Ryerson University Baja SAE Technical Report

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ABSTRACT

This report outlines the Ryerson Engineering RB18 Baja design goals, decisions, and outputs.

This year, high level goals included finishing design in September, towards having a ready car before the winter semester (which invited keeping design simple).

In terms of lower level design goals focus was put on Reducing Driver fatigue (see *Ergo* and *Steering*), Obstacle Clearing (See *Suspension* - Rear bias, rake, raised arms), Maneuverability (See *Suspension* - Shortened wheelbase, ARB, Roll center), and overall Weight Reduction while maintaining reliability. So far several design goals were met, and more will be evaluated as the car nears its testing phase.

INTRODUCTION

Baja SAE® consists of competitions that simulate real-world engineering design projects and their related challenges. The goal is to design a single seat all-terrain vehicle to be marketed and sold. The product characteristics of such vehicle include safety, reliability, ergonomics, and maintainability. There are three regional competitions in the 2018 series and Ryerson University has chosen to participate in the competitions located in Oregon and Kansas.

This report outlines the design and fabrication of Ryerson's RB18 Baja vehicle, with key system goals and design outputs.

CHASSIS

GOALS – Manufacturability, improved packaging, accessibility, and weight

- Packaging: The chassis was designed to accommodate a spacious cockpit, as well as adequate suspension and drivetrain packaging and load paths. Vehicle dynamics goals were accommodated by packaging and will be discussed in the Suspension section of this report. A sketch-relational dynamically adjustable master assembly aided the packaging iteration greatly.

- Manufacturability: Long bent frame members were used extensively to reduce the need for jigs, and reduce tube cuts as well as weld process.

Figure 1 – Front View Master Assembly

- Accessibility: Engine and CVT access was improved, with a more open rear end and longer CVT belt

- Weight: The fully welded frame weighs 71.5 lb which is slightly above target, but still a near 10lb improvement over previous designs. MIG welding was chosen as a compromise between added weight and weld time, weighing 2.5lb but taking less than 6h.

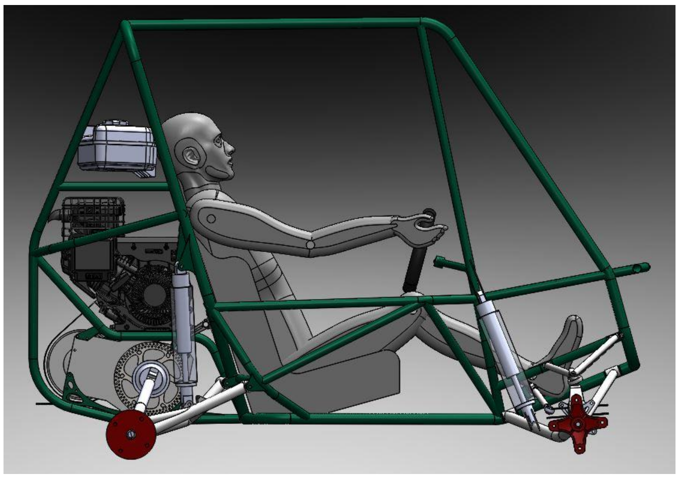

Figure 2 – Side packaging

SUSPENSION

GOALS: Obstacle Clearing, Maneuverability, Weight reduction, Simplicity

The suspension makes use of drilled TRX450 spindle shafts and accompanying hubs in the front, and Foreman 500 hubs and CV shafts in the rear. The setup was proven and, in this case, purchased components allowed for high level goals to be met. Elka Stage 5 coilovers were used, for their availability to the team and tuning potential.

- Obstacle Clearing: 22 deg of front rake plus a significant rear bias (predicted 70% rear) were implemented for exploration of reducing speed loss over abrupt obstacles, and improved forward grip. Rear semi-trailing arms (with rearward arcing path), along with an axle in line with the front LBJ provided further increased clearance, with the selected 12in ride height accounting for 20% droop. Travel was set to 12in in the front, and 10.5 in the rear, with bottom out ride height at around 2in, to account for tire deflection.

- Maneuverability: The wheelbase was reduced dramatically to 53in (desired consequence of the rear bias while keeping a spacious cockpit), while track was widened slightly. To make appropriate use of the spool in vehicle handling, A more robust rear antiroll bar was implemented (it was discovered to be too soft the previous year), with adjustment range from 35 to 180% of the designed spring rate, to allow for experimentation. The rear roll center was set above the front, but that was simply good practice and not a primary design parameter.

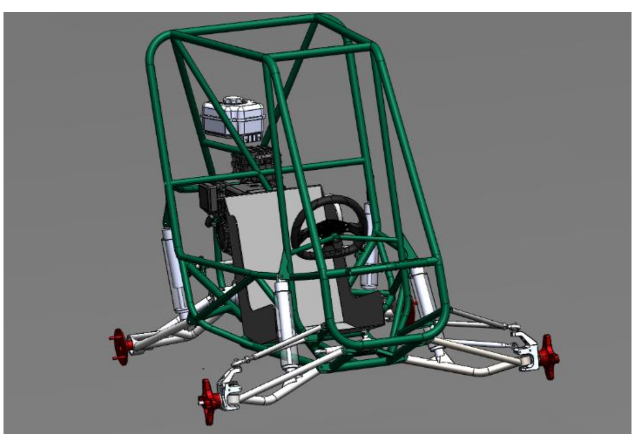

Figure 3 – Suspension configuration

- Weight Reduction: All designed component were simulated in SW, for worse case scenarios– 2.5 times full compression bump for the front and rear arm shock mounts (observed adequate for previous year), and 3G one wheel landing (twisting the wheel) were used for the trailing arm and knuckle.

- Simplicity: The trailing arms offered reduced part count and jigging points, as well as fixed alignment, perhaps desirable for a mass-produced product. Waterjet, then 3-axis CNC finish machined Knuckles with bolt on sheet clevises and purchased hub-bearing units mean easier serviceability and modularity. A sheet knuckle design was considered, but abandoned due to machining sponsorship opportunity, and subsequent reduced labor.

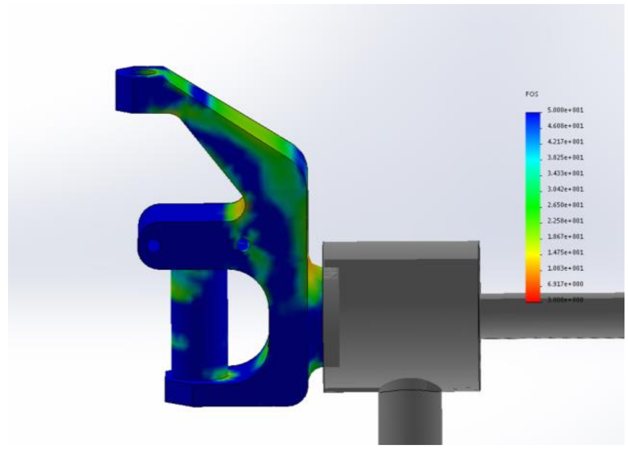

Figure 4 – Front Knuckle, with bending fixture, and mock LBJ

STEERING

- GOALS – Maneuverability, Improved Feedback, Adjustability

- Maneuverability: 60% Ackermann allowed higher lock angle before linkage reversal. Adjustable by clevis.

- Improved Feedback: Caster was reduced to 4deg (Less can work wonders in some applications but some caster was hypothesized to help point the car in ruts and disturbances – road feedback, not just pneumatic trail). This allowed for reduced lock to lock while also reducing steering force. Scrub was also reduced to .4in by increased kingpin, and bump steer was reduced to under .5deg for the entire 12in of travel.

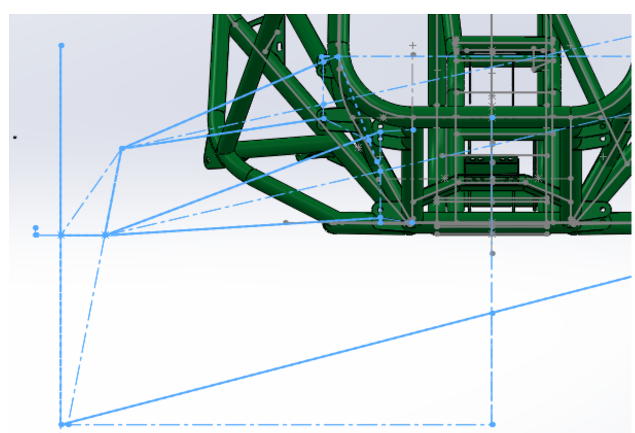

Figure 3 –Suspension and steering geo, 3D sketch

- Adjustability: Caster was made adjustable (washers), 4-9 deg. In comparison to the fixed 10deg of the previous year. Ackermann is also adjustable through a bolted clevis. Front camber was also made adjustable but deemed less critical for the round profile tires and adequate camber gain in place.

DRIVETRAIN

- GOALS – Simplicity, Speed/torque compromise

- Simplicity – A Spring/V-belt type CVT was selected for its ease of operation and mechanical simplicity The CVtech had good performance, cost, adjustability and operating range, with a min ratio of 3:1 and a max ratio of 0.43. A purchased double reduction FNR gearbox provided the final drive, although the reverse has rarely been proven necessary, and perhaps not worth the weight penalty.

- Speed/Torque compromise: A compromise was made to satisfy a max required torque over an 80 degree grade, past which the car would likely roll. For this, an overall ratio of least 28:1 was sufficient, requiring at least a 10:1 gearbox reduction. Through experimentation, a 12:1 box seemed to provide some benefit while not detracting top speed, as the CVT does not reach full engagement. More tuning time will yield further discoveries to be implemented in the future.

BODY PANELS

- GOAL – Simplicity

- .025 Aluminum sheet was readily available and easy to work with, providing reliable results more easily and quickly than composites tried in the past.

ERGO

- GOAL – Reduced driver fatigue, Easy EGRESS

- Reduced driver fatigue: an aluminum seat was selected because it was appropriately sized for all the team's drivers, with EPDM foam padding added for additional comfort and vibration absorption. A fairly upright 70deg seat angle was seen as beneficial for offroad driving, contrasting a formula car which it was analyzed alongside. The steering wheel was positioned at a distance comfortable for all drivers, and angled at 75deg as it was found to reduce forearm and wrist fatigue, while adequately upright to match the seat angle. The pedal distance was set for relaxed legs even for taller drivers, out of the way of the steering wheel and allowing a healthy ankle angle. Throttle actuation was set to 3in, as it was a natural motion, and allowed adequate throttle resolution.

- Easy EGRESS: The cockpit was kept wide enough to allow egress without removal of the steering wheel, while still not compromising its position. This also allowed for elimination of the heavy quick release.

BRAKES

- GOAL – Ease of operation

- A 5:1 pedal ratio was employed for good actuation, with correctly sized cylinders mounted up high for easier bleeding. A single rear caliper was used to save weight and potential complexity of bearing carriers. ATV calipers were selected for their abundance and reliability in Baja conditions. Rear rotors were designed, with modest pocketing to reduce weight, 1.5lb was saved compared to a solid rotor.

CONCLUSION

This car set out to build upon previous years' lessons, and produce a vehicle that meets the competition requirements, and adds new ideas that can set it apart both in competition and in the market. In particular, the improvements in Ergo and Vehicle dynamics will likely make a quantifiable difference in the performance of the vehicle in the coming competitions and set the stage for further validation and refinement.

ACKNOWLEDGMENTS

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REFERENCES

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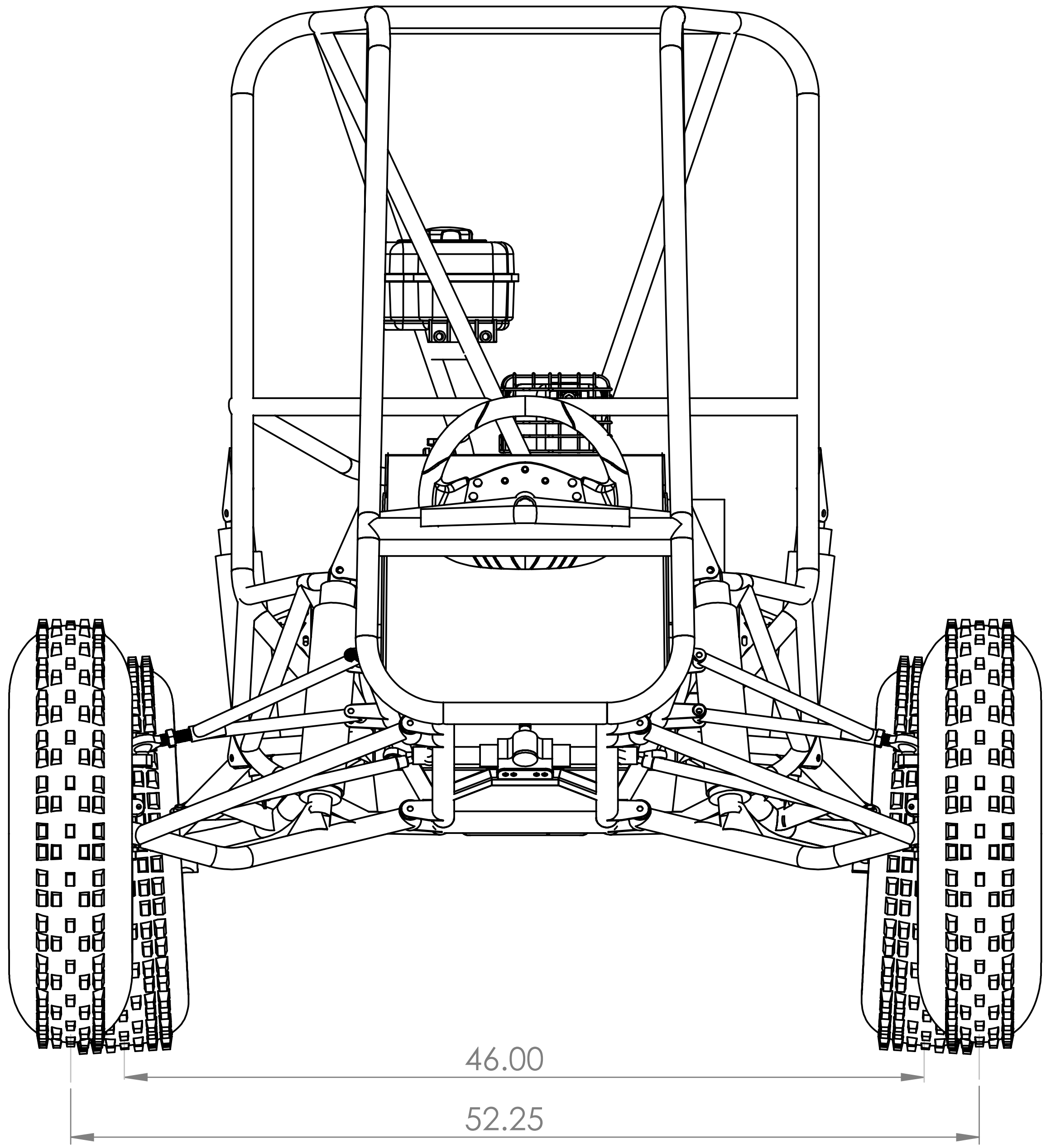
DEFINITIONS, ACRONYMS, ABBREVIATIONS

CVT: Continuously Variable Transmission

LBJ: Lower ball joint, only up front

ARB: Antiroll Bar



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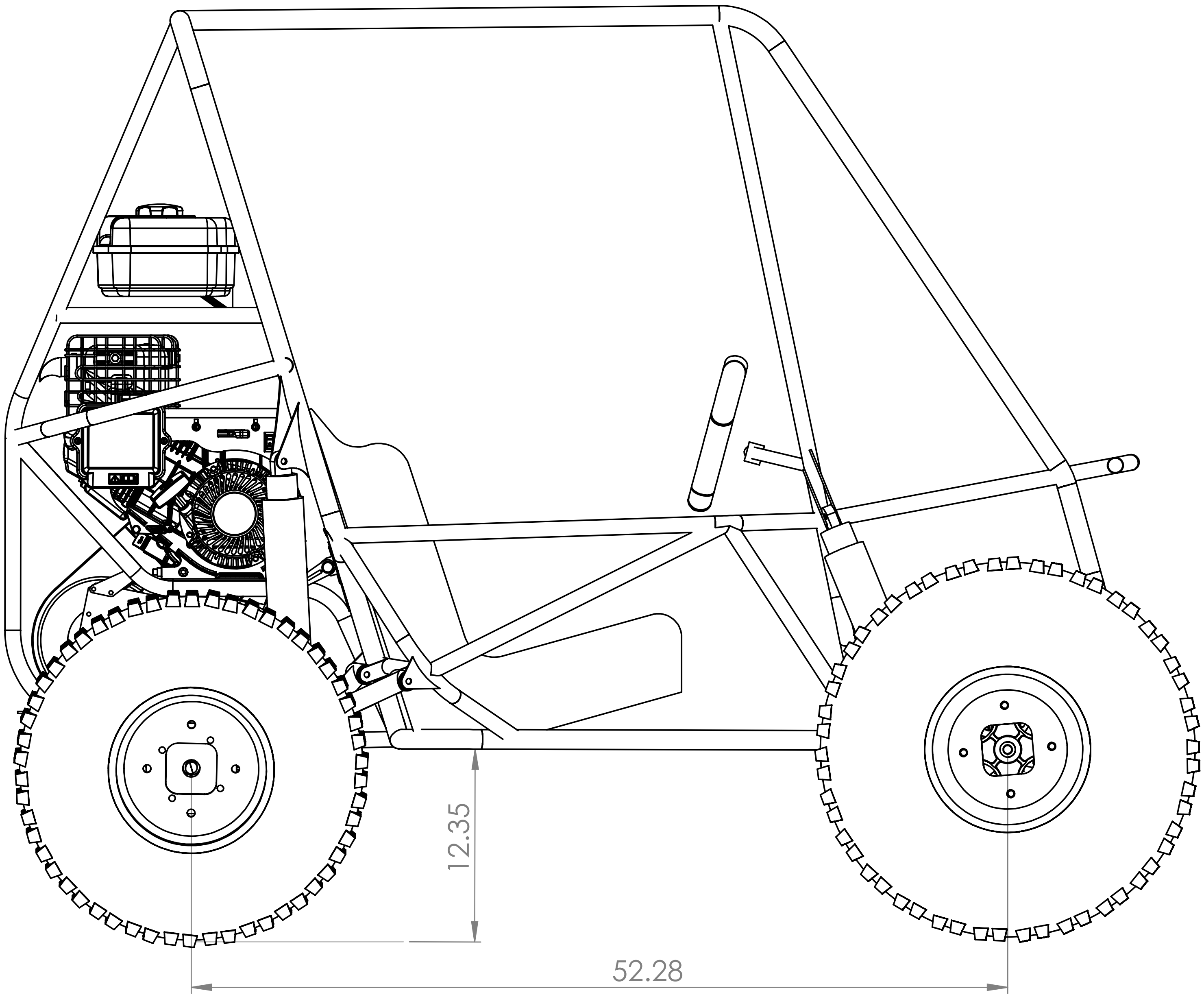

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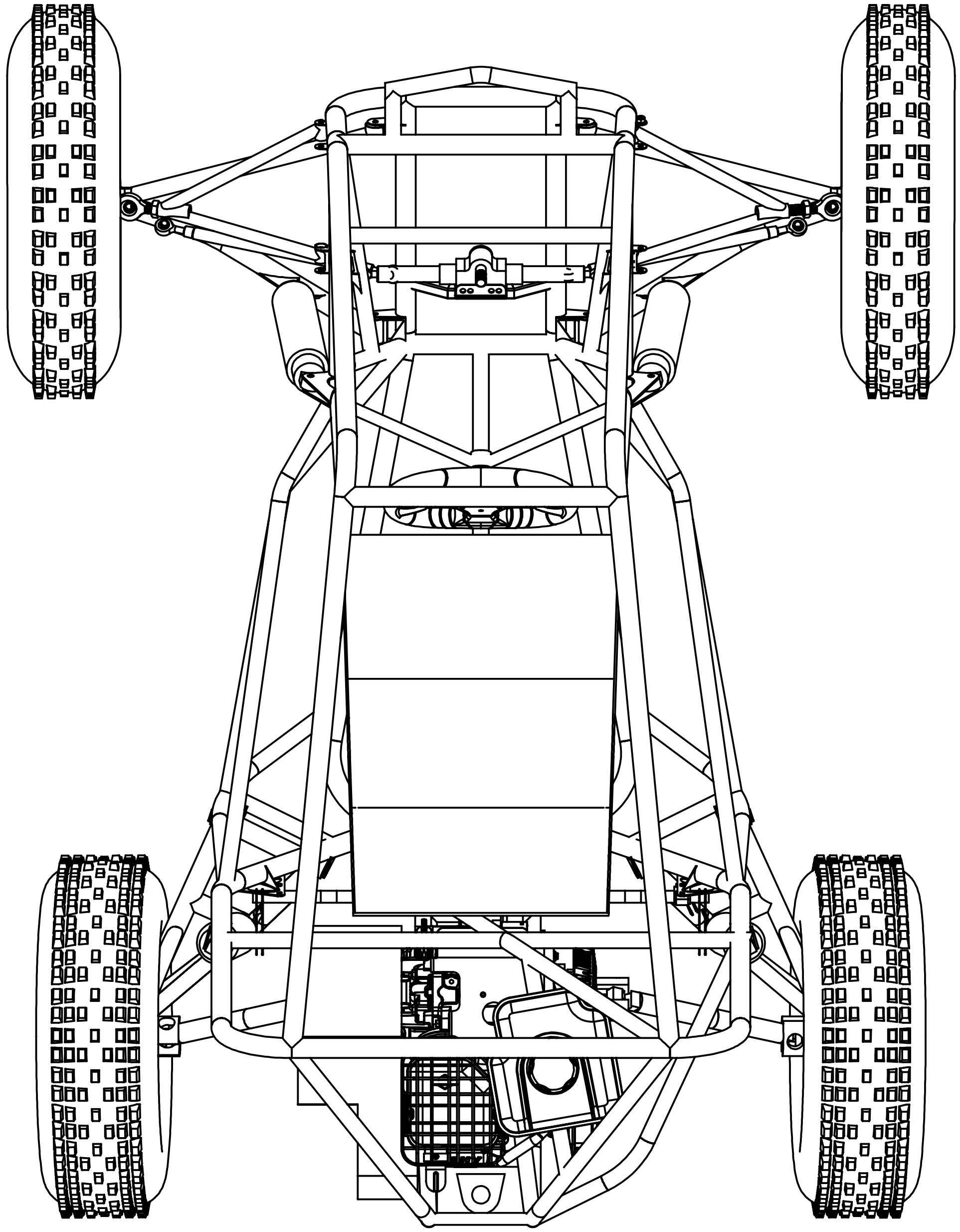

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