Tire Envelope Swept Volume
Using
CATIA V5 DMU Kinematics

- The following licenses are required to create this Swept Volume simulation:
  - Digital Mockup Kinematics
  - Mechanical Part Design

- To create the correct tire clearance envelope, there needs to be an understanding of basic suspension geometry.
- This example will touch upon areas such as Ackermann Steering, Front/Rear Steer, Jounce/Rebound, Clearance Zones and Turning Radius.
- The result will be a swept volume using CATIA DMU Kinematics.

BND TechSource

- Certain parameters were set in this particular design.
  - Track: Front/Rear = 1490/1510mm
  - Wheelbase = 2489.2mm
  - Tire Size:
    - Front = P245/45ZR-17

      (Tire Radius = 326.15mm)
    - Rear = P275/40ZR-18

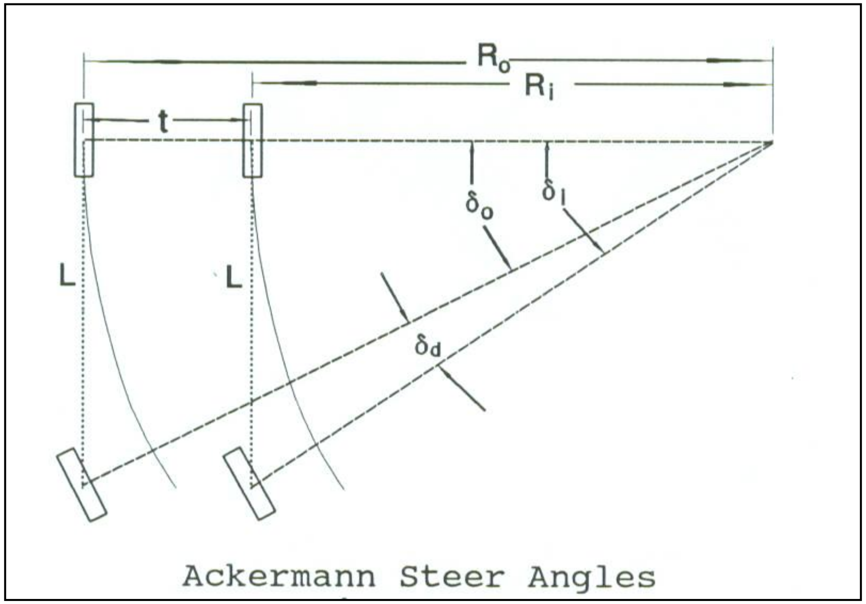
      (Tire Radius = 338.60mm)
  - Wheel Size:
    - Front = 17 x 8.5 in, Offset = 56mm
    - Rear = 18 x 9.5 in, Offset = 63mm

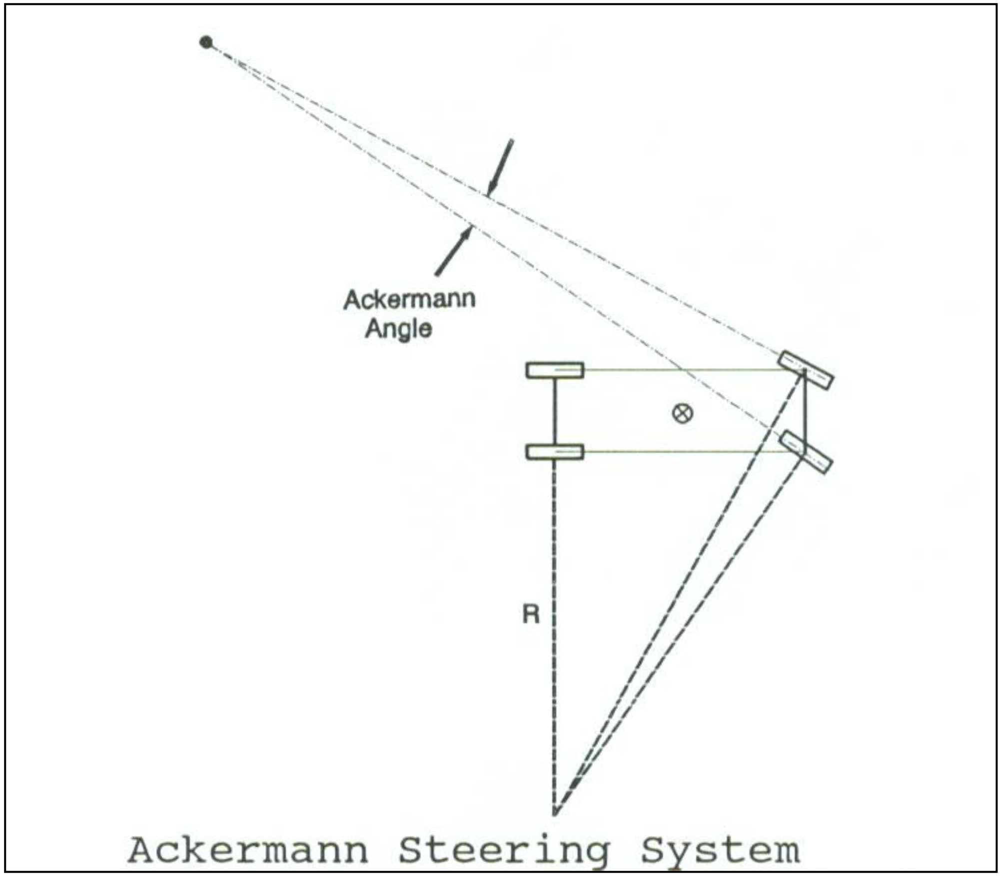
BND TechSource

- Parameters (cont'd).
  - Scrub Radius = +10mm
  - Steering Axis Inclination = 8.8°
  - Caster Angle = 6.5°
  - SLA Ratio = 1.43:1
  - Ackermann Steering = 83.2%
  - Shock Extension/Compression = 50 mm / 48mm
- All of these parameters affect Tire Clearance Envelope.

BND TechSource

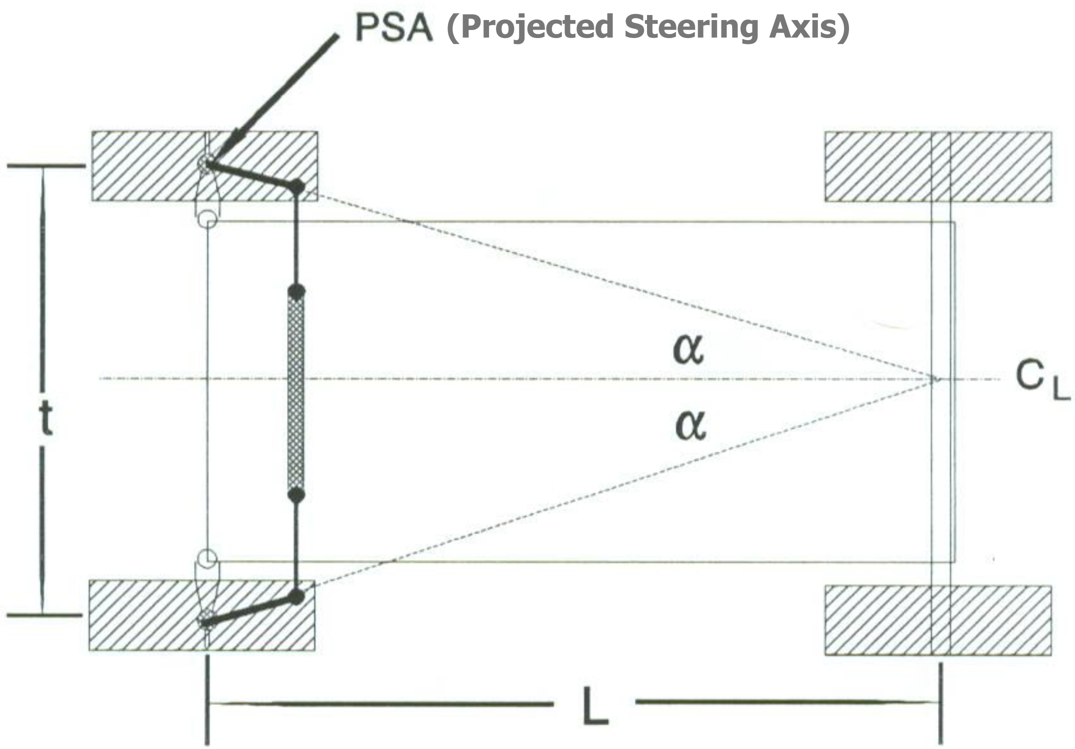
- Ackermann Steering Principle.





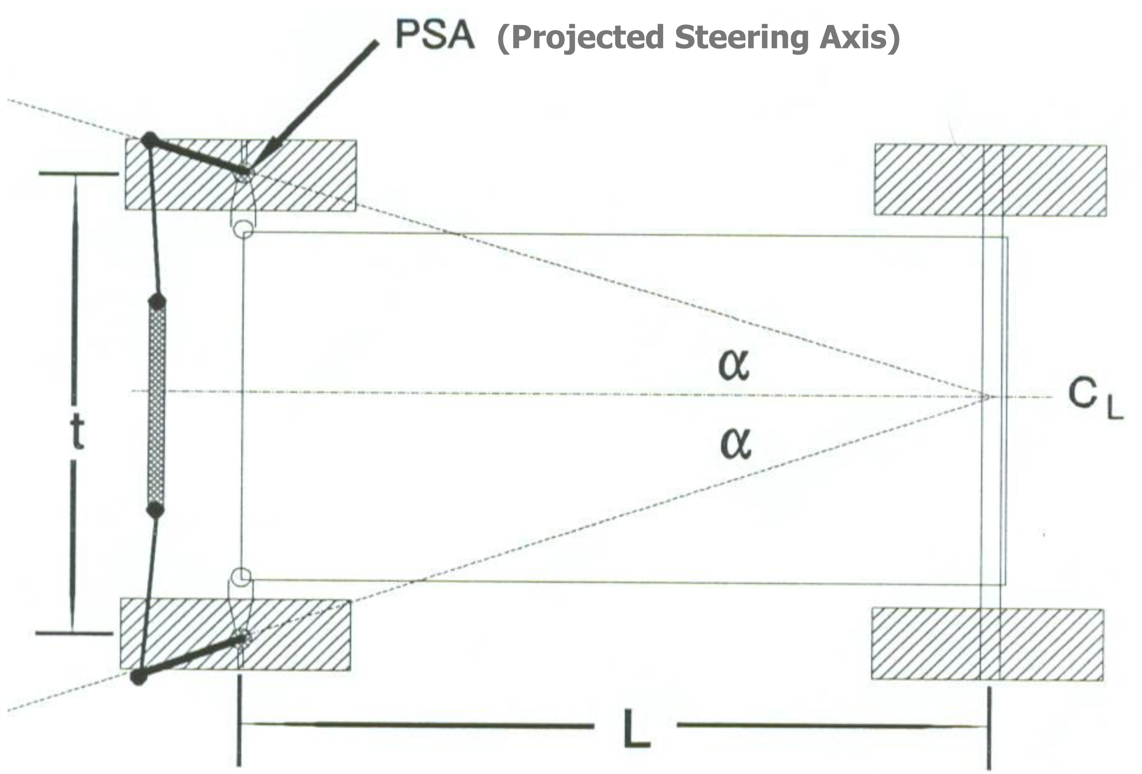
BND TechSource

- Rear Steer is used with Recirculating Ball Steering Gear.



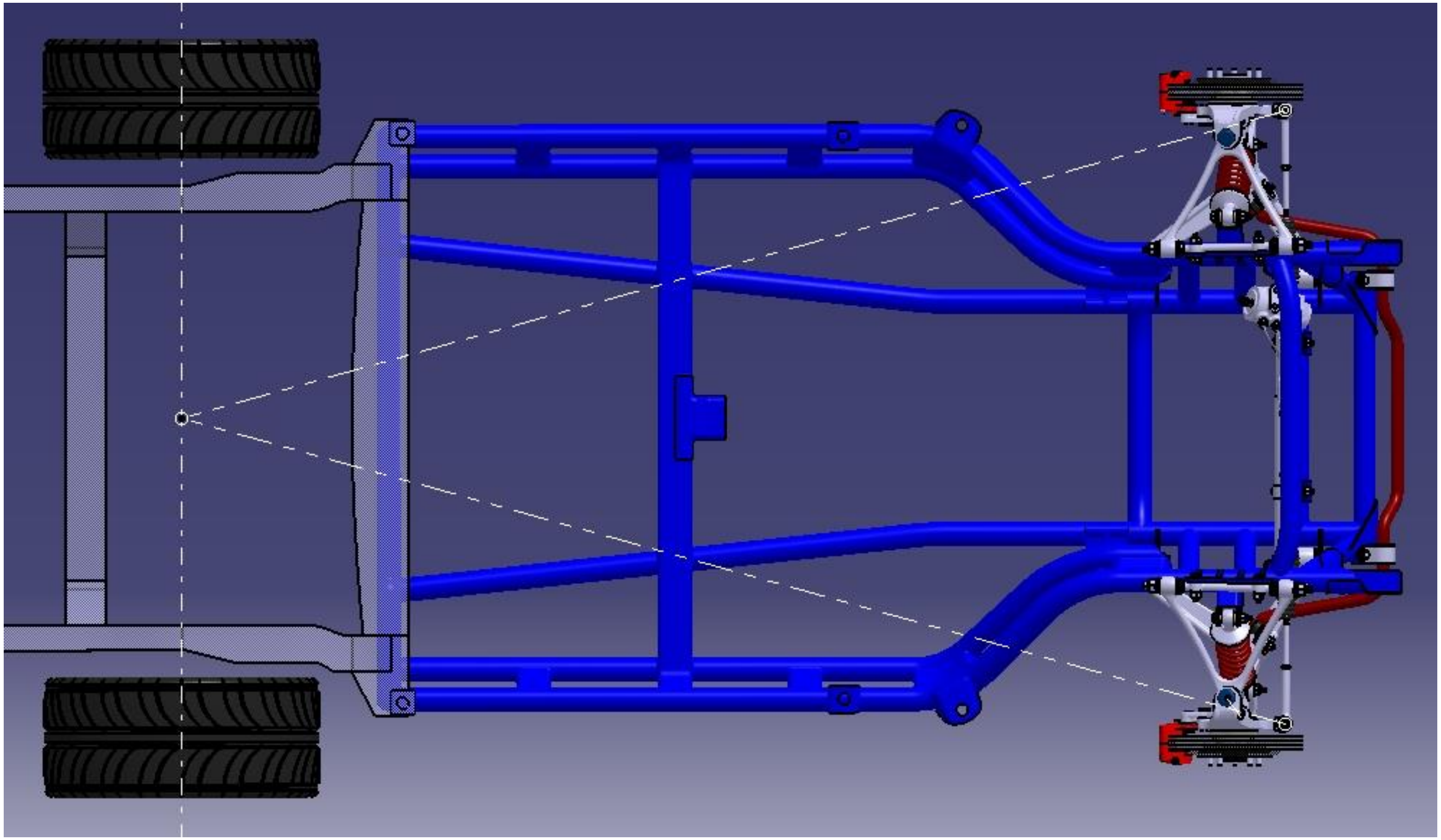
Rear Steer Suspension

- Front Steer is used with Rack & Pinion Steering Gear.



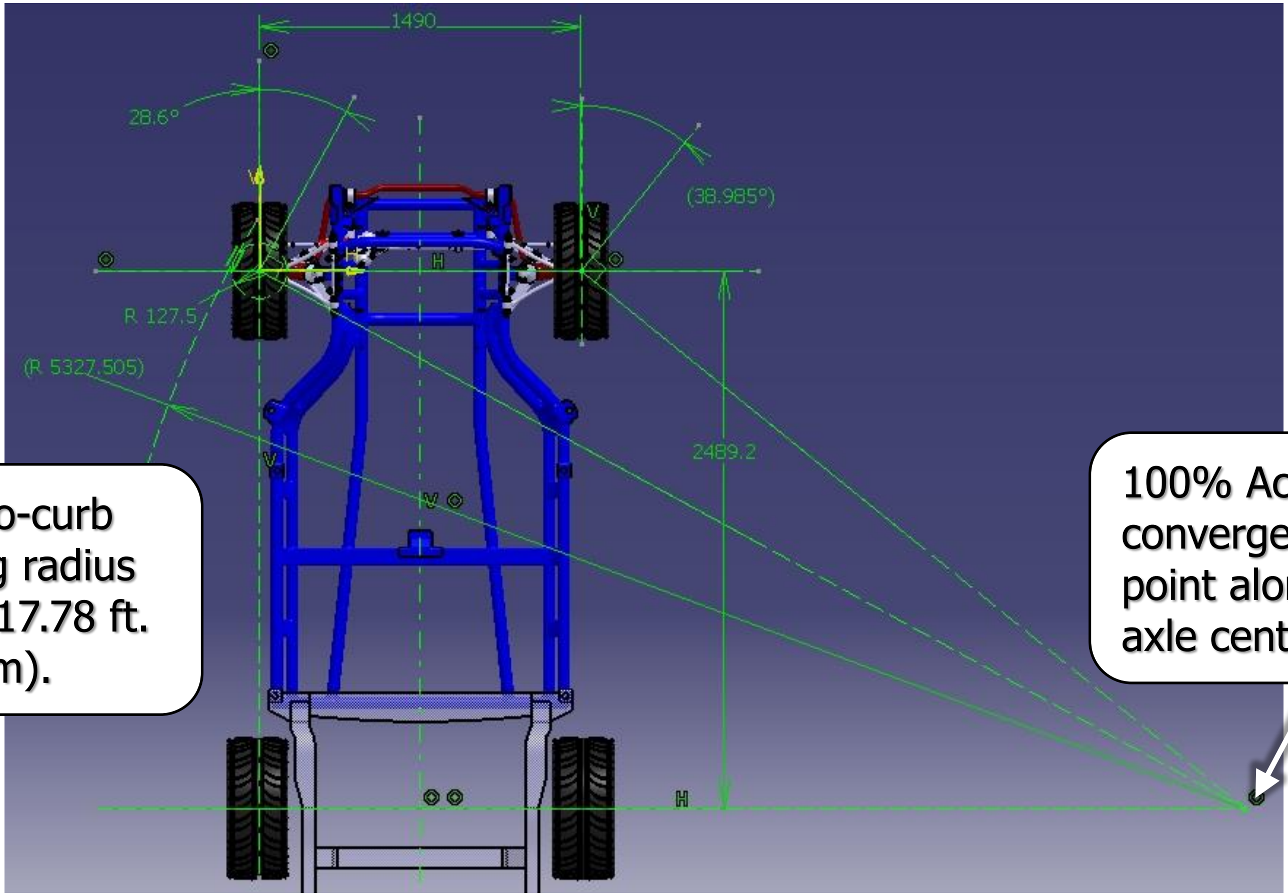
Front Steer Suspension

- Ackermann angles set up the Tie Rod Ends.



BND TechSource

- 100% Ackermann angles and the resultant Turning Angles.

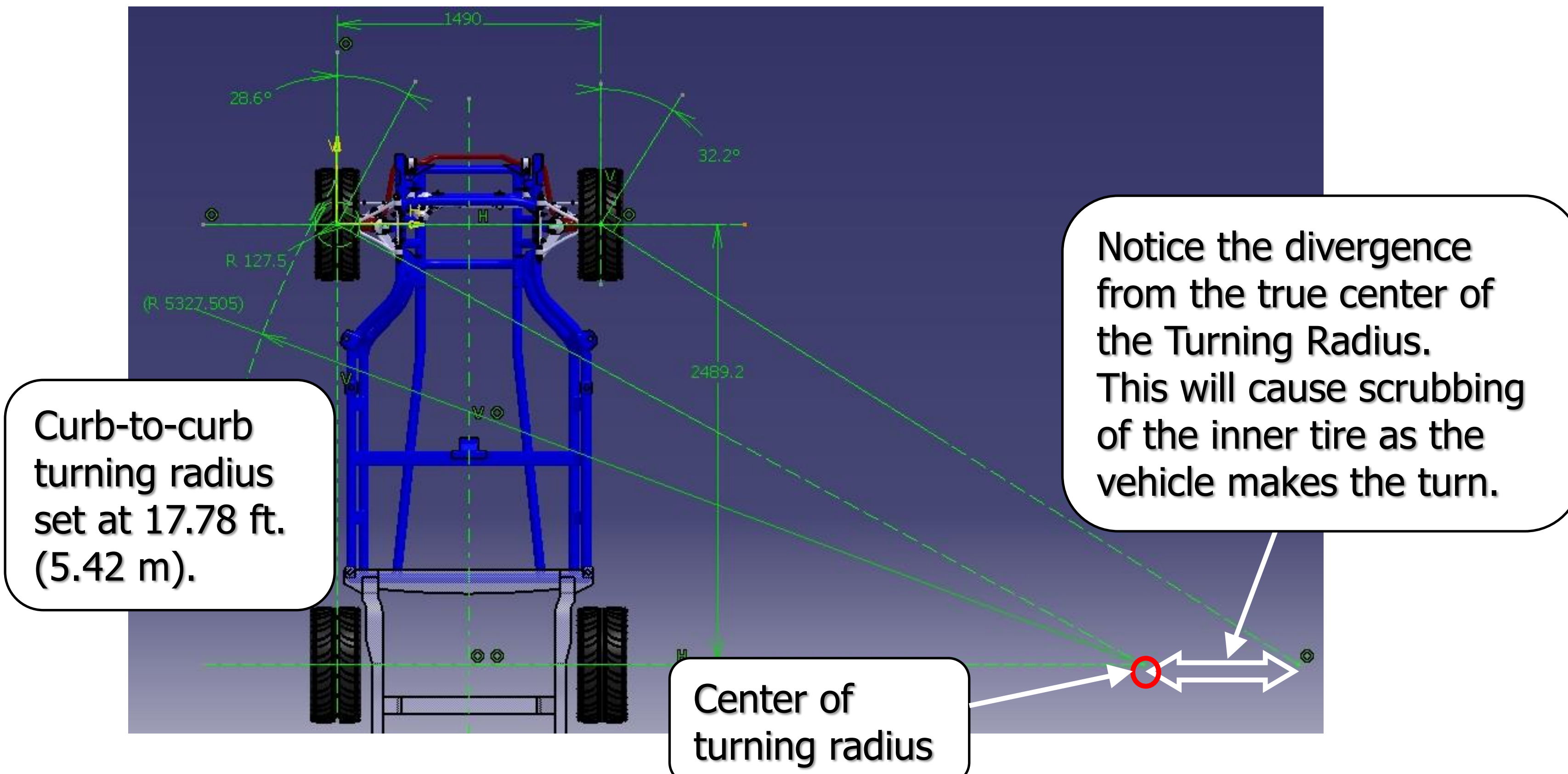


Curb-to-curb turning radius set at 17.78 ft. (5.42 m).

100% Ackermann will converge at the same point along the rear axle centerline.

BND TechSource

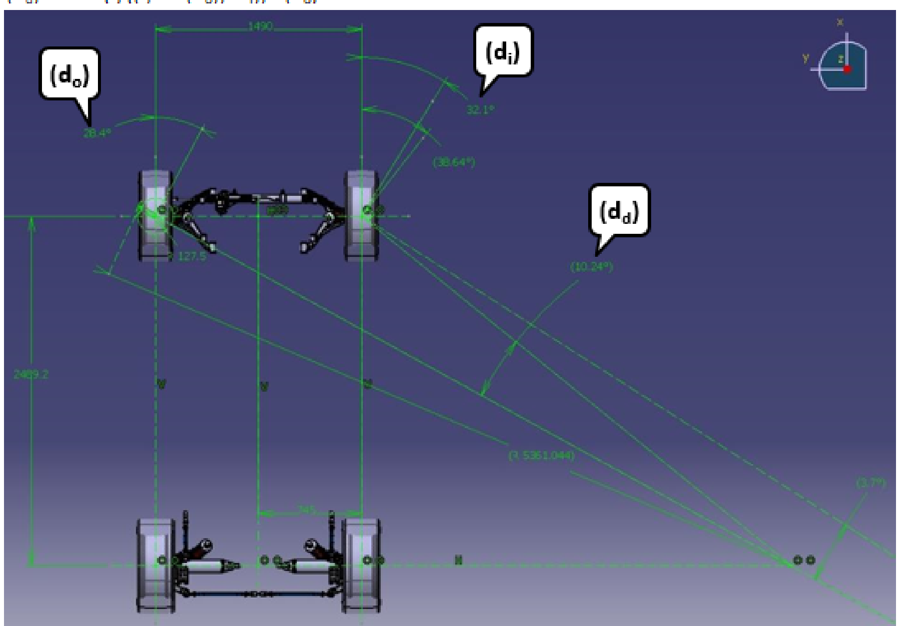
- Ackermann angles and the resultant Turning Angles.



BND TechSource

To avoid tire scrub when a vehicle is turning draw perpendicular lines from all four tires. If the **perpendiculars** from the front tires intersect along the lines drawn from the unsteered rear tires then you have classic Ackermann for **one** particular steering angle. Example: Turning radius curb-to-curb = 5.36m

% Ackerman = [Angle Inside Wheel ($\mathbf{d}_i$) - Angle Outside Wheel ($\mathbf{d}_o$)]/100% Ackerman Angle ($\mathbf{d}_d$)
Where the 100% Ackerman Angle ($\mathbf{d}_d$) is:
$\tan^{-1}$(WB/((WB/tan(Angle outside wheel)) - Front Track)) - Angle of outside wheel =
$(\mathbf{d}_d) = \tan^{-1}(L/((L/\tan(\mathbf{d}_o)) - t_f)) - (\mathbf{d}_o)$



$(\mathbf{d}_d) = \tan^{-1}(2489.2/((2489.2/\tan(28.4)) - 1490)) - (28.4) = 10.24$deg

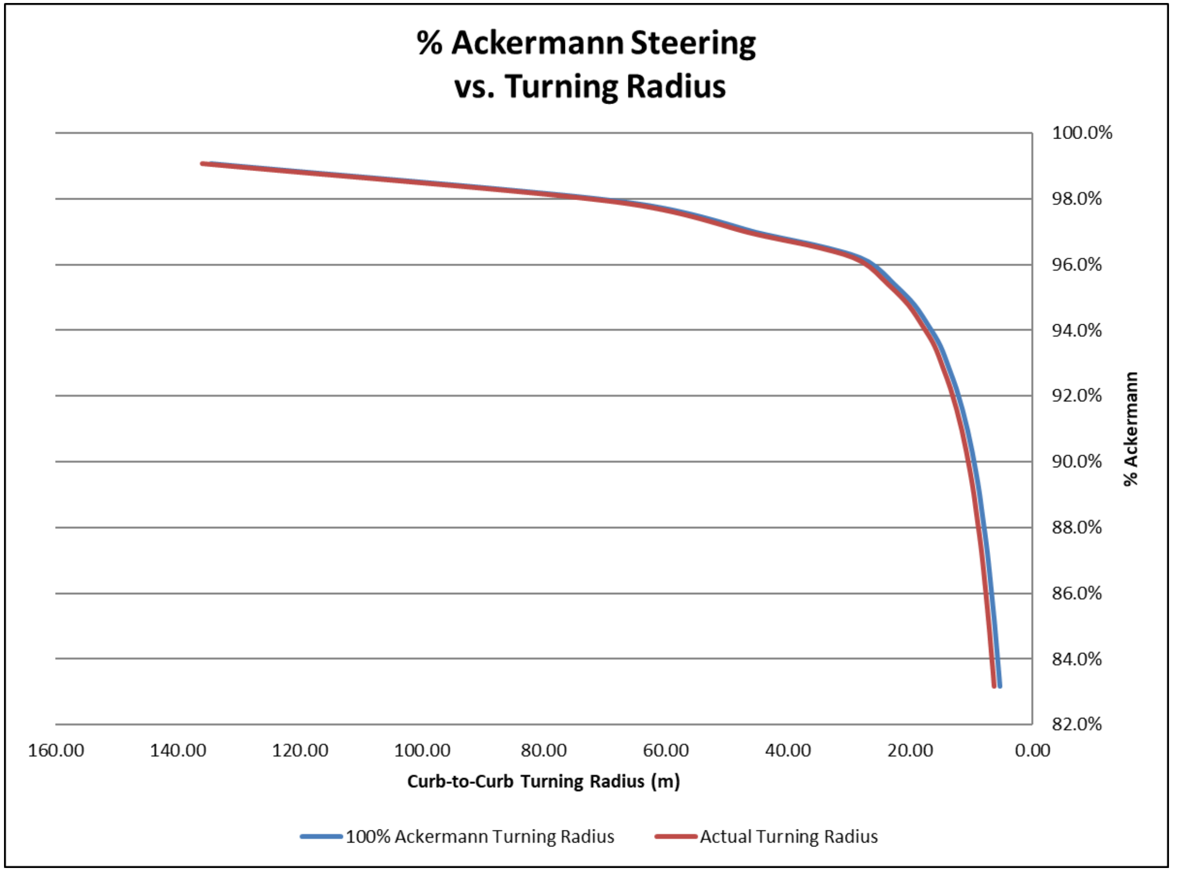
Data from CAD Simulation

(d_o) deg CAD SIM	(d_i) deg CAD SIM	(d_i) deg @100%	(d_d) deg @100%	% Ackermann	100% Ackermann Curb-to-Curb Turning Radius (m)	Actual Curb-to-Curb Turning Radius (m)	Skidpad Radius (m)
28.40	32.13	38.64	10.24	83.2%	5.36	6.30	5.42
27.33	30.77	36.81	9.48	83.6%	5.55	6.48	5.61
26.27	29.42	35.01	8.74	84.0%	5.75	6.68	5.81
25.21	28.09	33.25	8.03	84.5%	5.97	6.90	6.03
24.15	26.78	31.50	7.35	85.0%	6.21	7.14	6.27
23.10	25.49	29.80	6.70	85.5%	6.47	7.40	6.53
22.05	24.21	28.13	6.08	86.1%	6.76	7.69	6.81
21.00	22.95	26.49	5.49	86.6%	7.07	8.00	7.13
19.95	21.70	24.88	4.93	87.2%	7.42	8.35	7.48
18.91	20.47	23.31	4.40	87.8%	7.81	8.74	7.86
17.87	19.25	21.78	3.91	88.4%	8.24	9.17	8.30
16.82	18.04	20.26	3.44	89.1%	8.73	9.65	8.78
15.78	16.85	18.79	3.01	89.7%	9.28	10.21	9.33
14.74	15.66	17.34	2.60	90.3%	9.91	10.84	9.97
13.70	14.49	15.93	2.23	90.9%	10.64	11.57	10.69
12.66	13.32	14.55	1.89	91.6%	11.48	12.42	11.55
11.62	12.17	13.20	1.58	92.2%	12.49	13.43	12.55
10.58	11.03	11.88	1.30	92.8%	13.69	14.63	13.76
9.53	9.89	10.57	1.04	93.5%	15.16	16.11	15.24
8.49	8.76	9.31	0.82	94.1%	17.00	17.96	17.09
7.44	7.64	8.06	0.62	94.8%	19.36	20.34	19.46
6.39	6.53	6.85	0.45	95.4%	22.51	23.51	22.64
5.33	5.42	5.64	0.31	96.1%	26.91	27.96	27.09
4.28	4.32	4.48	0.20	96.5%	33.50	34.64	33.76
3.22	3.23	3.33	0.11	96.9%	44.48	45.79	44.92
2.14	2.14	2.19	0.05	97.9%	66.78	68.18	67.31
1.06	1.06	1.07	0.01	99.1%	134.48	135.91	135.04
0.00	0.00	0.00	0.00	100.0%			

% Ackerman = $[d_{i\ CAD\ SIM}/d_{i\ @100\%}]*100$

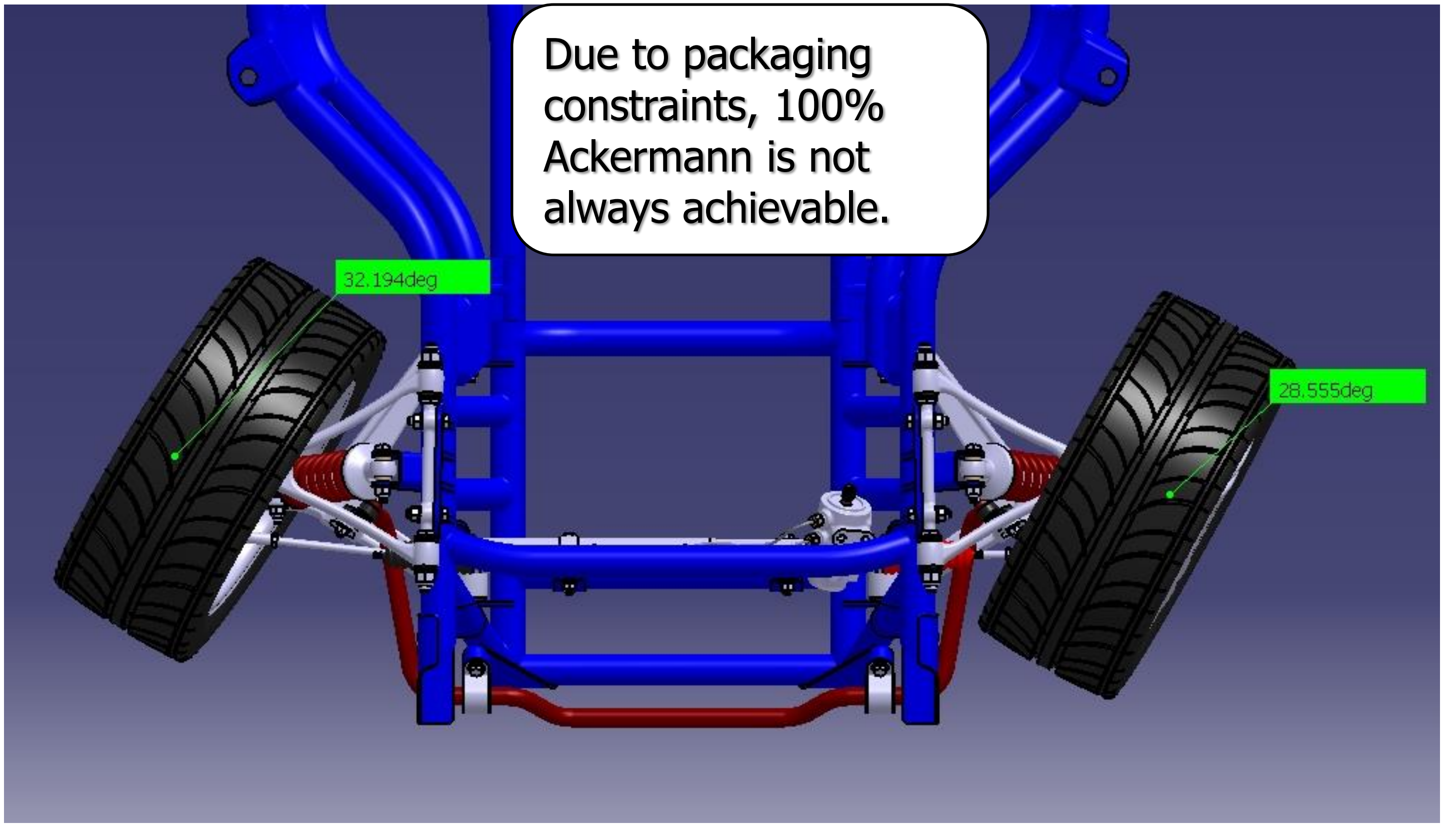
BND TechSource

- % Ackermann Steering vs. Turning Radius.

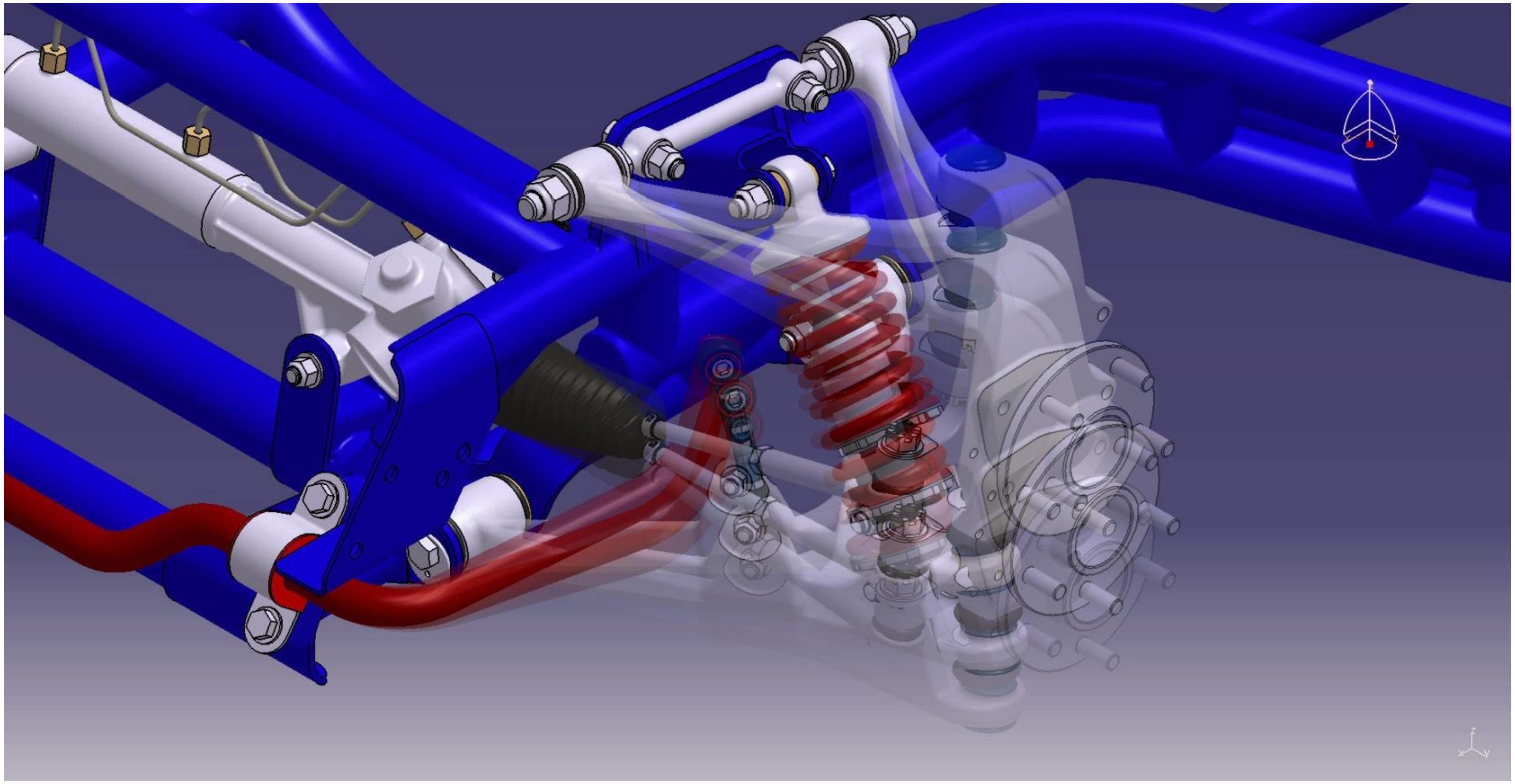


BND TechSource

- Less than 100% Ackermann is a normal compromise in today's passenger vehicles.

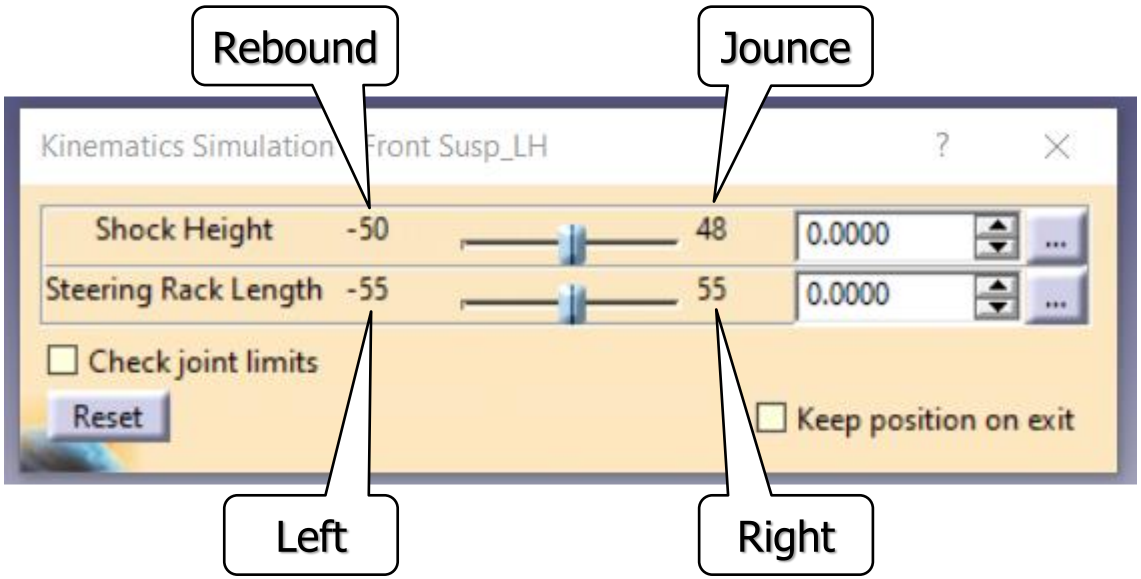


- The jounce (full compression up) and rebound (full extension down) must be determined.



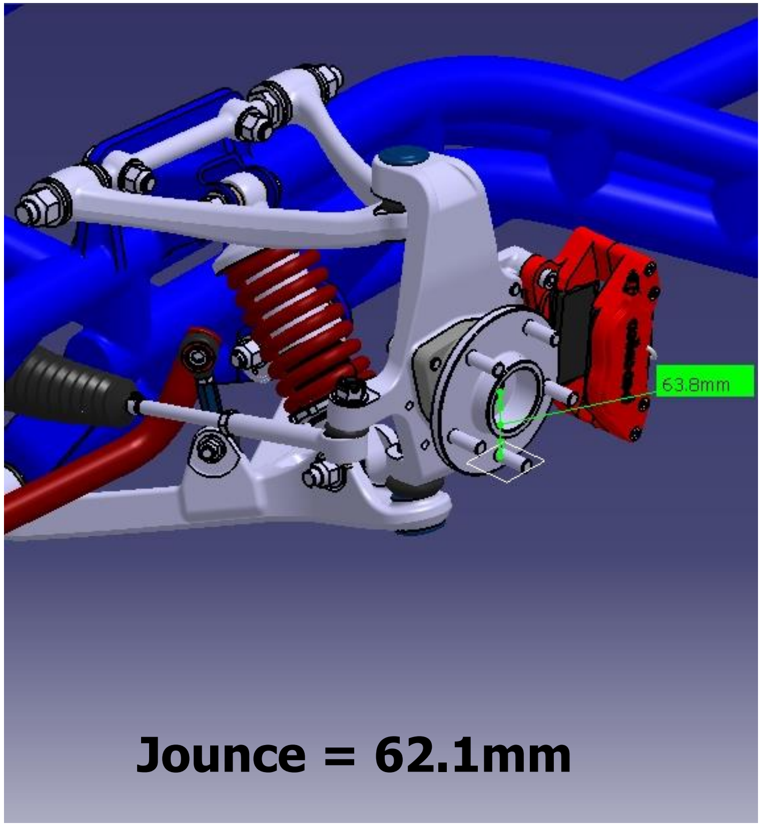
BND TechSource

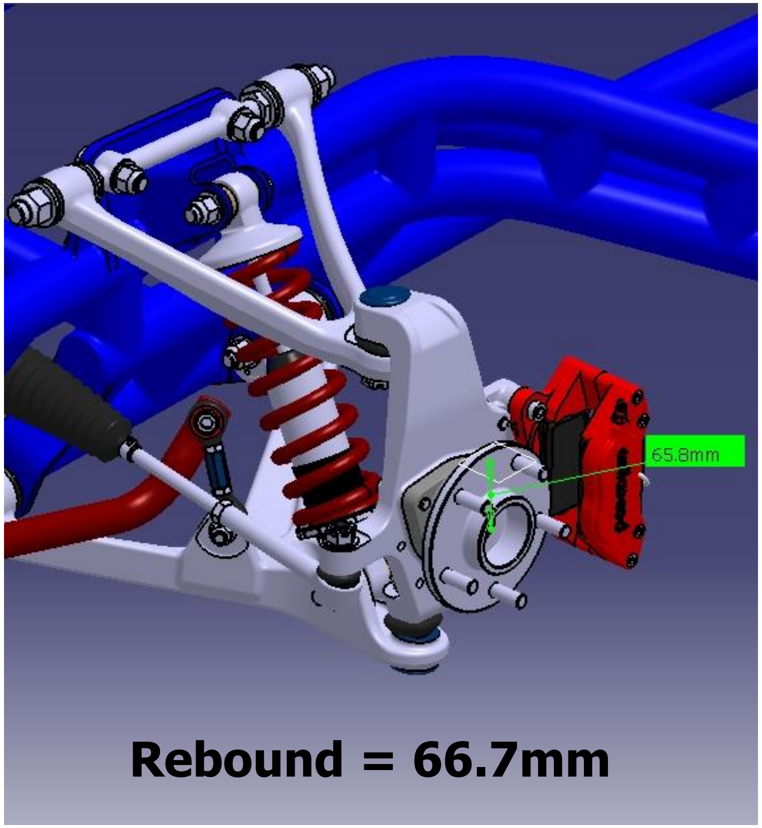
- To achieve the maximum steering angles and jounce/rebound distances, the CATIA kinematics must be at the following settings:



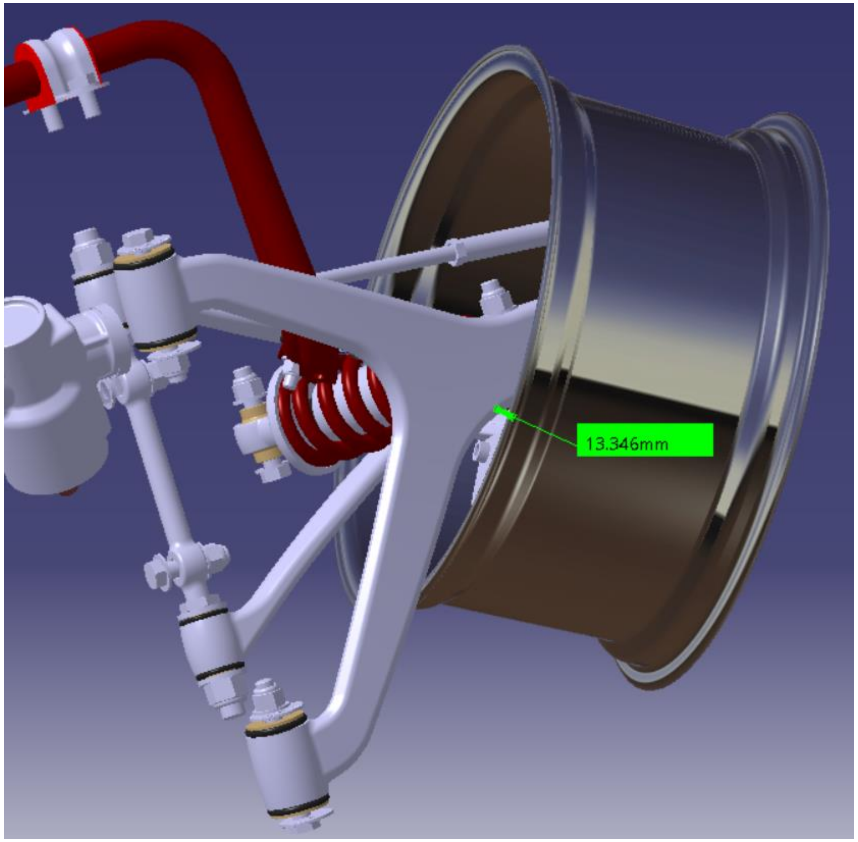
BND TechSource

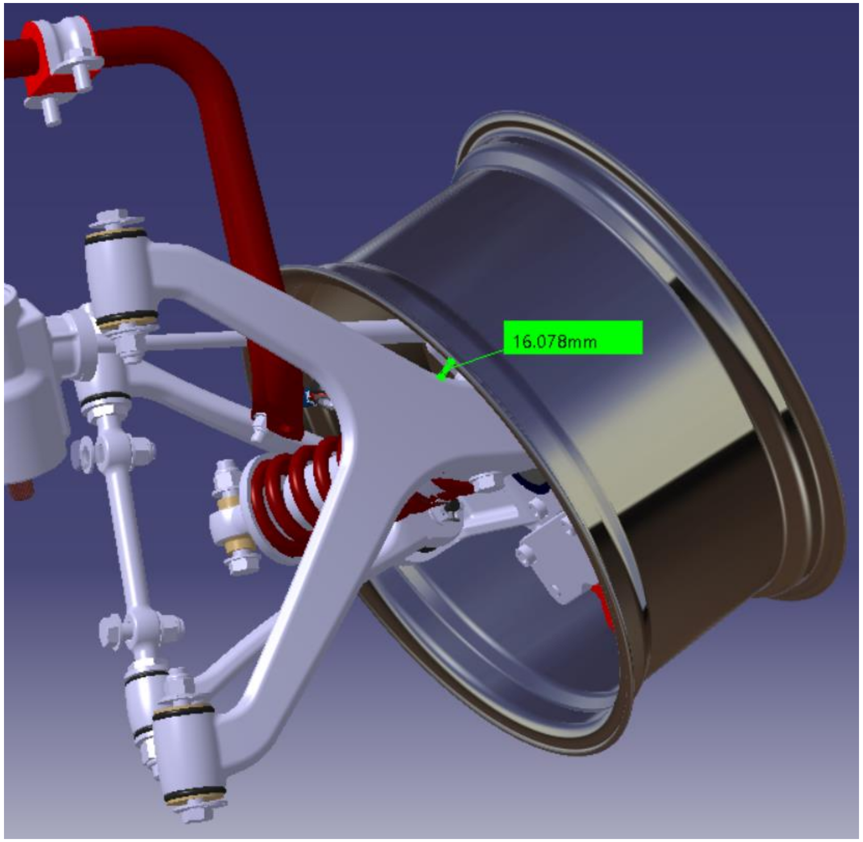
- Measure the jounce (full compression up) and rebound (full extension down).





- The worst condition is at full jounce and full turning angles.



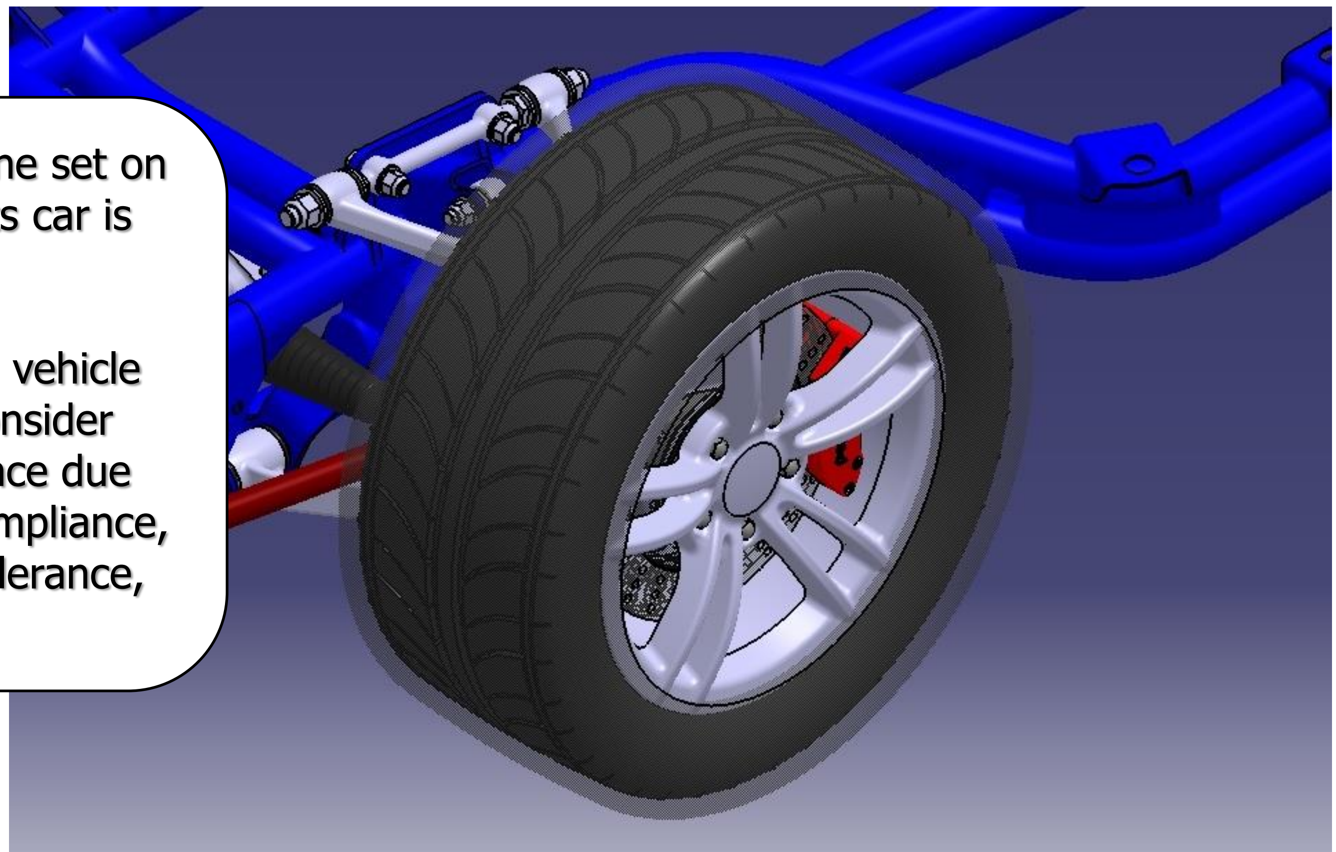


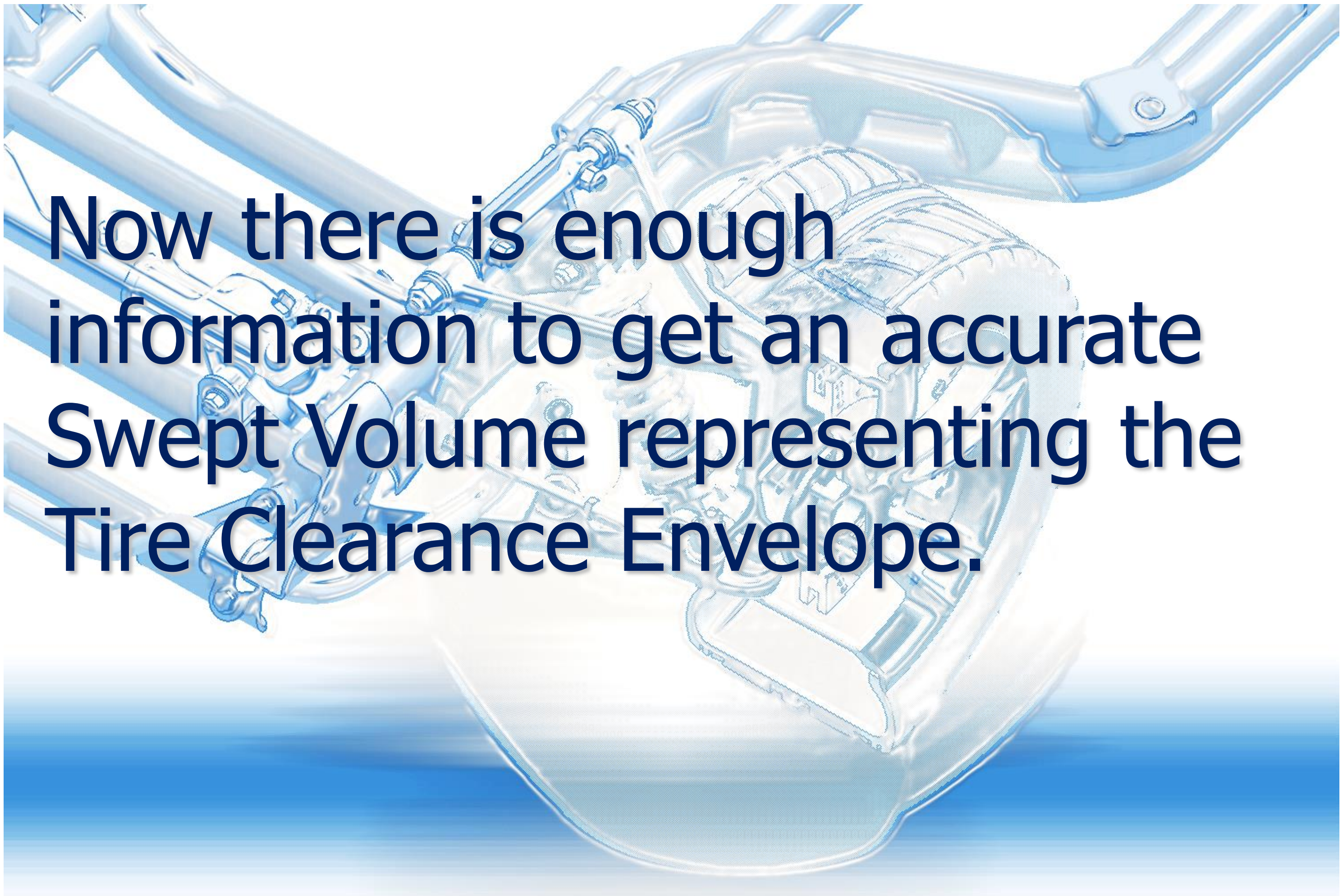
BND TechSource

- Another parameter is the clearance zone required around the tire.

The clearance zone set on this one-off sports car is 12 mm.

A mass produced vehicle would need to consider additional clearance due to suspension compliance, manufacturing tolerance, tire chains, etc.

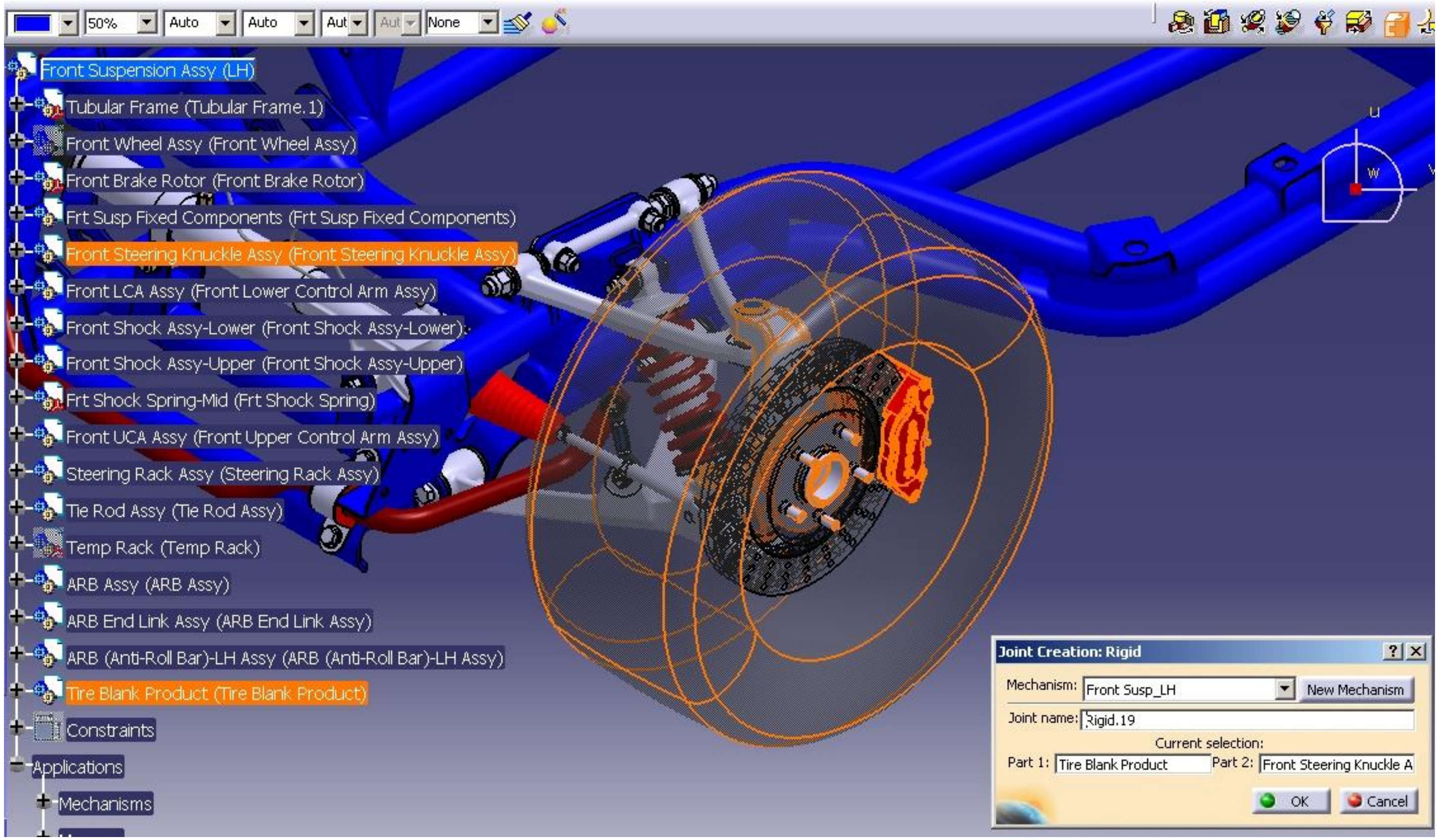




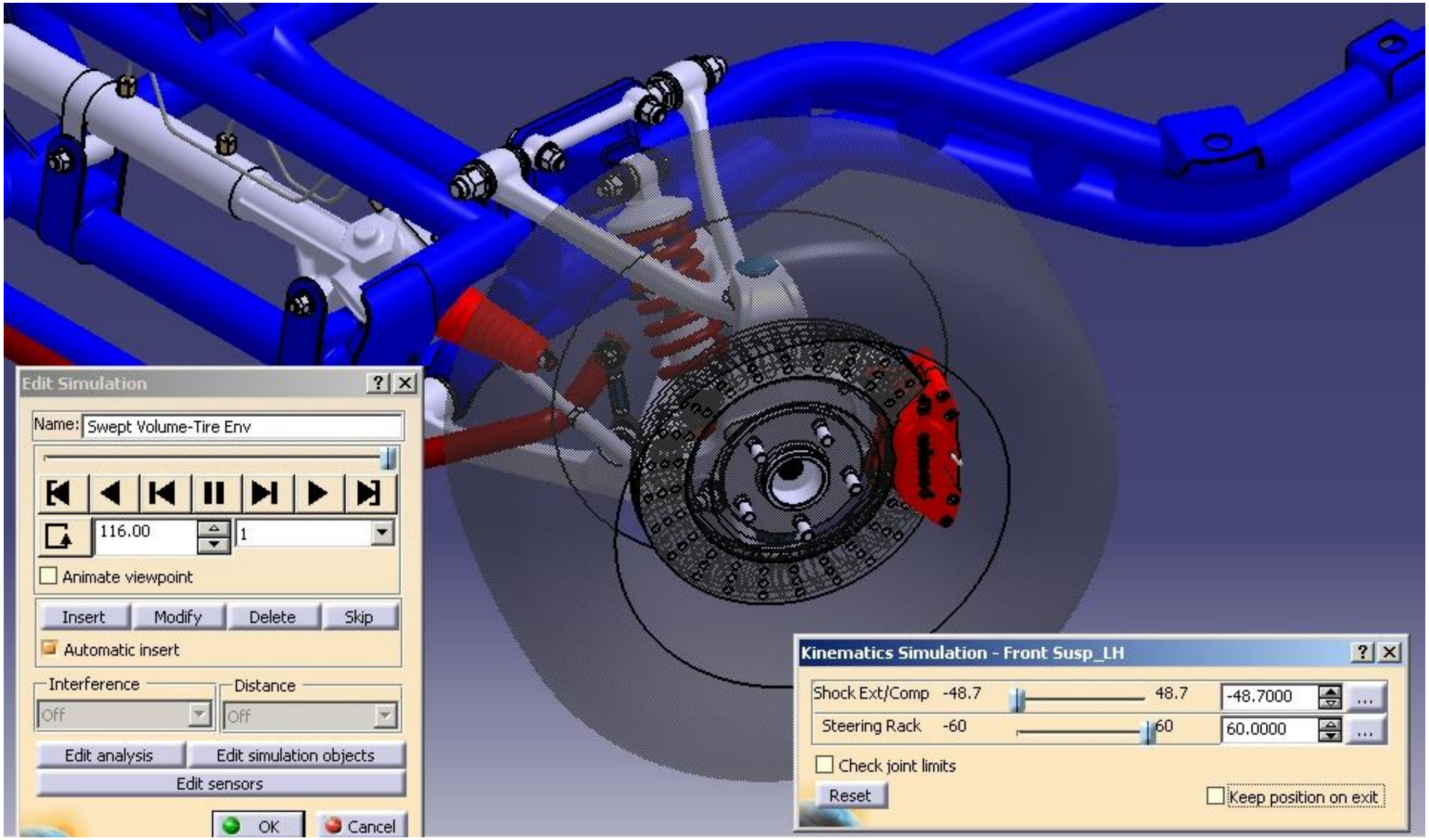
Now there is enough information to get an accurate Swept Volume representing the Tire Clearance Envelope.

BND TechSource

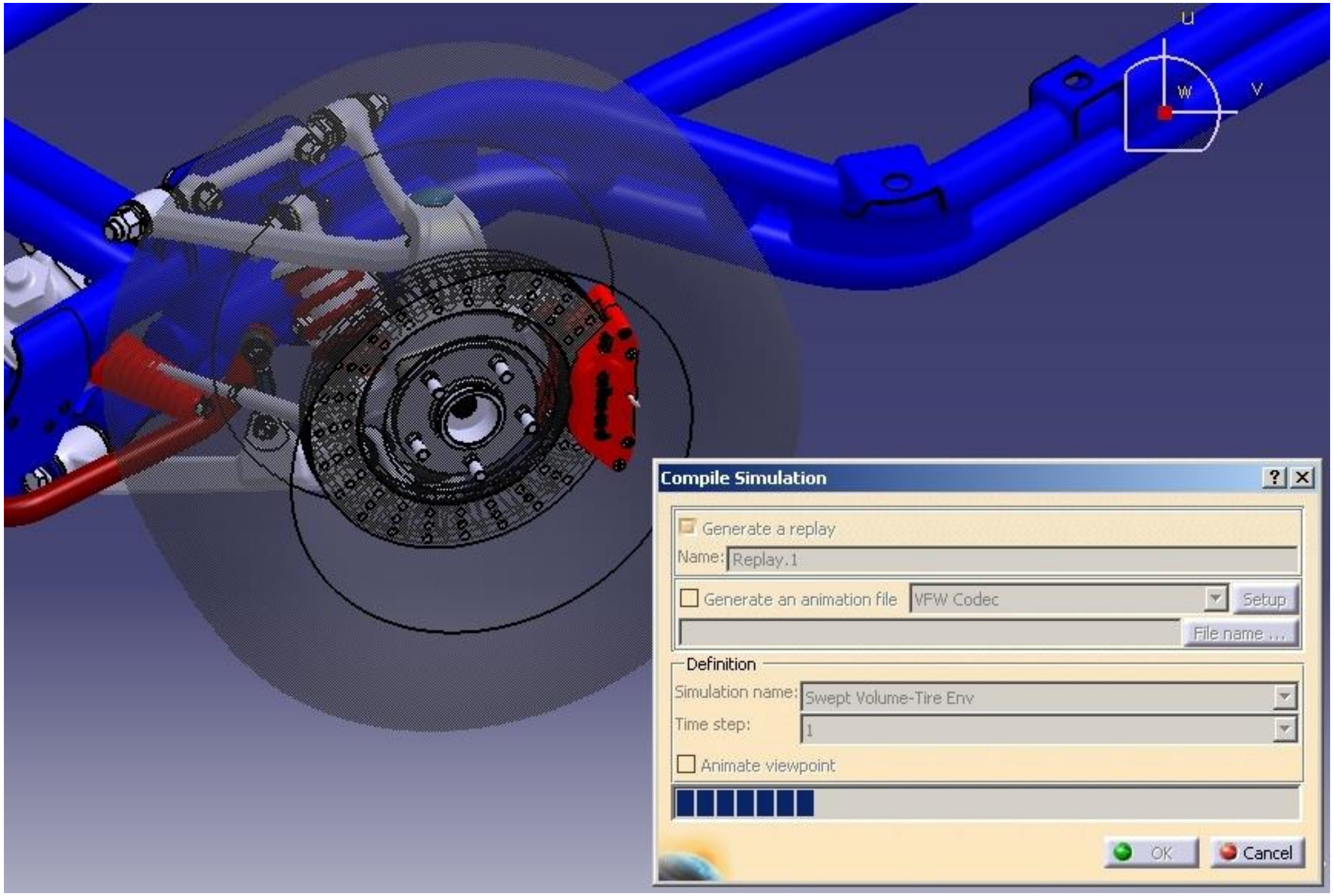
- Step 1: Create a Rigid Joint for the Tire Clearance Zone product in the current Kinematic Mechanism.



- Step 2: Create a Simulation in DMU Kinematics.

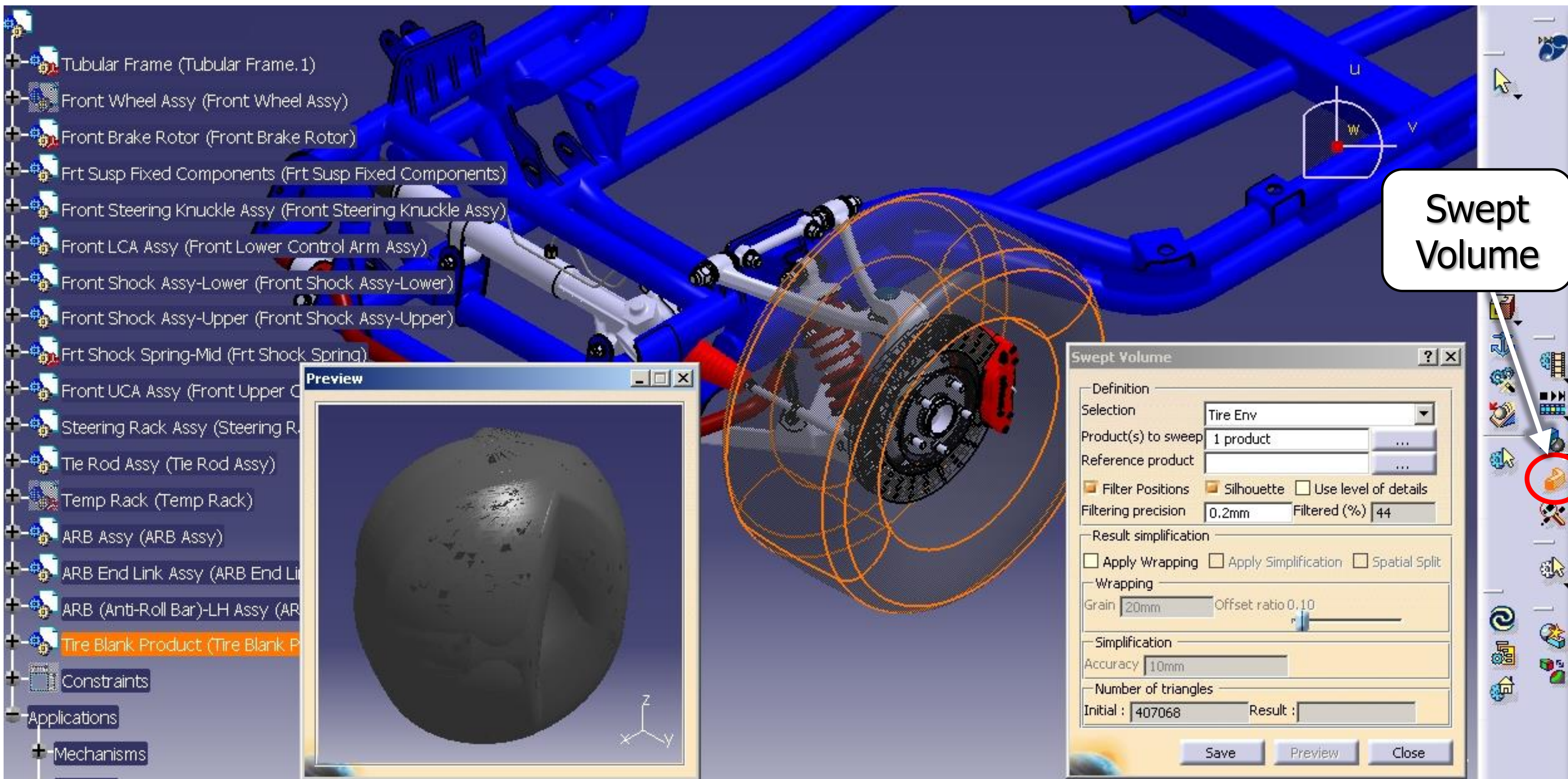


- Step 3: Compile the Simulation in DMU Kinematics.

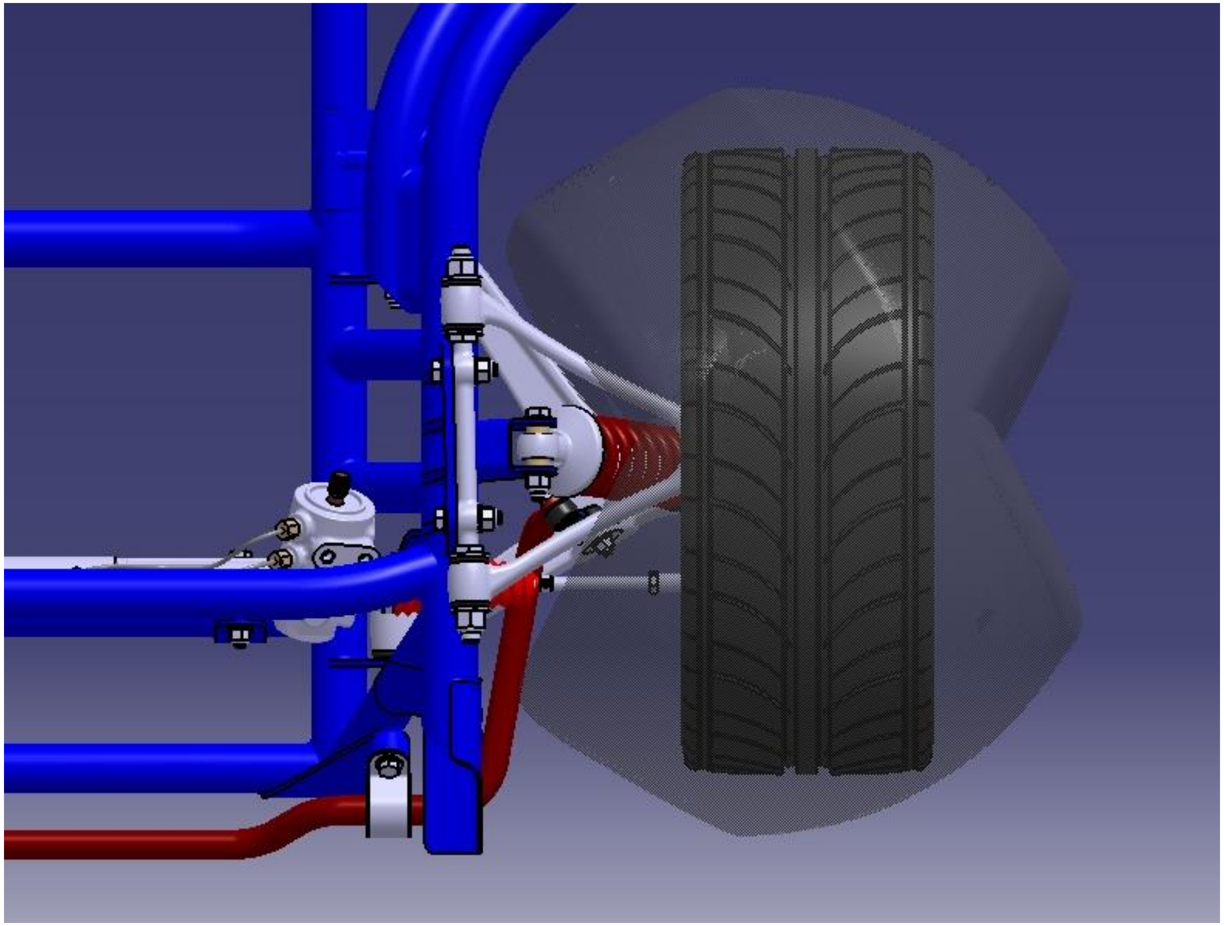


BND TechSource

- Step 4: Generate the Swept Volume in DMU Kinematics.



- Step 5: Add the Swept Volume into the Product.



BND TechSource

- Conclusion:

This is an example of how to use CATIA DMU Kinematics to create Trace Elements.

We hope this will help those who need this type of simulation.

As always, we are open to any discussions this may bring.

Please ***subscribe*** to our YouTube channel!