SAE Baja: Engineering Analysis
Suspension and Steering

Benjamin Bastidos, Victor Cabilan, Jeramie Goodwin, William Mitchell, Eli Wexler

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Overview

- Introduction
- Analysis of Suspension Components
    - Geometry
    - Body Forces
    - Suspension Materials
- Analysis of Steering Components
    - Rack and Pinion
    - Tie Rods
- Gantt Chart
- Conclusion

Introduction

Client: Professor John Tester

- Explain Suspension/Steering Analysis
    - Dimensions
    - Geometry
    - Body Forces acting on System

Analysis of Suspension Components

Front Suspension

- We started by assuming the following specs
- 20” front frame width
- About 12” A-arms
- 205-80-12 tire size

Analysis of Suspension Components

Kingpin Angle and Scrub Radius

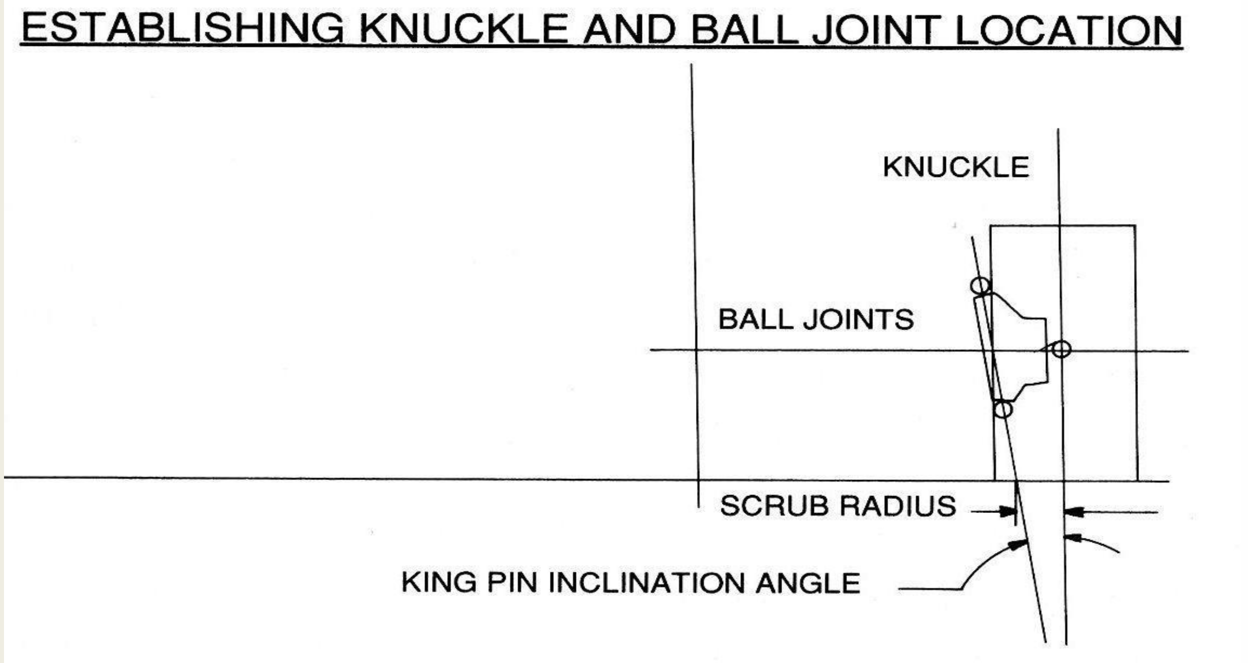

Figure 1: Knuckle & Ball Joint

Source: Chassis Engineering

Analysis of Suspension Components

Ideal Scrub Radius

- The ideal scrub radius is zero
- This minimizes steering effort.
- This minimizes twisting forces from bumps and cornering forces.

Analysis of Suspension Components

King Pin Angle

- Typical Kingpin Angles are between 5-10 degrees.
- Excessive king pin angle causes the tire to flop from side to side as it is steered.

Analysis of Suspension Components

Other Considerations

- The general Compression to Droop ratio is about 60% to 40%
- We want moderate camber loss on compression.

Analysis of Suspension Components

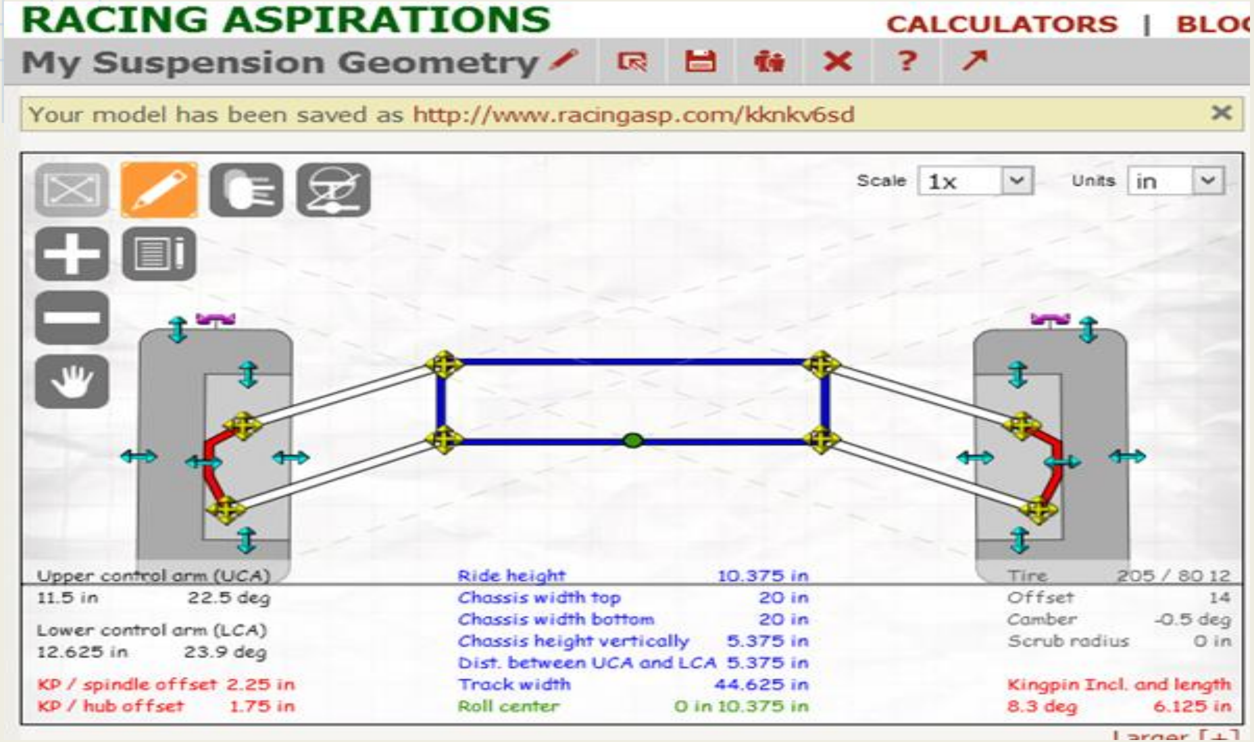

Figure 2: Suspension Analysis

Analysis of Suspension Components

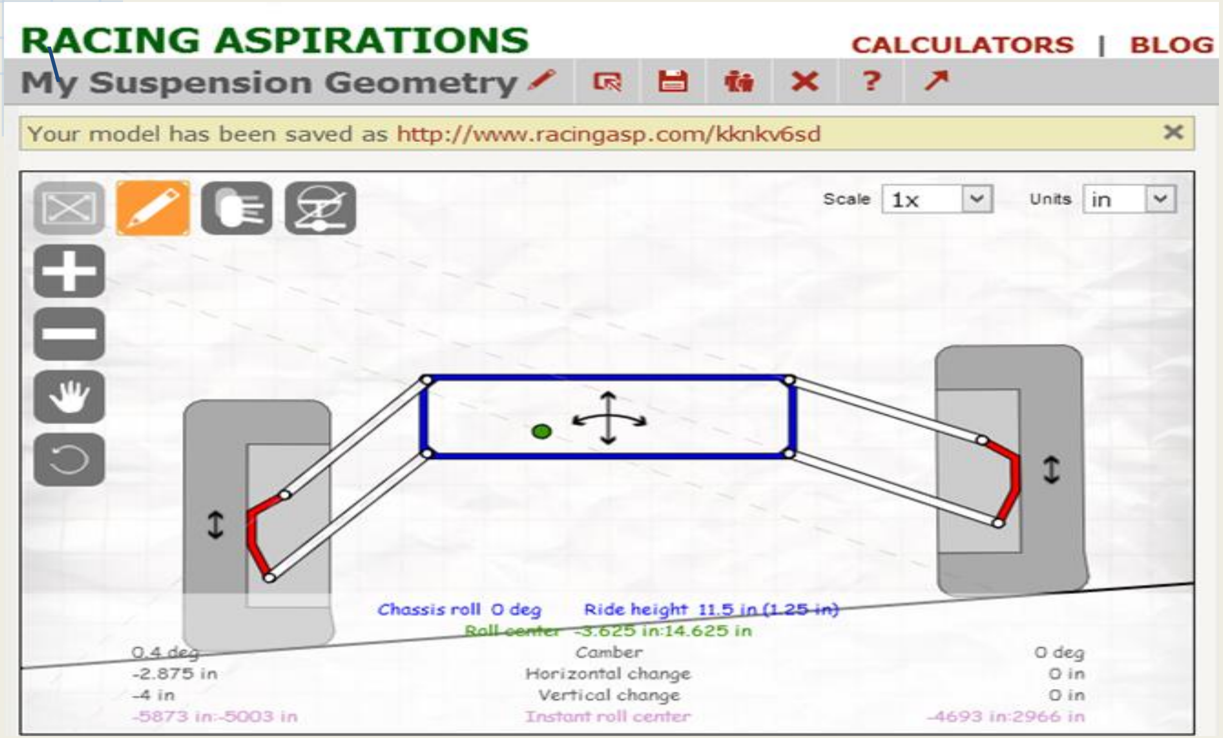

Figure 3: Suspension Analysis

Analysis of Suspension Components

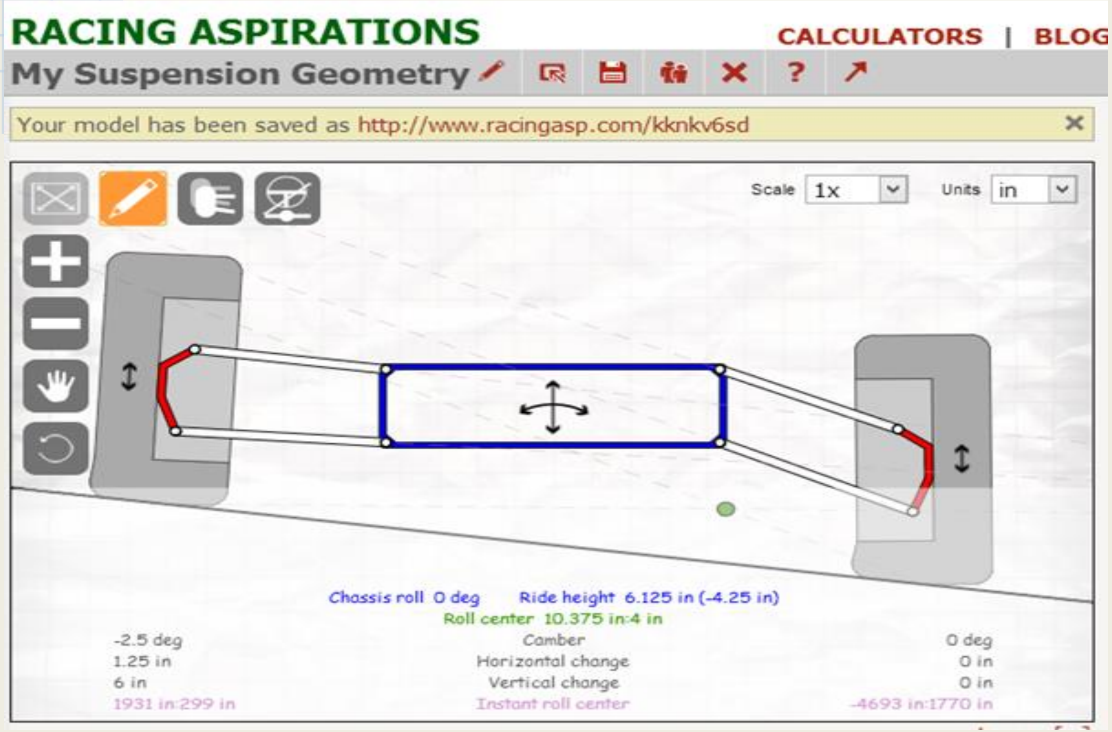

Figure 4: Suspension Analysis

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Analysis of Suspension Components

Drop Test Assumptions:

- Fi = Force of impact
- Fs=500 lb Weight
- h= 6 ft Drop Height
- K= 160 lbin Spring rate constant (using shocks from Polaris RZR 570)
- Force assuming worst case landing on one wheel
- $Fi\ =\ Fs + \left((Fs)^2 + 2 * K * 12 * FS * h\right)^{\frac{1}{2}}$ (Source SAE Brasil)
- Fi=1022.53 lb

Analysis of Suspension Components

Shock Mounting

- In order to keep from having an over engineered shock, the length away from the pivot and the angle away from vertical
- The longer lever arm on the shock, the stronger it has to be
- The larger the angle away from vertical the shock is mounted, the less effective it is

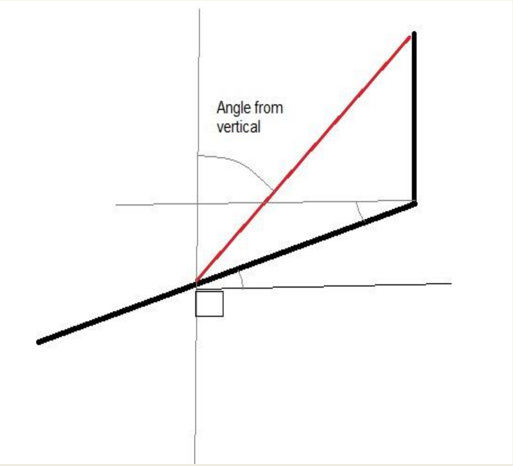

Figure 5: Shock Mounting

Analysis of Suspension Components

Shock Mounting (cont.)

- From Matlab code, from a given mounting distance, the angle away from vertical and the shock length are found
- Compromising between the mounting position and the angle away from vertical, the team decided on mounting 9 inches away from the frame
  - Shock length is 11.5 inches
  - The angle away from vertical will be 39 degrees
- Shock will have to be ~1.5 times stronger compared to a vertical shock

Analysis of Suspension Components

Suspension Materials:

Table 1: Suspension Material

Material	Properties					
	Sy (ksi)	Ts (ksi)	E (ksi)	ρ (lb/in^3)	G (ksi)	v
AISI 1018 (CD)	54	64	29000	0.284	11600	0.292
AISI 4130 (normalized)	63	97	29700	0.284	11600	0.292

Analysis of Suspension Components

Why AISI 4130?

- High tensile strength
- High yield strength
- Meets SAE rules for approved materials
- Maintains physical properties after welding
- Widely used in off-road designs

Analysis of Suspension Components

3-link Trailing Arm

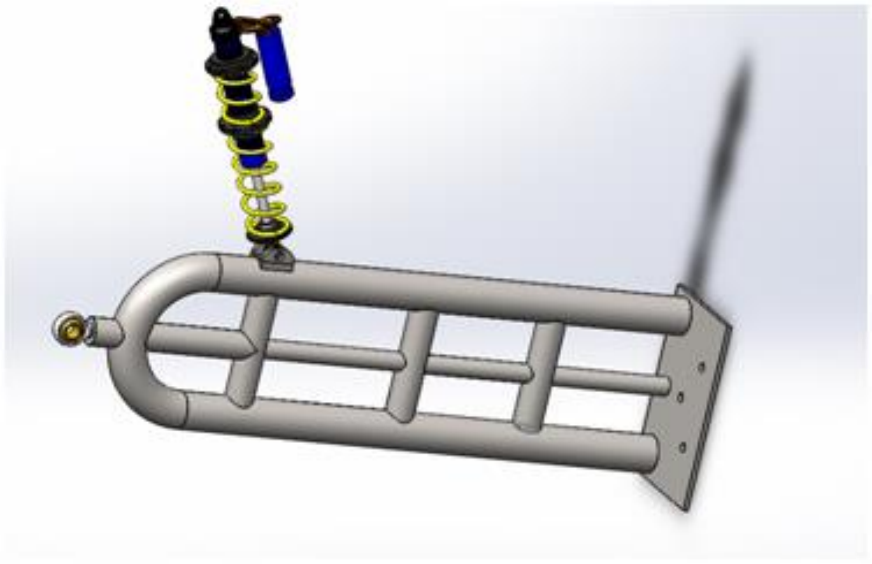

Figure 6: Trailing Arm

- Shown without additional links and knuckle
- Material: AISI 4130 normalized
- L = 28 in
- OD = 1.5 - 2.0
- t = 0.083
- End plate attaches to knuckle
- Assuming square shafts, attached to wall

Analysis of Suspension Components

Drop Test Results:

Table 2: Drop Test results

Force Location (in)	Force (lbf)	Yield Strength (ksi)	Deflection (in)
25	6600	97	0.000069
26.5	5543.34	97	0.125

Analysis of Steering Components

Steering System

- Rack and Pinion
  - Calc. for designing
    - Most likely buy
  - Gives ideas of material selection

- Dimensions for Pinion
  - Several Assumptions (Driver 0.1-10 lbf)
  - Rack teeth => pinion turns 180 deg max

Analysis of Steering Components

Table 3: Dimensions of Pinion and Rack

	teeth number	face width (in)	bending stress (kpsi)	radii for pitch circle (in)	radii for base circle (in)	Adden (in)	Dedden (in)
pinion	20	0.74	0.04 - 3.9	0.787	.739	0.078	0.098
rack	20	0.74	-	inf	inf	0.078	0.098

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Analysis of Steering Components

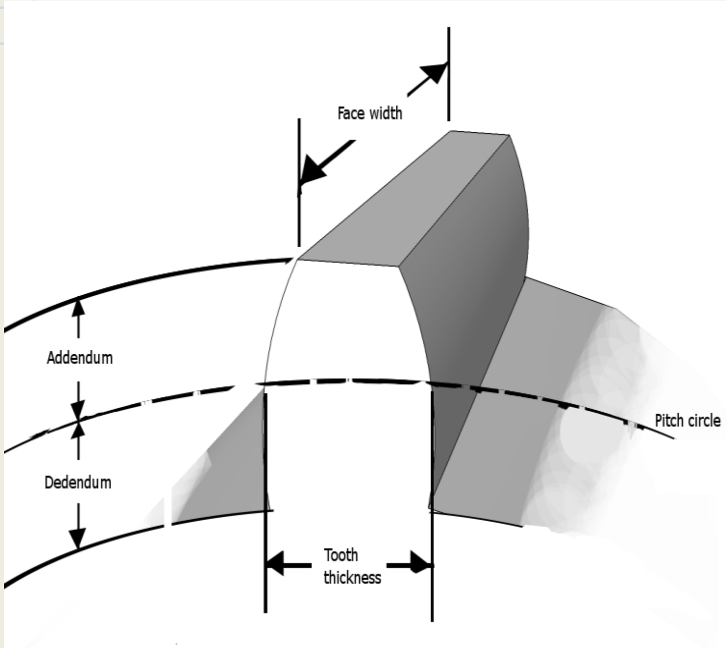


Figure 7: Pinion Geometry
Source:http://psas.pdx.edu

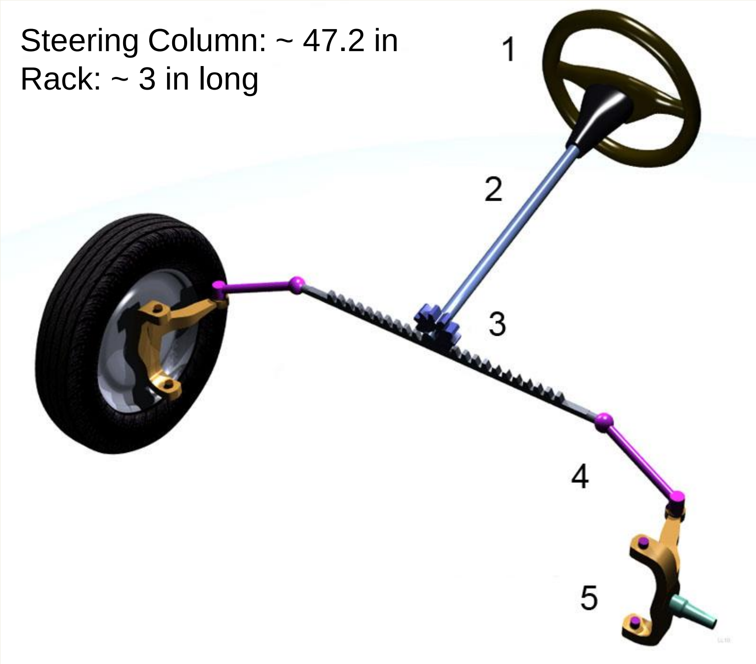


Figure 8: Rack & Pinion
Source: wikipedia

Analysis of Steering Components

- Analysis of Tie Rod (Chromoly AISI 4130)
  - Force exerted by environment
  - Force exerted by driver

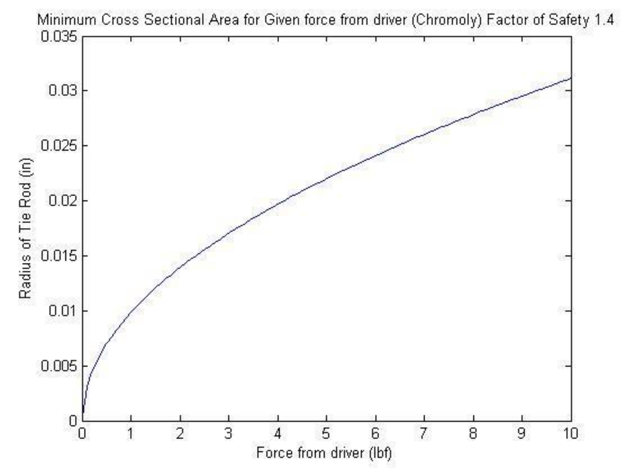


Figure 9: Force by Driver

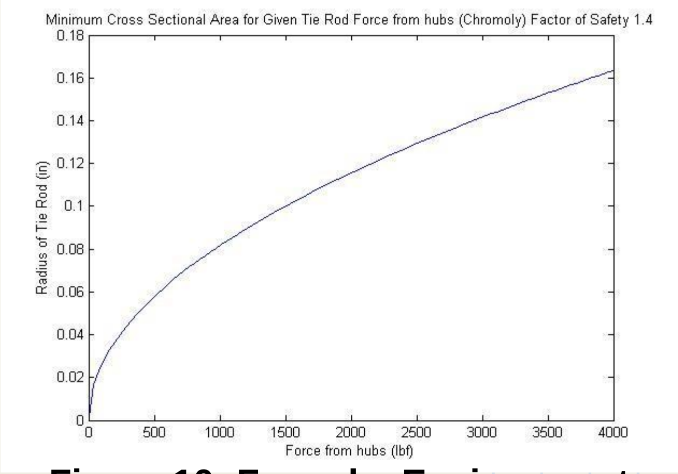


Figure 10: Force by Environment

Analysis of Steering Components

- Force exertion by hubs and driver (Chromoly AISI 4130)
  - Tie-Rod radius increases as Driver and Hub Force increase together

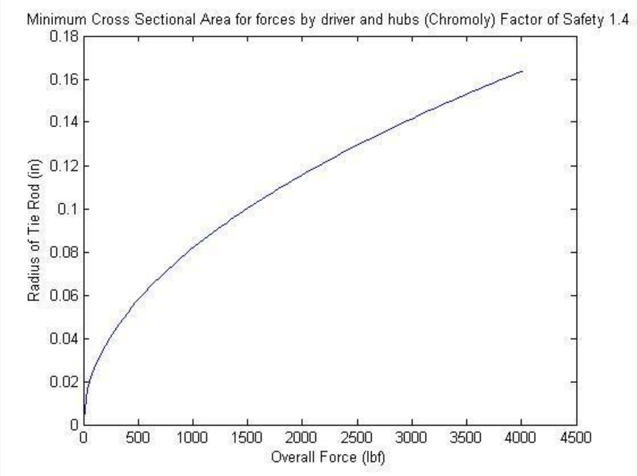
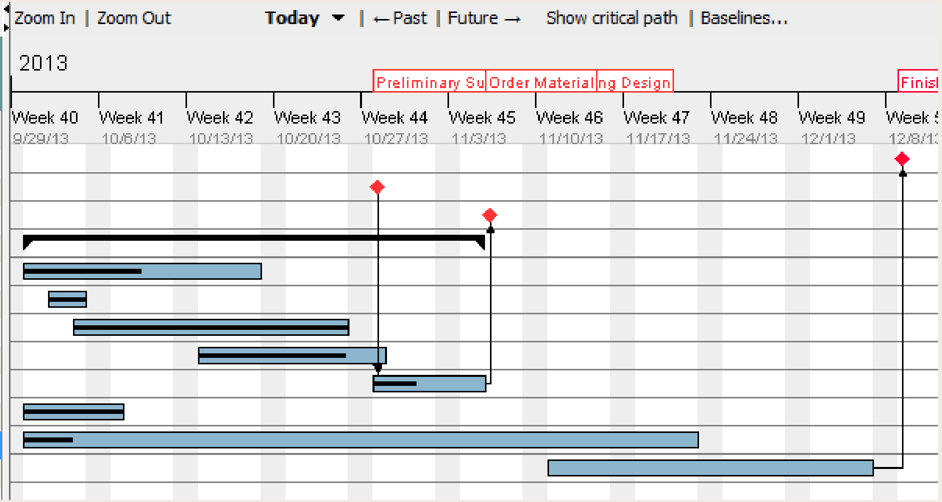


Figure 11: Overall Force

Gantt Chart

Name	Begin date	End date
Finished Suspension/Steeting	12/9/13	12/9/13
Preliminary Suspension/Steering D...	10/28/13	10/28/13
Order Material	11/6/13	11/6/13
Steering/Suspension Design	9/30/13	11/5/13
Safety Considerations for Ste...	9/30/13	10/18/13
Material Selection	10/2/13	10/4/13
Design Profile for Steering/Sus...	10/4/13	10/25/13
Solidworks Suspension/Steerin...	10/14/13	10/28/13
Stress Analysis	10/28/13	11/5/13
Constraints and Requirements	9/30/13	10/7/13
Sponsorships	9/30/13	11/22/13
Suspension/Steering Construction	11/11/13	12/6/13



Conclusion

- Suspension Component Analysis
  - Spring & Joint Mounting Locations
  - Calculated Deflections at Maximum Drop Force
- Steering Component Analysis
  - Gearing of Rack and Pinion at given situations
  - Tie rod thickness at given situations

References

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