American Solar Challenge

Innovators Educational Foundation

Formula Sun

Solar Car Suspension Design

Considerations for achieving an efficient and stable vehicle

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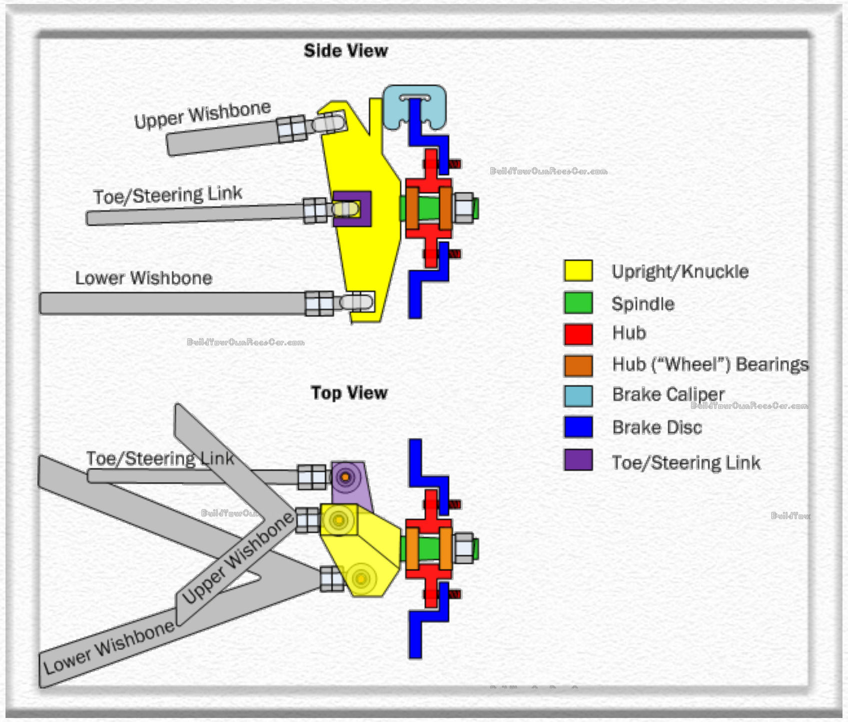
About the Presenter

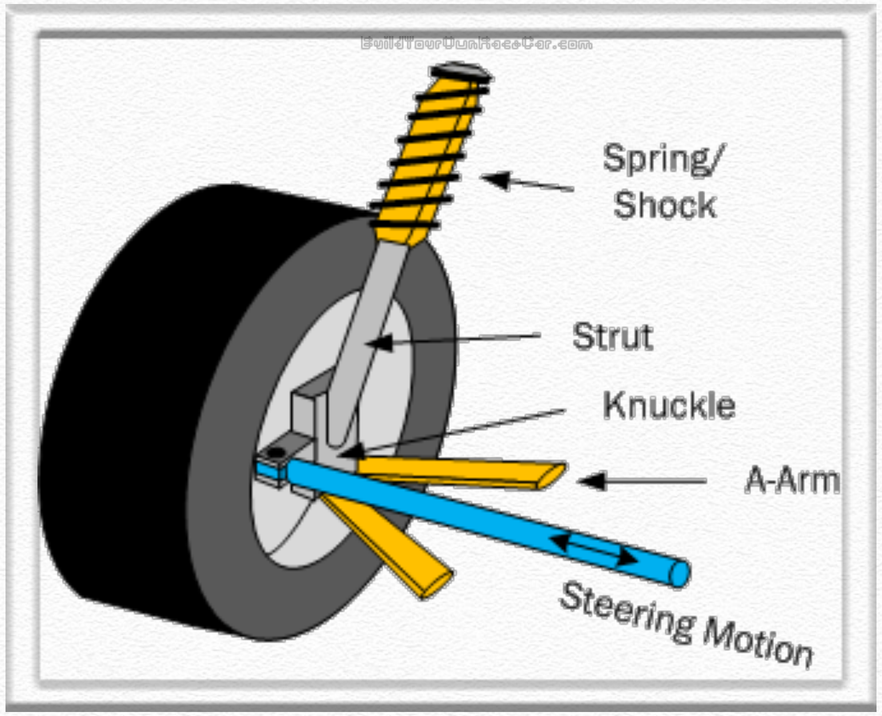
- **Education: Iowa State University**
  - Mechanical Engineering B.S.
- **Solar Car: Team PrISUm**
  - 2009-2011: Media Director
  - 2011-2012: Project Director
  - Solar Car Driver for ASC 2010, FSGP 2011, and ASC 2012
- **Event Volunteer: IEF**
  - 2012-2017: Webmaster
  - 2014-Present: Team Coordinator
  - Event Staff since 2013 including ADSC 2015
- **Employment: Caterpillar**
  - 2012-Present: Electric Drive Systems Engineer in Peoria, IL
- **Current Vehicle: 2018 Tesla Model 3**

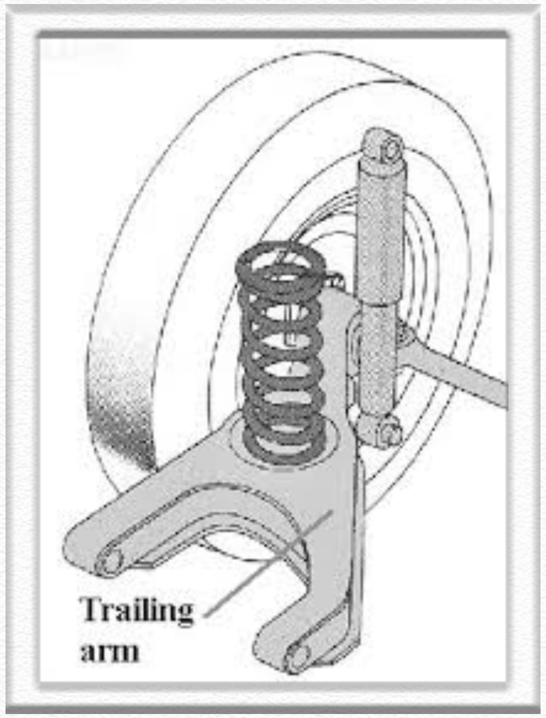
Why have a suspension system?

- Serves to always keep your tires in contact with the ground
  - Acceleration, steering, and braking forces act on the tire contact patches
  - You want traction on all tires to remain in control!
- Protects the vehicle and onboard cargo from damage
- Lots of tradeoffs between comfort and efficiency

Common Suspension Types

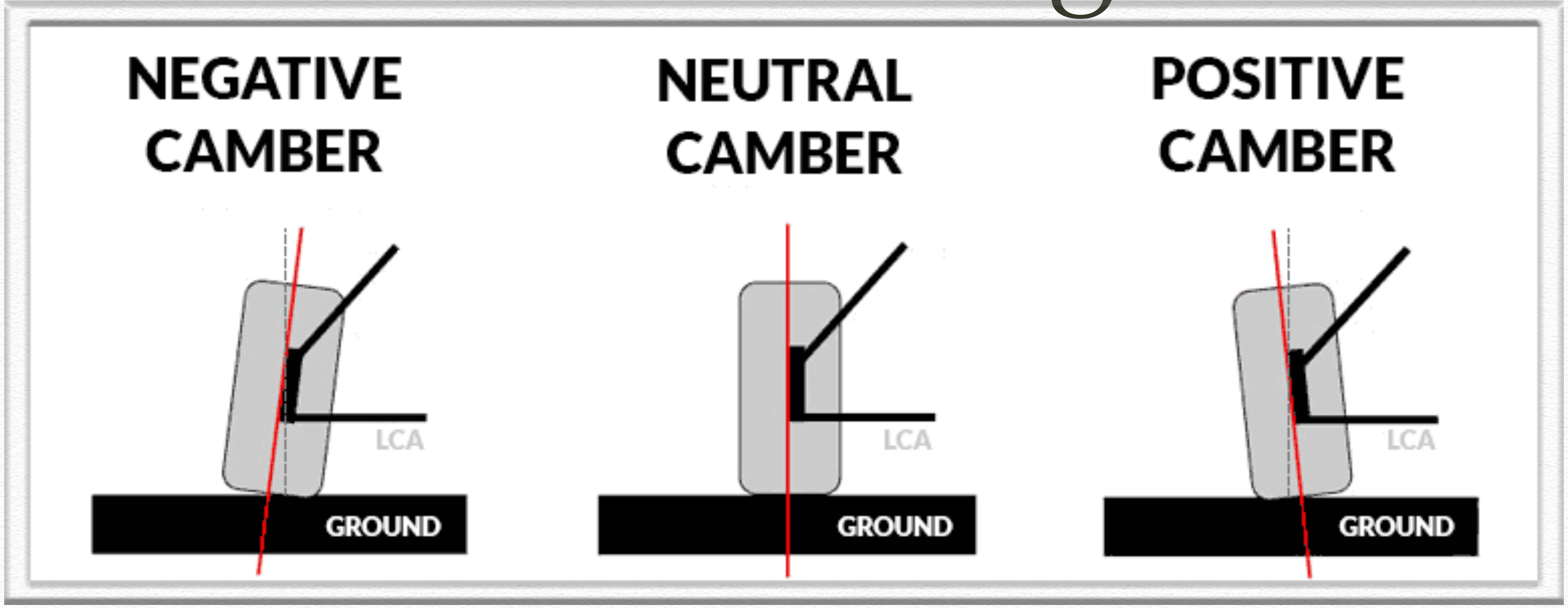






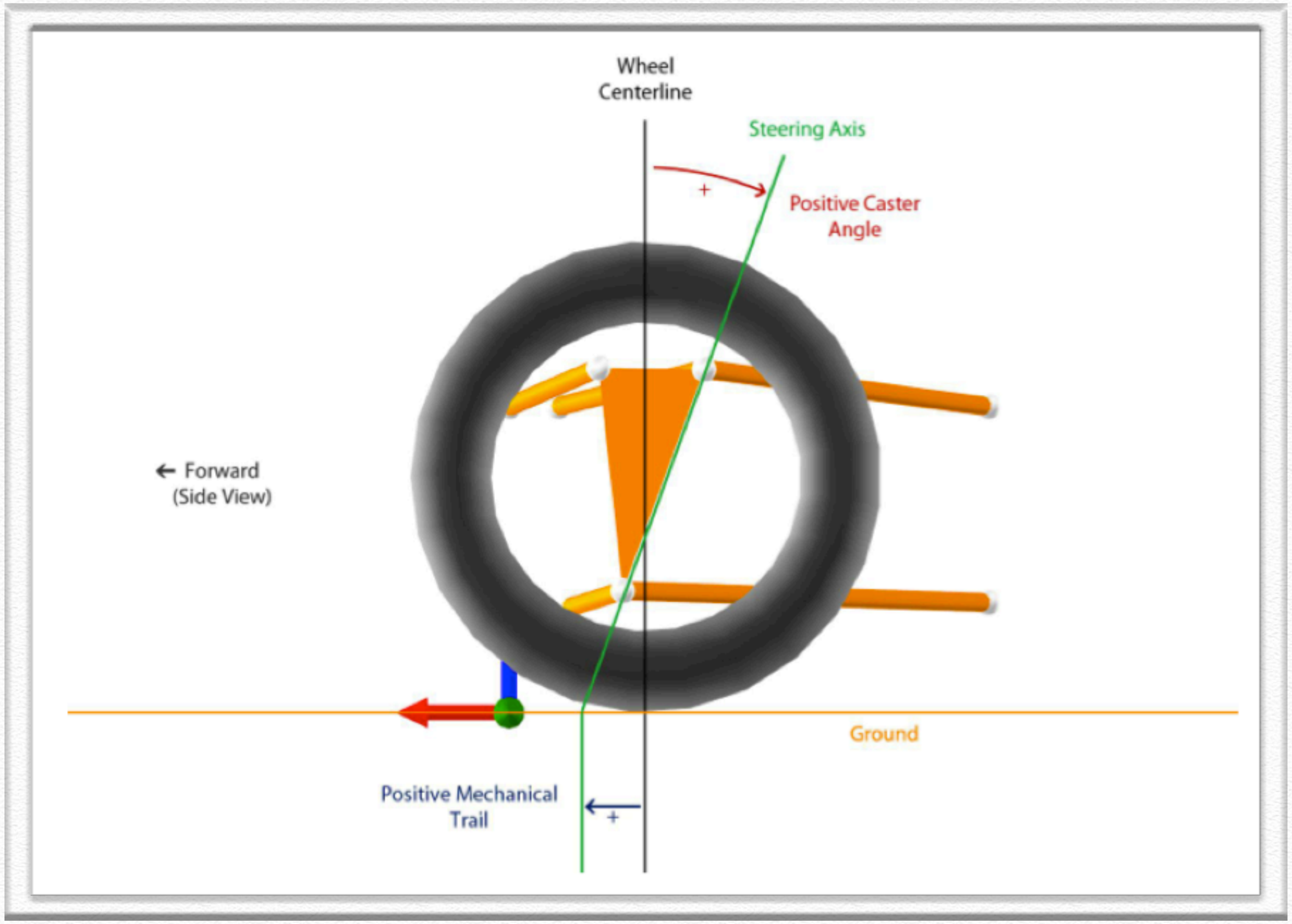
- Double Wishbone
- Macpherson Strut
- Trailing Arm

Camber Angle



- The goal of camber is to keep the tire oriented perpendicular to the ground (maximize grip) during turning
- Lateral tire scrub is increased when you try to optimize camber angle in your suspension
  - For solar cars, minimizing lateral scrub is arguably more important than optimizing camber for efficiency reasons
  - Solar cars typically don't need to have great cornering capability at race car speeds

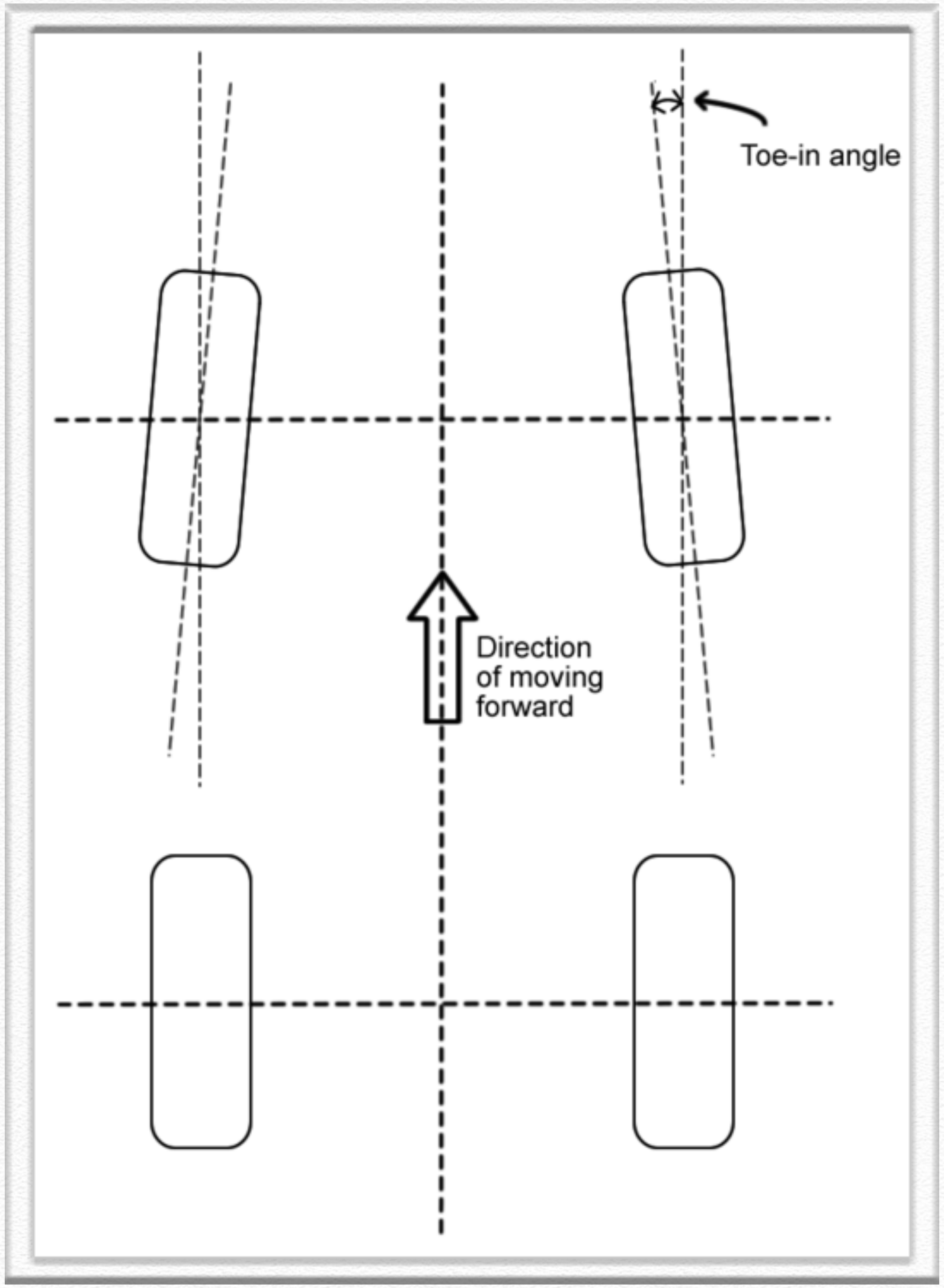
Caster Angle



- Positive caster helps with straight line tracking if the driver lets go of the steering wheel
- Adding caster also increases tire scrub when steering

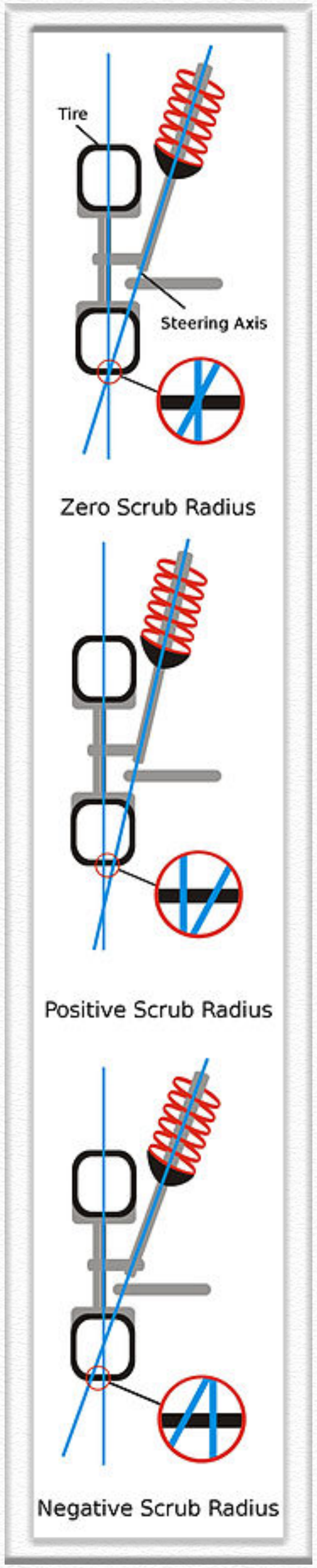
Toe Angle

- Most efficient is zero toe
- Some toe in can help improve stability of vehicle at the cost of increased tire scrub

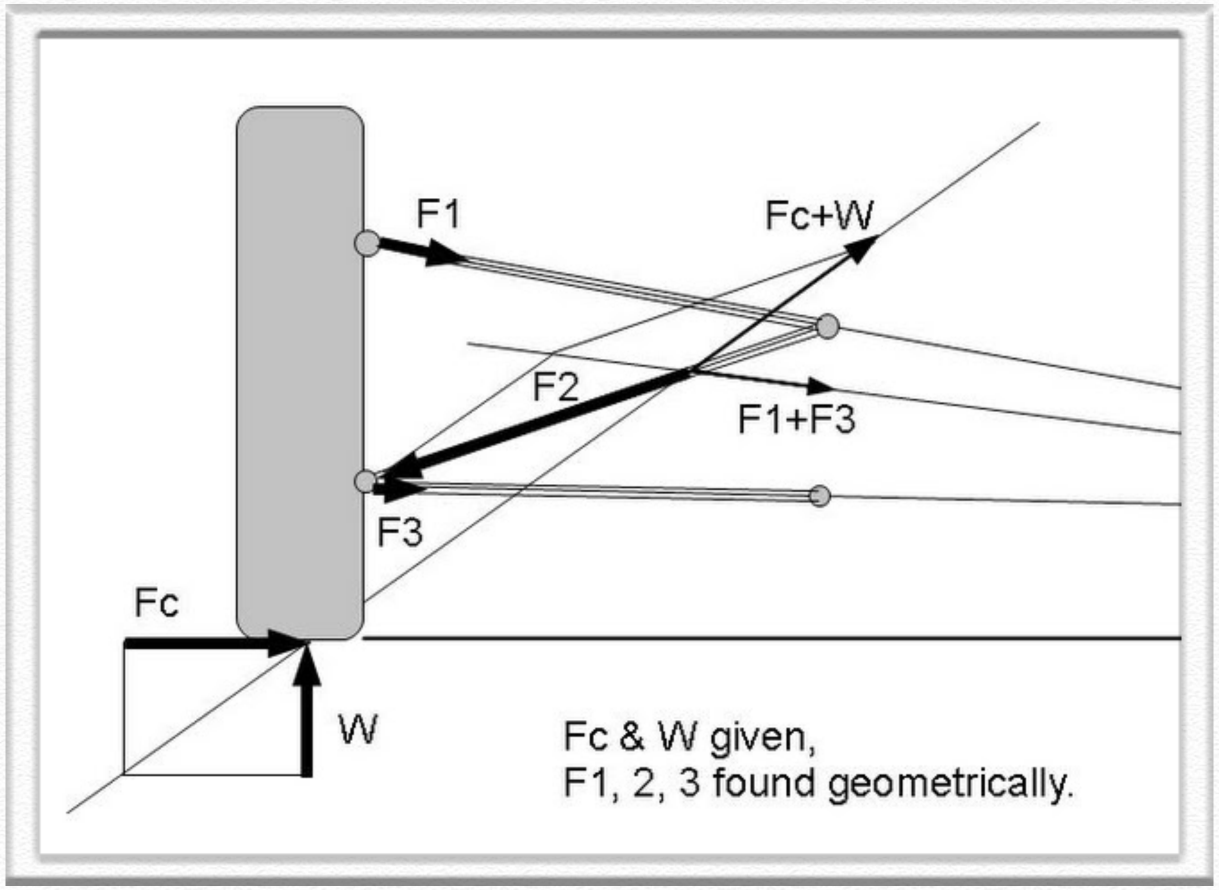


Scrub Radius

- True zero scrub radius is most efficient but can result in less stable steering feel
- On rear wheel drive cars, a positive scrub radius in the rear suspension can help improve straight line tracking when the steering wheel is released
- On the front, a slight negative scrub radius can help with maintaining stability in scenarios like sudden tire deflation or hitting standing water



Free Body Diagrams



- Draw free body diagrams for your various suspension components to calculate input loads
- Consider brake, bump, and steering loads

Fasteners

- Friction is not an acceptable method of constraining structural members
- Loctite is not allowed to restrain fasteners
- Make sure your frame can support suspension loads
  - Try to put suspension/shock mount locations near structural nodes on the frame
    - Minimize frame tube bending loads!
- No unrestrained fasteners are allowed in structural applications
  - Flex lock nuts are OK
  - Cotter/Spring Pins are OK
  - Safety wire is OK

Rod Ends vs. Spherical Bearings

- Rod ends should not be put in bending
  - If you do have to put the in bending, there is a rod end sizing calculation sheet on the ASC website that must be used!
  - Consider spherical joints instead of rods ends

Suspension Adjustability

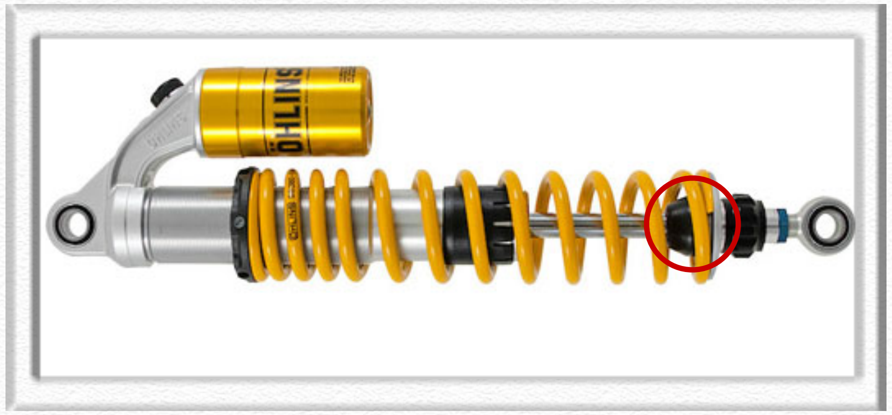
- The goal is to enable adjustability without resulting in binding or inefficient force path
- What to do with frame mounts to enable adjustability/account for manufacturing tolerances
  - If you put a slot in the frame, make it perpendicular to the control arm link

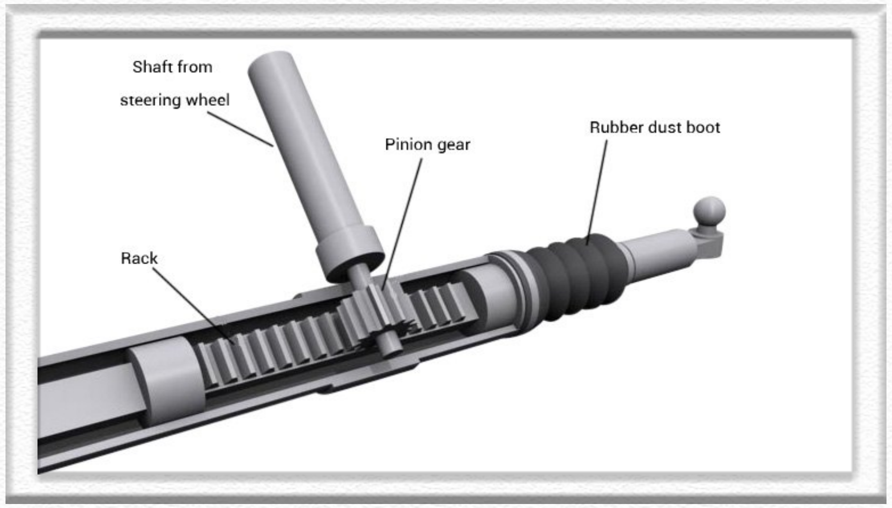
Loads Into Nodes

- Efficient mechanical design can be used to minimize the weight components
- Minimize bending loads and if they must be used try to put them into components that can have a rectangular/oval cross section or ribs/gussets with extra bending strength

Eliminate Binding

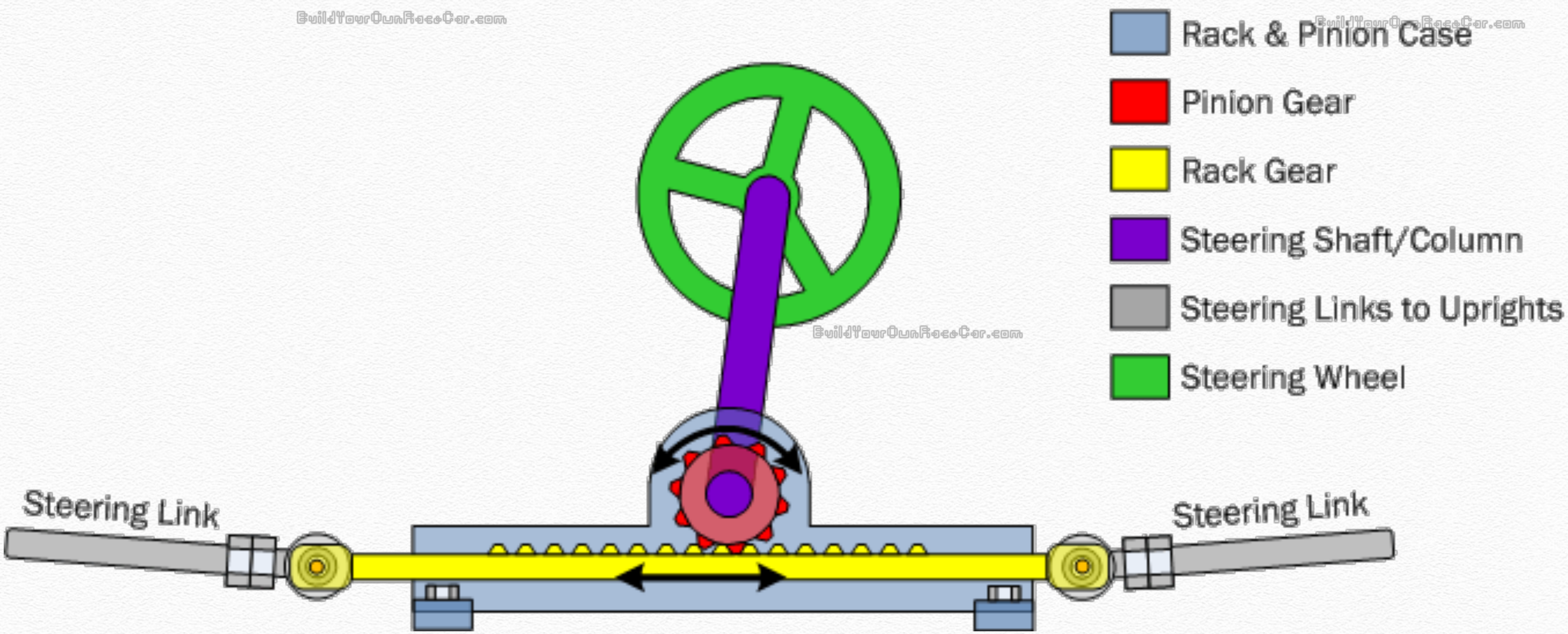
- Don't over-constrain your suspension such that binding is possible
  - What should stop vertical motion? - Rubber bump stops are built into shocks
  - What should stop steering motion? - Steering bump stops
    - ASC doesn't allow use of the pinion gear as the steering stop
    - Must implement external steering stops that prevent the pinion gear from colliding
    - Rubber steering stop is recommended





- Ensure your suspension system has interference free travel through it's full range of vertical and steering motion
  - To test this, take your spring off your shock absorber and manually move your suspension through it's extremes of vertical and steering travel
  - The shock or steering bump stops should be the only things that ever interfere
  - If you notice any other interference points that don't allow the bump stops to be engaged this interference needs to be eliminated by modifying your suspension components (grinding/redesign)
- Why does it matter?
  - If you have hard metal to metal interference in your suspension travel this will result in grinding/wear stress concentrations and can put parts in bending that were not intended to be in bending resulting in premature failure

Rack & Pinion Steering

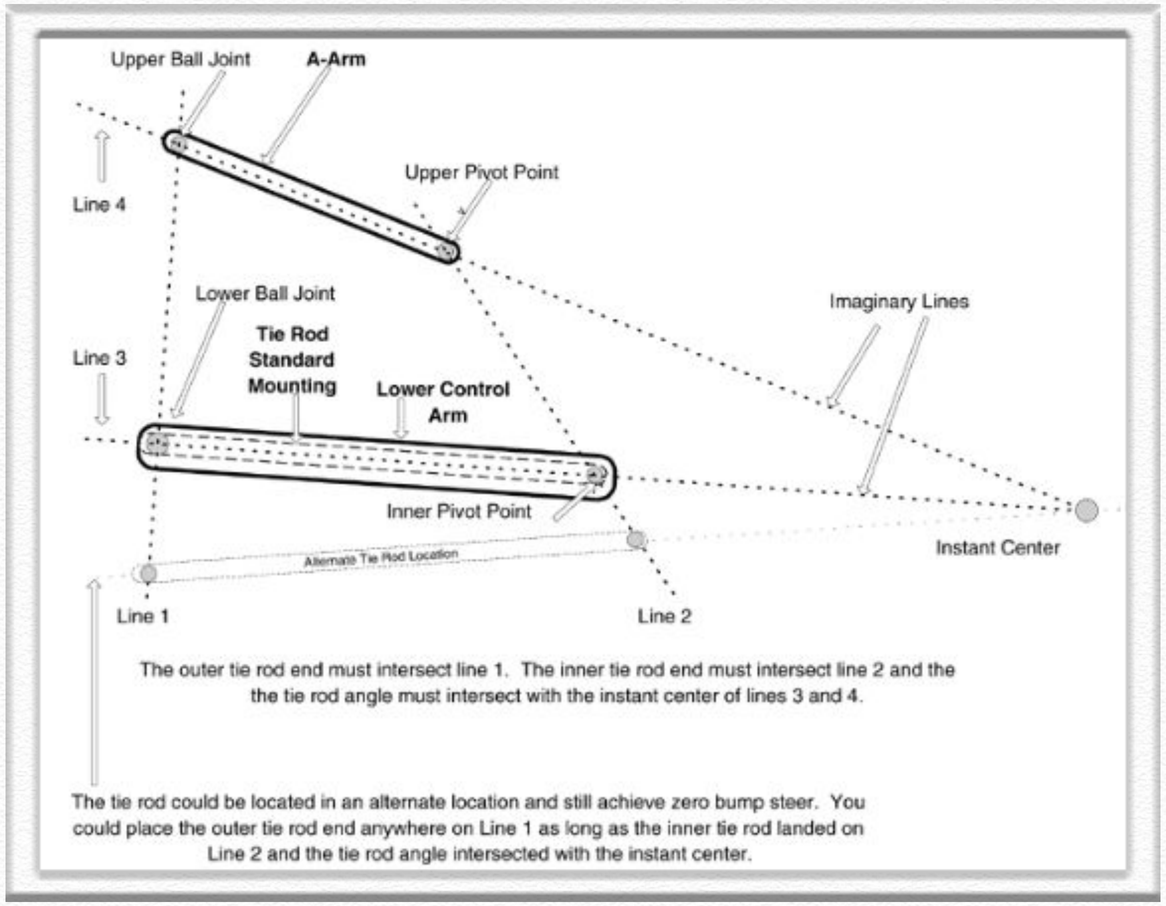


Other Notes

- Lower A-arms should be either the same length as or longer than uppers, and should have a nearly horizontal resting position. The upper arm should never be longer.
- Verify that your wheels spin freely
  - Try to use retracting brake calipers
  - Consider turning brake rotors on hub to be flat
- Steering shaft connections should be splined with a spring pin holding the tube on.
- In general, mountain bike components (shocks, brakes, etc.) are not sufficient for components for solar cars

Steering

- Ackermann steering
  - https://www.youtube.com/watch?v=TBwa1HvpHMY
- Steering ratio
  - Get a rack and pinion with a reasonable steering ratio - to sensitive to steering wheel movement will be difficult to control and not sensitive enough will make it difficult to complete the Scrutineering figure 8 test
- Ensure stable, reliable control of your vehicle
  - Eliminate sources of steering slop
  - Bump Steer
    - Bump steer is where the front wheels turn when going over a bump
    - To eliminate bump steer ensure your steering tie rod locations are lined up between your upper and lower suspension pivots as shown below



Open Discussion