BAJA SAE

University of Colorado Boulder
2020-2021

Mechanical Engineering
UNIVERSITY OF COLORADO BOULDER

BAJA SAE®

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Introduction

Baja SAE is an international competition organized by the Society of Automotive Engineers (SAE) where collegiate teams design, build, and race single-seat off-road vehicles. The CU Boulder team consists of 14 mechanical engineering seniors who are driven by their passion for automotive engineering and their desire for a technically challenging, capstone design project.

With critical University resources limited due to the COVID-19 virus, this year's Baja SAE team opted to test and optimize an already-manufactured four-wheel drive vehicle completed by last year's team. This was a completely new design challenge to the CU Boulder Baja program this year and allowed our team to complete a comprehensive testing and analysis program on all subsystems. The program aimed to gather information on areas of lost performance to inform our redesigns of critical subsystems, while conforming to the regulations and constraints set by the Baja SAE rulebook.

Overall, the goal of the year was to prepare the vehicle for competition in the in-person SAE Validation event held in Tucson, Arizona where our team would race head-to-head against other collegiate Baja SAE programs. The vehicle must be able to excel in a variety of dynamic events such as a suspension challenge, maneuverability course, hill climb/sled pull, and a 4-hour endurance race. In tandem with the validation event, our team competed in the virtual SAE Knowledge events. While these events were held on-site at the validation event in years past, these online events tested our team's overall knowledge of the engineering and design of the vehicle, quality of cost reports for each vehicle subsystem, and the viability of a pro-forma business plan for an off-road racing series.

Our team was divided into four sub teams corresponding to critical subsystems of the vehicle: chassis, controls, drivetrain, and suspension. Each of these sub teams confronted unique challenges that were addressed to improve the overall performance and reliability of the vehicle.

Chassis

Introduction

The chassis sub team focused primarily on ensuring the vehicle would pass technical inspection during competition in the physical validation event. This included manufacturing any required components that were left out of the 2019 - 2020 prototype and adjusting existing components to meet required SAE specifications. They also improved the overall aesthetics of vehicle exterior and maintained optimal system integration with the chassis.

The chassis team also conducted finite element analysis (FEA) on load bearing chassis members to validate studies completed by last year's team. This was meant to address the need for additional chassis members in areas of high loading from the suspension and to reduce bending in those members.

Testing

The chassis sub team carried out testing using strain gauges to measure the amount of force experienced by the suspension mounting members in the vehicle frame. These members were chosen for testing because they mainly experienced bending loads from the suspension, with the member supporting the front suspension being of particular concern as it was entirely in bending from the front shock.

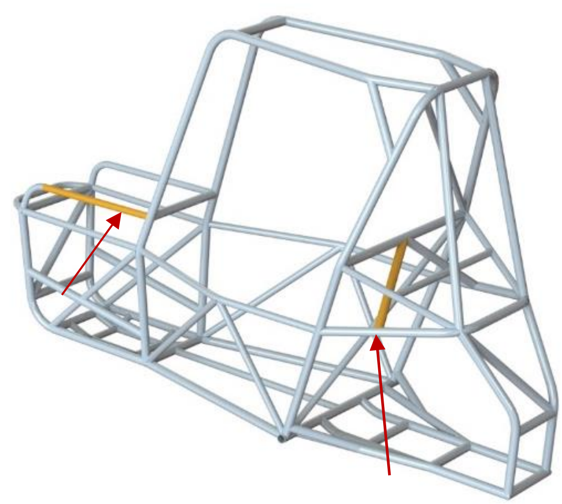

Figure 1: Bare Chassis with high-load members (orange) and direction of external forces from shocks (red arrow)

Identifying the forces going into these members allowed the team to run updated FEA studies to determine whether extra support would be needed, as well as validate approximated FEA run by the 2019-2020 team.

To capture data, 350Ω Type-B Strain gauges and Elecrow Strain Gauge modules were used, connected to a custom Arduino data acquisition (DAQ) Unit. These modules were incredibly helpful as they were easy to use and eliminated the need for complicated circuits in the DAQ unit. Calibration was completed using known resultant shock forces based on shock compression (see Suspension Sub Team Testing Section). The shocks were compressed in increments of 0.5” and the corresponding Arduino output was recorded. This provided the known external loads to critical chassis members given certain Arduino measurements.

FEA Analysis on Chassis

FEA studies were run using a combination of results from the suspension maximum shock force and strain gauge testing on front suspension control arms and rear suspension toe links. Examples of these studies, showing FOS distributions, are shown in Figure 2 for the front and rear chassis respectively. Within these studies, it was possible to isolate single members and calculate the axial loading within those specific members. These calculated values were used in comparison to the measured loads from strain gauge testing.

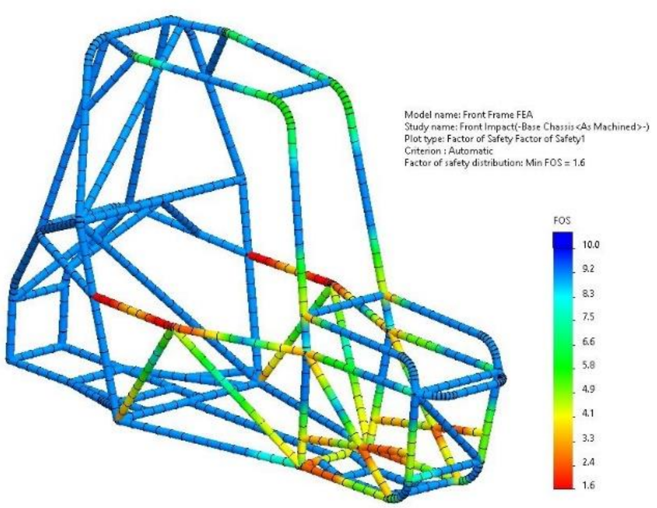

Figure 2: FEA Study on Chassis Front of Rear Roll Hoop

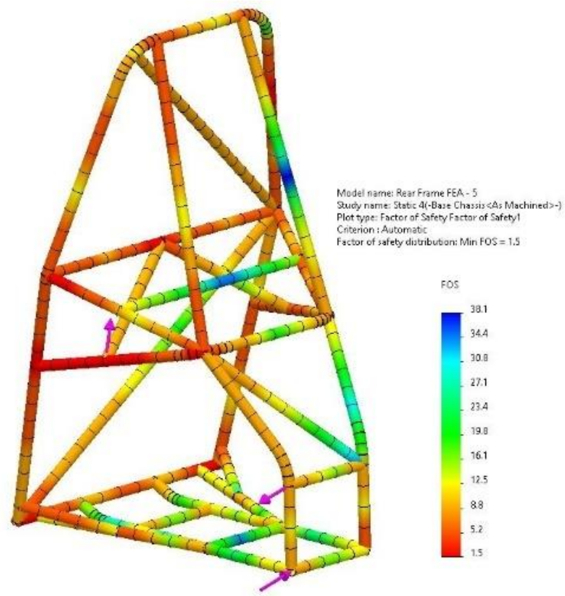

Figure 3: FEA analysis on rear section of vehicle frame

Redesign

Firewall

The firewall is an extremely important component of the vehicle, shielding the driver from any danger rear of the rear roll hoop. To accomplish this, no gaps may exist between pieces of the firewall, and cutouts should only exist where necessary such as for the shoulder harness and wiring that runs through the cockpit. A two-piece design was chosen to facilitate installation and removal. The firewall was made of 0.025” 6061 Aluminum as it was the thinnest and lightest material that would satisfy the rules set by SAE.

Body Panels

While a design for the body panels was completed by the 2019-2020 team, it was decided to redesign the panels to improve ease of access and decrease overall weight. Both goals were achieved by reducing the total number of panels from 10 to 6, reducing the amount of required hardware, and changing the material from 0.125” polycarbonate to 0.060” haircell ABS. Additionally, the design moved away from requiring removal of suspension components to disassemble and reassemble the body panels from the vehicle. Thus, making it possible to quickly remove individual panels for maintenance or technical inspection.

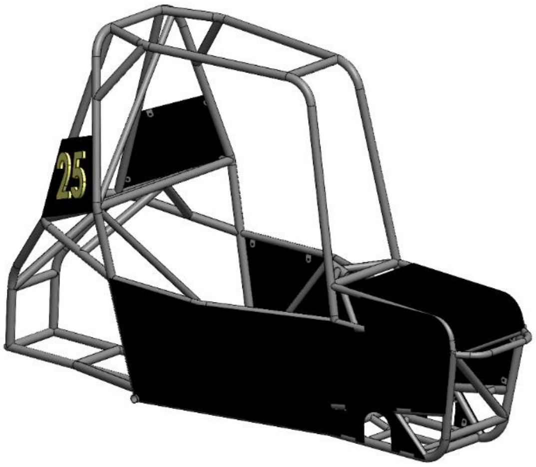

Figure 4: Bare Chassis with Redesigned Body Panels

Driveshaft Protection

Last year's 4WD design incorporated a driveshaft that runs directly under the seat, and through the cockpit of the vehicle. To keep the driver's extremities from getting caught in the rotating shaft, a 3" ID ABS tube was placed over the driveshaft this year. The tube was held in place by two .125" thick Aluminum driveshaft hoops, that were bent around the tube and bolted to the chassis at the under-seat member. These hoops served to both ensure the tube did not interfere with the driveshaft, as well as protect the driver in the case of driveshaft failure. In addition to these pieces, the false floor was redesigned to add more room in cockpit while protecting the driver from steering linkage failures.

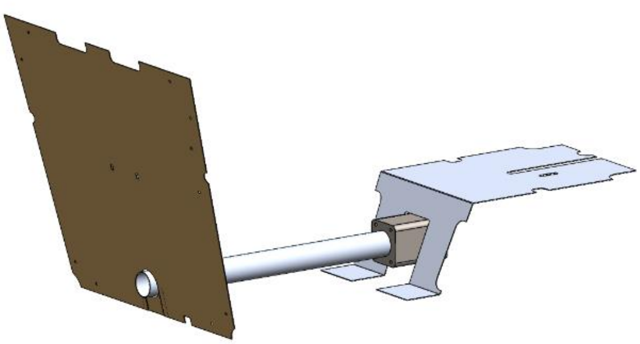

Figure 5: Driveshaft Protection Redesign with Lower Firewall (left), Driveshaft Cover (Center) and False Floor (Right)

Point A Tubes

The primary issue discovered with the 2019-2020 chassis during a mock technical inspection involved the joining of critical chassis members too far apart at a lower node of the rear roll hoop. To overcome this rule violation, an additional member, shown in Figure 6 in magenta, was added connecting the FAB Low member to the rear roll hoop within the specified tolerance of 2" between centerlines of tubes.

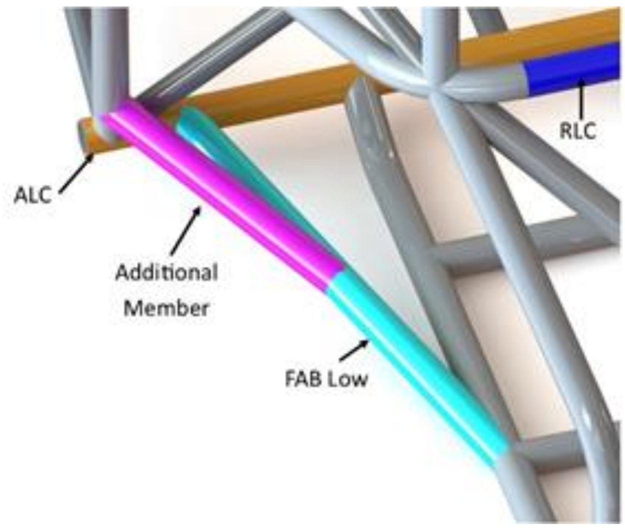

Figure 6: The chassis modified with an additional member between FAB Low and the rear roll hoop. Viewed from above the rear left quarter panel.

Controls

Introduction

The controls sub team was responsible for the brakes, electrical system, safety equipment, and cockpit ergonomics. At the beginning of the year, many of the SAE required controls specifications were missing from the vehicle and needed to be addressed to pass technical inspection in Arizona. The controls team also wanted to address the unnecessary weight and unacceptable ergonomics from the 2019 – 2020 pedal assembly. Thus, the team redesigned most of the controls interface including the differential switches, brake light, safety harness, and the pedal box. These components and equipment were designed to optimize functionality for the driver, ensuring controls interfaces were easy and comfortable to use for long driving sessions as would be experienced during the endurance event at competition.

Electrical System

The electrical system includes two separate circuits. The first circuit includes the engine, and both kill switches. This circuit remains entirely separate from the main vehicle harness as the brake lights must work regardless if the engine is powered or not. This meant that the switches must be wired in parallel so that pressing either one completes the circuit and kills the engine. The main wiring harness includes the battery, differentials, differential switches, brake pressure sensors, and a brake light. There are two hydraulic brake pressure sensors that are routed in-line with the front and rear braking circuits. Each differential is controlled by an SPST switch, which allows the driver to operate the vehicle in FWD, RWD, or 4WD. The differentials and kill switch are connected to the engine with automotive grade Deutsch connectors. This makes it easy to remove the wiring harnesses to diagnose any issues and keeps the connections at these points sealed from dust, dirt, and water ingress.

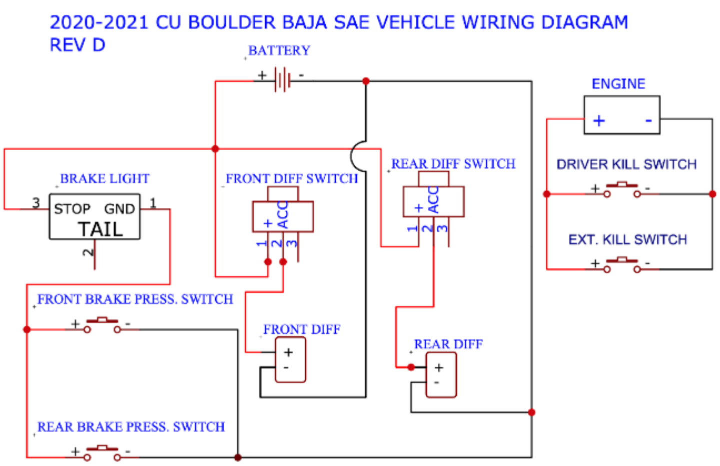

Figure 7: Wiring diagram for the differentials, brakes, and kill switches.

Pedals

The original pedal box design from last year was tested under various driving conditions at the beginning of the year and it was determined that the brake pedal force to lock the wheels, the long throttle pedal throw, and heavy components were not acceptable for our design. The controls team designed a new pedal box that could decrease the max braking force, decrease the throttle travel, reduce weight. The new design also incorporated a cutting brake that independently actuates the front and rear braking circuit. This was desirable as the driver could lock the rear brakes and improve the turning radius of the vehicle which would assist in the completing maneuverability challenge.

Other key changes implemented in the new pedal box design included vertically mounting 0.625” Tilton master cylinders accompanied by remote reservoirs which replaced the horizontally mounted 0.75” Wilwood master cylinders with fixed reservoirs. The smaller master cylinders contributed to decreasing the force required to lock the brakes, making it easier for the driver to press the pedal and reduce driver fatigue over the course of operation. The remote reservoirs allowed the team to use a new 7075 aluminum base plate as pedal restraints, which also helped shed weight. Longer brake pedals, a lower profile throttle endstop, and an extended throttle pedal below the pedal box were incorporated into the split brake pedal design to increase driver comfort when operating for extended periods of time. The extended brake pedals increased the pedal ratio from 4 to 4.5, decreasing the brake locking force making the system more comfortable for the driver. The new pedal box also has a fewer number of overall parts and hardware which attributed decrease weight from 10.4 lbs to 6.5 lbs.

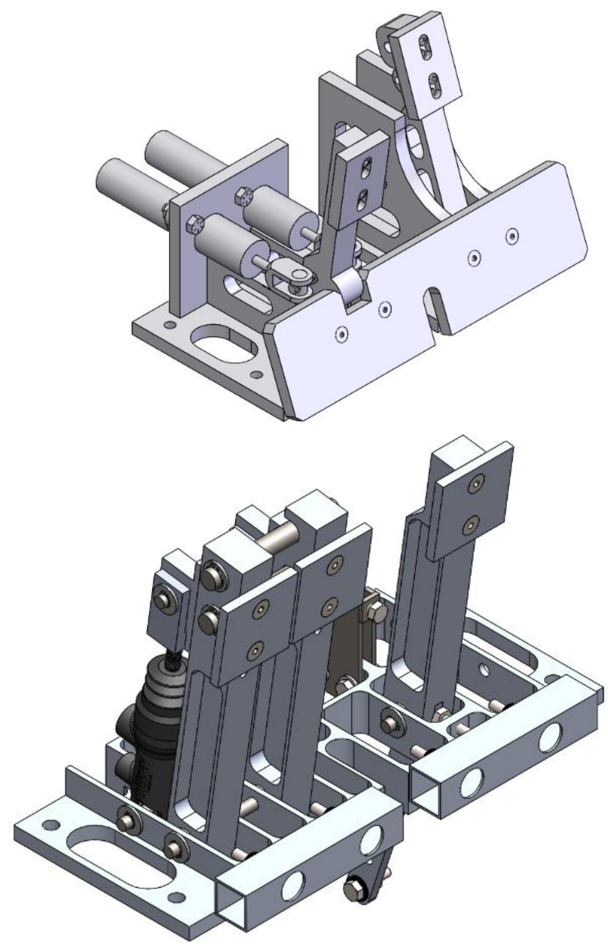

Figure 8: Original pedal design (Top), New pedal design with split brake pedal (Bottom).

Brakes

In the first few testing sessions at the beginning of the year, the controls team noticed the current braking system does not lock all four wheels on dirt and pavement. This ability is required for competition in Arizona and needed to be addressed.

The brake rotors were mounted inboard by the 2019 – 2020 team to reduce unsprung weight and improve upright packaging with the four-wheel drive system. This was desirable for improved suspension performance in steering and in harsh terrain and was kept for the design this year.

The 2019–2020 rear brake circuit included a Wilwood brake proportioning valve, which allowed the driver to adjust the braking ratio and reduce brake pressure in the rear circuit by 57%. This was kept in the design so the driver could adjust front to back brake ratio while driving and improve the braking performance based on terrain. The team also switched the front and rear calipers since the original configuration held the larger piston diameter in the rear. This resulted in the rear wheels locking while the fronts continued to rotate in hard braking which was unacceptable for the design requirements. A combination of downsized master cylinders and rotated calipers reduced the front brake locking force from 250lbs to less than 150lbs required by the driver.

The controls subteam also identified an accessibility issue with the old caliper mounts which prevented the team from installing and bleeding the brakes efficiently. The team decided to adjust the brake caliper mounts to improve the accessibility of the calipers and to make it easier to remove the entire

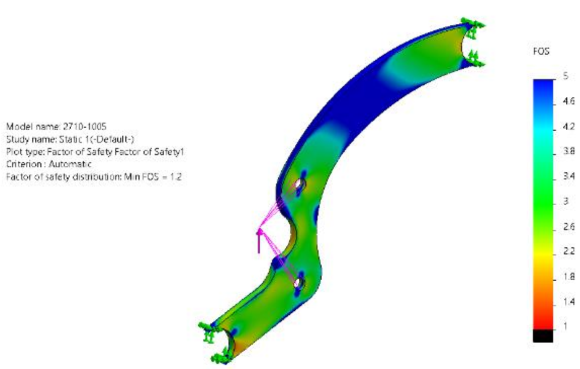

Figure 9: FEA Analysis of Redesigned Brake Caliper Mount

front differential assembly from the vehicle. The new caliper mounts, shown in Figure 9, were designed around a maximum frictional braking force generated by the caliper of 925lbs. This force was calculated from the driver applying a 250lb force to a ⅝” master cylinder via a 5.5:1 pedal ratio. FEA studies were run with this load case to test new caliper designs and test the factor of safety with a hard braking scenario. The new caliper mount design reduced the component weight by 28% and made the calipers much easier to install and bleed.

Manufacturing & Assembly

Much of the manufacturing was undertaken by the Idea Forge machine shop, as well as the ITLL machine shop. The caliper mounts and some steel components for the pedal box were cut on the abrasive waterjet at the workplace of a team member. The remaining machine work for the pedal box was done at the ITLL using a CNC mill and lathe.

Drivetrain

Introduction

The 2019 – 2020 drivetrain system was designed around the 10 horsepower, Briggs & Stratton Vanguard 19 engine. Given the upcoming competition requirement next year of vehicles requiring 4WD capability, last year’s team opted to design a selectable drive system that toggles front, rear, and four-wheel drive. This year, the drivetrain sub team aimed to test and improve this system’s efficiency and reliability.

Most of the testing for the drivetrain team surrounded tuning the Continuously Variable Transmission (CVT) and selecting the correct chain drive gear ratios for either higher top end speed or improved acceleration. The team noticed a significant difference in top speed between the 2019 – 2020 theoretical max of 29mph and the vehicle’s actual top speed of 19mph. Thus, the team set out to tune the drivetrain to help increase the performance and efficiency before competition.

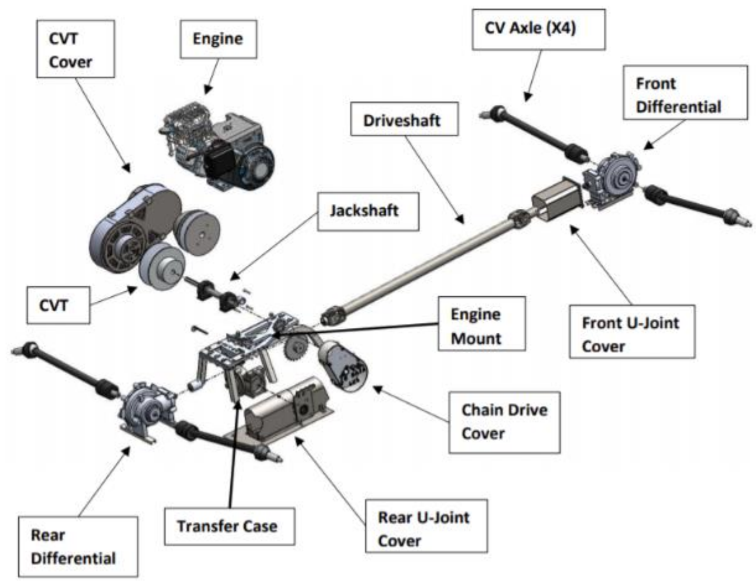

Figure 10: Exploded View of 2021 Drivetrain System

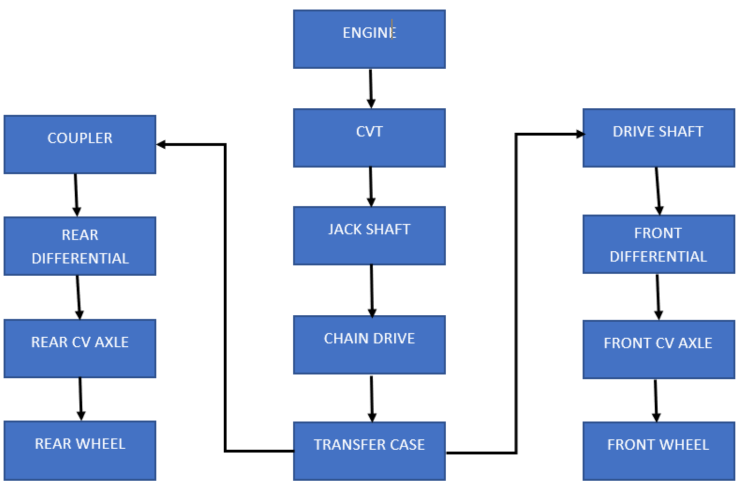

Figure 11: Flowchart outlining the power transfer from engine to wheels.

Testing

Testing was performed by collecting RPM of the primary and secondary pulley of the CVT. The team identified the CVT as the main source for efficiency loss due to its high variability with spring preload and belt tension. It was also relatively easier to change out springs compared to replacing an entire differential or transfer case with better gear reductions. RPM data was gathered using hall effect crankshaft position sensors mounted to the primary CVT pulley and the jackshaft (CVT secondary output). These sensors generate a high impulse signal when a magnet passes by and can be converted to RPM using the time interval between impulses.

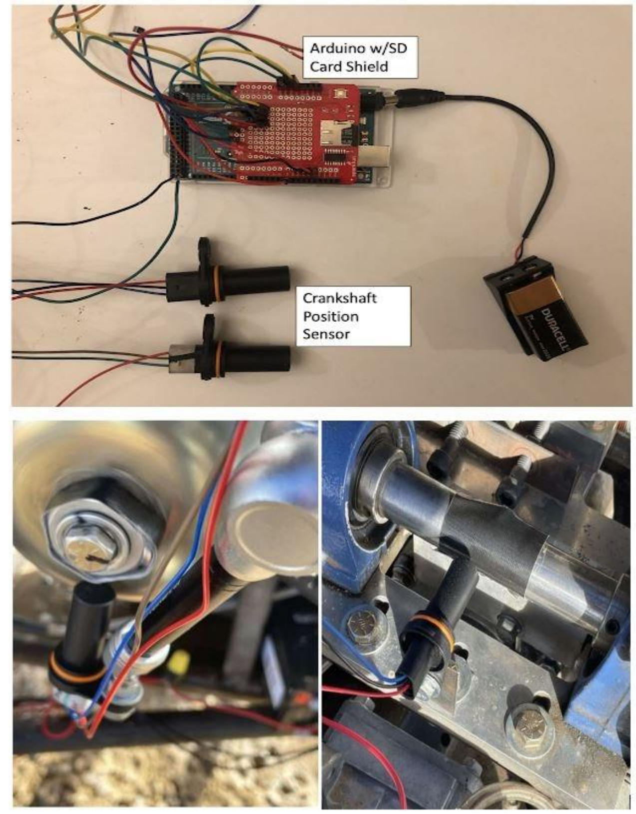

Figure 12: Arduino setup with SD card shield and crankshaft position sensors (Top), Primary CVT pulley sensor placement (Left), Secondary Jackshaft sensor placement (Right)

CVT (Continuously Variable Transmission)

A Continuously Variable Transmission is a system of two pulleys that are connected by a belt. The primary pulley is connected to the output of the engine and the secondary was connected to the chain drive via a jackshaft. As the engine speed changes, a mechanical system of springs, ramps, and flyweights engage to change the diameter of the pulleys. This changes the gear ratio of the system and, in turn, acts the same as changing gears in the transmission of a car.

The testing setup in Figure 11 allows for the ability to plot primary RPM, secondary RPM, and the gear ratio as a function of time. For ease of analysis the secondary speed was converted into wheel speed through a calculation of the overall ratio throughout the rest of the drivetrain. Overlaying primary vs. secondary data allowed the team to find the engagement and shift RPM for each CVT setup in relation to the target values. This provided the team with a method of evaluating different CVT setups to identify the most optimal gear ratio to achieve better acceleration and top speed closer to the theoretical maximum calculated by the 2019 – 2020 team. All of which are required to place well in the SAE Validation events. With the combination of chain drive primary sprockets, the CVT was tuned to achieve a maximum top speed of 23 mph which is an improvement based on the system at the beginning of the year.

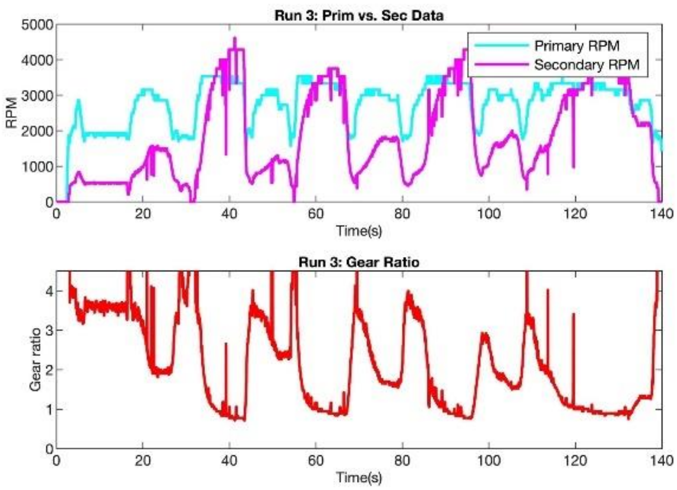

Figure 13: Primary versus secondary CVT RPM values from testing (Shown in Magenta and cyan). Spikes in Primary vs Secondary Data occurred during acceleration runs from a complete stop. Corresponding gear ratios over the same testing interval are shown in red.

The heat plot in Figure 13 was used to identify and predict the performance of third-party springs suitable for the targets that fit the dimensional requirements of primary pulley.

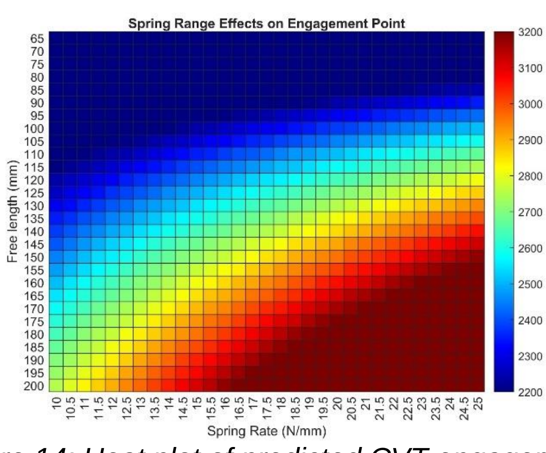

Figure 14: Heat plot of predicted CVT engagement RPM based on modeling and spring force calculations. Our target is between 2600 and 2700 RPM.

Chain Drive

The chain drive consists of two sprockets that connect the secondary pulley of the CVT via the jackshaft to the transfer case. A chain connects the two sprockets and transfers power to the rest of the system. To tune the chain drive, the sprocket sizes can be changed to find the optimal gear reduction in the system. A value judgement was made to continue using smaller diameter driving sprockets, as the larger sprockets tested drastically decreased the acceleration of the car. Ten, twelve, and eighteen tooth primary sprockets were tested for different CVT primary spring setups to gauge the acceleration and top speed of each sprocket. Both the ten and twelve tooth primary sprockets were considered for use at competition as they provided the highest top end and fastest acceleration while fitting within the current chain drive covers.

Transfer Case and Differentials

Figure 15: Polaris Sportsman Front Differential

Polaris Sportsman front differentials were used as both as a transfer case and traditional differentials in the vehicle. These were chosen by the 2019 – 2020 team for their ability to be electronically controlled by the driver. Power is transferred via the secondary sprocket of the chain drive into the transfer case, which distributes the power through the front and rear driveshafts to the differentials. The differentials and transfer case were not adjusted from last year's design as implementing other off-the-shelf components into the drivetrain would cause a cascade of manufacturing adjustments which was not possible given the lack of resources available to the team this year.

Suspension

Background

The suspension sub team was responsible for the front suspension system, which consists of the control arms, tie rods, steering uprights, front shocks, and CV axles, and rear suspension system, consisting of the trailing arm, rear toe links, rear uprights, rear shocks, and CV axles.

This year, the suspension sub team performed several tests on the 2019-2020 CU Boulder Baja front suspension system and used the data collected to inform a full redesign of the front suspension system.

Front Suspension

The Front Suspension system for the 2020 – 2021 vehicle is a Double A-Arm system comprised of two control arms to articulate the wheel through 10” of travel. These being the Upper Control Arm (UCA) and Lower Control Arm (LCA). To provide ample clearance for the new CV axles in the 4WD system, the front shocks were mounted to the UCA.

Both the UCA and LCA connect to the Steering Upright. The Tie Rods connect the upright to the Steering Rack and control the steering of the vehicle.

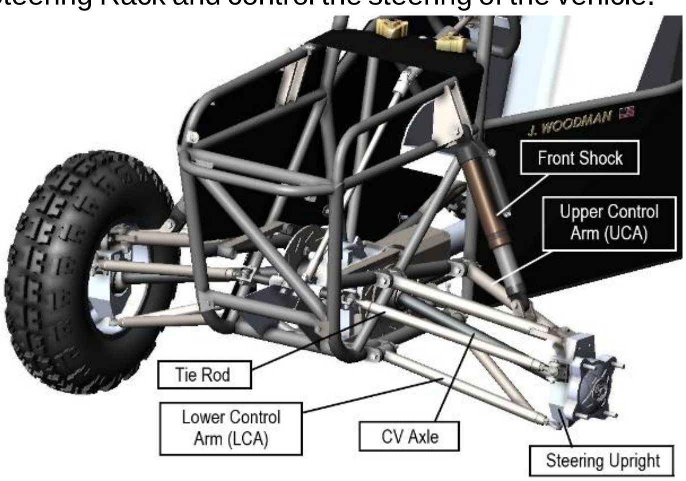

Figure 16: Overview of Front Suspension System

Rear Suspension

The Rear Suspension system features a linked trailing arm design where the Trailing Arm attaches to the rear of the chassis via two Toe Links per side. By configuring the support of the trailing arm in this manner, the system was more resistant to lateral impacts. The implementation of adjustable length toe links and a heim joint at the front mounting point of the trailing arm allows for adjustment of the camber and toe of the rear wheels. Integrated into the trailing arms were the aluminum uprights which house the wheel bearings. This design was introduced last year and was not changed for the vehicle this year.

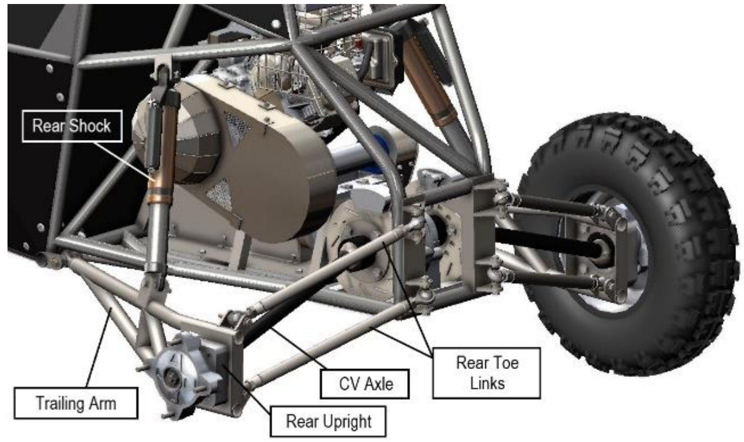

Figure 17: Overview Rear Suspension System

Testing

Testing for the Suspension sub team was primarily focused on the front suspension components. After the first few track days, poor kinematics in the system were identified by observing unacceptable maneuverability and handling characteristics. Manufacturing errors were also identified with this system from incorrect interference between components and errors in weld fixturing. If not remedied, the vehicle would not complete the maneuverability challenge at competition. In addition to fixing the poor performance, the suspension team wanted to validate external loading conditions that had been hand derived from previous Baja teams. Ensuring that the suspension dynamics and FEA models were accurate to the actual driving conditions of the vehicle. This helped make more informed design decisions and achieve the goal of improving suspension performance in corning and over rough terrain.

The team also designed a new remote Data Acquisition System with an Arduino Uno and a microSD card shield so to complete data logging without the need for bulky equipment. All the sensors used during the testing phase of the project were modular and connected to the centralized DAQ unit at the front of the cockpit via CAT5 cables. A modular DAQ unit provided the ability to complete multiple testing setups without significant change in the hardware or code. Data was synced with live video of the testing runs using RaceRender Software. This software was used to identify exactly what the loading conditions created specific features in the data.

Maximum Shock Force Testing

The first suspension test utilized Sharp Low Range Infrared Proximity sensors to measure the shock displacement versus time in a full bump or “bottom out” scenario. This would help in identifying the factor of safety of the 2019-2020 components and help evaluate if any parts were overbuilt based on incorrect loading conditions.

The 2017 - 2018 Suspension sub team completed an Instron test on the shocks to create a plot of shock displacement vs external loading at various shock pressure setups. Using this calibration curve, the team could characterize the spring force from the amount of displacement in the shocks at certain shock pressures. The damping force was then derived by finding the shock speed from the displacement data. Shock speed was compared to a set of curves given by Fox Factory which correlated shock speed with damping force at certain pressure setups. Summing both forces, a total external load being applied to the shocks and the suspension system could be found.

After completion of testing, the team found that the shocks observed a maximum of 850lbf spring force and 150lbf damping force with a total resultant force of 1000lbf. However, looking at the displacement data, the team found that they did not bottom out the shocks entirely and were about 1” away from full bump. If full bump was achieved, the maximum shock force observed would be 1600lbf. This value is significant as it was the maximum derived load calculated by the 2015-2016 team. Observing this value in actual testing conditions compared to simplified hand calculations meant that the team could validate the work done by previous suspension teams. This meant that this force was appropriate to use when deriving maximum loading cases for redesign analysis.

Strain Gauge Testing

The second set of tests used 350Ω Type-B Strain Gauges and Elecrow Arduino Strain Gauge Modules to measure the internal strain and forces during various driving conditions and terrain. The suspension team wanted to identify the internal loading of our suspension members to further characterize the external loading on the system in certain terrain features. This data helped identify more appropriate external loading conditions to use for FEA and Hand-Derived loading models during redesign. Additionally, this test was unique as no previous CU Baja team has been able to implement strain gauges successfully into their testing programs.

Force versus time data was gathered on the control arms, tie rods, and toe links. Calibration was completed on the gauges using a physical calibration method where axial loads were applied directly to suspension members and measured using a Load Cell. Arduino counts were collected from the gauges and associated with an applied axial load. This method worked well for simply supported members like the tie rods and toe links but proved to be much more difficult for the control arms. The suspension team identified areas of high stress concentrations from the 2019 - 2020 FEA studies and placed strain gauges in those locations. After completion of the test, loading data from the strain gauges was used to isolate axial versus bending loads. This was cross referenced with RaceRender video overlay to confirm the tensile versus compressive trends for certain suspension members was accurate.

Since the strain gauge system was calibrated to measure force, strain had to be derived from the force output. This was important because the suspension team could derive the maximum strain during testing runs, see where the event occurred, and compare the derived strain to outputs of FEA models. The team could then validate FEA results and initial boundary conditions to ensure that the models created were accurate to actual testing conditions. Using more accurate models sped up the iterative design process and allowed new suspension designs to be tested with simulated driving conditions close to what would be experienced out at the track.

Roll Rate Testing

The suspension team’s final test used a combination of a +/- 3g, 3-axis accelerometer and IR Proximity sensors to measure the amount of acceleration per degree of body roll or roll rate. This data helped us understand the maximum amount of body roll the car experiences at certain shock setups in a steady state turn which was important for developing an accurate Lotus SHARK Suspension Dynamics Model. The Lotus model was then used to create an ideal geometry to base the Front Suspension redesign from.

For this test, the DAQ microprocessor was upgraded to an Arduino Mega; allowing up to six analog inputs (six different sensors) to be read at once. Additionally, it ultimately maintained the read/write speed from the sensors to the microSD Card which was important for ensuring data was not clipped from the DAQ. This setup will be used during the final testing suite and passed down to future teams for more remote data logging with a proven system.

After reviewing the first set of data from this test, the data was found to be incredibly noisy. It was determined that the accelerometer was too sensitive and picked up engine vibrations as the test was conducted. To filter out this noise, the team used a Savitzky-Golay Filter which uses convolution with a high-order polynomial to filter out noise. This method was deemed acceptable for filtering noise in the lateral acceleration data sets after comparison to an ideal acceleration calculation. However, it was not acceptable for all longitudinal acceleration during the test. It was discovered that the filter worked only for isolated braking scenarios thus, the team only used the filtered longitudinal data immediately surrounding braking events. Regardless, the lateral acceleration data was appropriate to calculate our roll rate.

The test yielded a maximum lateral acceleration of the vehicle of 0.58G, maximum braking deceleration of 0.89G, and a maximum Roll Rate of 6.26 deg/G. In conjunction with the Center of Gravity test completed by the controls sub team, the suspension sub team added these results to the Lotus SHARK Suspension Dynamics Model.

Redesign - FEA and Lotus

Redesign efforts sought to make use of the data acquired in testing to inform a fully revised front suspension package. The system was designed using a top-down approach, beginning with the constraints the frame placed on the inboard geometry and the hubs placed on the outboard components, a new geometry was developed using Lotus to perform three dimensional kinematic simulations and quickly iterate through viable options. Particular emphasis was placed on camber control during both steering input and body roll, the need to minimize the scrub radius to reduce steering forces, and increasing steering articulation to the limit of the CV Axle Joints. All of these would help improve the vehicle's handling characteristics over variable terrain while reducing turning radius in steady state cornering. Ultimately, this would increase performance in the suspension challenge and maneuverability events.

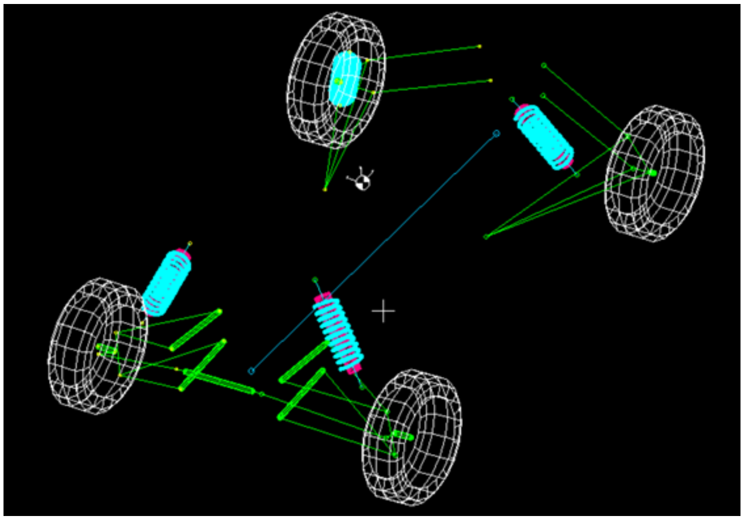

Figure 18. Full 3-D Lotus SHARK model used for kinematic simulation.

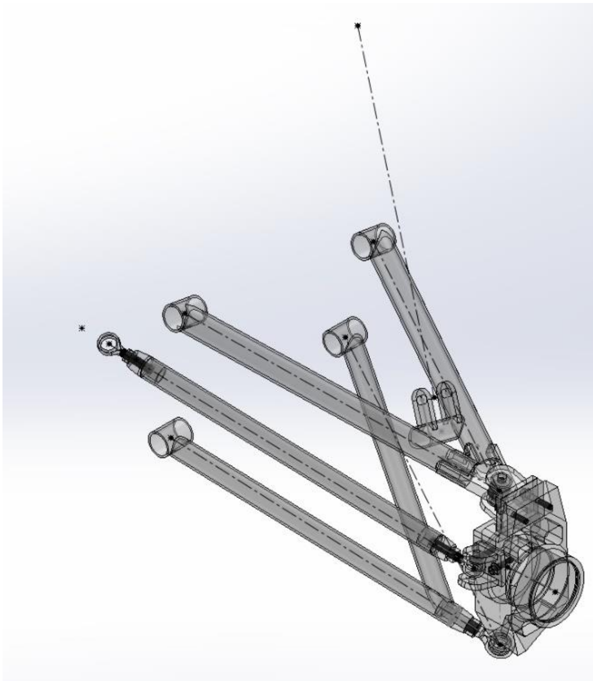

Figure 19. CAD assembly of redesigned suspension overlaid with top level geometry derived from kinematic simulations.

Strain gauge data allowed for the validation of suspension load cases and improved FEA studies that were previously based on rough estimates. Refined FEA studies were run on the control arms, tie rods, and uprights, and the stress concentrations identified were compared to strain gauge data collected during analogous suspension loads. This allowed for a reduction of unsprung mass in all parts of the front suspension, while being confident in the minimum factor of safety of 1.2. Reducing the unsprung mass reduces the steering forces felt by the driver and allows them to maintain better control of the vehicle through harsh terrain which is very desirable when trying to race for long periods of time.

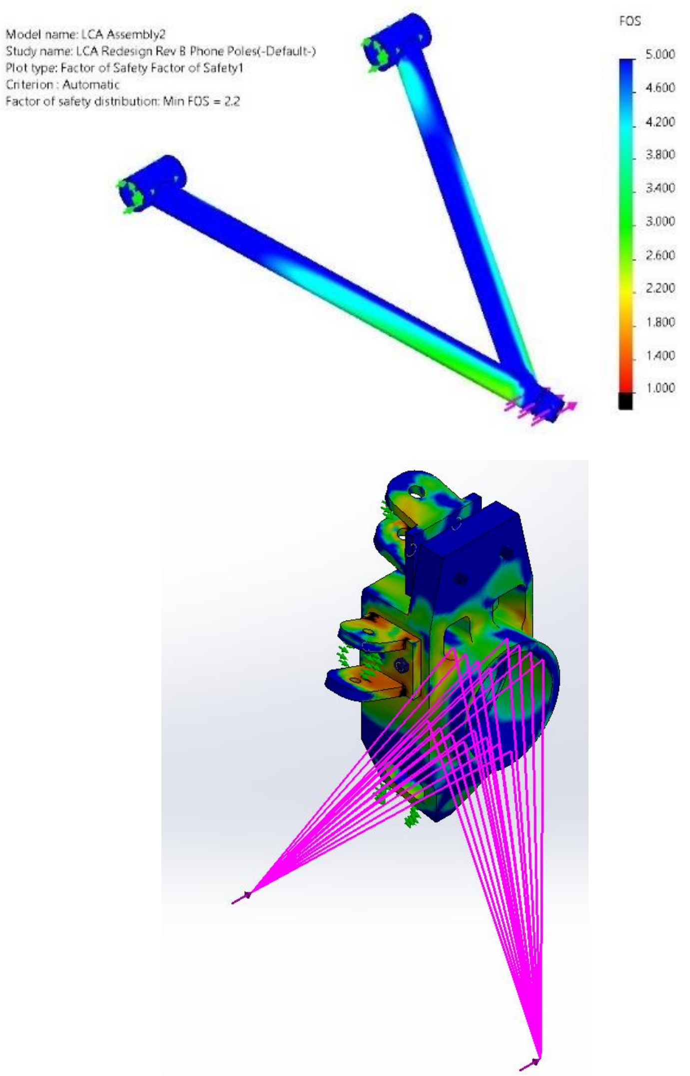

Figure 20. Lower Control Arm FEA in the Front Impact Study (Top) and Front Upright Assembly FEA using remote tire loads derived from impact data

Manufacturing

Due to the restrictions brought on by the pandemic the team outsourced most of the parts to be fabricated. The tubes for the redesigned front suspension were cut and coped in the Idea Forge before being welded together by a member of last year's Baja team. The geometry of the front suspension members needed to be very accurate to achieve the suspension characteristics the team had designed for, so fixtures were laser cut out of a piece of medium density fiberboard (MDF). Using these fixtures, the coped members of the control arms were properly aligned and held in place while tack welded together. Similar methods were used to create the tie rod and UCA mounts for the front uprights.

Figure 21. UCA fixtured in place during welding.

The uprights themselves were milled using a three-axis CNC milling machine in the ITLL. The uprights were designed for this method of machining to reduce machine time by minimizing tool changes and the number of times the billet needed to be reoriented. After the uprights were milled, the bearing housing needed to be bored out and a groove for a c-clip was cut using a lathe. Since the space between the wheel and upright was very tight, the UCA mounting bracket could not be fastened in place with a typical nut and bolt. To counter this, the through holes were tapped so that no extra nut or exposed threads could impact the wheel.

Figure 22. Redesigned Steering Uprights after CNC Milling Operations

The tabs of the shock mounts and the bearing plate inserts for the UCA water jet out of sheet metal. For the bearing plates further machining was needed to create the partial hole that the spherical bearing was later press fit into.

Figure 23. Redesigned Front suspension components including UCA, LCA, Steering Uprights, and Tie Rods

Conclusion

As the project comes to a close this spring, our team is eager for the opportunity to represent the University in the SAE Collegiate Design Series.

SAE International has decided to move forward with the in-person validation event this year in Tucson, Arizona and we will be travelling to test our technical knowledge and engineering designs in head-to-head racing with other Baja SAE programs. As we get the vehicle ready for competition, we are continuing to assess the physical performance gains of each redesign to ensure its aptitude for use in competition.

Overall, this project has been incredibly valuable to all our members and has given us an immense amount of knowledge towards completing a successful design project with a large team of dedicated engineers. We will be taking this experience with us into our careers and the rest of our lives.


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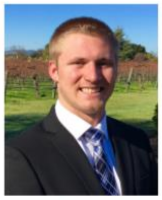
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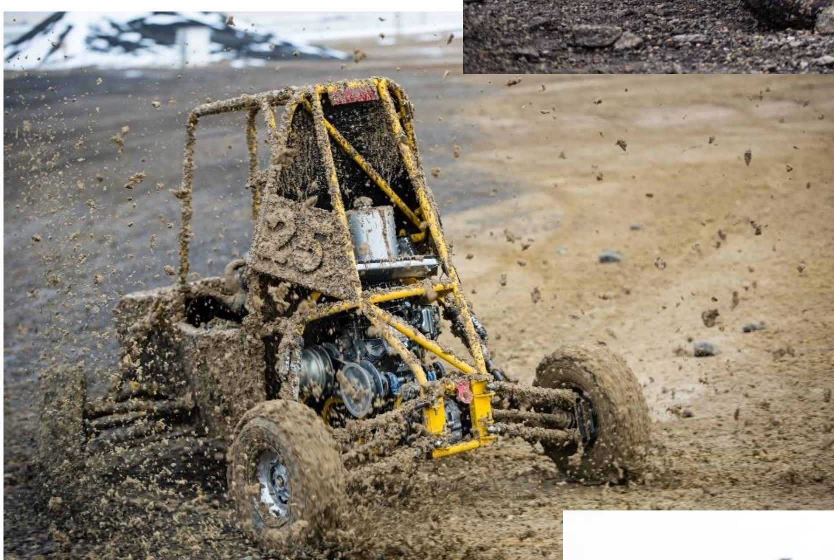
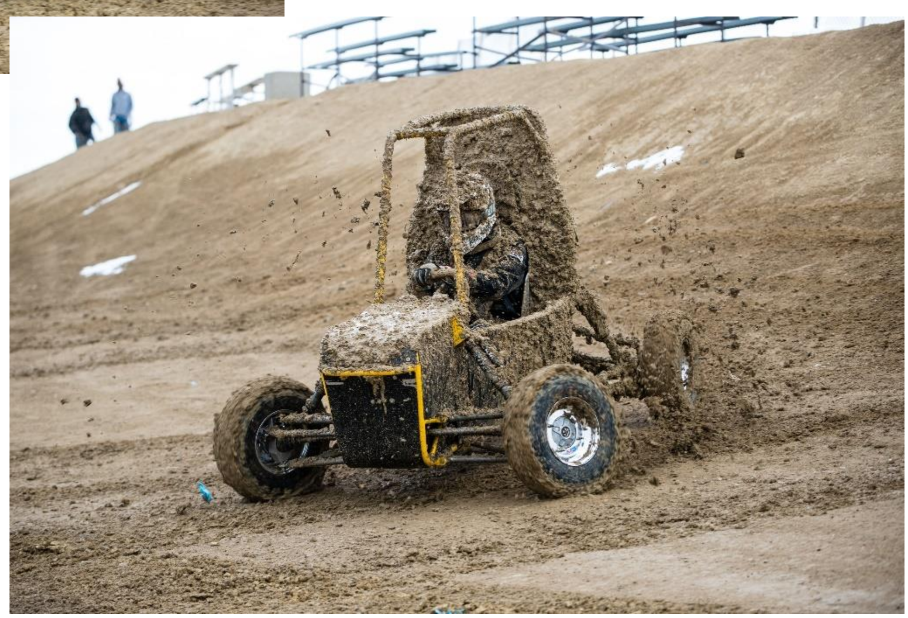
Additional Photos



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