events.

Figure 15: 4WD guarding on TG21

1.7 Future Improvements

There are several areas for improvement I hope to see in future iterations of the 4WD guarding. First, the overall design could be much more airtight to better resist mud water and debris, and improve propshaft efficiency. In hindsight, I overlooked this aspect while designing more than I would have liked.

More specifically, the connection between the bearing casing and the middle HROE guarding could be improved upon. As mentioned previously, the outer diameter of the HROE tubes was increased to accommodate the sprag yoke, but the dimensions of the bearing casing remained unchanged from TGXX's design. This mismatch created a small gap between the two components. It was determined that the gap wouldn't cause major issues, so it was left unaddressed, but in the future, a tighter fit would be ideal.

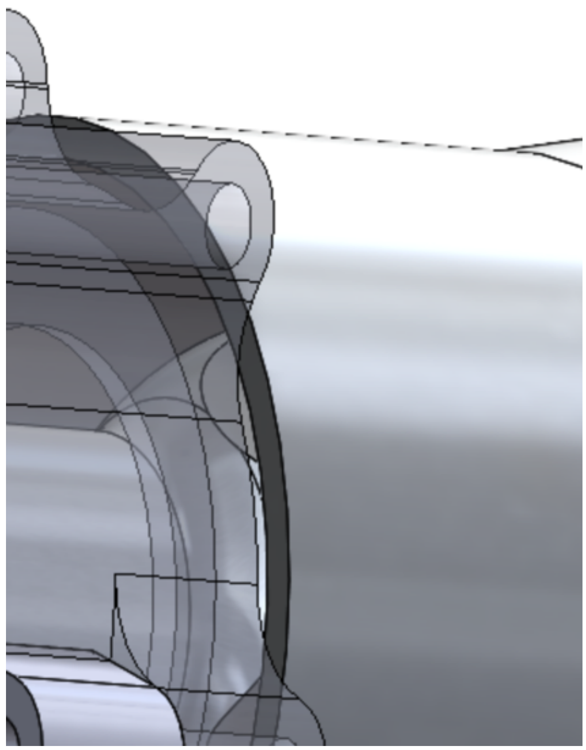

Figure 16: Gap between central HROE and bearing casing

While I made improvements to the overall installation process, a few bolts remain difficult to access. Most notably, a tiny bolt at the bottom of the front HROE. It's extremely difficult to reach with an Allen key due to other components in the way, and accessing it requires removing the skid plate.

The process of locating and welding the tabs and hoops to the car led to inconsistencies between spare sets of guarding. Since these features locate the PPAE and keep it concentric with the propshaft, misalignment can be problematic. Because they were welded without fixturing, there were compounding variations between sets. Additionally, seat interference created further clearance issues between the guarding and the driveshaft. These problems could be mitigated in the future by developing a better fixturing system for the hoops and tabs to maintain consistency and alignment during fabrication.

Finally, heat-set inserts routinely strip away from their 3D-printed parts during installation. This remains one of the most persistent issues and should be addressed with stronger insert retention strategies or alternative fastening methods.

2 Personal Reflection

I had an absolute blast on Baja this semester. It was a pretty big improvement from last semester, mostly because I felt way more comfortable on the team. Taking my part all the way from JanFab to competition was an amazing experience. I learned more than I ever imagined, about design, how the car works, and a ton of hands-on skills throughout the manufacturing process. On top of these, I learned how to develop a part from start to finish and made major improvements in foundational skills like Ansys, SolidWorks, and machining, including getting my green apron. It was a lot of work, but all of it was incredibly rewarding.

I loved going to competition, and I'm so excited for Maryland. Looking ahead to next year, I want to take on more responsibility on the team, spend more time working on the car, and take ownership over a more complex part that I can really dive into. I want to become a better engineer and better at everything Baja.

I'm so excited to see this car and this team succeed. I honestly couldn't be more hyped for what's to come.

A Appendix

A.1 References

- Julia Deffner's Fall 2023 Tech Report