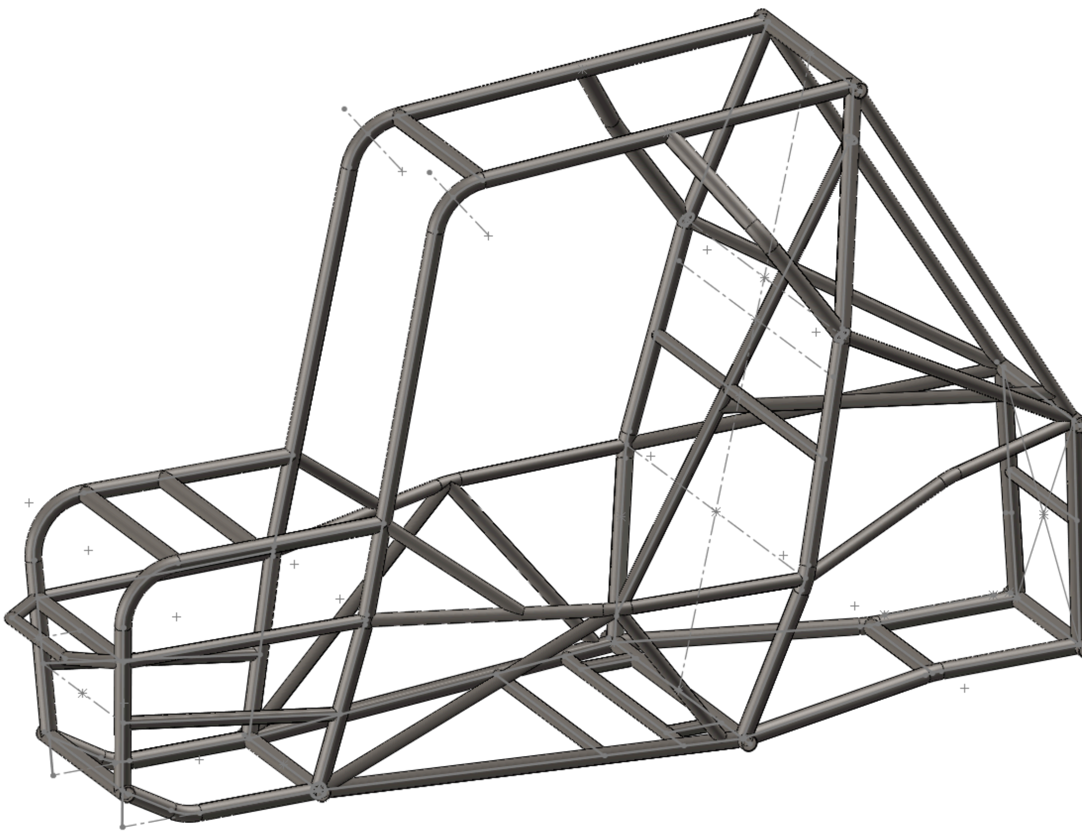
Northwestern Baja SAE
2025-56 Frame Design



MECH_ENG 399 Final Report
Fall 2025

Prepared by Ryan Kalgreen
Prepared for Oluwaseyi Balogun

Introduction

Baja SAE® is an annual student engineering design competition hosted by the Society of Automotive Engineers (SAE International) where student teams design, fabricate, and race a rugged all-terrain vehicle. Several competitions are held every year, where teams compete in a number of events including a 4-hour wheel-to-wheel endurance race. The designed vehicle must contend with a variety of obstacles, including sand, mud, dirt, rocks, logs, jumps, and snow. The Northwestern Motorcats Baja SAE team designs a car every year, with design work beginning almost immediately after the previous year's competition concludes. The car is designed entirely by students, with around 85% of components manufactured on campus. The car is typically completed in late March, leaving about a month for testing before the national competition (typically in early May).

This document will detail the design process for the chassis/frame for the 2025-26 competition cycle. The frame, referred to in the detailed competition rules as the "roll cage," has the primary responsibility of protecting the driver. Secondary design goals include compatibility with suspension design, accommodations for powertrain packaging, and designing around the ergonomics of a wide range of drivers.

The previous frame made a lot of positive changes, but there were still improvements to be had. The following points were particular areas of concern:

1. The shortened wheelbase resulted in very little room in the driver compartment, which made taller drivers not rules compliant and unable to drive the car.
2. Our most experienced welder Arman, who welded the last two frames, graduated. He gave some design recommendations to accommodate newer welders.
3. For a safety-critical component of the car, factors of safety for our existing load cases were as low as 1.01 for impact cases. We wanted to increase our margin of safety there.

Considering the above, we established the following goals for the frame design:

1. Leave little ambiguity with respect to rules compliance. This was a strong point of last year's design, and we wanted to continue to be successful in this area.
2. Increase all factors of safety for existing load cases to at least 1.2 for better confidence in the safety of our car in a crash scenario.
3. Accommodate the packaging and integration needs of all subteams, including the new electronics subteam. Without doing so the car will not function.
4. Increase room in the driver compartment, especially for taller drivers, while still making sure shorter drivers remain rules compliant.
5. Keep weight increase below 10%. We anticipated a weight increase, using thicker wall secondary tubing for ease of welding, but wanted it to remain low.

Frame Design

The competition rules and guidelines give very strict requirements for tube placement, tubing selection, and structural design. The other primary design considerations are the interaction with the suspension design, namely the suspension points, packaging powertrain components, and ensuring that our wide range of drivers (5'5" at the shortest, 6'2" at the tallest) are comfortable and rules-compliant.

SAE Rules Compliance

Over 24 pages of rules dictate the frame design for Baja SAE vehicles, ensuring the safety of student participants and encouraging fair competition. The roll cage design rules dictate that all frames must be steel tubular space frames, and further specifies structural frameworks, tube dimensional and strength requirements, driver clearance, and more. At competition, the design is subjected to strict scrutiny regarding rules compliance. This has been an issue for the team in the past, but last year was a marked improvement with no frame design features being problematic to the technical inspectors. This section details the critical design constraints imposed by the rules for the frame design. It is not exhaustive, only highlighting design-driving criteria.

Primary Members, Secondary Members, and Roll Cage Materials

Rules sections 3.2.2, 3.2.3, and 3.2.16 define the necessary primary structure, secondary structure, and corresponding material and dimensions required for tubing. Primary members form the core of the driver cell and front impact structure as seen below in Figure 1, adapted from the SAE rulebook.

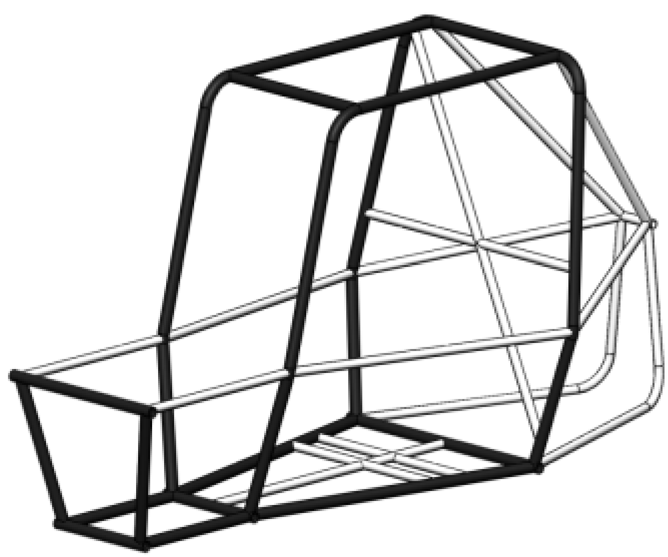


Figure 1: Primary roll cage members, adapted from Figure B-8

The primary members of this year's frame design can be seen below in Figure 2. In addition to those required by rules, primary members are used in the rear impact structure for driver safety.

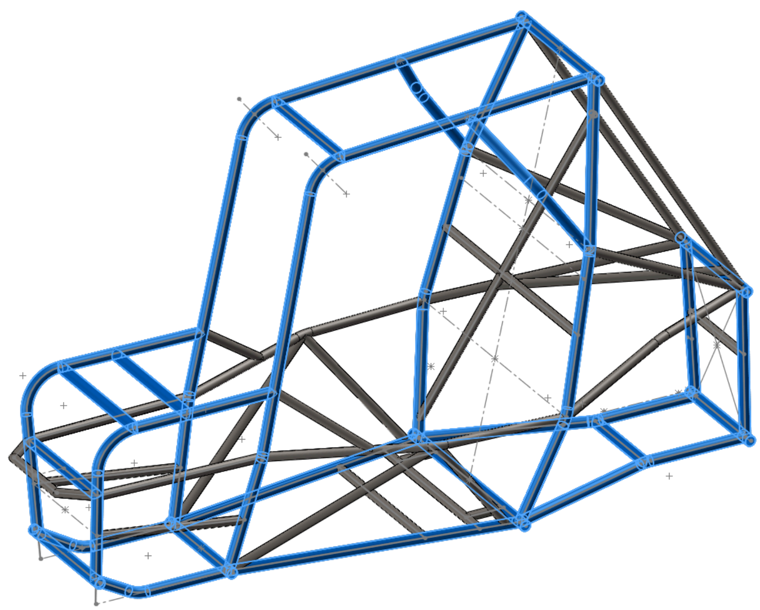


Figure 2: Primary members, 2025-26 frame

Per rule B.3.2.16, primary members must be " "A steel shape with bending stiffness and bending strength exceeding that of circular steel tubing with an outside diameter of 25 mm (0.984 in.) and a wall thickness of 3 mm (0.118 in.). The wall thickness must be at least 1.57 mm (0.062 in.) and the carbon content must be at least 0.18%, regardless of material or section size." Stiffness K_b and bending strength S_b are defined as

$$K_b = EI$$

$$S_b = \frac{S_y I}{c}$$

For a hollow circular tube: $I = \frac{\pi}{4}\left(\left(\frac{D}{2}\right)^4 - \left(\frac{D}{2} - t\right)^4\right)$

where E is Young's Modulus, I is the second moment of the cross-sectional area, S_y is the material yield strength, c is the distance from the neutral axis (outer radius), and t is the wall thickness. 1.250"x0.065" 4130 steel tubing is utilized for its weldability, availability, and strength characteristics. Northwestern Baja SAE has a long-running relationship with VR3 engineering, who provides tubeset manufacturing services to us at a discounted rate. Of the sizes they offer, 1.250"x0.065" is the lightest that also satisfies the bending stiffness and strength requirements. Below in Table 1 is a comparison of the rules-required 1018 steel tubing and the 4130 tubing we select for our primary frame members.

Table 1: Comparison of SAE 1018 tube requirements and selected 4130 primary tube

Steel	D (mm)	t (mm)	c (mm)	E (GPa)	I (m^4)	S_y (MPa)	K_b (kN/m)	S_b (kN-m)
1018	25	3	12.5	205	1.28e-8	365	2.62	0.186
4130	31.75	1.651	15.875	205	1.77e-8	460	3.64	0.257

Secondary members and tubes form various bracing structures, side impact structures, and other lesser frame elements. Below in Figure 2 are the secondary members and tubes of this year's frame design.

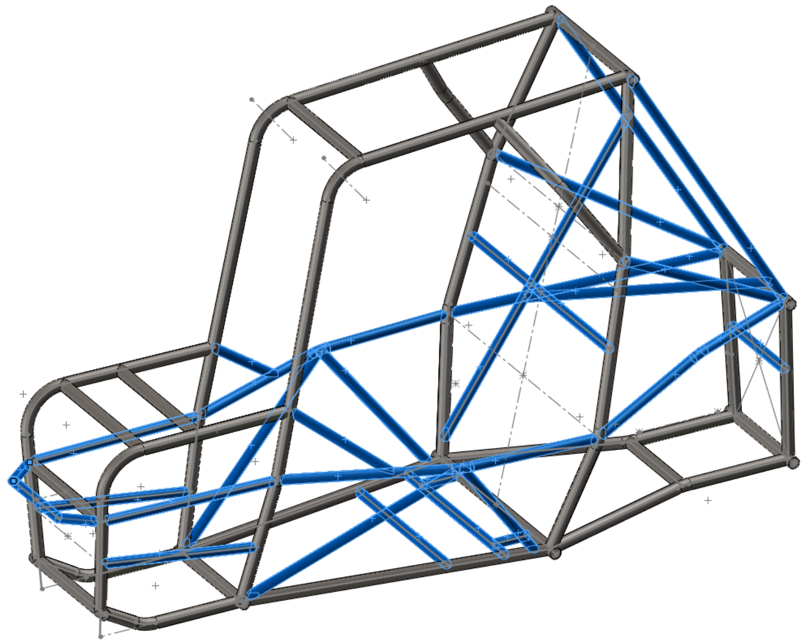


Figure 3: Secondary members and tubes, 2025-26 frame

Secondary members are required to be round tubes that have "a minimum wall thickness of 0.89 mm (0.035 in) and a minimum outside diameter of 25.4 mm (1.0 in)" or rectangular tubes with "a minimum wall thickness of 0.89mm (0.035 in) and a minimum outside dimension of 25.4 mm (1.0 in)." For this year's frame, all secondary members and tubes were designed to be 1.000"x0.049" tubing. This comes at a weight penalty compared to the minimum wall thickness of 0.035", but previous welders noted that it was easy to accidentally burn through the thinner-walled tubing especially at joints with the much thicker primary material. This weight increase was accepted early in the design process, as we felt it was outweighed by the increased ease of manufacture and safety benefits.

Additional Support Tubes

Some of the secondary tubes highlighted above are designed to in compliance with rule B.3.2.4 - Additional Support Tubes. This rule specifies length conditions for straight and bent tubes that necessitate additional support tubing if exceeded. Table 2, below, provides a logical matrix of the requirements for additional support.

Table 2: Requirements for additional support tubes, adapted from Figure B-9

Bend \ Length	<33in	>33in, <40in	>40in	
0 deg	0	0	1	Within 2in of midpoint
<30 deg	0	1	1	Within bend tangents
>30 deg	1	2	2	

All frame members and tubes were checked against this table (see Appendix A), and two locations on each side (4 in total) were identified as needing additional support tubes. The bent side impact member (SIM) and bent upper section of the rear roll hoop (RRH) necessitated support (see Figure 4, below).

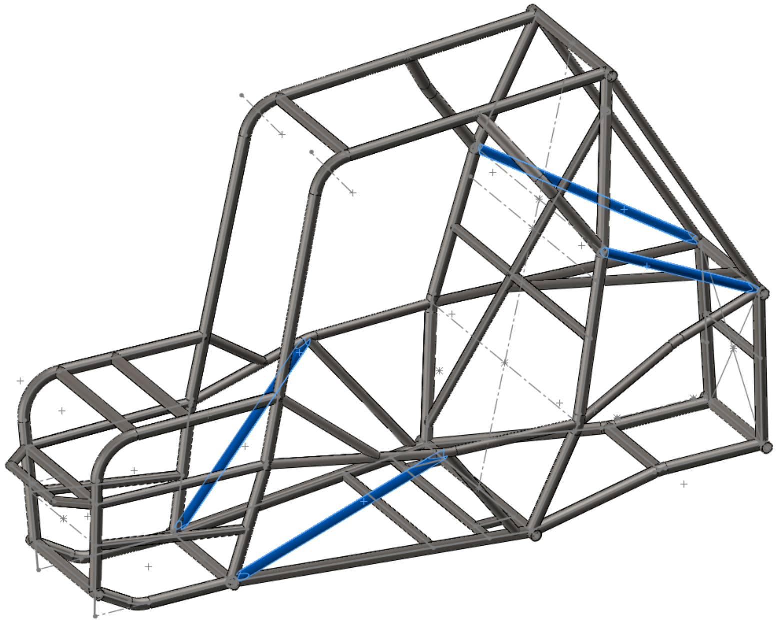


Figure 4: Additional support tubes

Rear Roll Hoop

The starting point for the frame design, and the most safety-critical component of the frame, is the rear roll hoop. This structure protects the driver's head and upper body, protecting from critical injury in the case of a rollover. The rules again provide a strict geometrical guideline for the dimensions of the rear roll hoop (see Figure 5). It also requires a diagonal bracing member which must be within 5in of the top and bottom corners.

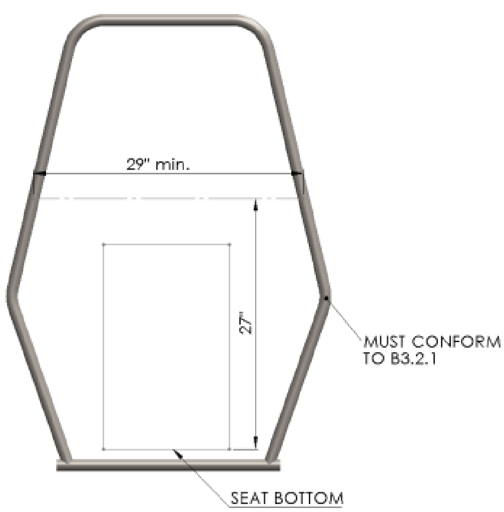


Figure 5: Rear roll hoop geometric requirements, adapted from Figure B-13

The rear roll hoop followed a similar design to last year's car, consisting of 2 vertical members with 2 bends each and 2 straight horizontal members. This layout allows the bottom of the driver area to widen quickly, expanding room in the cockpit for the driver, powertrain components, and potentially batteries for onboard electronics new to this year's car. See Figure 6 for the sketch that the RRH is derived from, with rules-critical dimensions highlighted in blue. The minimum width requirement is given ample clearance.

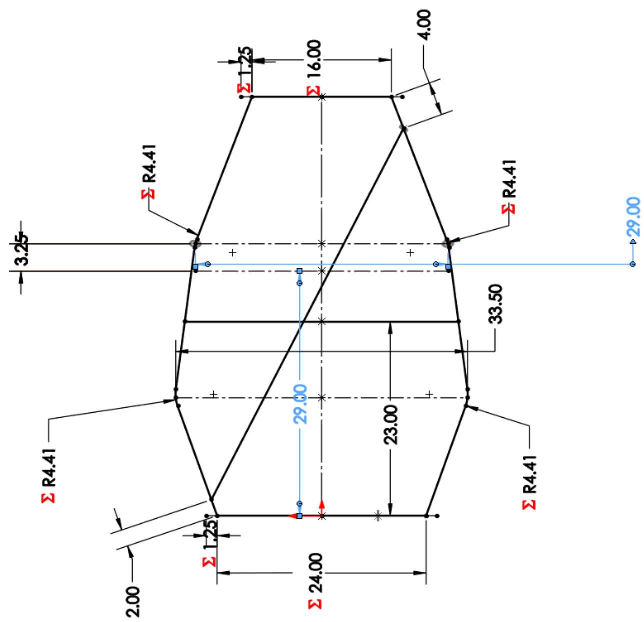


Figure 6: RRH sketch

Completing the Driver Cell

The front bracing members and side impact members complete the core components of the driver cell, or what is primarily responsible for protecting the driver. These members are also tightly regulated for safety purposes. Rules B.3.2.8 and B.3.2.10 define guidelines for the position of these members, based on a template that represents the approximate size and position of the driver. See Figure 7 below for the template diagram.

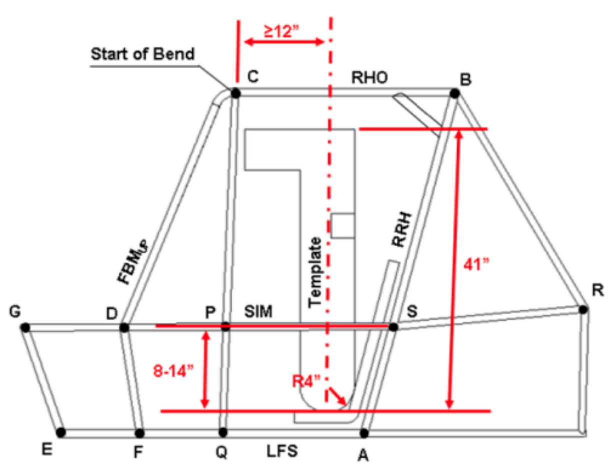


Figure 7: Driver cell template, adapted from Figure B-16

This diagram was replicated in a series of CAD sketches, seen below in Figure 8. The design complies with all requirements established by the template.

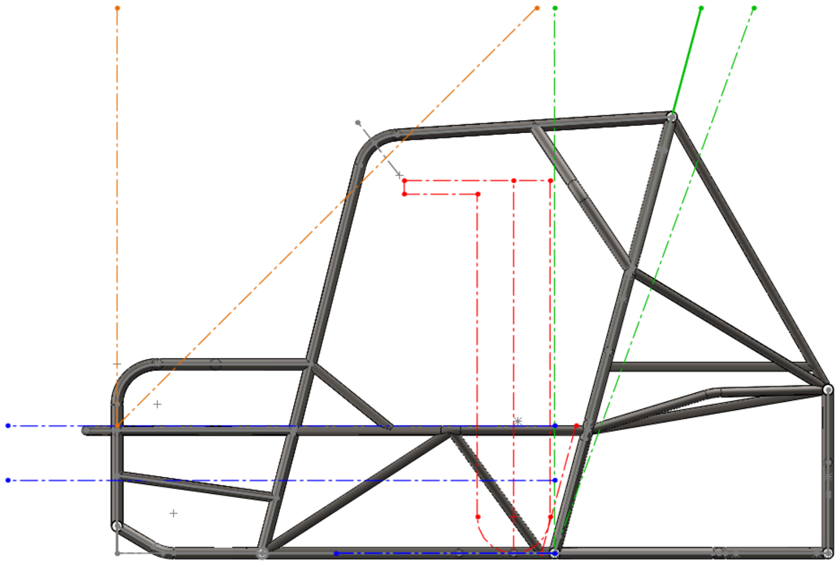


Figure 8: B.3.2.8-10 Compliance

Rear Bracing

The rules specify that there must be provisions further securing the top of the roll hoop in space. Triangular fore-aft bracing is required, and the rules provide guidelines for either front or rear triangulation. Although early Northwestern Baja SAE cars utilized front bracing, all cars since the switch to 4wd have utilized rear bracing. This is mainly due to the fact that considerable rear structure is necessary anyways to support the engine, rear suspension, and other drivetrain components. Per rule 3.2.13.2,

> "Rear Bracing systems shall create a structural triangle, in the side view, on each side of the vehicle. Each triangle shall be aft of the RRH, include the RRH as a vertical element, have one vertex at Point B, and one vertex at either Point S or Point A. The members forming this structural triangle shall be continuous and comply with Rule B.3.2.1. The third vertex is the intersection of these two continuous members and is joined by a Lateral Crossmember (RLC) defining Point R which shall additionally be connected to Point S or A, whichever is not part of the structural triangle."

Figure 9 highlights the rear bracing structure on the frame design, with named points labeled for clarity. It can be seen that the member from point S to point R on one side is bent; this is acceptable within the rules, and is necessary to ensure that the engine can be removed from the car.

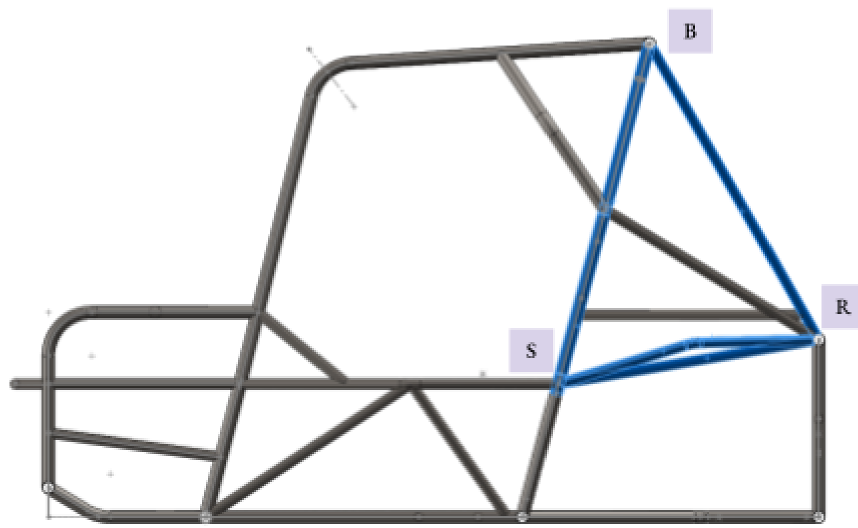


Figure 9: Rear bracing compliant to B.3.13.2

The rear bracing structure of the new design is one of the biggest departures from previous Northwestern Baja frames. Seen below in comparison to the 2024-25 frame in Figure 10, the new rear bracing extends fully to the rear of the car. This has a two key benefits:

1. The load from a potential rear impact is much better braced and distributed to the rest of the frame.
2. Rear packaging volume for the engine and other powertrain and electronics components is greatly increased. The engine is able to be fully enclosed without needing additional tubing.

These benefits come at no cost to the wheelbase, and do not come with a considerable weight penalty either.

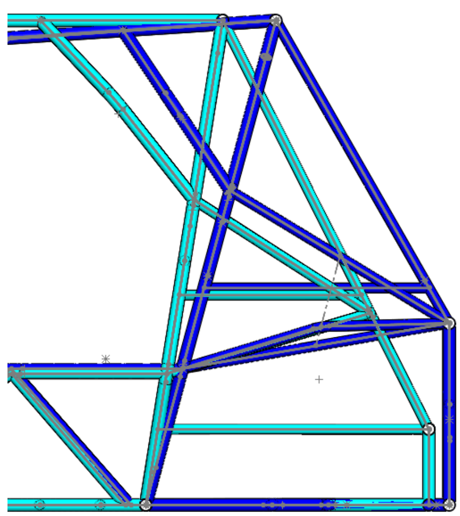


Figure 10: Rear bracing comparison, 2024-25 car (teal) vs 2025-26 car (dark blue)

This concludes the overview of major rules-required design details and considerations. As stated earlier, this overview was not exhaustive. For a full overview of the chassis rules and the design's compliance with them, reference Appendix A and the full competition rules found here.

Interference Considerations

As the core structure of the car, the chassis design must also consider the interaction between all other subsystems. It is central to the interfaces between subsystems, and therefore must consider the interactions between each subsystem and the chassis as well as the interactions between other subsystems. This section details the frame design decisions that serve to ease system integration.

Suspension

The biggest loads that the chassis undergoes outside of crash scenarios are the loads transferred by the suspension during impacts or cornering. The suspension geometry, or points, determines much of the frame geometry; tubing must be placed in locations that can effectively take the suspension loads and fit the pivot points of suspension arms. Seen below in Figure 11 is one side of the suspension alongside the frame. Tubes critical to the suspension system are highlighted.

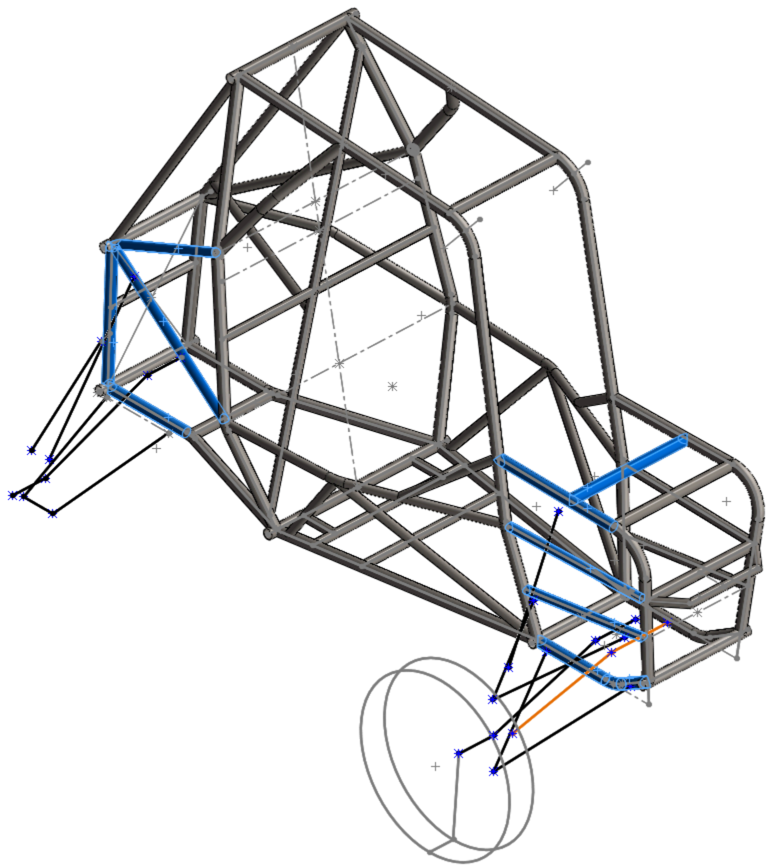


Figure 11: Critical tubes for suspension system

The wheelbase, which was very short last year, was lengthened slightly. The front caster was changed slightly as well. A big change was the shift from air shock to coilovers, but this had little impact on the frame. Otherwise, the overall layout of a rear H-arm and camber link design combined with a front double wishbone design was retained from the past several years with modifications to geometry.

Ergonomics

One of the biggest areas for improvement from last year was driver comfort and rules compliance. It is nearly impossible for tall drivers (6'2" and above) to drive the previous car while remaining rules compliant. Also, one of our shorter drivers at competition last year was told he couldn't continue mid-race for being too far below the seatbelt bar. A couple of steps were taken to improve comfort and cockpit room. Most notably, the rear roll hoop was reclined further and the toebox was extended and made taller (see Figure 12).

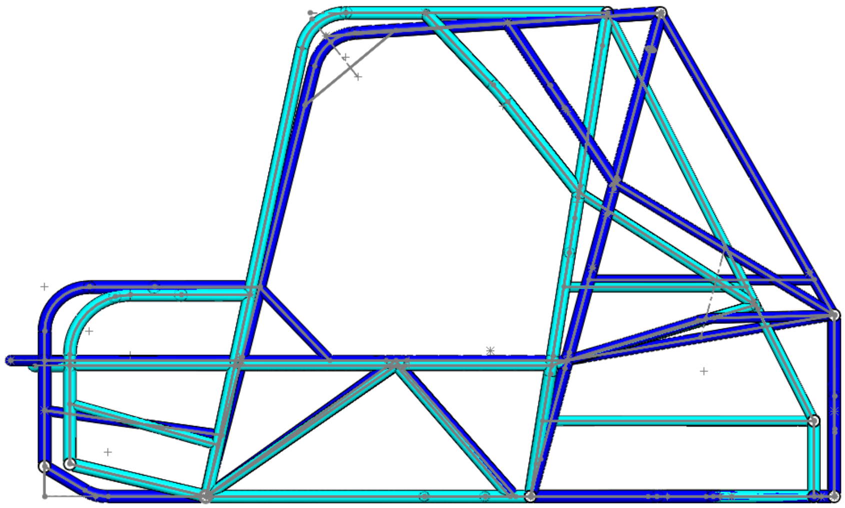


Figure 12: RRH recline, toebox changes highlighted

This gives a 2.5" (5.5%) increase in legroom (measured from the base of the RRH to the front of the car). Also increased was the driver compartment volume; measured coarsely with CAD tools, volume in front of the roll hoop increased from $0.694m^3$ to $0.745m^3$ for this year's car, a 7.3% increase. See Figure 13 for a comparison.

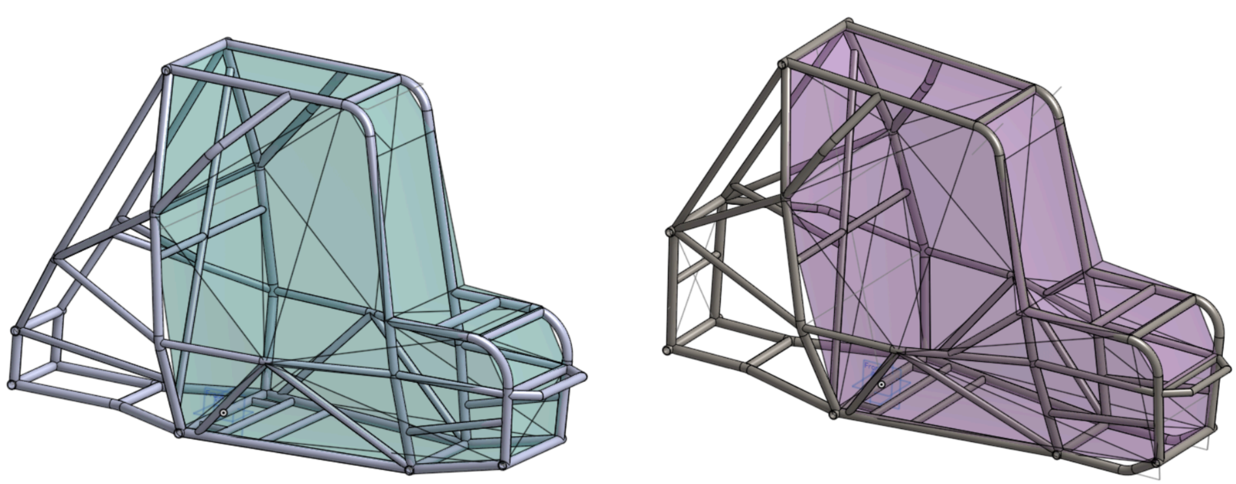


Figure 13: Approximate driver compartment volume comparison (2024-25 left, 2025-26 right)

We also conducted driver clearance checks, as in years past, with our Solidworks human model Todd. See Figure 14 below, for an example, and Appendix A for the full check table.

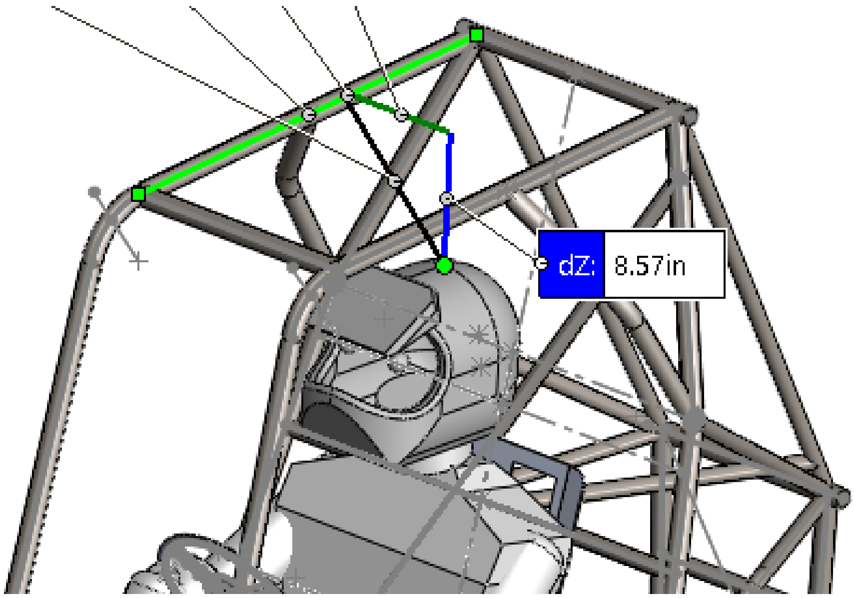


Figure 14: Helmet height check (driver clearance, dZ > 6")

It is difficult to know what driver comfort and rules compliance will be until the car is built, but these changes should do nothing but improve upon last year.

Powertrain/Electronics

Last year, the front driveshaft switched from passing underneath the seat to moving around the right hand side of the seat. This design was retained for this year, so the RRH remained relatively wide to accommodate the driveshaft. Due to the old rear bracing structure, compared earlier, the rear structure was asymmetrical and required an additional tube to support the engine. With the tweaks made to the rear bracing, the engine is fully enclosed without the additional tube. This also results in an increase in packaging volume aft of the firewall for powertrain or electronics components. Using similar estimates as earlier, volume increases from 0.264m^3 to 0.296m^3, a 13% change (see Figure 15).

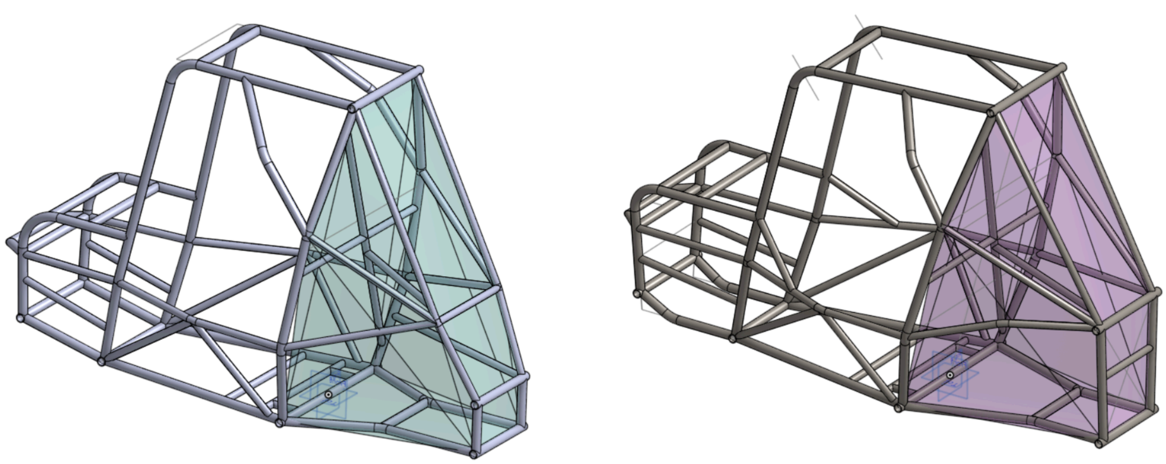


Figure 15: Approximate rear packaging volume (2024-25 left, 2025-26 right)

Design Validation

The primary purpose of the validation work done for this design was to ensure that the frame is robust and the driver is kept safe in worst-case crash scenarios. The SAE rulebook provides guidelines that make sure the driver is safe, but it is important to also perform independent analysis to validate this design. We also want to make sure that we are able to continue competing if we hit (or are hit by) an obstacle or another car. Ensuring the frame does not yield in a set of impact load cases will support the design goals of a safe, robust frame. Static finite element analysis (FEA) simulations were conducted in Ansys, with load cases defined as described below.

Load Cases

In an ideal scenario, we would have data as a team from crashes seeing what sort of accelerations the car experiences during a variety of crash scenarios. This is the sort of data that the SAE design judges want to see used in analysis. Unfortunately, with our aggressive annual design and manufacturing schedule, Northwestern Baja as a team has lacked that sort of data and the testing hours to gather it (hopefully, that is changing with some new data acquisition projects this year!). Without any real-world data to use, I decided to use the frame load cases that were redefined last year by Jason Chen. This provides a way for us to benchmark our analysis results with the previous design, and see what areas have improved or need further refinement.

In summary, Jason linearized 35mph full frontal barrier crash test data from National Highway Traffic Safety Administration (NHTSA) for a 2014 Honda Accord[1] to find a value for the average deceleration during impact – 20Gs. Scaled to the approximate top speed of our cars (28 mph), the predicted deceleration experienced during a top speed frontal impact is 16Gs. Dynamic side impact data was scaled similarly for the rear impact case, assuming a rear impact would be in a dynamic scenario. The final predicted rear impact deceleration is 8Gs. Lastly, for both the full overhead rollover and 45 degree frontal rollover, the IIHS roof strength test for the same 2014 Honda Accord requires the roof to withstand 3 times its curb weight. This was scaled up to 5 times the curb weight for our application, since there is a greater risk of rollovers and rollovers may result from more violent impacts, like striking sharp rocks or landing poorly off of a jump. Estimating that the car will weigh 600lbs (272kg) total, static approximations of impact forces were calculated using Newton's Second Law. These static load cases are below in Table 3.

Table 3: Impact Case Loads for 2025-26 Car

Impact Case	Impact Force
Front Impact	$272kg \cdot 16 \cdot 9.81m/s^2 = 40,000\ N$
Rear Impact	$272kg \cdot 8 \cdot 9.81m/s^2 = 20,000\ N$
Overhead Rollover	$272kg \cdot 5 \cdot 9.81m/s^2 = 13,350\ N$
45 Degree Rollover	$272kg \cdot 5 \cdot 9.81m/s^2 = 13,350\ N$

[1] National Highway Traffic Safety Administration (NHTSA). Crash Deformation Data Research. Publication No. 13377-EDAG. Accessed December 6, 2024. https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/13377-edag_crashdeformation_040418_v3_tag.pdf.

Analysis

Setup

Prior to running simulation, the Solidworks part file was exported as a .step file and brought into Ansys Discovery. There, tubes were simplified to beam elements and any resulting gaps in the model were closed. Shared topology was used to ensure best possible simulation behavior. Beam elements were used since the frame is all made of tubes with consistent cross sections, and it can be simulated with much better computational accuracy compared to an equivalently fine tetrahedral or quadrilateral mesh. The structure in Ansys was such that the materials, geometry, and mesh were identical for each load case for the sake of consistency and repeatability. Below in Figure 16 is the project schematic in Ansys Workbench.

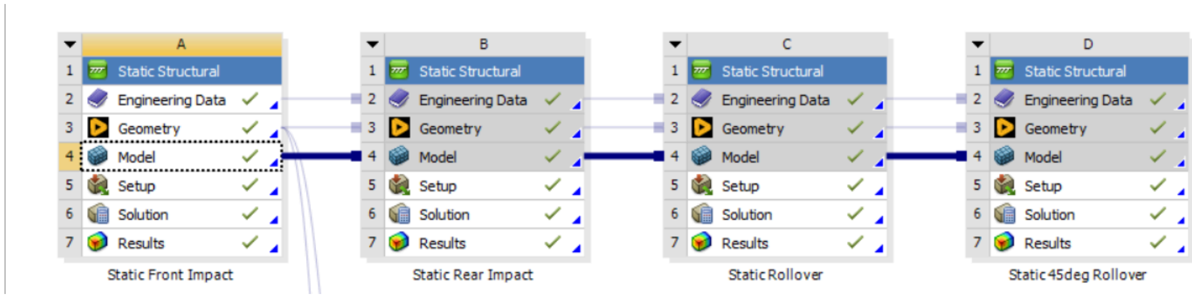


Figure 16: Ansys Workbench schematic

A fine beam mesh was used, with an element size of 5mm. Figure 17, below, shows the main mesh parameters beside the mesh used for all load cases.

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	5.e-003 m
Sizing	
Use Adaptive Sizing	No
Growth Rate	Default (1.85)
Mesh Defeaturing	Yes
Defeature Size	Default (2.5e-005 m)
Capture Curvature	No
Capture Proximity	No
Bounding Box Diagonal	2.4646 m
Average Surface Area	0.0 m²
Minimum Edge Length	1.5417e-002 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Element Quality	Default (5.e-002)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	2
Growth Rate	1.2
Inflation Algorithm	Pre
Inflation Element Type	Wedges
View Advanced Options	No

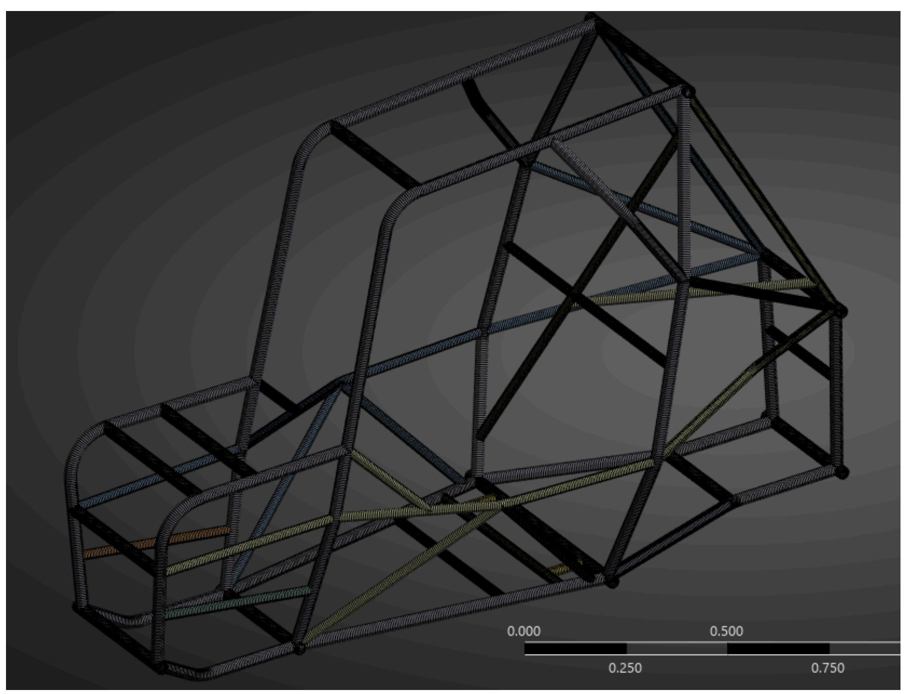


Figure 17: Ansys mesh and mesh parameters

The force for each load case was applied as a remote load at the frame center of mass, acting on the nodes responsible for securing the driver, powertrain components, and suspension components (the majority of the car's weight). This is a rough approximation of the real center of mass, but has been reasonably accurate in past years. It is also an oversimplification of how the load is applied, but is the best static approximation that is compatible with beam elements. For each load case, the nodes at the point of contact were fixed in space, and the load was applied in the instantaneous direction of travel at impact. See Figures 18-21, below for the setup for each load case.

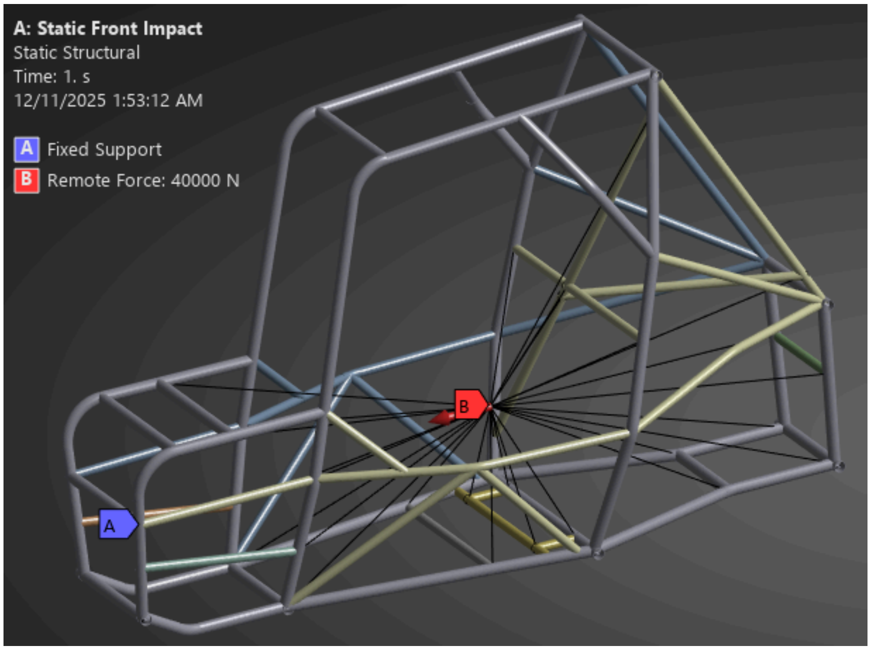


Figure 18: Front impact simulation setup

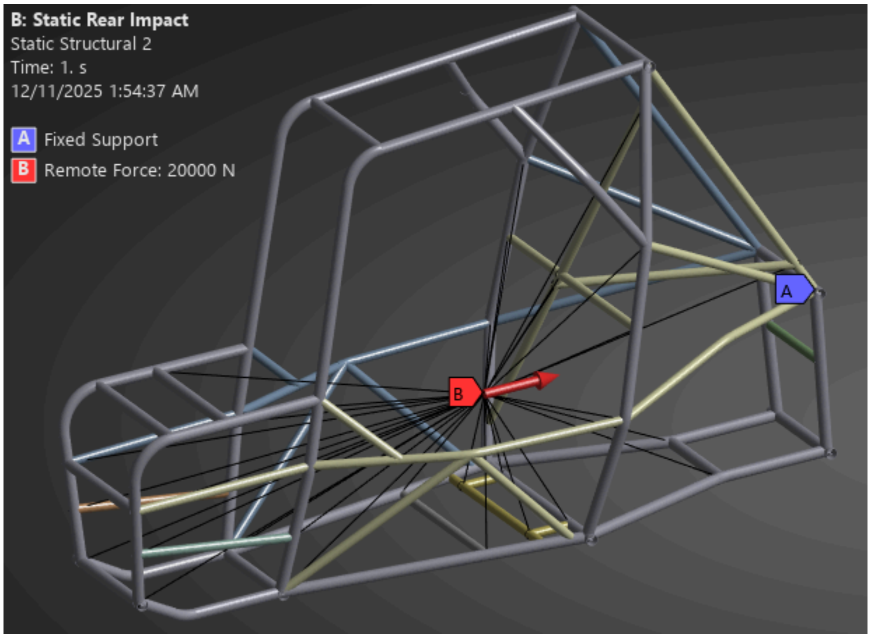


Figure 19: Rear impact simulation setup

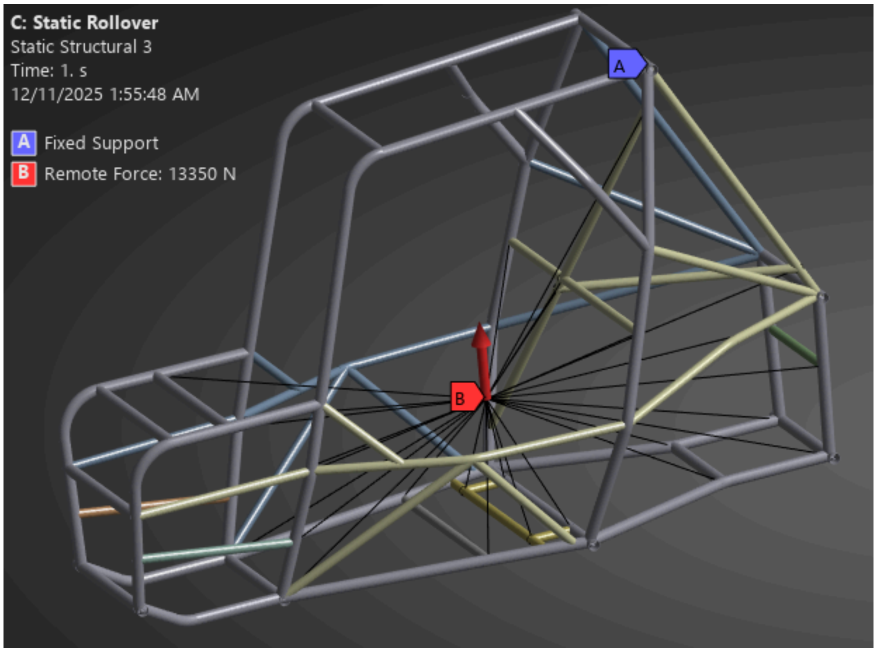


Figure 20: Overhead rollover simulation setup

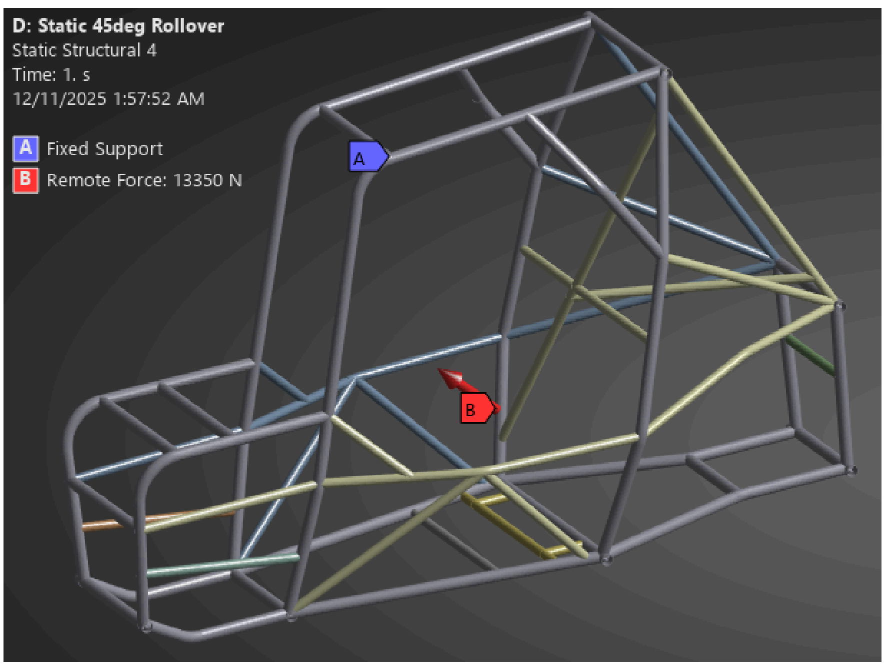


Figure 21: 45 degree rollover simulation setup

Results

Below in Figures 22-25 are the stress results from each load case. Max stress locations are indicated, and values can be read off the scale on the left. Models are oriented to replicate the orientation of the simulated crash; assume the ground is down when looking at the plots. Factor of safety with respect to yield (460MPa) is noted.

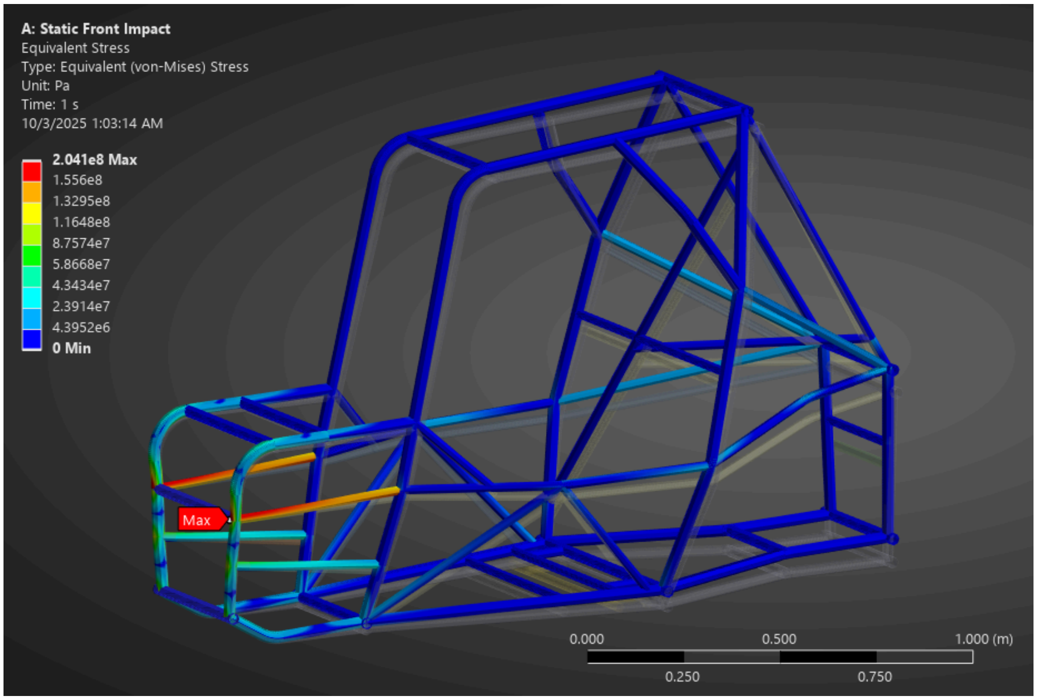


Figure 22: Front impact stress plot (FoS = 2.25)

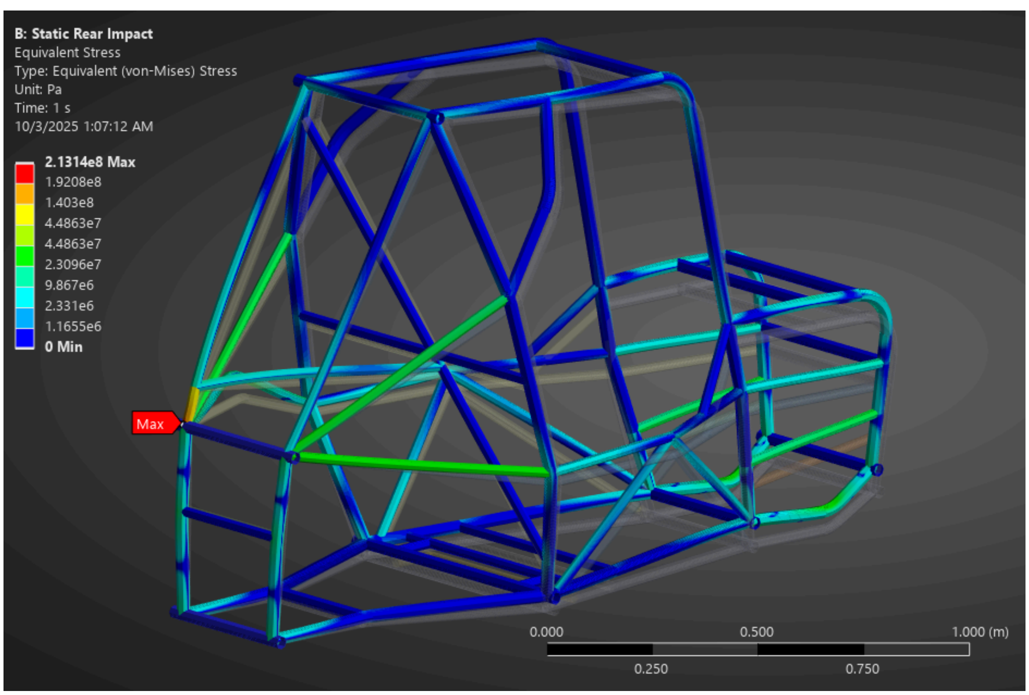


Figure 23: Rear impact stress plot (FoS = 2.16)

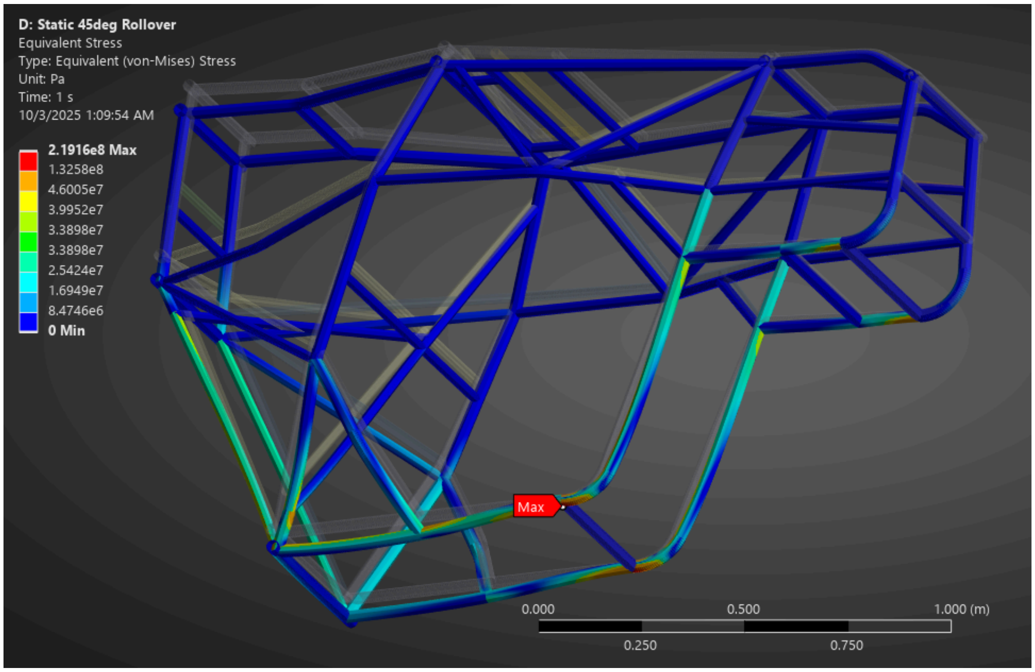


Figure 24: Overhead rollover stress plot (FoS = 2.10)

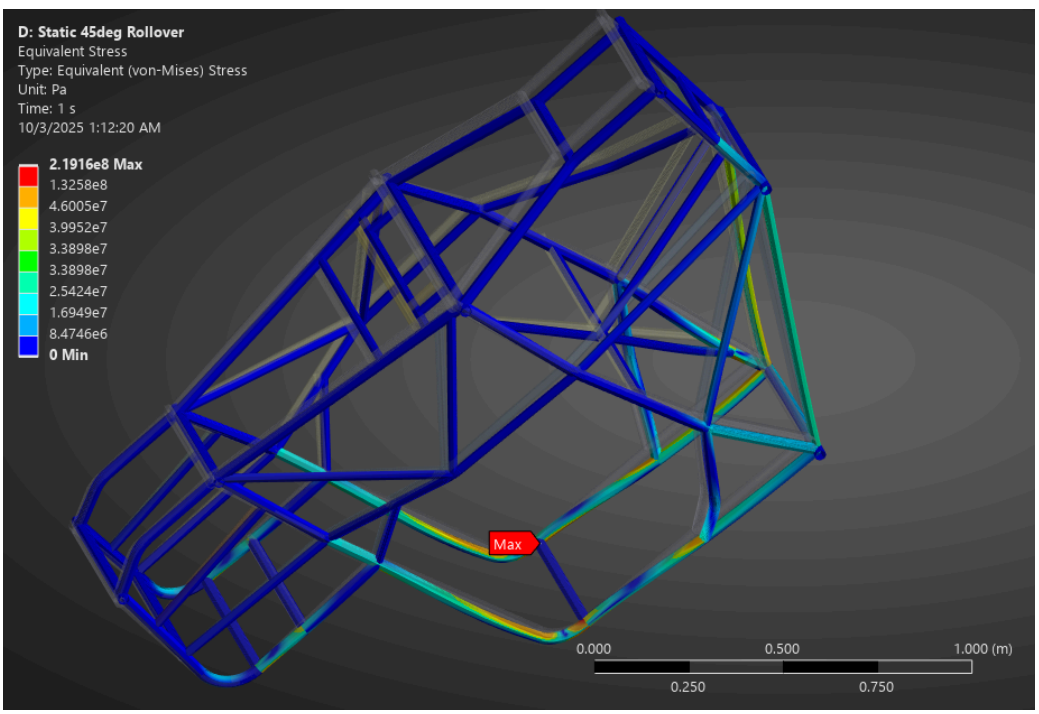


Figure 25: 45 degree rollover stress plot (FoS = 2.10)

Von-Mises stresses were chosen as the most conservative estimate of total stress. The above results are summarized in Table 4 below.

Table 4: Summary of Static Analysis Results

Load Case	Max Stress (MPa)	Yield Strength (MPa)	Factor of Safety (25-26)	Factor of Safety (24-25)
Front Impact	204.1	460	2.25	1.08
Rear Impact	213.1	460	2.16	1.01
Overhead Rollover	219.2	460	2.10	3.32
45 Degree Rollover	219.2	460	2.10	2.42

Discussion

These results show considerable improvement in front and rear impact cases compared to last year's frame design. For each, the FoS more than doubled under the same loading conditions. Both rollover cases saw decreases in FoS, with the overhead case in particular seeing a more significant drop, but both remain over 2. From these results, the goal of having every factor of safety over 1.2 is achieved. It suggests that there is considerable room for lightweighting, but it is difficult to truly optimize for low weight for the frame with the amount of qualitative and overlapping design considerations as detailed in the previous section of this report.

Last year, it was questioned whether or not these load cases were too extreme since it was difficult to get impact factors of safety above 1. These results demonstrate that, while the current design is perhaps an overcorrection due to to extenuating circumstances, a frame can be built to withstand these load cases that is the same weight or lighter that the 2024-25 frame.

Limitations and Future Work

The static simulations are still very rough approximations. I tried for almost two months straight to get dynamic simulations working using LS-DYNA, but repeatedly ran into licensing issues and errors that I could not resolve on my own. I want to get simple drop-test style simulations working to present to the SAE design judges at our competition in May, but was unable to do so during this quarter. At the very least, I want to learn how to set up dynamic simulations for future Northwestern Baja engineers to validate their designs, whether for the frame or other components.

I still want to do additional static load cases, particularly to quantify the torsional stiffness of the chassis using suspension shock loads. Torsional stiffness is an important design criteria in motorsport chassis design, albeit slightly less so for off-road vehicles, and I will have this simulation for our May competition.

Summary

The final frame model is below, in Figure 26.

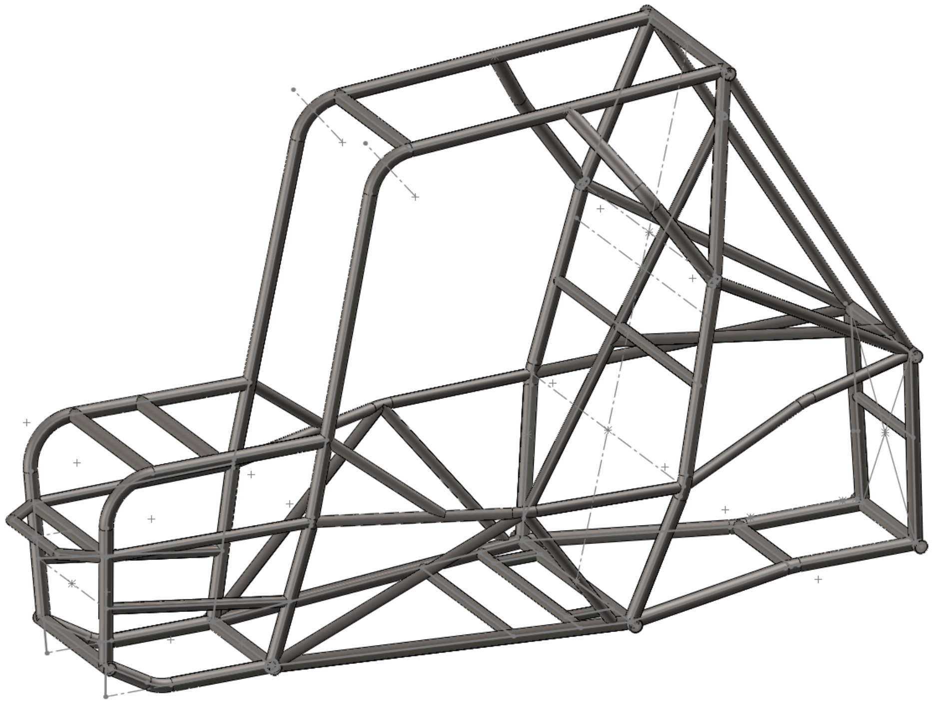


Figure 26: Final frame model

Design criteria and metrics are summarized below in Table 5, comparing to the previous year's frame.

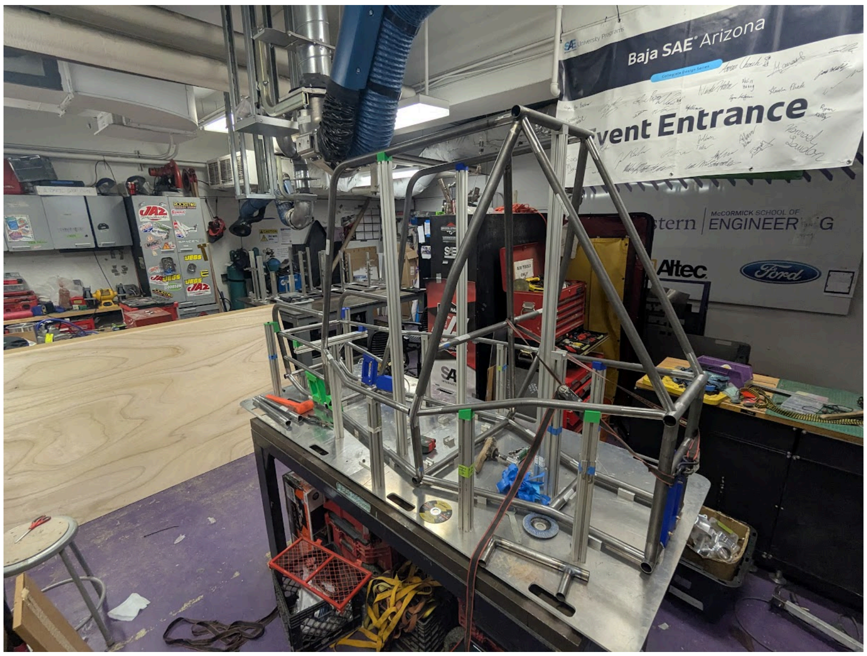
Table 5: Design Criteria and Comparison

Year	# of Tubes	Weight (lbs)	Center of Gravity (in)	Cockpit Volume (m^3)	Rear Volume (m^3)
2025-26	57	74.9	17.60	0.745	0.296
2024-25	58	67.1	17.68	0.694	0.264
% Change	-1.7	+11.6	-0.45	+7.3	+13

Overall, the design goals established last June were largely achieved. Concerning impact factors of safety were improved significantly, cockpit volume increased, rear packaging volume increased, and rule compliance was tracked even more diligently. The center of gravity was lowered slightly and one less tube was used. Weight increase was not kept under 10%, but it did not exceed this target by too much.

The load cases derived last year were effective in their use as a benchmark for design, but hopefully we will be able to move beyond static load cases for more than early design iterations. I still hope to complete some more advanced dynamic simulation work for the next frame designer to use as a jumping off point for next year. I also hope that data acquisition efforts are successful this year and into the future, and we can better support our engineering decisions with firsthand data.

I can not wait to see this car come together and compete this upcoming May in Washougal, Washington. I would like to give a huge thank you to the whole Northwestern Baja team, but in particular to my fellow subteam leads and executive leads, our welders Irvin Ma, Carlos Lazo, and Charlotte Erickson, my fixturing designer Linden Berte, and previous chassis designers Jason Chen and Mikey Diamond. At present, the rear roll hoop is welded and the rest of the fixturing is completed and starting to be assembled.



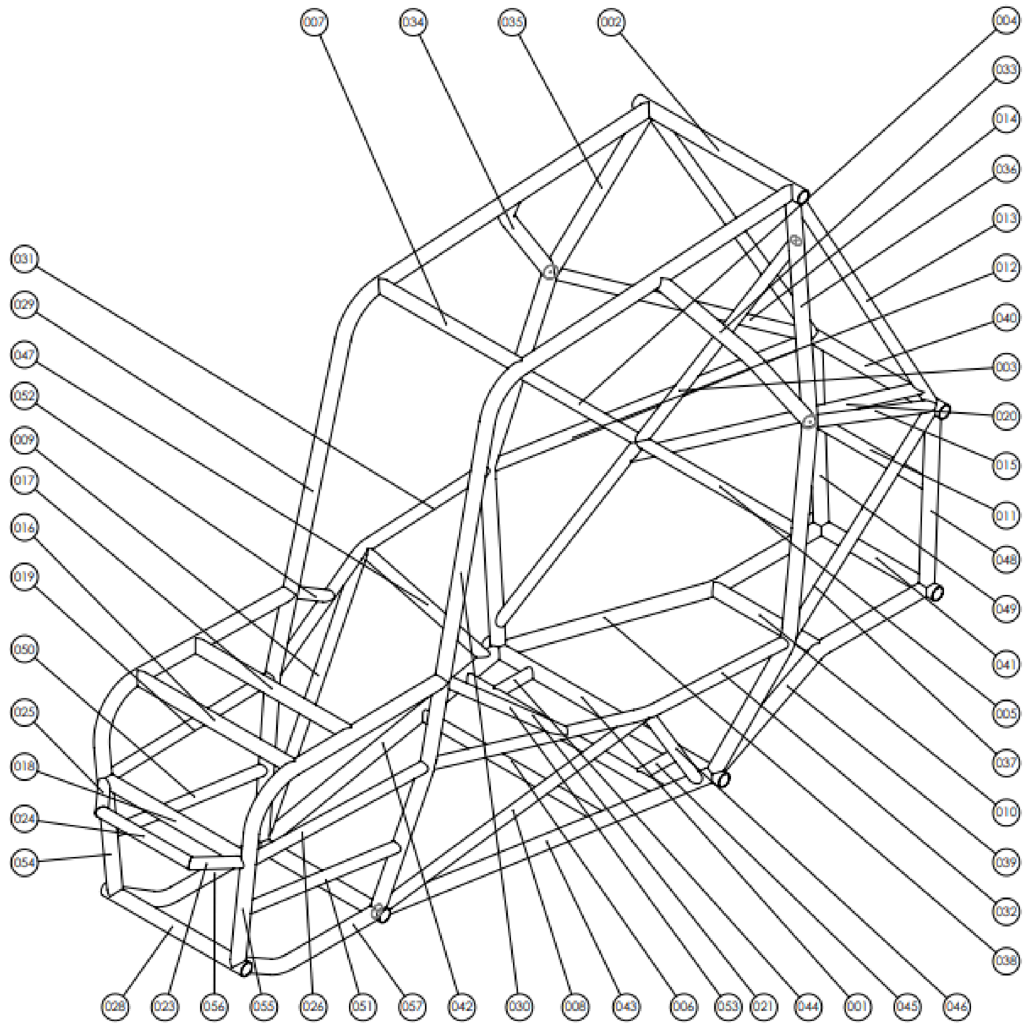
Appendix A: Rules Compliance Spreadsheet

This spreadsheet contains rules compliance checks for frame members, driver clearance, fuel system requirements, and stiffness and strength calculations for primary material.

Appendix B: Manufacturing Drawings

See below for manufacturing drawings that were sent to VR3 engineering for tube manufacturing.

PARTNUMBER	QTY.	DESCRIPTION	LENGTH
001	1	Tube 1.250 x 0.065	26.5
002	1	Tube 1.250 x 0.065	18.5
003	1	Tube 1.250 x 0.065	48.52
004	1	Tube 1.000 x 0.049	13.25
005	1	Tube 1.000 x 0.049	17.43
006	1	Tube 1.000 x 0.049	19.65
007	1	Tube 1.250 x 0.065	15.99
008	1	Tube 1.000 x 0.049	25.73
009	1	Tube 1.000 x 0.049	25.73
010	1	Tube 1.250 x 0.065	11.89
011	1	Tube 1.000 x 0.049	11.89
012	1	Tube 1.000 x 0.049	27.78
013	1	Tube 1.000 x 0.049	33.83
014	1	Tube 1.000 x 0.049	25.68
015	1	Tube 1.000 x 0.049	25.69
016	1	Tube 1.250 x 0.065	17.59
017	1	Tube 1.250 x 0.065	17.37
018	1	Tube 1.250 x 0.065	16.07
019	1	Tube 1.000 x 0.049	18.68
020	1	Tube 1.000 x 0.049	25.04
021	1	Tube 1.000 x 0.049	21.71
022	1	Tube 1.000 x 0.049	33.83
023	1	Tube 1.000 x 0.049	4.39
024	1	Tube 1.000 x 0.049	10.45
025	1	Tube 1.000 x 0.049	4.39
026	1	Tube 1.000 x 0.049	18.68
027	1	Tube 1.250 x 0.065	14.74
028	1	Tube 1.250 x 0.065	15.67
029	1	Tube 1.250 x 0.065	79.67
030	1	Tube 1.250 x 0.065	79.67
031	1	Tube 1.000 x 0.049	32.93
032	1	Tube 1.000 x 0.049	32.93
033	1	Tube 1.250 x 0.065	20.8
034	1	Tube 1.250 x 0.065	20.8
035	1	Tube 1.250 x 0.065	51.81
036	1	Tube 1.250 x 0.065	51.81
037	1	Tube 1.000 x 0.049	28.07
038	1	Tube 1.250 x 0.065	31
039	1	Tube 1.250 x 0.065	31
040	1	Tube 1.250 x 0.065	15.84
041	1	Tube 1.250 x 0.065	14.27
042	1	Tube 1.250 x 0.065	32.55
043	1	Tube 1.250 x 0.065	32.55
044	1	Tube 1.000 x 0.049	4.13
045	1	Tube 1.000 x 0.049	4.13
046	1	Tube 1.000 x 0.049	16.82
047	1	Tube 1.000 x 0.049	16.82
048	1	Tube 1.250 x 0.065	18.02
049	1	Tube 1.250 x 0.065	18.02
050	1	Tube 1.000 x 0.049	16.92
051	1	Tube 1.000 x 0.049	16.92
052	1	Tube 1.000 x 0.049	12.1
053	1	Tube 1.000 x 0.049	12.1
054	1	Tube 1.250 x 0.065	37.25
055	1	Tube 1.250 x 0.065	37.25
056	1	Tube 1.250 x 0.065	16.7
057	1	Tube 1.250 x 0.065	16.7



Northwestern Baja SAE

TITLE: Northwestern Baja Frame 2026

	NAME	DATE
DRAWN	Ryan Kai	10/11/25
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ANGULAR: MACH BEND TWO PLACE DECIMAL THREE PLACE DECIMAL

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: 4130

FINISH

DO NOT SCALE DRAWING

PROPRIETARY AND CONFIDENTIAL

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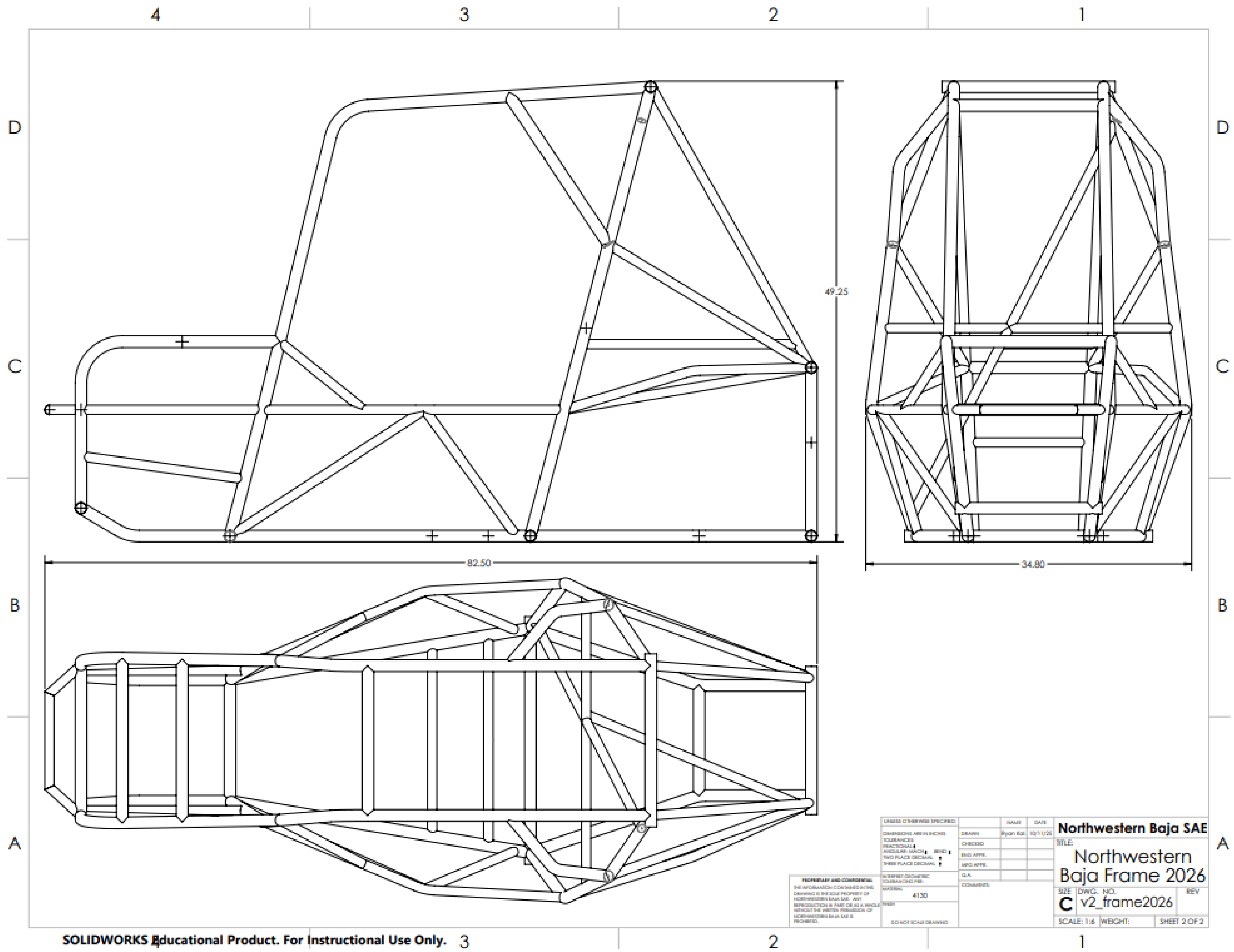
SIZE C | DWG. NO. v2_frame2026 | REV

SCALE: 1:6 | WEIGHT: | SHEET 1 OF 2



49.25
82.50
34.80
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
CHECKED
Q.A.
COMMENTS:
MATERIAL
4130
DO NOT SCALE DRAWING
Northwestern Baja SAE
TITLE:
Northwestern Baja Frame 2026
SIZE
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DWG. NO.
v2_frame2026
REV
SCALE: 1:6
WEIGHT:
SHEET 2 OF 2

Appendix C: Bill of Materials

Tube Set Summary / Material List							
Customer/ School Nar		Northwestern University					
Team Contact person:		Ryan Kalgreen	ryankalgreen2026@u.northwestern.edu				
Project Description:		Tube Set: BAJA SAE 2026 Frame					
Customer dwg no / rev		xxx / Rev xx / date					
Date:		10/11/2025					
Ass'y Dwg	Qnty	Dim 1	Type	Dim 2	Dim 3	Special Features	
Item No	(per set)	outside dim	(rd,sq)	wall thickness	aprox length	# bends	bend radii
		(in.)		(in.)	(in.)		(in.)
001	1	1.250	rd	0.065	26.5		
002	1	1.250	rd	0.065	18.5		
003	1	1.250	rd	0.065	48.52		
004	1	1.000	rd	0.049	13.25		
005	1	1.000	rd	0.049	17.43		
006	1	1.000	rd	0.049	19.65		
007	1	1.250	rd	0.065	15.99		
008	1	1.000	rd	0.049	25.73		
009	1	1.000	rd	0.049	25.73		
010	1	1.250	rd	0.065	11.89		
011	1	1.000	rd	0.049	11.89		
012	1	1.000	rd	0.049	27.78		
013	1	1.000	rd	0.049	33.83		
014	1	1.000	rd	0.049	25.68		
015	1	1.000	rd	0.049	25.69		
016	1	1.250	rd	0.065	17.59		
017	1	1.250	rd	0.065	17.37		
018	1	1.250	rd	0.065	16.07		
019	1	1.000	rd	0.049	18.68		
020	1	1.000	rd	0.049	25.04		
021	1	1.000	rd	0.049	21.71		
022	1	1.000	rd	0.049	33.83		
023	1	1.000	rd	0.049	4.39		
024	1	1.000	rd	0.049	10.45		
025	1	1.000	rd	0.049	4.39		
026	1	1.000	rd	0.049	18.68		
027	1	1.250	rd	0.065	14.74		
028	1	1.250	rd	0.065	15.67		
029	1	1.250	rd	0.065	79.67	2	4.41
030	1	1.250	rd	0.065	79.67	2	4.41
031	1	1.000	rd	0.049	32.93	1	5.88
032	1	1.000	rd	0.049	32.93	1	5.88
033	1	1.250	rd	0.065	20.8	1	4.41
034	1	1.250	rd	0.065	20.8	1	4.41

035	1	1.250	rd	0.065	51.81	2	4.41
036	1	1.250	rd	0.065	51.81	2	4.41
037	1	1.000	rd	0.049	28.07	1	5.88
038	1	1.250	rd	0.065	31	1	4.41
039	1	1.250	rd	0.065	31	1	4.41
040	1	1.250	rd	0.065	15.84		
041	1	1.250	rd	0.065	14.27		
042	1	1.250	rd	0.065	32.55		
043	1	1.250	rd	0.065	32.55		
044	1	1.000	rd	0.049	4.13		
045	1	1.000	rd	0.049	4.13		
046	1	1.000	rd	0.049	16.82		
047	1	1.000	rd	0.049	16.82		
048	1	1.250	rd	0.065	18.02		
049	1	1.250	rd	0.065	18.02		
050	1	1.000	rd	0.049	16.92		
051	1	1.000	rd	0.049	16.92		
052	1	1.000	rd	0.049	12.1		
053	1	1.000	rd	0.049	12.1		
054	1	1.250	rd	0.065	37.25	1	4.41
055	1	1.250	rd	0.065	37.25	1	4.41
056	1	1.250	rd	0.065	16.7	1	4.41
057	1	1.250	rd	0.065	16.7	1	4.41
tube size	wall	# of pcs	Length	Material			
		per set	(in)	Spec			
1.000	0.049	29	557.70	4130N			
1.250	0.065	28	808.55	4130N			
	Total no of	57	pcs				
	Total tube l	1366.25	inches				
	# bends	# tubes					
		w/ bends					
	1bend	11					
	2bends	4					
	3bends	0					
	4bends	0					
	5bends	0					
	No of tube:	15					