Overview of Tasks

The following list of tasks gives a brief overview of the tasks that need to be completed in order to make a functional vehicle eligible for the e-BAJA 2025 competition. Further down the document, information is given as to how each component of the vehicle is made and how its functioning is validated.

Initial Preparation:

- Design and Manufacture Jigs-I.
- Procure Components from vendor.

Manufacturing Phase-I:

- Process and place tubes in Jigs-I.
- Work on the Design and Manufacture of Jigs-II.
- Finalize the mounting locations for suspension, steering and powertrain components in CAD software.

Manufacturing Phase-II:

- Process and place tubes in Jigs-II and continue till Jigs-III and Jigs-IV are completed.
- Perform Roll Cage Drop Test.
- Fabricate the front suspension and rear suspension arms.
- Verify location and attach mounts.

Manufacturing Phase-III:

- Attach Suspension components.
- Manufacture steering components.
- Attach Steering components.
- Perform Rolling Chassis Test.
- Attach Powertrain components.
- Attach Brakes.
- Perform Brake Test.

Testing Phase:

- Perform DVP&R.
- Optimize the vehicle by conducting tests simulating the endurance round.

Final Integration:

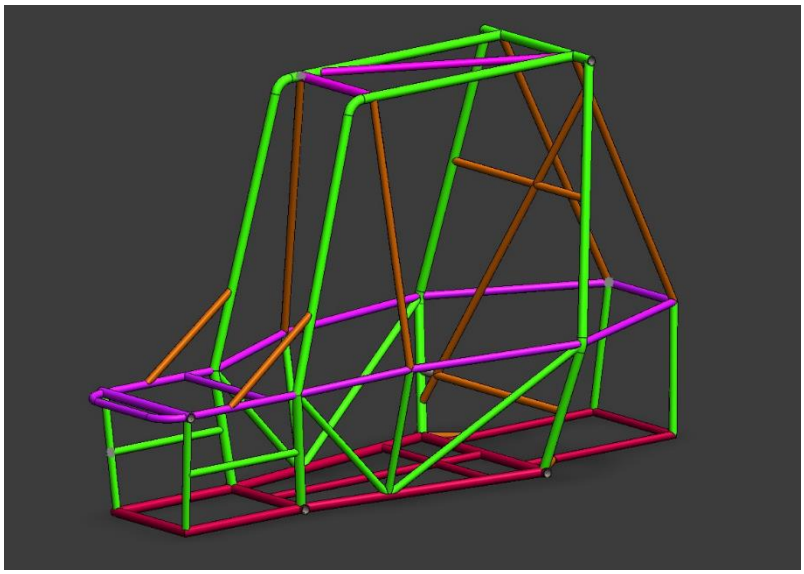
- Install all components which are required by the competition.
- Evaluate the vehicle based on the rulebook checklist.

Roll Cage

Design of Jigs

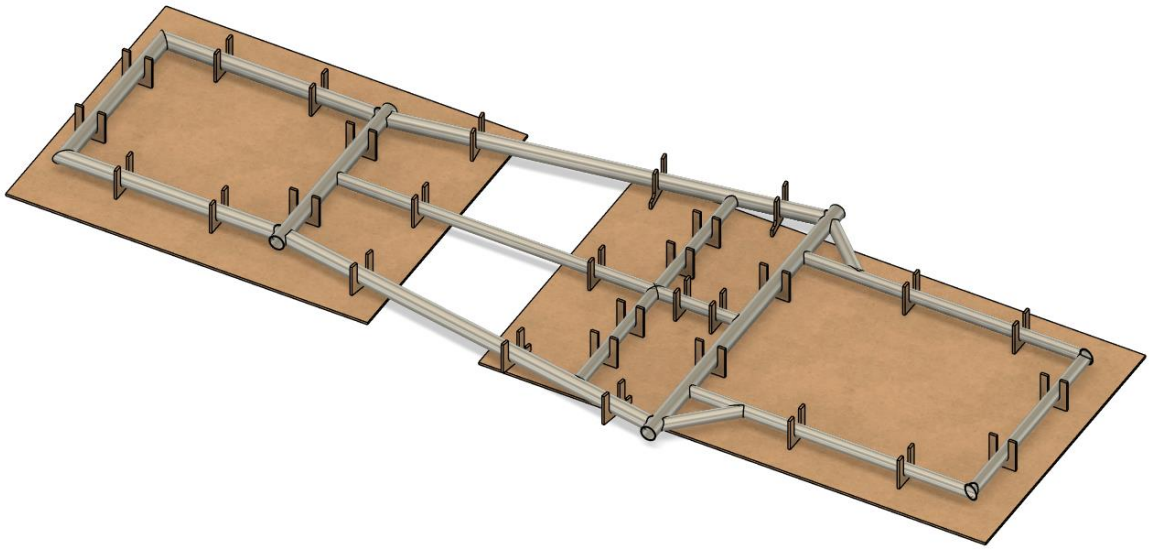
Purpose of Jigs: Jigs also mentioned as chassis jigs is of tool manufactured by us. It is made of MDF, and it holds all the tubes/members of the chassis in 3D-space. This allows for welding with minimal warping and greater accuracy.

The Jigs are designed so that they aid in building the roll-cage in three phases:



- **Phase-I** – [LFS, FLC, ELC, ALC, USM, FAB Rear]
- **Phase-II** – [RRH, FBM, RHO, BLC, FAB Rear]
- **Phase-III** – [GLC, RLC, CLC]
- **Phase-IV** – [FAB Rear, LDB, FAB Front] + Additional members + Gussets.

Jigs – I:



1. Laser cut the required items from the Jigs-I design file on MDF sheets.
2. Assemble the MDF pieces by inserting each piece into its designated slot with application of fevikwik.
3. Space the two MDF sheets apart and bolt them with the help of another piece of MDF sheet at the correct length.
4. Verify the distances between the mounting points to make sure that the manufacturing is correct.
5. Process tubes to place them in the jig.
    a. Label the name of the member on the tube
    b. Cut the tube to the length of the member
    c. Mark a scribe line on the tube
    d. Put a notching template on the tube and notch the tube with an angle grinder.
    e. Repeat this process for all base members.
6. Place the tubes on the jigs and align them.
7. Verify the distances and troubleshoot if any discrepancies are found.
8. Tack-weld all the members in place.

Jigs - II:

1. Laser cut the required items from the Jigs-I design file on MDF sheets.
2. Bolt the two MDF sheets together as shown in the figure to complete all the parallel slices of the jig.
3. Place all the parallel slices at their approximate location on the tubes. Use spacers to fix their distances.
4. Put the sidewall MDF sheet and slot in all the parallel slices in it. Attach the MDF sheet to the base.
5. Verify the lengths between holes.
6. Process tubes to place them in the jig.
    a. Label the name of the member on the tube
    b. Cut the tube to the length of the member
    c. Mark a scribe line on the tube
    d. Put a notching template on the tube and notch the tube with an angle grinder.
    e. Repeat this process for all Phase-II members.
7. Set all members to their positions.
8. Verify the lengths.
9. Tack-weld all members in place.

Jigs-III:

1. Process tubes to place them in the jig.
    a. Label the name of the member on the tube
    b. Cut the tube to the length of the member
    c. Mark a scribe line on the tube

   d. Put a notching template on the tube and notch the tube with an angle grinder.
   e. Repeat this process for all Phase-III members.
2. Place the tube between the two points and tack-weld it in place.
3. Repeat step 2 for all tubes.

Jigs-IV:

1. Process tubes to place them in the jig.
   a. Label the name of the member on the tube
   b. Cut the tube to the length of the member
   c. Mark a scribe line on the tube
   d. Put a notching template on the tube and notch the tube with an angle grinder.
   e. Repeat this process for all Phase-IV members.
2. Place members at their location and tack-weld.
3. Repeat step 2 for all tubes.

Weld all the tubes of the Roll cage.

Place the entire Roll cage on wooden blocks at ride height (12 in).

Mounts

Mounts are metal laser-cuts which are directly welded to the members of the Roll cage. Sub-assemblies are bolted to the mounts. Since all the sub-assemblies attach to the main chassis via the mounts, it is essential for them to be welded thoroughly on the Roll cage.

Manufacture of mounts:

1. Design the mounts in 3d CAD software.
2. Outsource the manufacturing job so that it can be laser cut.

Assembly of mounts:

1. Mark the position of mounts according to the 3d-CAD model and tack the mounts accordingly.
2. **Suspension mounts:**
    a. Assemble the suspension sub-assembly [*refer Suspension]*.
    b. Check the motion of the suspension.
    c. Verify the critical angles of the knuckle (Caster, KPI).
    d. Attach the shock and verify the angle between the hole and the tube of the mount, make sure it is aligned to the shock at ride-height.
3. **Steering mounts:**
    a. Assemble the steering sub-assembly [*refer Steering*].
    b. Verify the total angle change of the wheels with the designed value.
    c. Verify the maximum and minimum toe-angle adjustment capability.
4. **Powertrain mounts:**
    a. Attach the motor.
    b. Check shaft alignment.
5. **Brake pedal mount:**
    a. Ensure that the master cylinder fits properly, and its piston moves with the action of brake pedal throughout its range.
6. **Skid plate mount:**
    a. Attach mounts parallel to the ground and tangential to the base members.
7. Fine-tune the position of mounts such that wheelbase, trackwidth, steering angle, shaft angle are according to design.
8. Weld the mounts.

Suspension

Suspension: Fabrication of Front suspension

ℹ️ This section contains details on how to fabricate the arms of the front suspension.

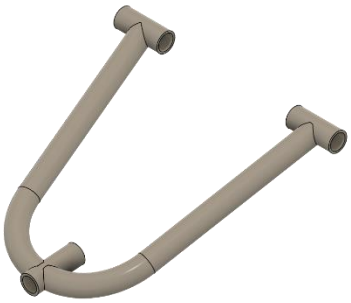
Note:

- This section does not contain details on calibration of the shock stiffness, camber angle, toe angle.
- The bent part of the arms is already bent by the vendor.

Fabricate upper wishbone:

a. Cut the tube which holds the ball joint to the designed length.
b. Notch the half-tubes so that they can hold the arm.
    i. Put both the tubes on a level floor and draw a reference line on them.
    ii. Stick the notching template at the design angle to the line.
    iii. Notch.
c. Notch the other ends of the half-tubes according to design.
    i. Use the reference line.
d. Cut two tubes of designed length and tack weld them to the half-arms.
e. Tack-weld the ball joint tube to the arm.
f. Put in a bushing in the tube with the right female thread size.
g. Insert the ball joint into it.

Fabricate Lower Wishbone:



h. Manufacture this like the upper wishbone.
i. Fabricate the middle tube.
    i. Choose the correct dimension tube.
    ii. Cut it to the correct length.
    iii. Make a reference line on it.
    iv. Put the notching templates at the correct angle using the reference line.
    v. Notch the tubes.
j. Attach the tube between the half-tubes, such that both the notches sit snugly in between.
k. Verify the position of the tube with measuring tape.
l. Weld it at that position.

m. Put in a bushing in the tube with the right female thread size.
n. Insert the ball joint into it.

Suspension: Fabrication of Rear suspension arms

ℹ️ This section contains details on how to fabricate the arms of the front suspension.

Note:

- This section does not contain the details of calibration of shock stiffness, camber angle, axle lengths.

Fabricate lower H-arm:

1. Cut the small tubes to designed length.
2. Fabricate the middle tube.
    a. Draw a reference line on it.
    b. Put notching templates on either end using reference line.
    c. Notch.
3. Fabricate the main arms.
    a. Draw a reference line on it.
    b. Put notching templates on either end ensuring proper relative angles using the reference line.
    c. Notch.
        ⚠️ *Ensure that the notch angles are precise!*
4. Tack-weld the four small tubes.
5. Position the middle tube, so that it fits snugly between the arms. Use the notch to put it in place.
6. Verify the lengths and angles.
7. Weld all tubes.

Fabricate the control rod:

1. Cut the tube to the designed length.
2. Weld right-hand thread nut to one end and left-hand thread nut to the other end.
3. Screw in the ball joints.

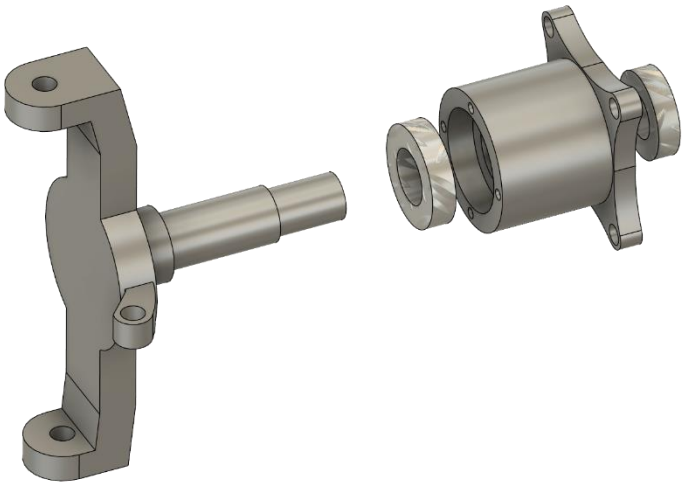
Suspension: Attach Knuckle & Wheel hub

ℹ️ This section contains info on how to mount the knuckle to the wheel-hub and also how to mount the knuckle-wheel-hub assembly to the arms.

Note:

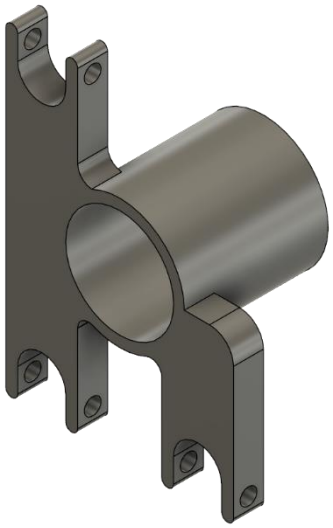
- This section does not contain information on how to calibrate the suspension.

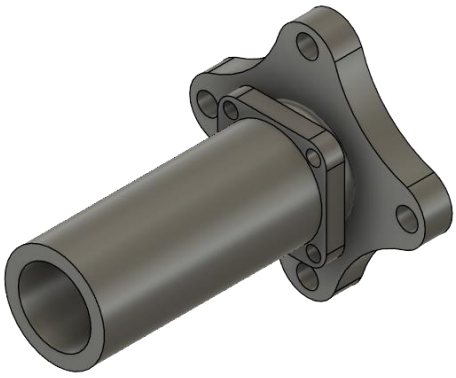
Attaching front knuckle to wheel-hub:



1. Mount the brake rotor to the wheel-hub.
2. Insert the 55mm OD ball bearings in the slots provided in the wheel-hub.
3. Slide the cylindrical extrusion of the knuckle through the wheel-hub.
4. Add a lock nut at the end of the knuckle to hold the assembly together.

Attaching the rear knuckle to the wheel-hub:





1. Mount the brake rotor to the wheel-hub.
2. Insert 90 mm OD ball bearings into the knuckle on either side.
3. Guide the wheel-hub through the ball bearings in the knuckle.
4. *FIGURE OUT HOW TO LOCK THE WHEEL-HUB IN THE KNUCKLE*.

Attaching the knuckle to the front wishbones:

1. Insert the ball joint on the top arm to the top hole of the knuckle. (The hole which protrudes out more than the other).
2. Put a lock nut on the lower side of the ball joint, tighten it and lock it with a key/cable.
3. Insert the ball joint on the bottom arm to the bottom hole of the knuckle.
4. Put a lock nut on the ball joint and tighten and lock it with a key/cable.

Attaching the knuckle to the rear H-arms:

1. Align the H-arm's two mounting holes with the knuckle.
2. Insert bolts through the knuckle and the H-Arm and tighten those nuts to spec.
3. Attach the ball joint on the control rod to the rear knuckle and lock the nut.

Suspension: Calibration

⚠️ **Make sure that the vehicle is at the correct ride height!**

- Raise the entire roll cage to the ride height (12 in) using wooden blocks.
- Attach all suspension components to the vehicle.
- Attach the wheels to the knuckle.

Front Suspension:

1. Attach all the front suspension components to the vehicle.
2. Inflate the tyres to the correct pressure rating.
3. Put a digital level meter and adjust the camber angle to the designed value by changing length of ball joint protrusion by rotating it at its base.
4. Ensure that the trackwidth of the car is close to the designed value. If not turn both the ball joints to the same extent to adjust the trackwidth without changing the camber setting.

Rear Suspension:

1. Attach all the rear suspension components to the vehicle.
2. Inflate tyres to the correct pressure rating.
3. Use a digital level meter and adjust the camber angle by turning the entire control rod about its axis.

Shock Stiffness:

⚠️ **This should be done before every test or if considerable amount of weight is mounted to the car.**

1. Attach the shocks between the mounting points on the lower wishbone on the front suspension arm and the roll cage mount, as well as the rear shock mounting point and the mount on the roll cage.
2. Ensure that the vehicle is over a flat surface.
3. Load the vehicle to its designed load rating (GVWR).
4. Measure the height of the vehicle from four corners of the roll cage, adjust the shock/spring pre-load by turning the adjustment nut on it.
5. Ensure that all corners of the vehicle are at ride height.
6. Verify the height of the center point of the vehicle and measure the angle it makes with the using a digital level meter.

Steering

Steering: Mounting the Steering wheel

1. Design and weld a ball bearing holding bracket onto the roll cage.
2. Take the appropriately sized tube and cut it to the designed length.
3. Insert a ball bearing in the bracket.
4. Insert the tube through the ball bearing.
5. Lock the tube in place by welding nuts placed on the tube on either side of the ball bearing.
6. Attach the steering wheel to the other end of the tube and lock it in place by tightening the nut on the steering wheel.
7. Attach a double cardan joint to the other end of the tube and tighten it with the bolt present on it.

Steering: Complete the rack & pinion assembly

1. Attach the pinion to the other end of the double cardan joint.
2. Insert the pinion into the rack structure. Make sure that the number of rack teeth on either side of the pinion gear is the same.
3. Attach the locking plate on top of the rack and pinion, so that the pinion doesn't slide out of the assembly.

Steering: Manufacture tie-rod

1. Take the designed dimension tube.
2. Weld a nut at one end of it.
3. Attach the ball joint to that nut.
4. Manufacture the U-shaped clamp by welding three metal plates together normally. Ensure that all the plates have the appropriately
5. sized hole for bolt.
6. Connect the U-shaped piece to the tie-rod.

Steering: Mount the rack & pinion assembly

1. Attach the tie-rod to the knuckle, by putting the ball joint in the hole provided in the knuckle and then use a lock nut to lock it in place.
2. Attach the other end of the tie-rod to the rack using the proper fasteners.
3. Weld a mounting plate (with proper holes) at the designed location at an angle such that the double cardan joint isn't straining too much.
4. Bolt in the rack and pinion on the plate.

Steering: Toe angle Calibration:

⚠️ **Make sure that the vehicle is at the correct ride height!**

1. Make sure that the entire suspension system and tyres are assembled.

2. Set the steering wheel to the neutral position. Mark a line on the steering column and the ball bearing. This is to ensure that the steering wheel stays in the neutral position.
3. Hold the front part of Jigs-I to the base of the roll cage. Attach an MDF sheet perpendicular to the base.
4. Measure the base perpendicular distance from the front edge of the wheel and the rear edge of the wheel.
5. This difference between these lengths and the diameter of the wheel can be used to calculate the toe angle.
6. Adjust the toe angle accordingly by rotating the tie-rod ball joint.

Brakes

Brakes: Mounting the hardware

1. Mount the brake caliper to the knuckle. Make sure that the brake rotor is not touching the brake caliper when brake is not applied. Use spacers to ensure this.
2. Attach the Master cylinder to the mounting point provided on the roll cage.
3. Hinge the brake pedal on the mounting point created on the roll cage.
4. Attach the master cylinder piston to the brake pedal.
5. Flare the brake lines and insert them into the master cylinder.
6. Route the brake lines along the designed path on the roll cage making sure that the brake lines follow the shortest path along the roll cage and avoiding areas where it may get damaged due to road debris.
7. Fix the brake lines to the roll cage using clamps.
8. Attach the brake lines to brake hoses and guide the brake hoses to the brake caliper on the suspension arms.

Brakes: Bleeding the brakes

Start with the brake caliper which is the farthest from the master cylinder.

1. Fill the brake fluid reservoir with DOT4 brake fluid.
2. Put a transparent pipe on the bleeder valve of the brake caliper.
3. Put a wrench on the bleeder valve ready to open it when necessary.
4. Pump the brake pedal a few times before depressing it completely and holding it there.
5. At this point, open the bleeder valve slightly and then close it.
6. Repeat this process multiple times, until the brake pedal is firm and no longer feels spongy.

Powertrain

Testing

Roll Cage Drop Test:

1. Ensure that all sub-assemblies are detached.
2. Drop the Roll cage from a height of x ft.
3. Check all the welds. If any weld is weak, inspect the area and reweld it properly.

Rolling chassis Test:

1. Assemble the suspension and steering components.
2. Roll the vehicle on a flat surface.
3. Judge the rolling friction.

Roll-Over Test:

1. Assemble the suspension, steering and brake components.
2. Set the vehicle on a decline and depress the brake pedal while standing outside the vehicle.
3. Roll the car over.
4. Inspect for damages.

Brake – Test:

1. Assemble all the powertrain, suspension, steering and brake components.
2. Accelerate the vehicle to 45 kmph.
3. Apply max brake pedal force.
4. Ensure the locking of all four wheels simultaneously.
5. Check for brake fluid level changes / Leakages in the circuit.
6. Check the brake pipe temperature.

DVP&R – (*Not decided entirely as of now*)

Gradeability Test:

1. Set the vehicle on an incline of designed gradeability of vehicle.
2. Test to see if the vehicle can propel itself forward without the front wheels lifting off the ground.

Top-Speed Test:

1. Accelerate the car to its max speed and measure it.
2. Verify the value with the design specification.

Evasive Manoeuvre test:

1. Test the manoeuvrability of the vehicle at its max speed.

Straight Line test:

1. Draw a straight line on a flat road.
2. Drive the vehicle while holding the steering at its neutral position.
3. Measure the deviation of the vehicle from the straight line.

4. Repeat the same test, without holding the steering wheel and check for unintended steering wheel rotation due to uneven friction. (Toe angles are not equal).

Turning Radius test:

1. On a flat surface, drive the vehicle in a circle by turning the steering wheel to its stop (extreme position).
2. Draw a line on the ground while doing so.
3. Measure the resulting radius of the circle.

Rulebook Validation

This requires thorough reading of the rulebook and checking to see if all the rules are followed.

Miscellaneous

Notching Templates:

For custom angles:

1. Use the website Notching Template, or use SolidWorks flatten tool.
2. Print the template on a piece of paper, cut it and roll it around the tube. Ensure that fit to scale is turned off in the print setting.
3. (Optional) Use vinyl cutter to directly cut the exact template and then wrap it around the tube.
4. Use an angle grinder/Fein multi-tool to notch the tube.

For standard angles:

1. Design a 3-D printable sleeve in CAD for different angles and different tubes.
2. Make sure to include a slit in the sleeve, so that it can slide in easily and fits in snugly.

Skid Plate:

1. Measure the area of skid plate material (not decided yet) required using the cad model.
2. Cut the material to the decided dimensions and include holes for bolting it.
3. Put the skid plate on top of the mounts and then bolt it in.
4. Grind the skid plate if dimensions are not perfect.

Seats:

- Mounting of the seat would depend on the seat. This would be decided after the seat is purchased.

Side Panel:

- Use plastic or fiberglass or metal side panels. (Further details would be explored after the testing phase of the vehicle).

Fire Extinguisher:

- Refer to the rulebook and attach the mounts accordingly.

Driver Safety Kit:

- Ensure the proper safety harness is used according to the rulebook.
- Ensure that the correct helmet is used.

Firewall:

- Attach mounts on the RRH member for the firewall.
- Cut a metal sheet of appropriate dimension and fasten it using metal fasteners.

- Ensure that it covers the area between the ALC and the BLC.