Building the Vehicle Frame

Chris Jones, Chief Race Judge

Building the Vehicle Frame

- **Materials**
- **Safety Cell, Roll bar and Crush Zones**
- **Suspension and Steering**
- **Wheels and Brakes**

Material for the frame

- **Mild/Carbon Steel**
  - Really easy to work with (MIG welding)
  - Inexpensive (~$2/foot)
  - Heavy
  - Can be easily changed/modified
  - Readily accessible
  - Comes in a large variety of sizes and wall thicknesses

Material for the frame

- Chromoly Steel
  - More expensive (~$12/foot) (+welding wire @ $15/lb)
  - Light weight
  - Can be easily changed/modified
  - Comes in a large variety of sizes and wall thicknesses

Material for the frame

- Aluminum
  - Very stiff for its weight
  - Harder to weld (TIG)
    - MIG is possible, but not wire-fed
  - Generally tubular; notch to get better fit
  - Needs more material to resist fatigue
  - Can be difficult to repair

Material for the frame

- Carbon Fiber (composites)
  - Lightest and stiffest
  - Can be formed to any shape
  - Expensive
  - Needs careful planning
  - Learning curve is steep
  - Very hard to repair on the side of the road
  - Need professional engineer certification and destructive testing if used for safety cell, roll bar, or crush zone

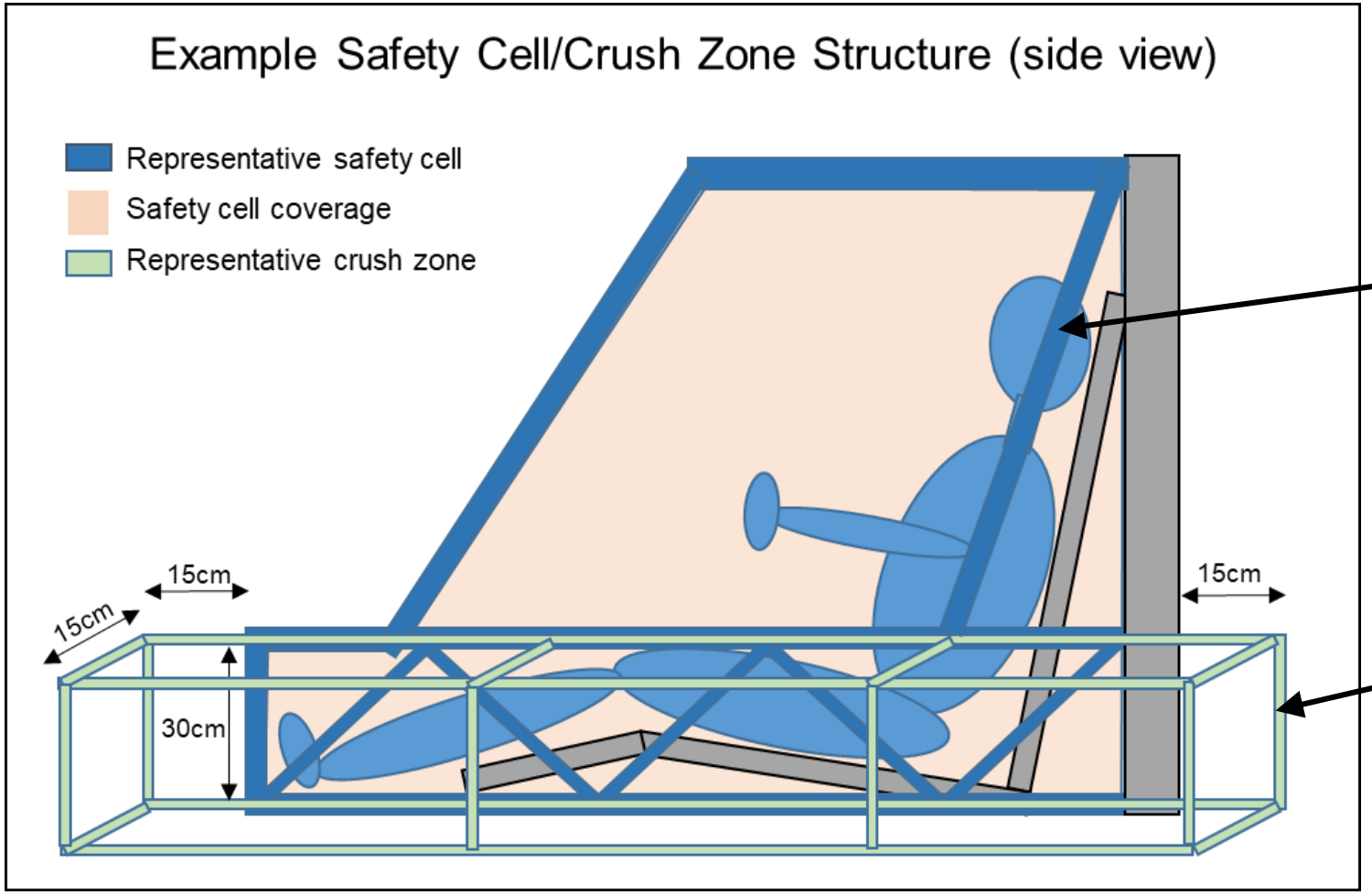
Building the Vehicle Frame

- Materials
- Safety Cell, Roll bar and Crush Zones
- Suspension and Steering
- Wheels and Brakes

Safety Cell, Crush Zone, Roll Bar

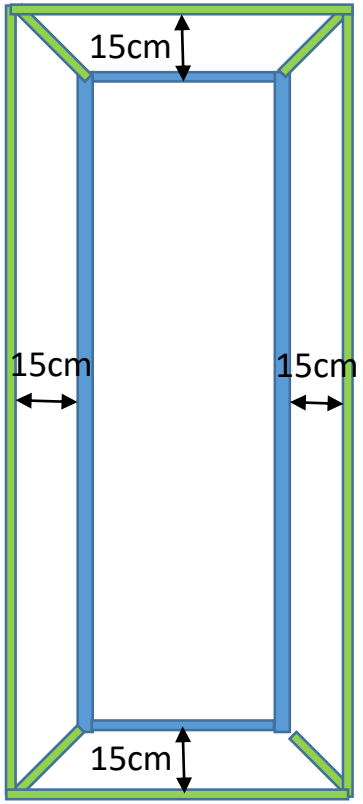
- Safety Cell (previously Roll Cage) – ***rigid protection*** encompassing entire driver; minimum OD of 1.9cm; minimum 5cm clearance to driver; minimum coverage
- Roll Bar – ***protects driver in event of rollover***; continuous piece of metal; minimum 5cm vertical clearance; minimum OD of 5cm; minimum wall thickness based on material; welded to frame (or 5G protection)
- Crush Zone – structural components ***designed to collapse*** on impact; minimum 15cm clearance to *outside of safety cell*; minimum height for left/right crush zone

Safety Cell Structure



Safety Cell encompasses driver's head, torso, legs, feet

Minimum height for left/right side crush zone = 30cm



Crush Zone

- **Crush zone must:**
  - **be designed to absorb impact from a collision**
  - **protect the driver from front, side, and rear collisions**
  - **have a minimum of 15 cm of horizontal distance from the outside of the safety cell**

- **Teams must be able to demonstrate a specific, adequate crush zone in order to compete. Insufficient regard for structural safety will result in disqualification.**

Safety Cell / Roll Bar / Crush Zone Good Example

Safety Cell Coverage – If wrapped in elastic fabric, no part of driver should touch fabric (other than arms holding steering wheel)

Roll Bar – continuous piece of metal; protects driver in event of rollover

Crush Zone structure – thin material designed to collapse on impact

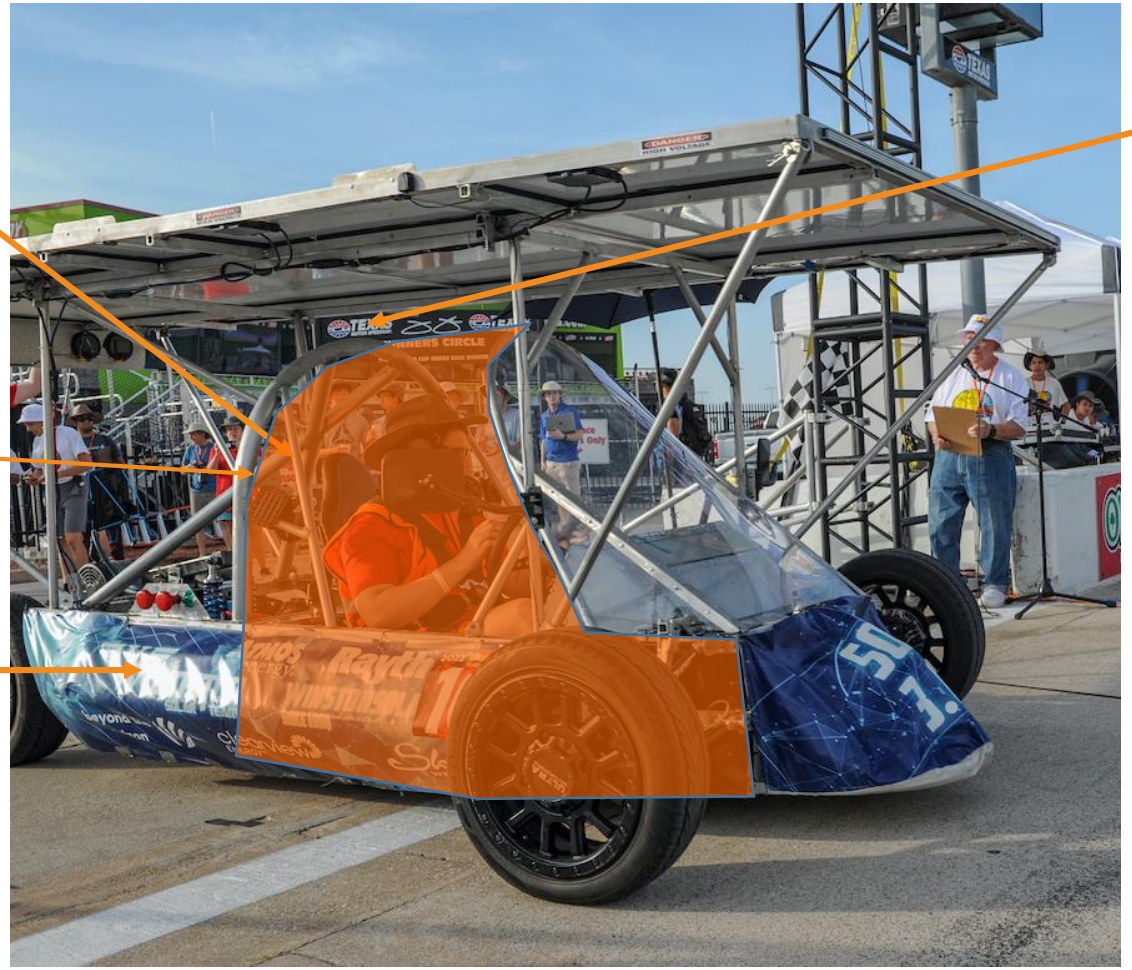
Safety Cell – rigid protection encompassing entire driver

Safety Cell / Roll Bar / Crush Zone Example

Safety Cell – rigid protection encompassing entire driver

Safety Cell Coverage (in orange)

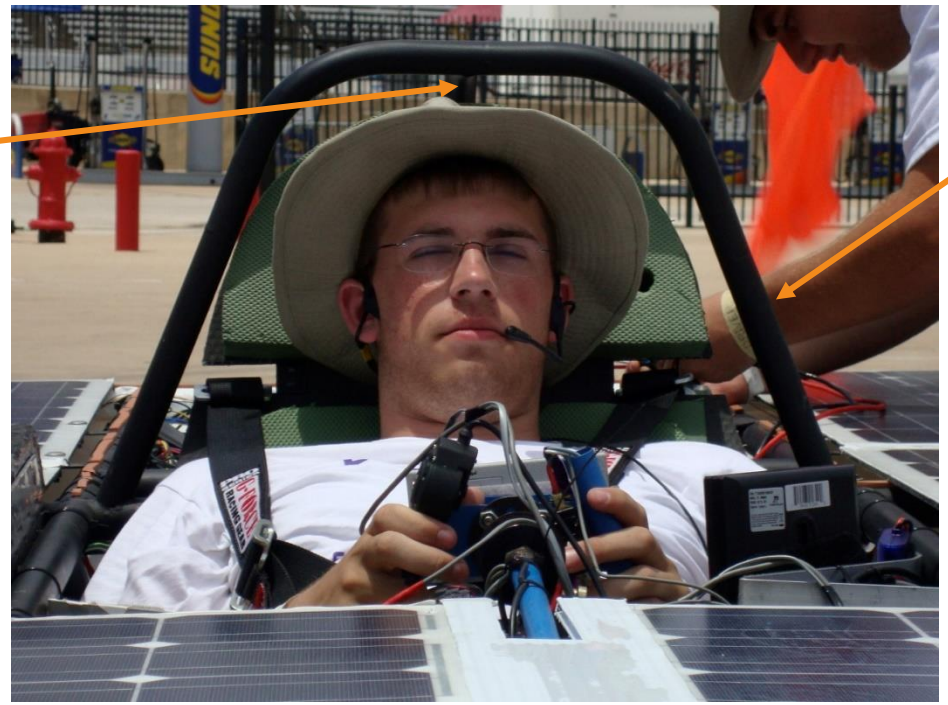
Crush Zone structure – may not meet 15 cm



Roll Bar – continuous piece of metal; protects driver in event of rollover

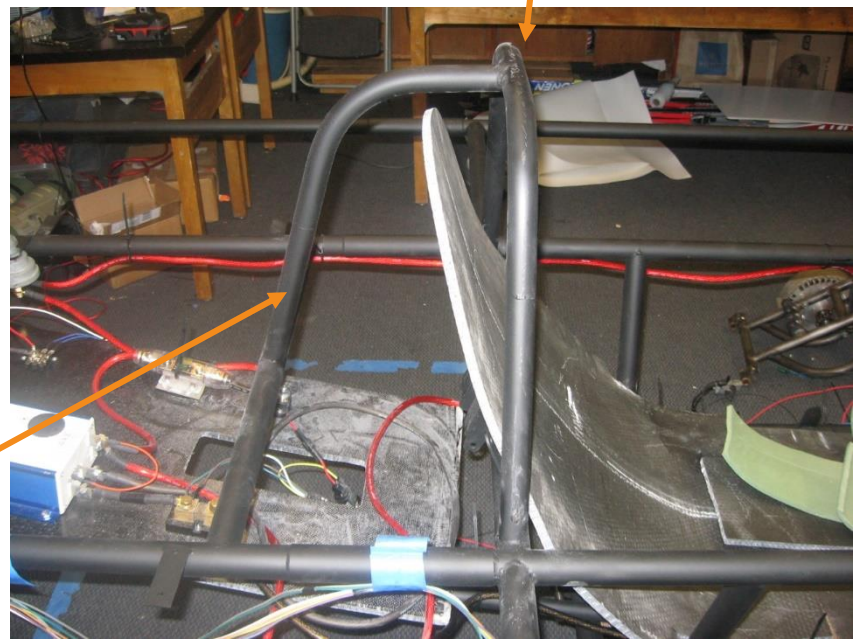
Roll Bar Example

Sufficient vertical clearance (5 cm between head and underneath of bar)



Continuous piece of metal

Side View



Front View

Material OD is less that what the rules specify but a waiver was granted

USE THE WAIVER PROCESS (RULE 5.21)

Roll Cage / Crush Zone Example

Crush Zone – would prefer structure less rigid and deflect away from driver

This is one dimensional and would not pass current rules

Safety Cell – good use of strong structural components; needs additional coverage for driver torso

Building the Vehicle Frame

- Materials
- Safety Cell, Roll bar and Crush Zones
- **Suspension and Steering**
- Wheels and Brakes

Suspension Design

Agenda

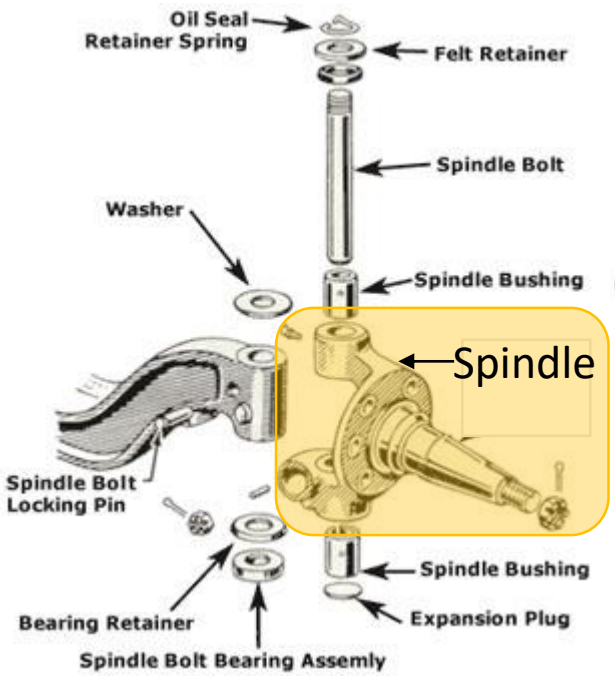
- Purpose of Suspension
- Suspension components
- Types of Suspension
- Basic Suspension Geometry
- Steering Geometry

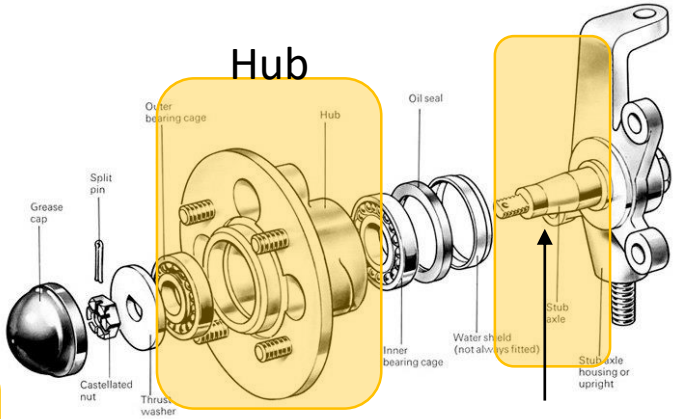
Suspension Purpose

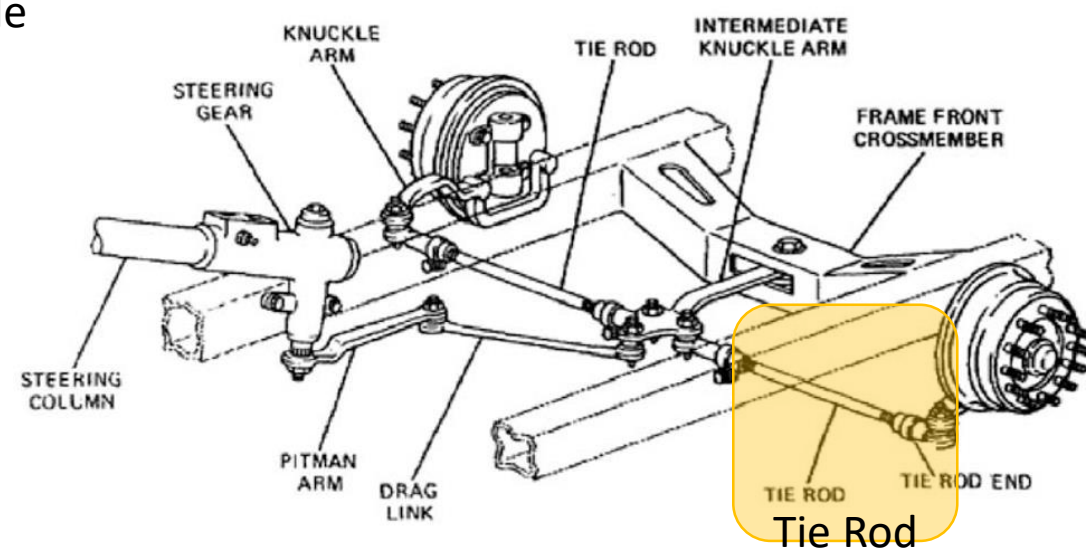
- Minimize shock to the driver and the car

- Enhance car stability while traveling on dynamic terrain
  - Keep the Tires on the Ground
  - Seriously, Your tires are the only connection the car has to the ground

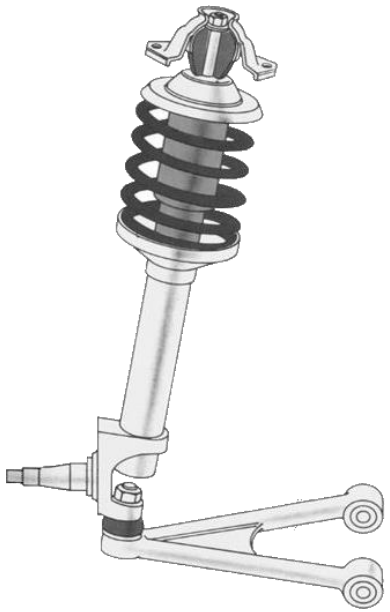
Suspension Components





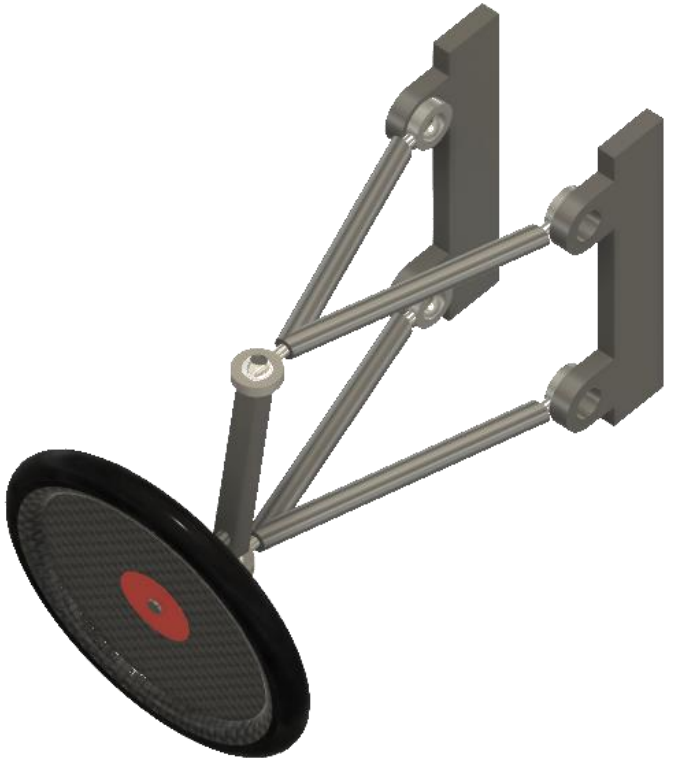


Common Front Suspension Types



MacPherson Strut

Solid Axle



Dual A Arm

Common Front Suspension Types

	Macpherson	Solid Axle	Double Wishbone (Dual A-Arm)	No Suspension
Pros	• Less Components • Easier to build	• Simple • Inexpensive • Easy to manufacture	• Versatile • Most popular (Easy to find parts) • Most Adjustability	• Less weight • Less components • Easy to make
Cons	• Limited Adjustability • Heavy • Undesirable Handling	• Heavy • Poor ride quality	• Complicated (lots of areas to make mistakes) • Difficult to manufacture	• Rough on other components • Require Strong Chassis(& Driver) • Will fail on road race

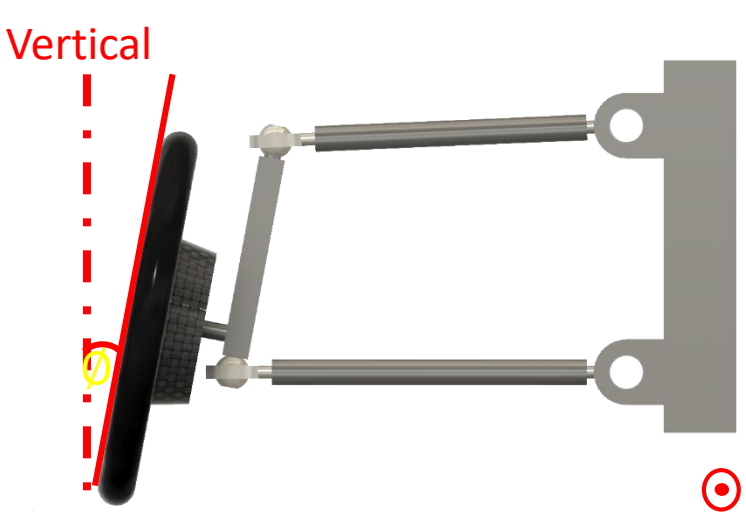
Some Tips about Suspension

Lets pause for a second…

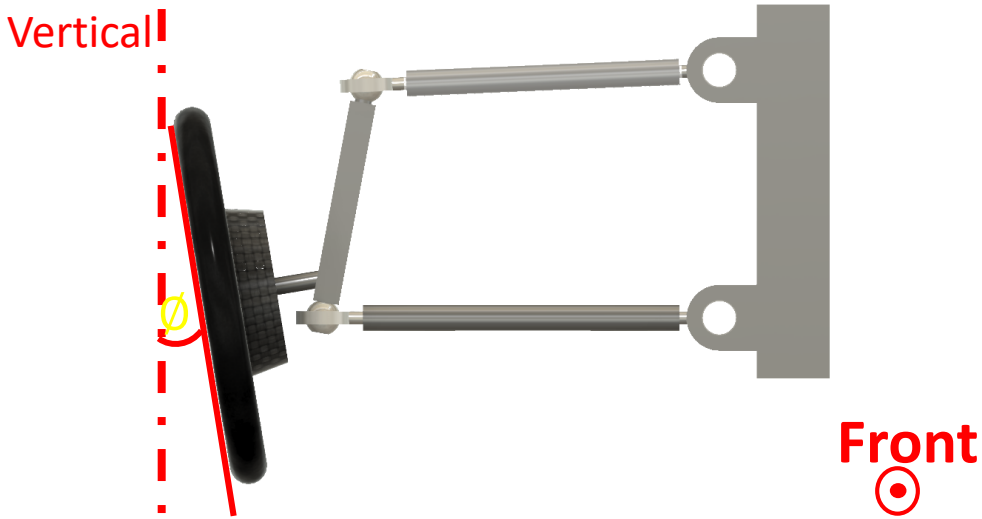
- **Suspension Can be very complex**
  - **Don’t Fall into the rabbit hole!**
  - **Design for Strength**
  - **Design for Adjustability if possible**

Suspension Geometry

- **Rear/Front View**
  - **Camber**



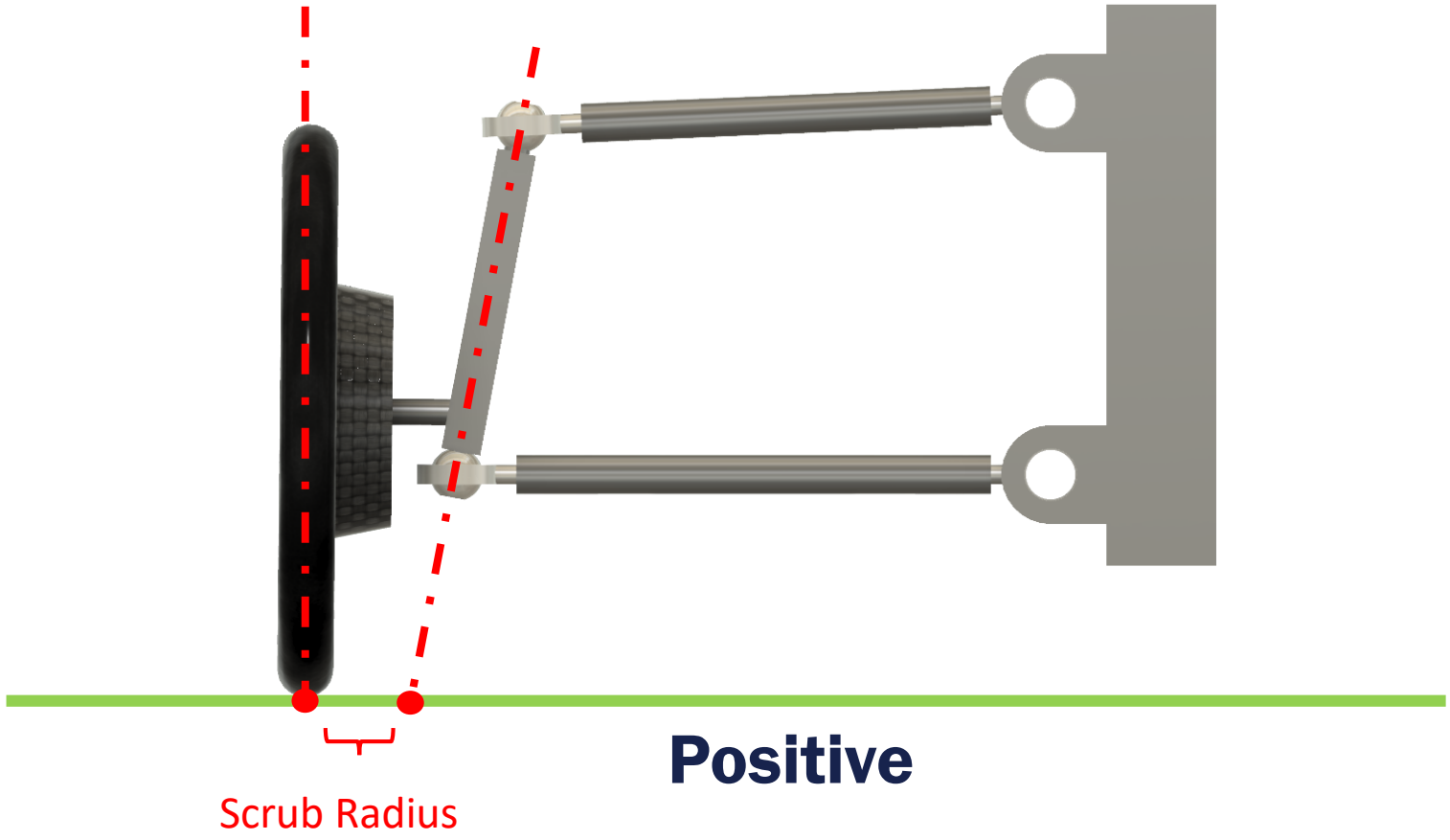
Negative



Positive

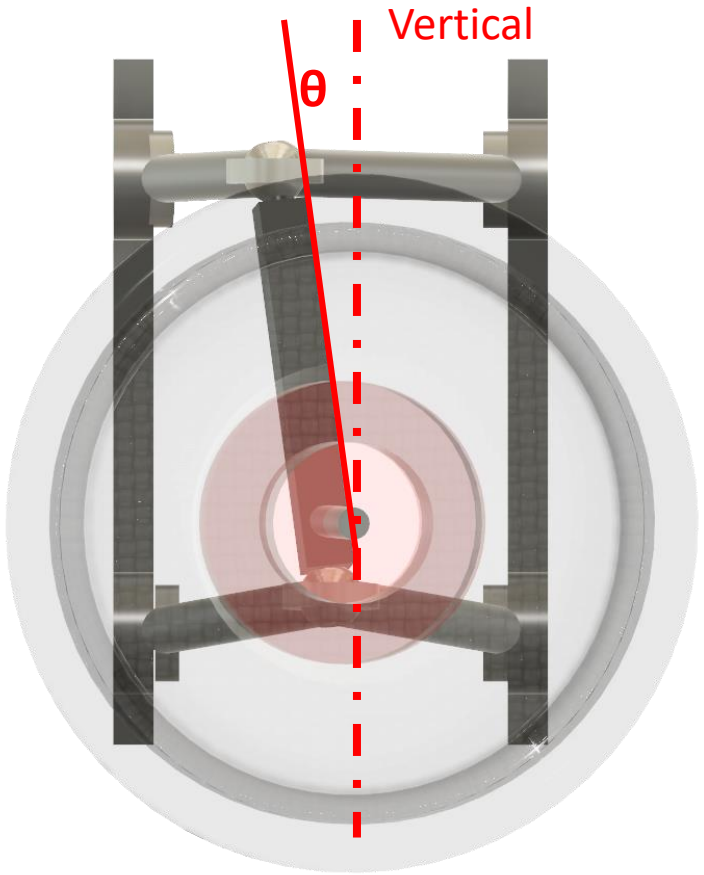
- **Affects grip and stability in cornering**
- **Not applicable to solar car racing**

Scrub Radius



- Harder to Turn
- Increase wear on tire
- Positive
  - Cause center seeking

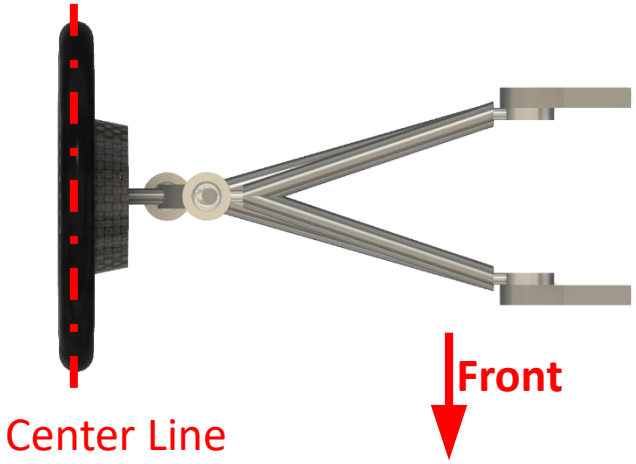
Caster (Side view)



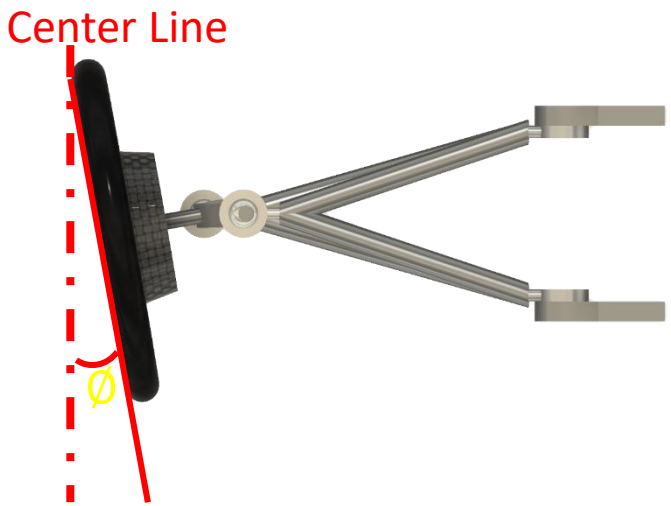
Positive

- Creates straight line stability
- Positive Caster
  - Steering wheel feedback
  - Makes car harder to turn
  - Causes wheels to self center
- Negative Caster
  - Unstable

Toe Geometry (Top View)

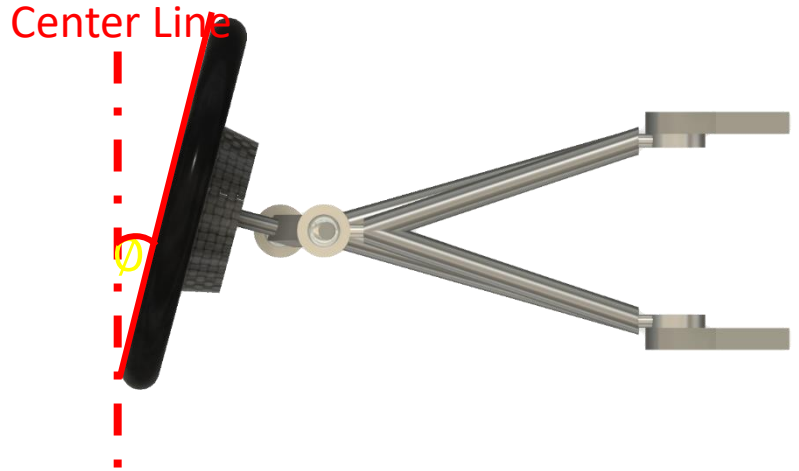


Neutral



In

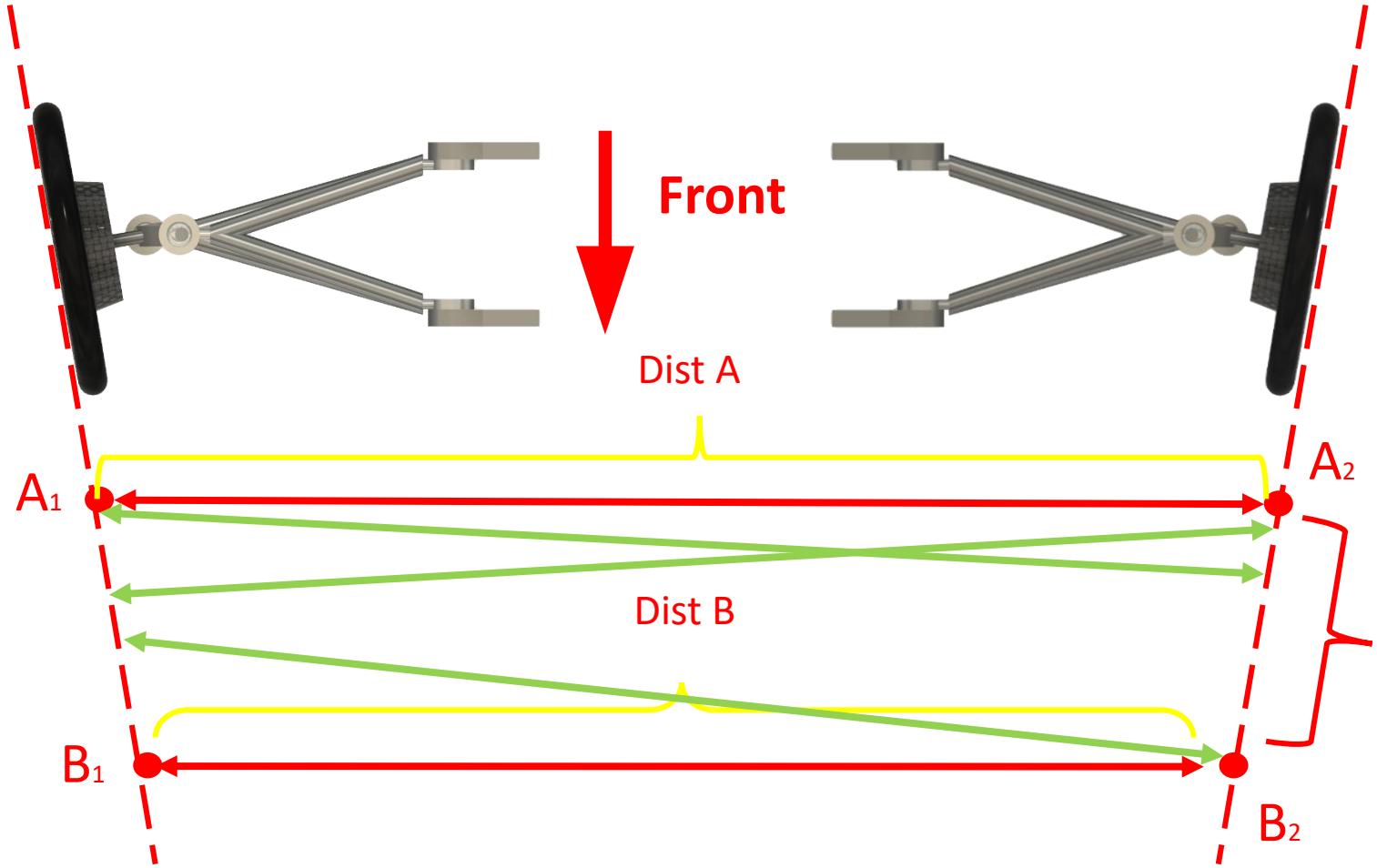
- **Improves straight line stability**



Out

- **Improves Steering Response**
- **Can make steering “jerky”**

Measuring Toe

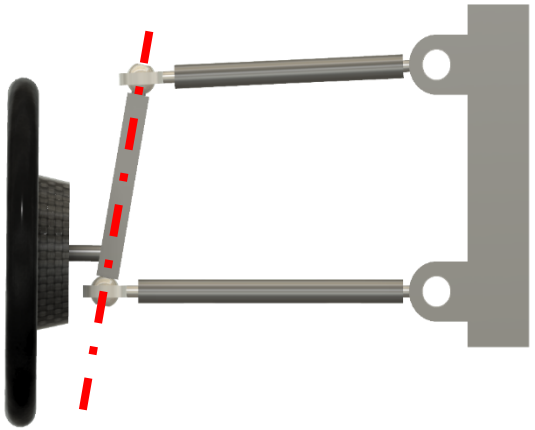


$$\emptyset = \sin^{-1}\left(\frac{\frac{(Dist\ A - Dist\ B)}{2}}{Dist\ C}\right)$$

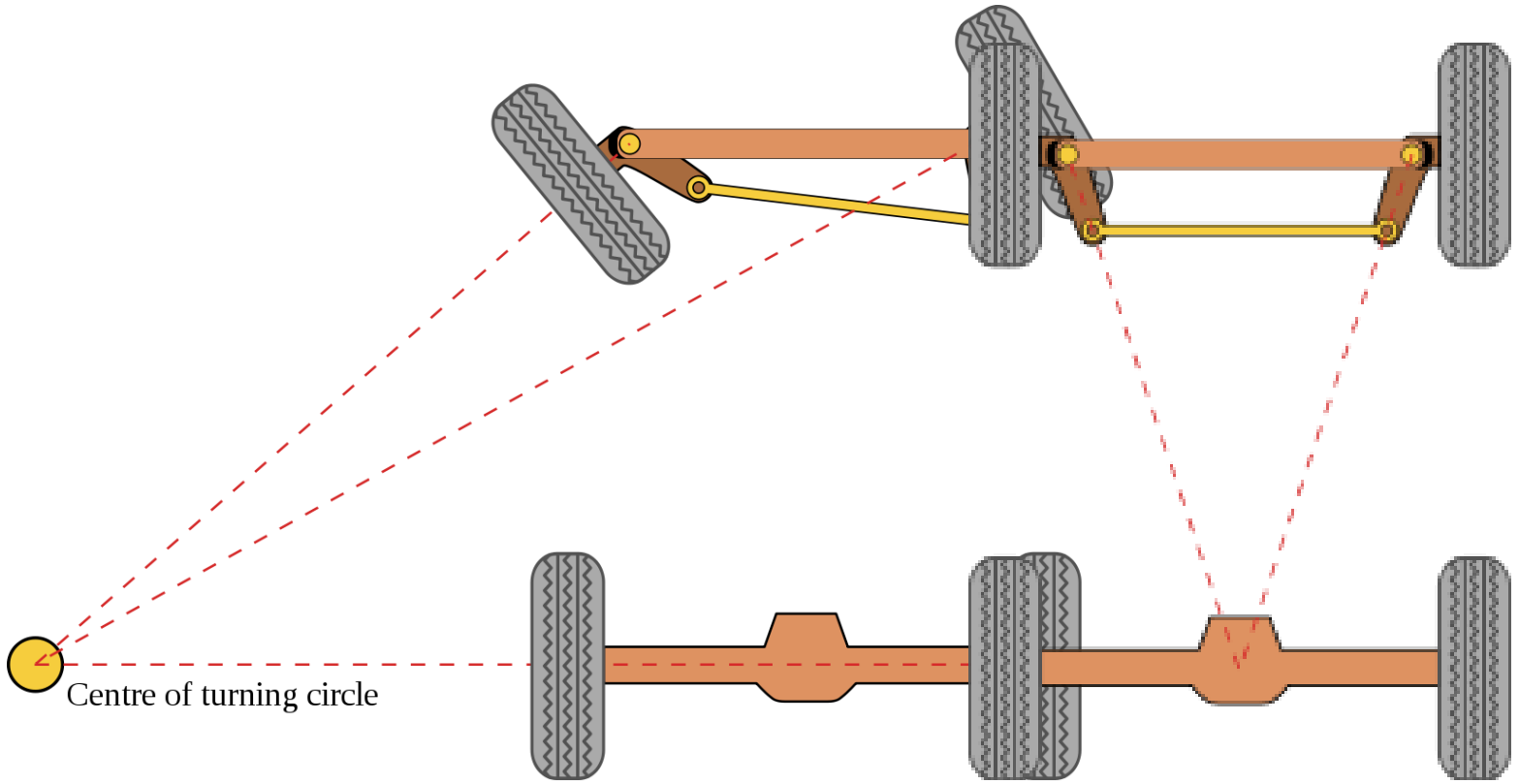
$$Toe = (Dist\ A - Dist\ B)$$

Suspension/Steering Considerations

- **Steering Axis**
  - **Line between two pivot points of the wheel**



Ackerman Steering



Getting your car rolling

- **Building the Vehicle Frame**
  - **Materials**
  - **Safety Cell, Roll bar and Crush Zones**
  - **Suspension and Steering**
  - **Wheels and Brakes**

Wheels

- One of the most difficult parts to source
- Choices need to be made very early in the design process
- Three wheel designs:
  - Lighter
  - Easier to align
  - Less expensive
  - Not as safe

Wheels

- Four wheel designs
  - More parts means higher cost
  - Harder to get alignment correct
  - Weight distribution less critical
  - Much safer in the event of a flat
  - Can “straddle” dead animals on the road

- Required for Cruiser Division

Wheels

- Wheel choices (must be able to handle the weight of the car and lateral forces from turning)
  - NGM wheels and tires
  - Motorcycle
  - Junior Dragster
  - Bicycle

Wheels

Motorcycle

Jr Dragster

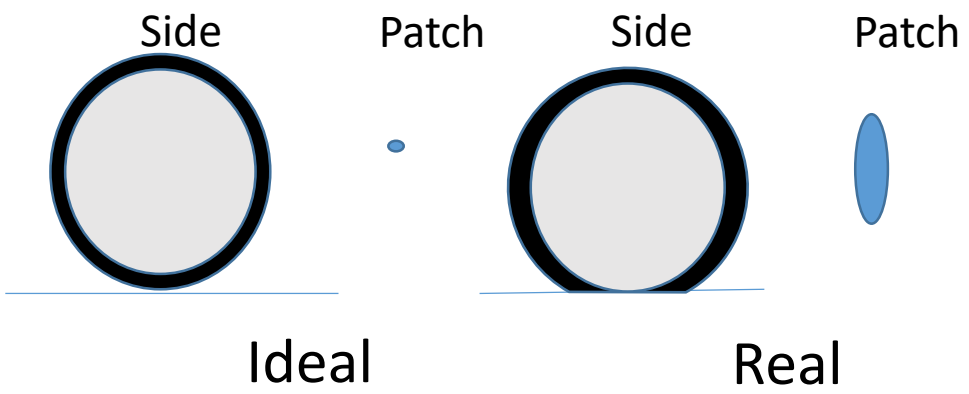
Jr Dragster

Wheel Considerations

- Weight
  - High Polar Inertia designs have potential for increased energy consumption
    - Extreme example is a flywheel
  - Affected by acceleration
- Solid vs. Spokes
  - Solid = better aerodynamics, may weigh more
  - Spokes = worse aerodynamics, less load capacity
  - Can be improved by wheel fairings

Tire Considerations

- Tire Width
  - Thinner = less rolling resistance
  - Thicker = supports more weight and more stable on road
- Contact patch
  - Minimize Contact patch = Minimize Energy loss (less rolling resistance)
  - Tire deforms where it contacts the road

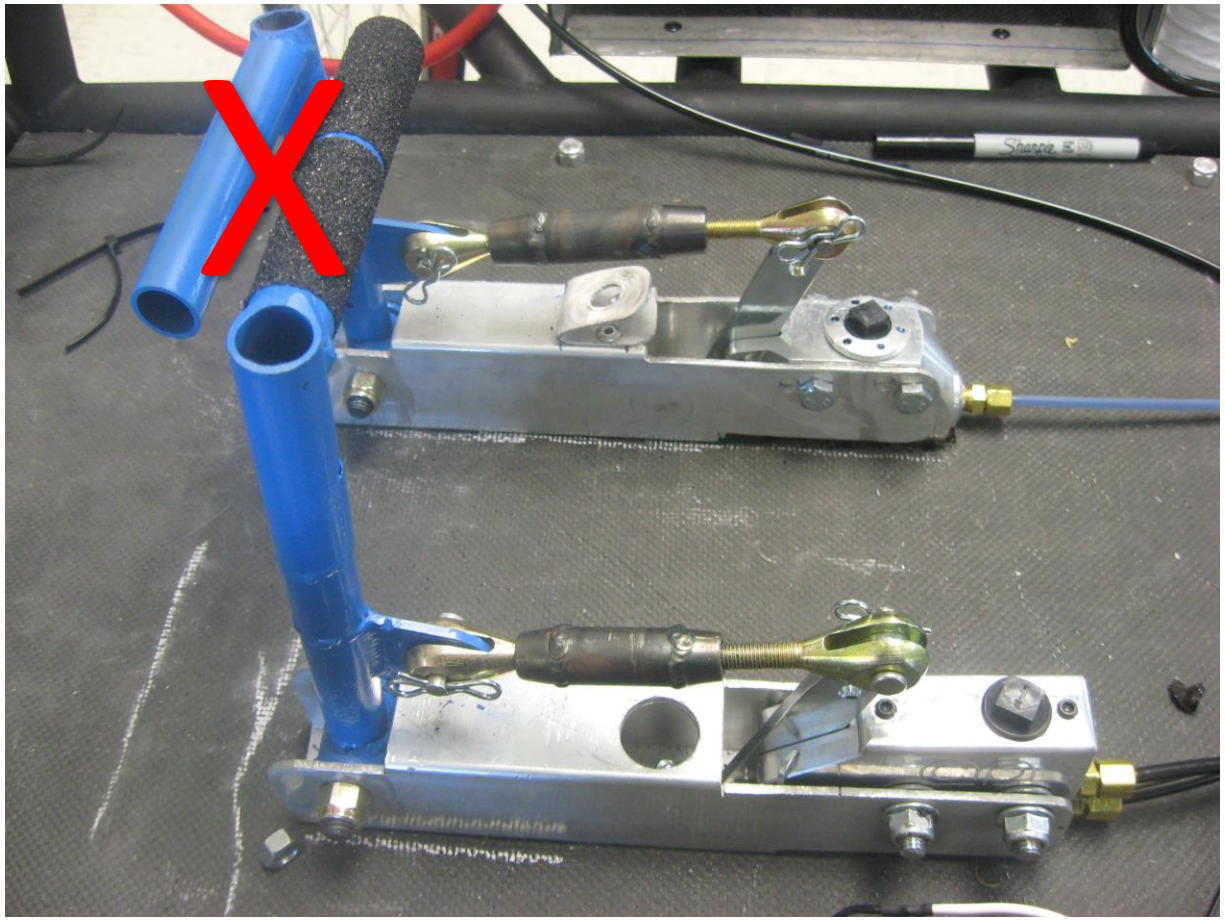


Brakes

- Solar car must have two, independent, braking systems that allow the driver to stop the vehicle safely and quickly.
  - Most cars use hydraulic disk brakes
  - MCP single caliper brakes are easy to install and relatively inexpensive.

Brake Pedals

- Brake pedals must also be independent
  - Pedals, master cylinder, etc. separate for each system
- Can **no longer** “link” pedals together
- Must be operated by foot (no hand brakes)
- Automotive style pedals must be used



Brake Testing

- Brakes are tested both statically and dynamically at the event.
  - Static = Test strength of brakes at rest
  - Dynamic = Test how fast brakes can stop car

- Many vehicles have brake problems. Brakes must be tested before you arrive at the event!

Building the Vehicle Frame

Chris Jones, Chief Race Judge