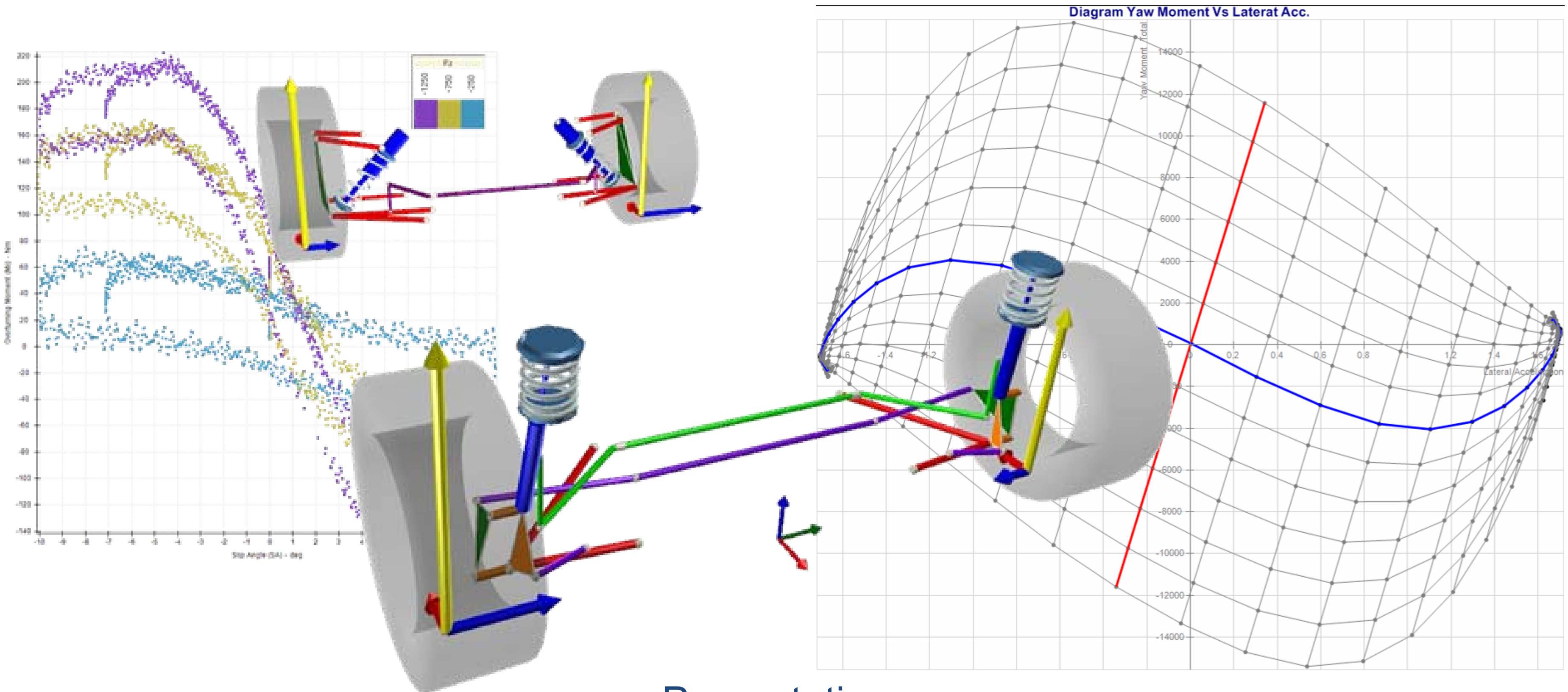
A new approach to steady-state and quasi-steady state vehicle handling analysis



Presentation

By Claude Rouelle

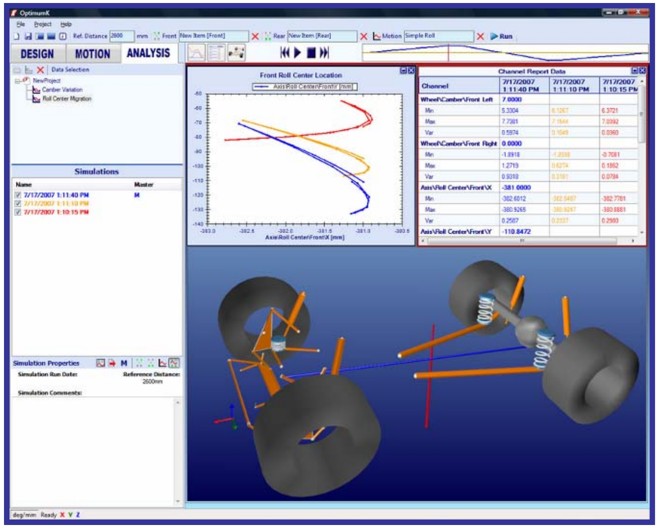
Vehicle Dynamics Expo

June 16nd-18th 2009

OptimumG - Overview

- Vehicle Dynamics & Data Acquisition Seminars
  - In-House Seminar
  - Public Seminar

- Consulting
  - Track Testing
  - Race Engineering
  - Data Acquisition
  - Mechanical Design
  - ...



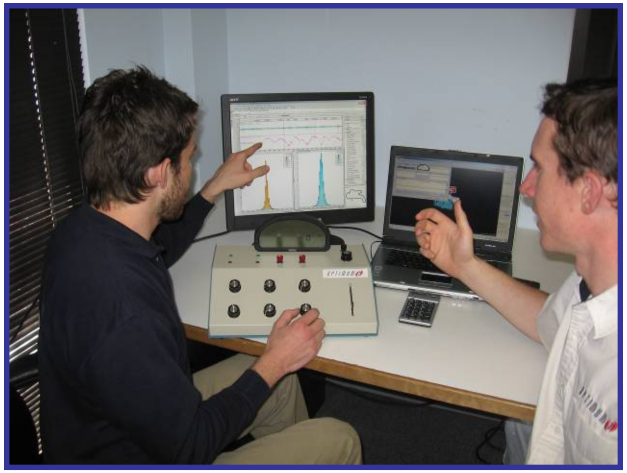
- Software Development
  - OptimumK
  - Simulation

OptimumG - Seminars

Vehicle Dynamics & Data Acquisition Seminars

- In-House Seminar
- Public Seminar
- One-on-One training

- From 1 to 12 days
- Design around customer needs
- 8900 Power Point Slides to choose from



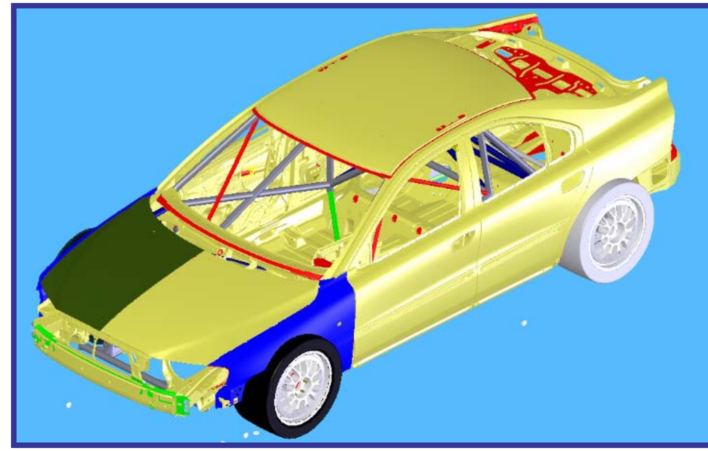
OptimumG – Seminars Customers

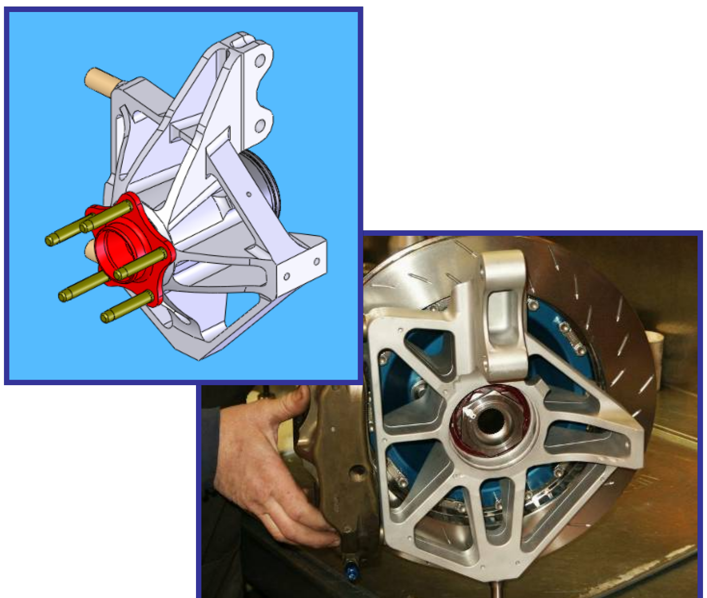
312 Seminars / 12 Years
Over 6000 Satisfied Customers

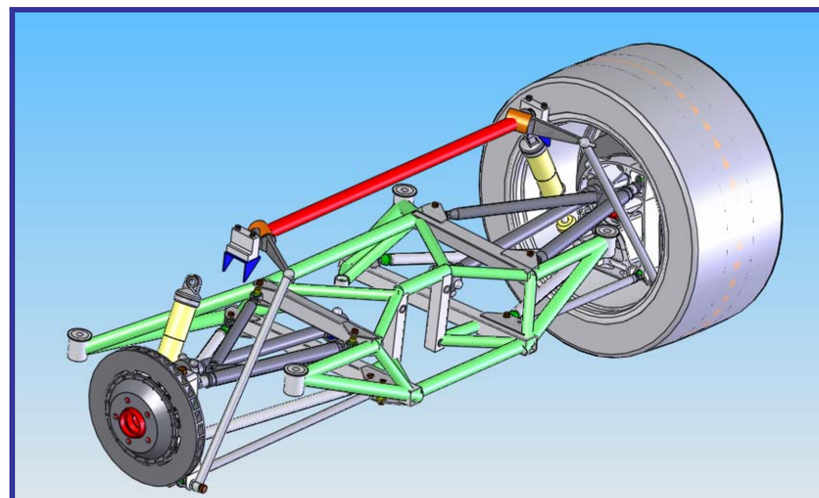
- Alcon
- AP Brakes
- Brembo
- Bridgestone-Firestone USA
- Bridgestone Tech. Center Europe
- BMW
- Citroen Sport
- Corrsys-Datron
- Chrysler
- Dunlop
- Ferrari
- Ford Advanced Vehicle Operations
- Goodyear
- Mac Laren
- Magneti-Marelli,
- Michelin
- Mitsubishi
- Multimatic
- MoTeC
- Nascar
- Ohlins
- Oreca
- Penske
- Pi Research
- Pirelli
- Porsche
- PSA Peugeot Citroen
- Toyota
- ZF-Sachs.

OptimumG - Consulting

- Mechanical Studies
- Chassis Design
- Suspension Geometry Design

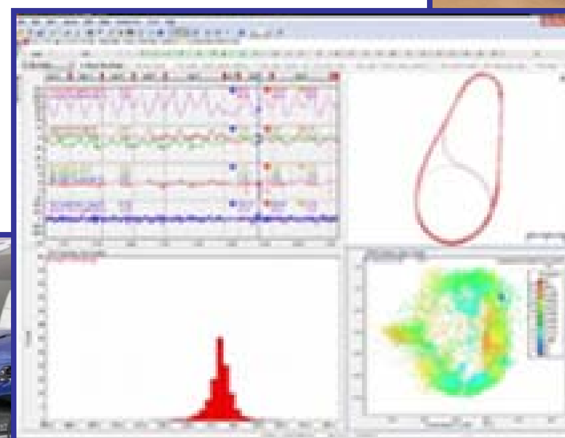






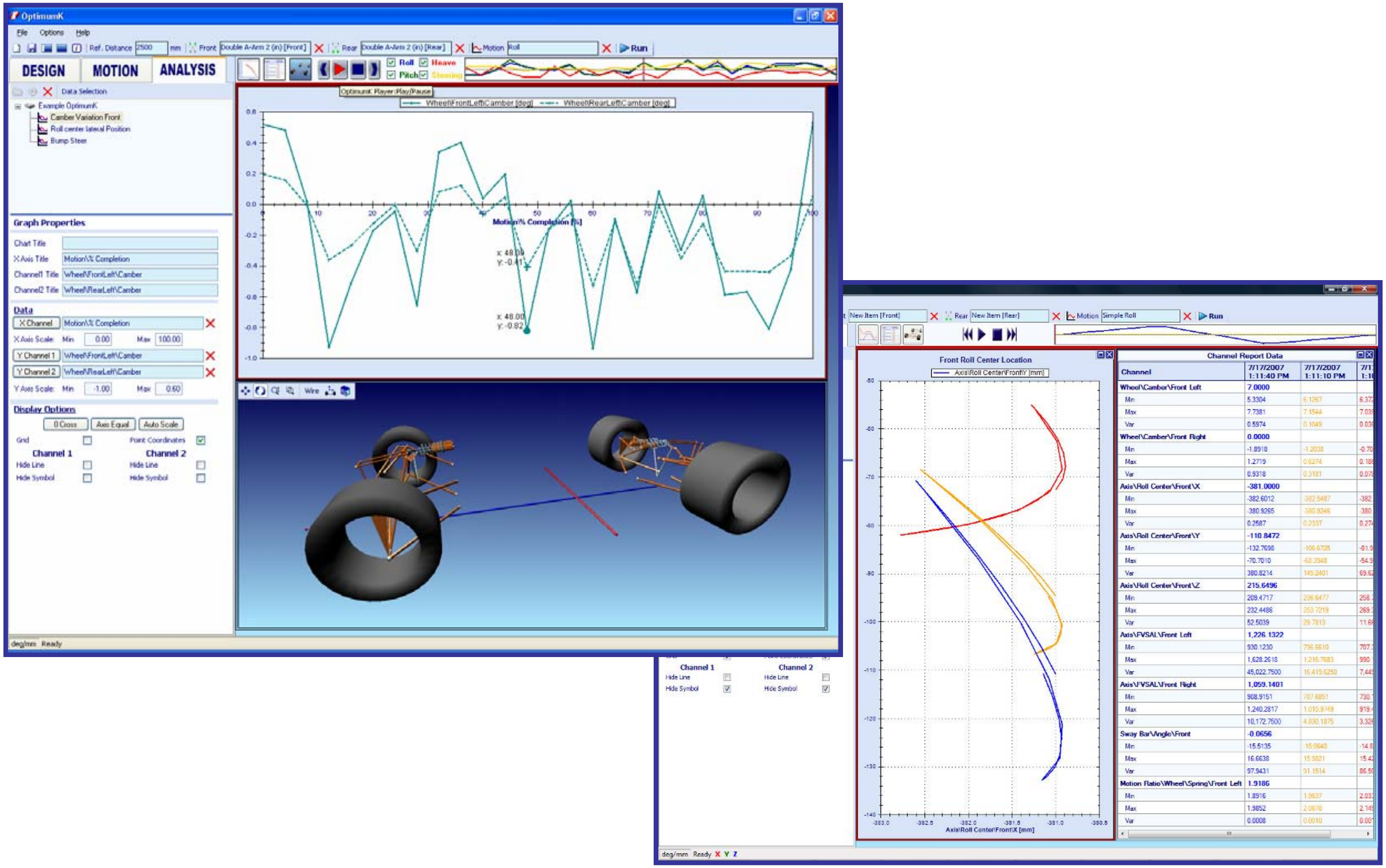
OptimumG - Consulting

- Race Car Engineering
- On Track Engineering
- On Track Testing
- Lab Testing
- Data Acquisition



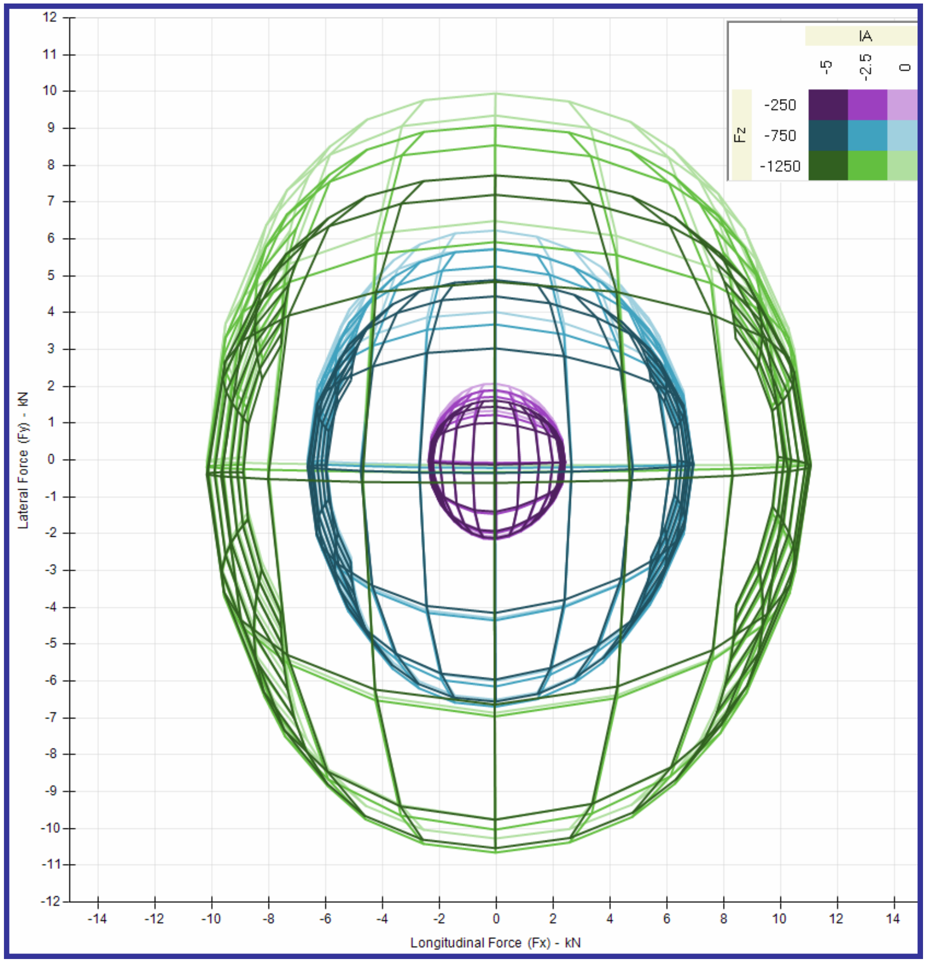
OptimumG – Software Development

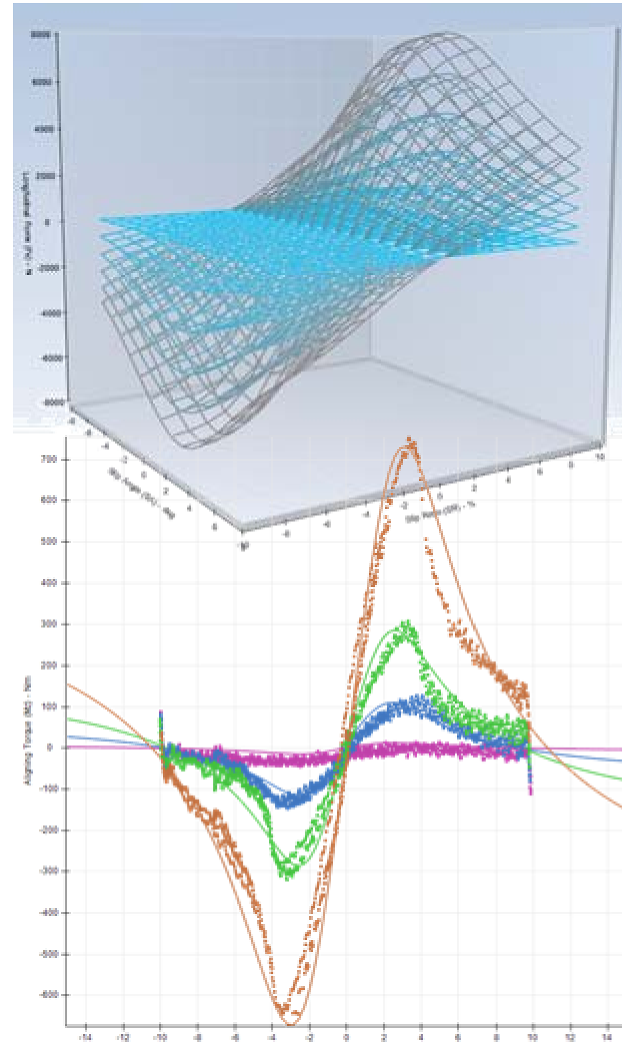
- OptimumK : Kinematics software



OptimumG – Software Development

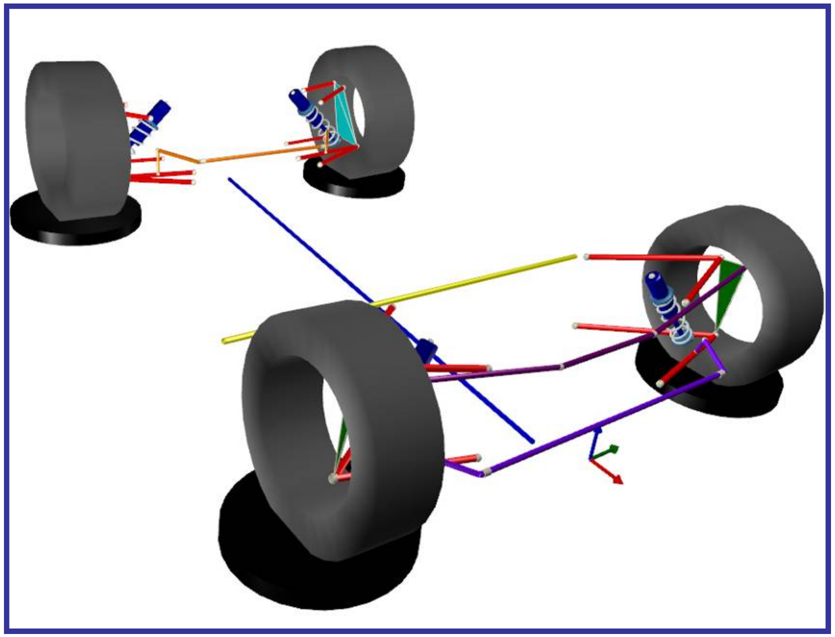
- OptimumT : Tire Data Fitting and Visualization Software

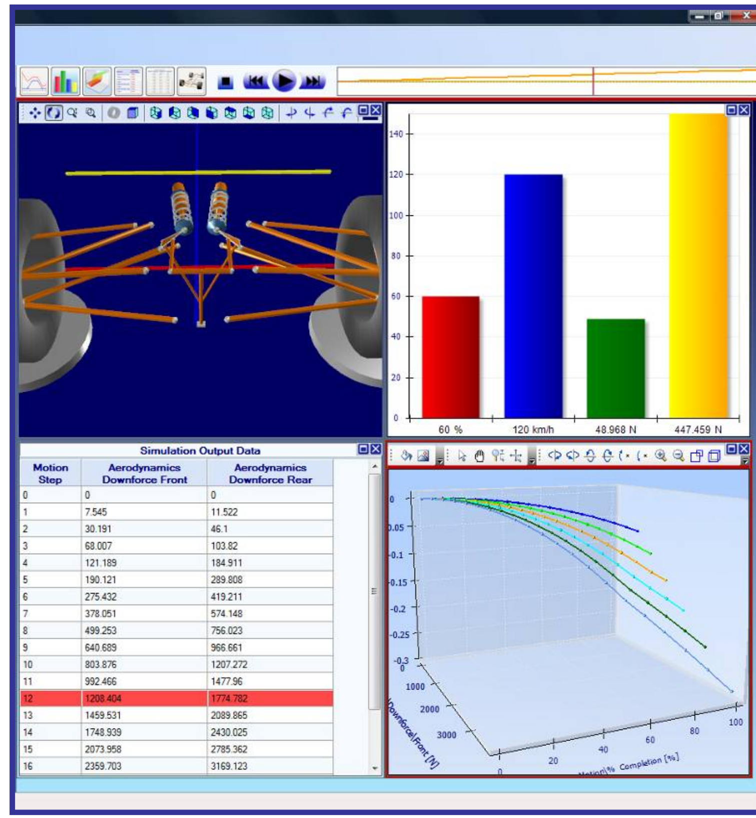




OptimumG – Software Development

- Computational Vehicle Dynamics
  - Steady State simulation
  - Quasi-Steady State simulation
  - Yaw Moment Diagram – Moment Method





- About CVD
- CVD Presentation
  - Design
  - Motion
  - Setup
  - Analysis

COMPUTATIONAL
VEHICLE
DYNAMICS

- Quasi Steady State Simulation
- Pure Steady State Simulation
- Steering Simulation
- Yaw Moment Diagram Simulation

About CVD

- CVD (Computational Vehicle Dynamics) calculates the behavior of the car in *steady state*

- Steady state: all the forces and moments are balanced in each step of the simulation

  → No inertia

  → No damping

- Calculation of lateral and longitudinal grip

  →Reaction of both suspended and non suspended mass

  →Weight Transfer

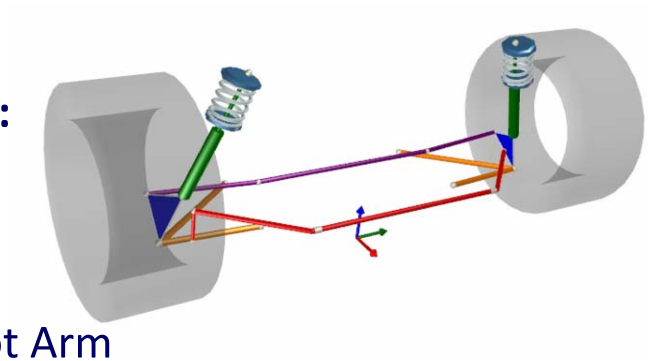
  →Tire Deflection

  →…

- However, CVD could consider the case where the yaw moment is not equal to zero allowing the user to analyze parameters like *understeer* or *oversteer*.

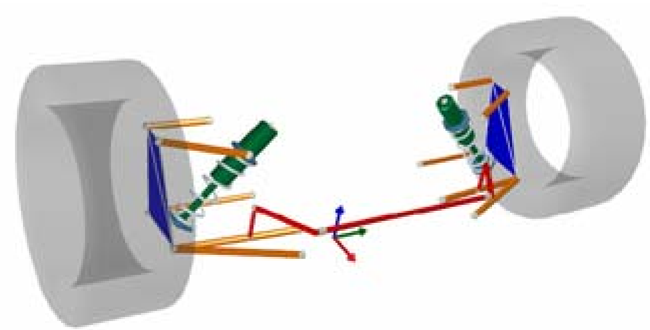
Front Suspension Templates:

- Double A-Arm
- Nascar
- Mac Pherson
- Mac Pherson Pivot Arm



Rear Suspension Templates:

- Double A-Arm
- Mac Pherson
- Nascar
- V8 Supercar
- Five Link



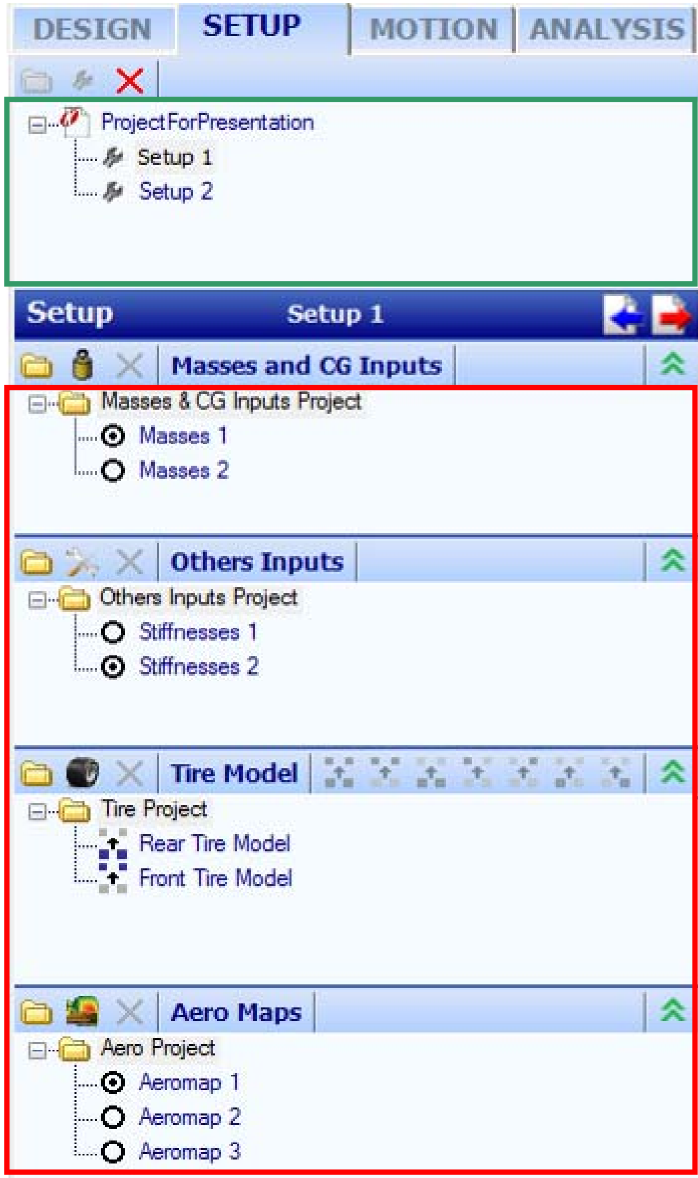
Summary | Mac Pherson Geometry | Options (mm)

Summary ☐ Symmetry

	Left X	Left Y	Left Z	Right X	Right Y	Right Z
Wishbone	X	Y	Z	X	Y	Z
Chassis Fore	-293	356.6	122.29	-293	-356.6	122.29
Chassis Aft	8.7899	379.04	135.29	8.7899	-379.04	135.29
Upright	-24	694	127	-24	-694	127
Strut						
Upper Point	58	487	676	58	-487	676
Lower Point	-4	635	283	-4	-635	283
Steering Type	Rack and Pinion					
Tie Rods	X	Y	Z	X	Y	Z
Rack	-111	333.85	219.1	-111	-333.85	219.1
Upright	-151.7	684.81	221.73	-151.7	-684.81	221.73
Steering Ratio						
Steering Rack Displacement/Steering Wheel Revolution						1
Wheel geometry						
Half Track		798			798	
Longitudinal Offset		0			0	
Vertical Offset		0			0	
Static Camber		0			0	
Static Toe		-0.43			-0.43	
Rim Diameter		450			450	
Tire Diameter		650			650	
Tire Width		270			270	
Spring	X	Y	Z	X	Y	Z
Upper Center	56	508	660	56	-508	660
Lower Center	41	553	512	41	-553	512
Anti-Roll Bar						
Pivot	X	Y	Z	X	Y	Z
Chassis Pivot	250	350	250	250	-350	250
Drop Link						
Attachment	Wishbone					
Anti-Roll Bar	0	600	230	0	-600	230
Attachment	0	600	130	0	-600	130

OPTIMUM G

CVD - Setup



Create as many Setup as you want

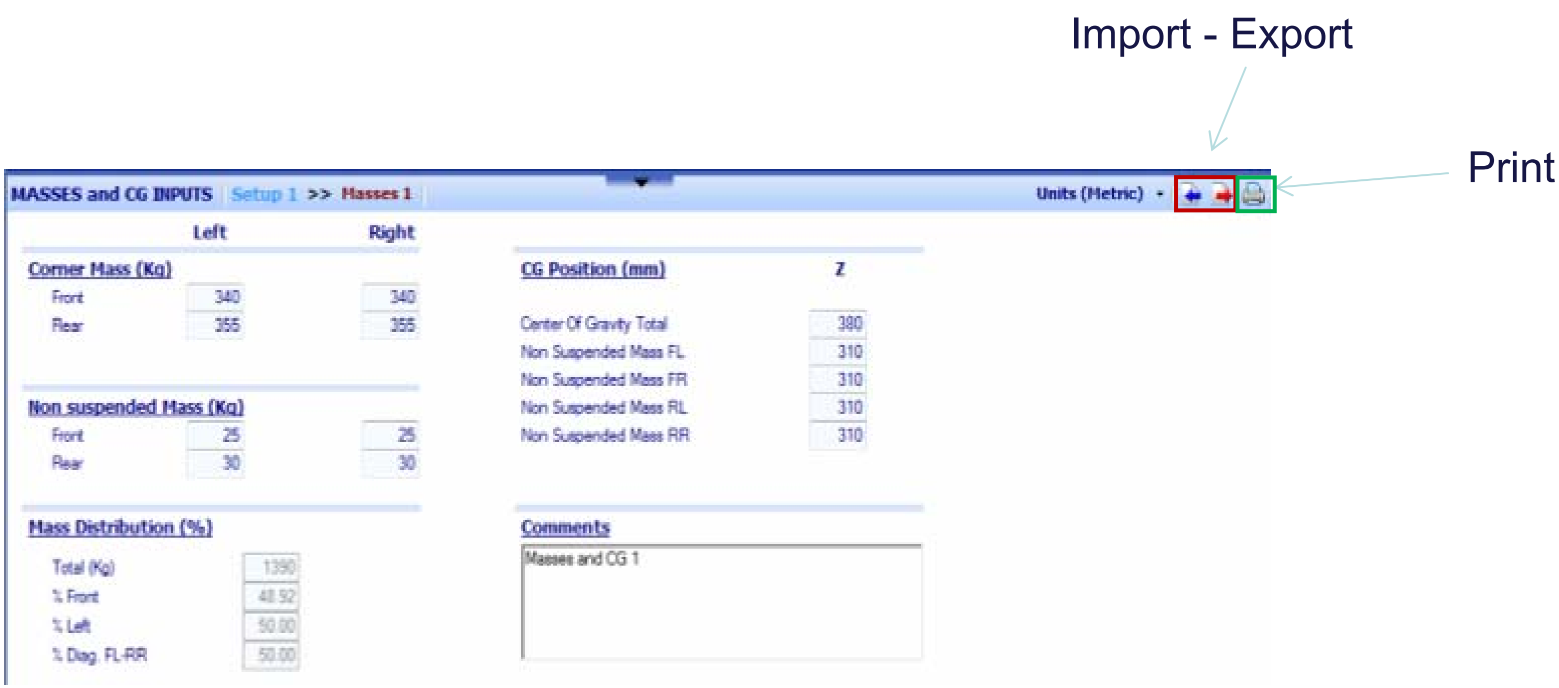
Setup split in 4 :

- Masses and CG
- Others (Stiffness, Brake, Diff…)
- Tire Model
- Aero Maps

Fast Setup changes

Masses and CG Inputs

- Corners Masses
- Non Suspended Masses
- CG Total Height
- Non Suspended Masses CG



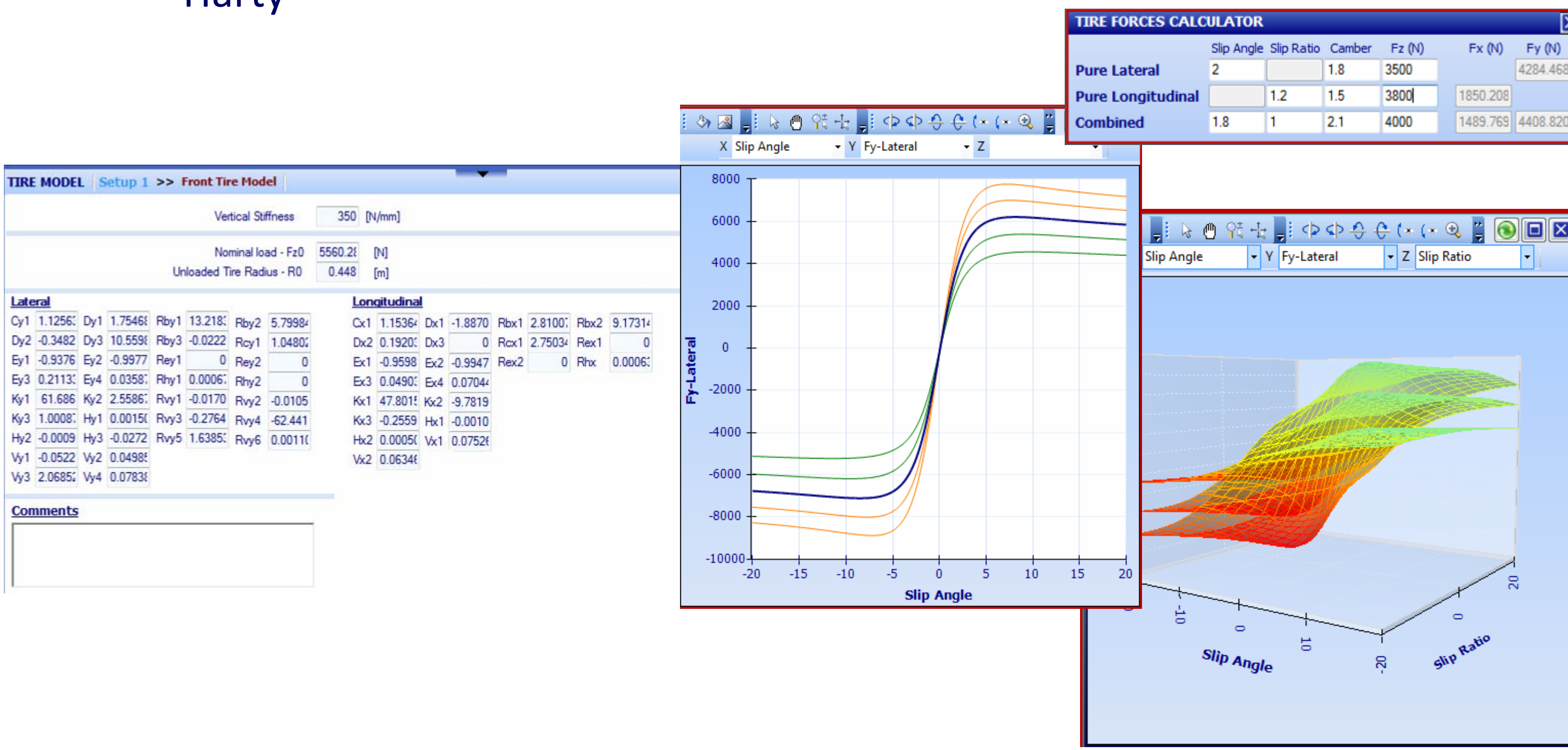
Other Inputs

- Spring Stiffness
- Anti Roll Bar Stiffness (or Belleville Washers Stiffness)
- Brake Distribution
- Drivetrain Configuration
- Static Ride Height
- Non Suspended Mass CGs
- Chassis Torsional Stiffness

Tire Model

- Pacejka
- Fiala
- STI
- Harty

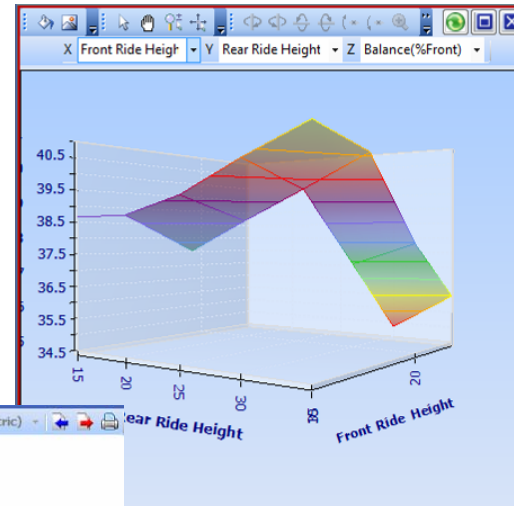
- Visualization Tools:
  - 2D Graph
  - 3D Graph
  - Tire Forces Calculator

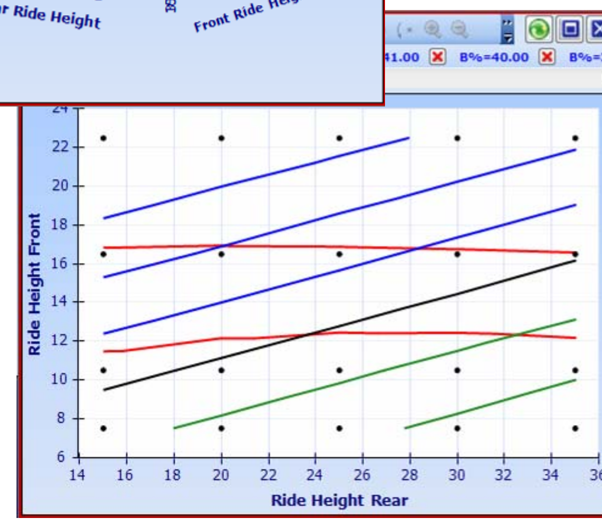


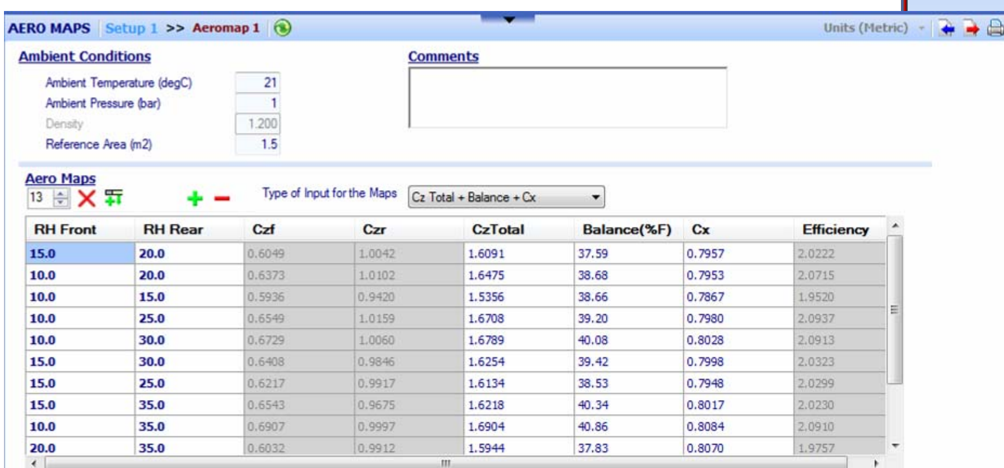
Aero Maps

- Cz Front and Rear
- Cx
- Aero Balance
- Efficiency

- Aero Map Visualization:
  - 3D Graph
  - Iso Lines







RH Front	RH Rear	Czf	Czr	CzTotal	Balance(%F)	Cx	Efficiency
15.0	20.0	0.6049	1.0042	1.6091	37.59	0.7957	2.0222
10.0	20.0	0.6373	1.0102	1.6475	38.68	0.7953	2.0715
10.0	15.0	0.5936	0.9420	1.5356	38.66	0.7867	1.9520
10.0	25.0	0.6549	1.0159	1.6708	39.20	0.7980	2.0937
10.0	30.0	0.6729	1.0060	1.6789	40.08	0.8028	2.0913
15.0	30.0	0.6408	0.9846	1.6254	39.42	0.7998	2.0323
15.0	25.0	0.6217	0.9917	1.6134	38.53	0.7948	2.0299
15.0	35.0	0.6543	0.9675	1.6218	40.34	0.8017	2.0230
10.0	35.0	0.6907	0.9997	1.6904	40.86	0.8084	2.0910
20.0	35.0	0.6032	0.9912	1.5944	37.83	0.8070	1.9757

OPTIMUM G

CVD – Motion

- In CVD the inputs are based on forces and speed

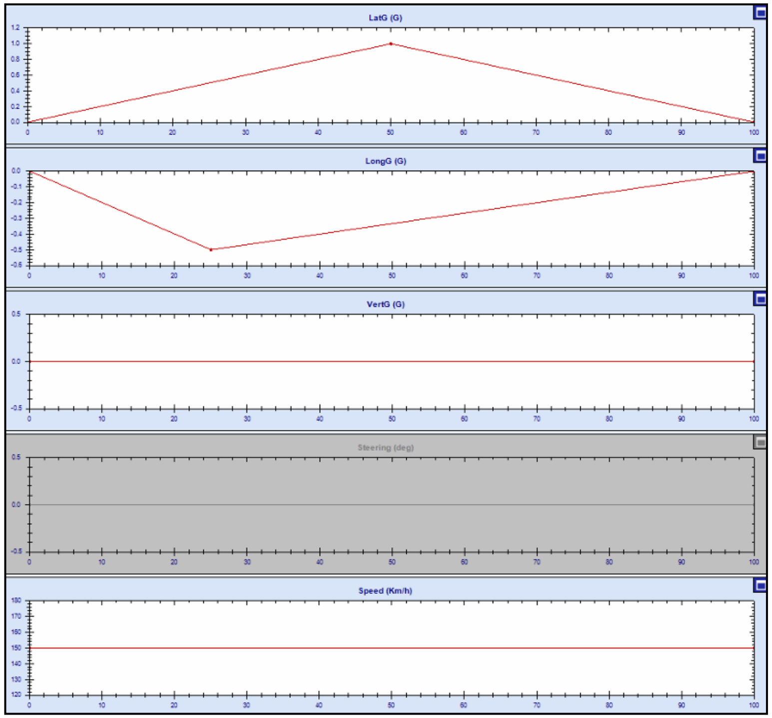
- 3 types of motion can be generated according to the need of the user.
  - Pure Steady State
  - Quasi Steady State
  - Yaw Moment vs. Lateral Acceleration diagram

Pure Steady State (PSS)

PSS motion:

Yaw moment equal to zero → Steering wheel angle is calculated in order to maintain the equilibrium.

→ Skid Pad Simulation



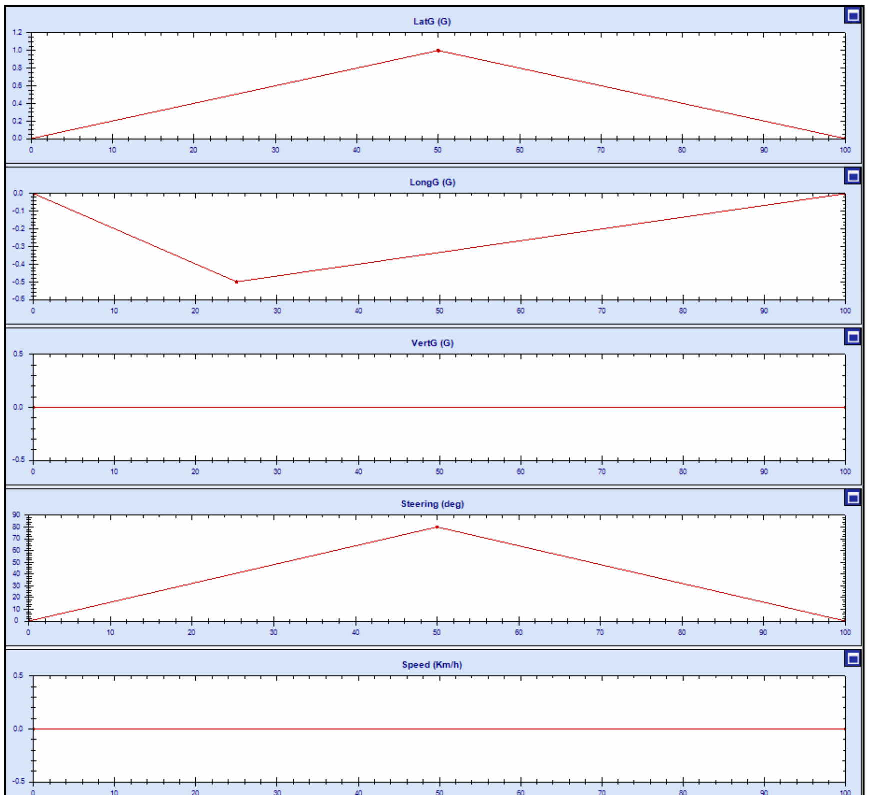
Parameters

Yaw Moment = 0
Lateral Acceleration = Input
Steering Wheel Angle = Output
Body Slip Angle = Output

Quasi Steady State (QSS)

• QSS motion: the steering angle is an input and therefore the yaw moment is not zero anymore.

➡ Forces, Roll and Pitch Moments are in equilibrium.

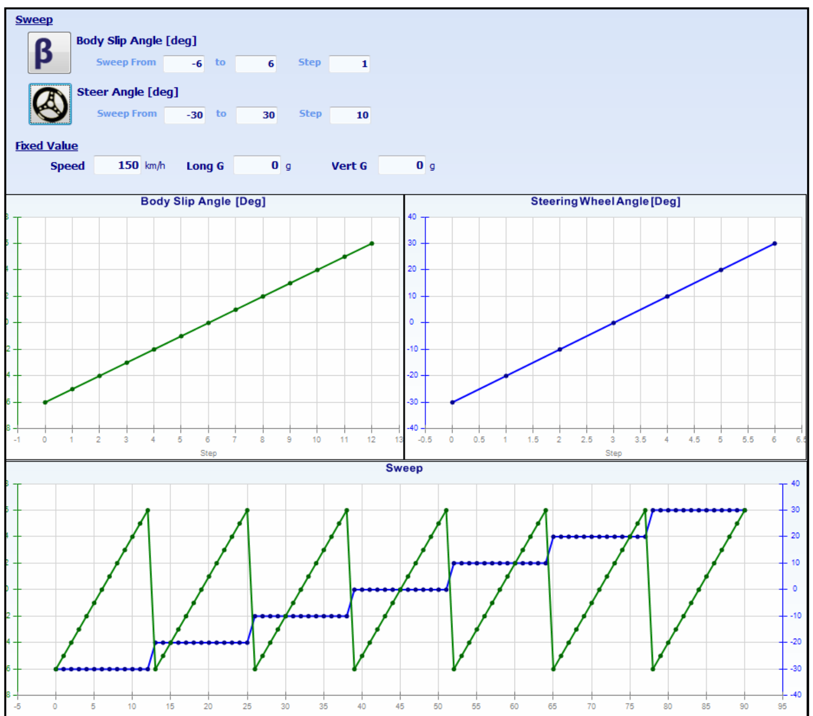


Parameters

Yaw Moment = Output
Lateral Acceleration = Input
Steering Wheel Angle = Input
Body Slip Angle = Output

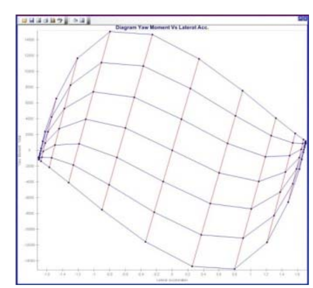
Yaw Moment Diagram

•In a diagram motion the input is a sweep for both body SA and steering wheel angle. For each point the lateral acceleration and yaw moment are calculated and then a diagram can be generated. This gives a quick visualization of parameters such as control, stability, behavior at the limit.

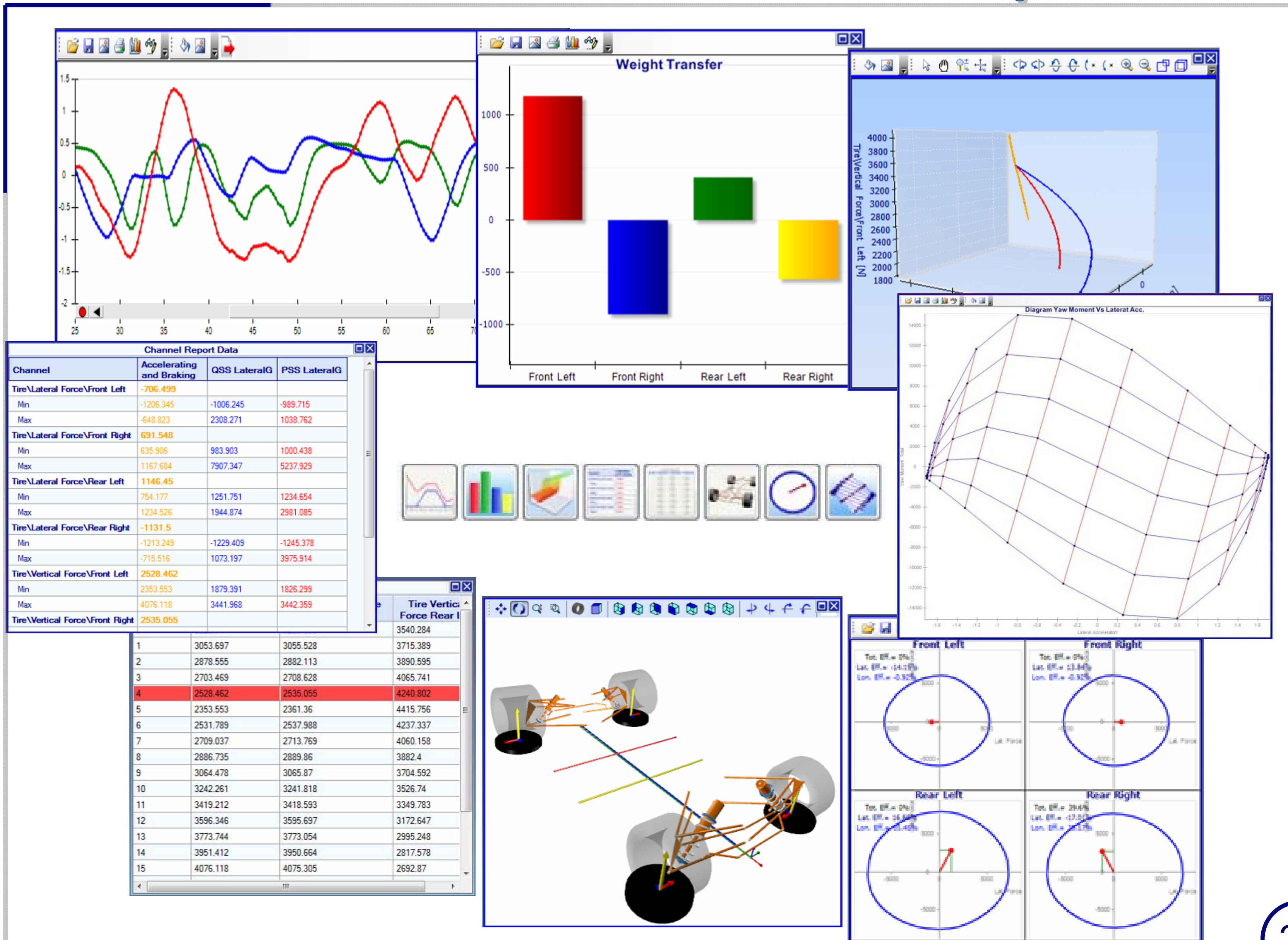


Parameters

Yaw Moment = Output
Lateral Acceleration = Output
Steering Wheel Angle = Input
Body Slip Angle = Input



CVD – Analysis Tools



Yaw Moment Diagram - Presentation

•For a given speed an longitudinal acceleration, the **yaw moment diagram** covers the full maneuvering envelope and presents the results graphically in one graph.

•Graphic analyze of the stability and control of an automobile.

•Analogy with aeronautical techniques.

•Force/Moment study instead of motion study avoids filtering effects of the inertias and give the ability to isolate results of small changes in the vehicle configuration not discernible in a transient response.

Yaw Moment Diagram - Construction

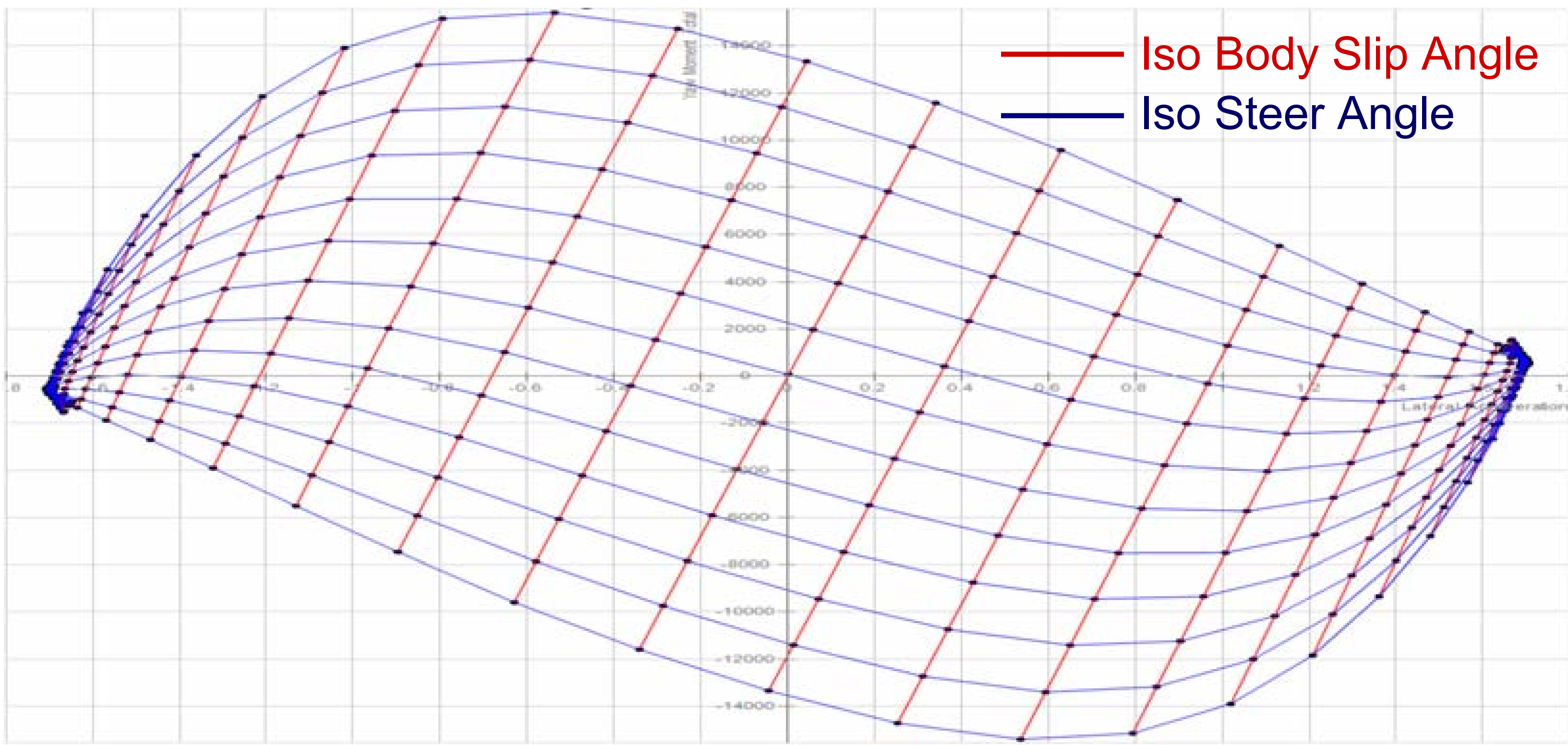
Sweep of Steering Wheel Angle

Sweep of Body Slip Angle

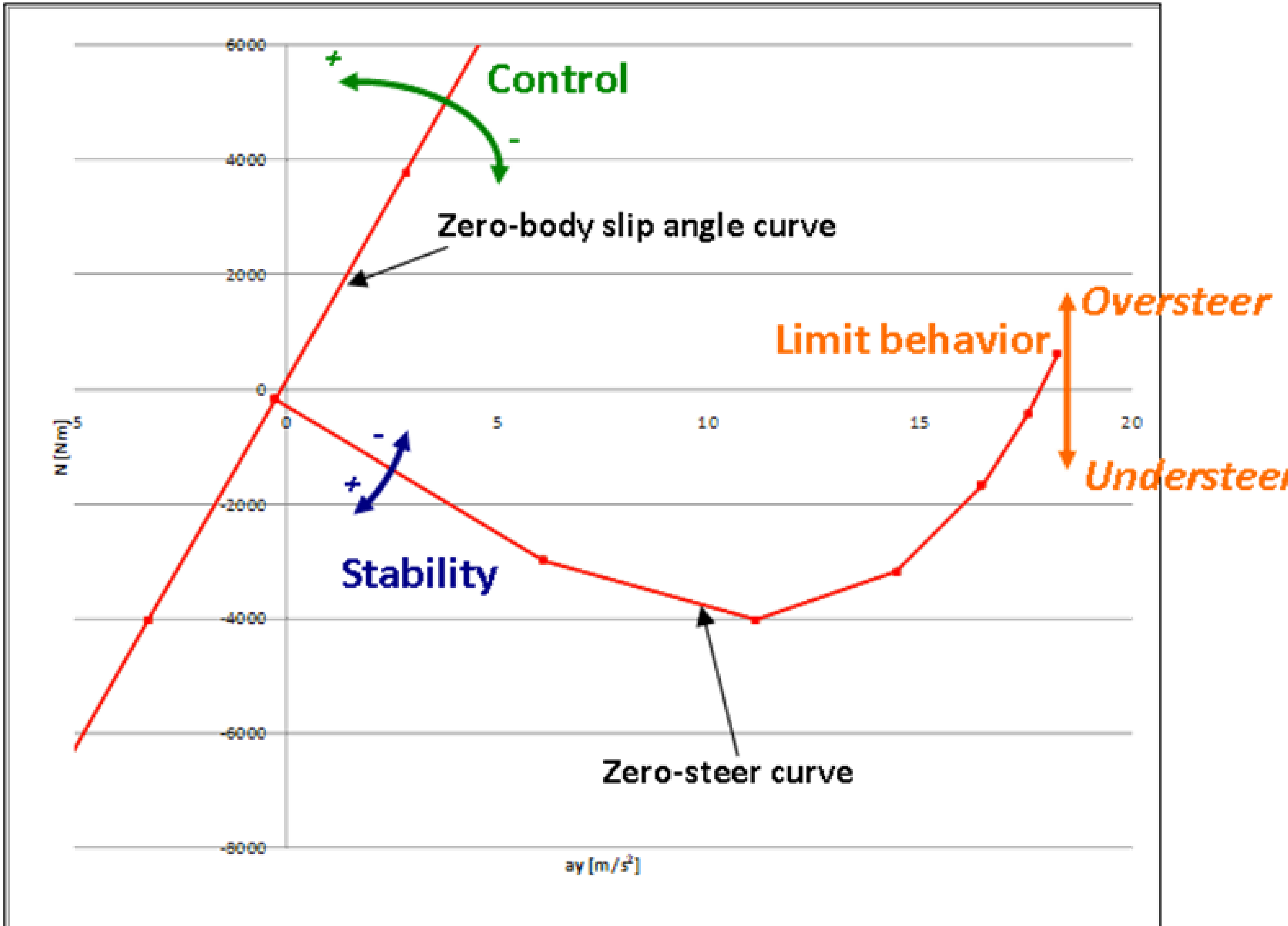
Vehicle Speed

Longitudinal Acceleration

Vertical Acceleration



Yaw Moment Diagram – How to use it?



Yaw Moment Diagram – How to use it? (2)

Stability

- **STABILITY:** The slope of the zero-steer curve shows the yaw moment (N) for different CG body slip angle (β). This is called the directional stability of the car.

- The magnitude tells you how much yaw moment is acting on the car with zero steering input. The sign is always the opposite sign as the lateral acceleration sign, thus this yaw moment tends to reduce the body slip angle.

OPTIMUM G

Yaw Moment Diagram – How to use it? (2)

Control

- **CONTROL:** The yaw moment generated at 1° of steering shows the derivative of yaw moment (N) with regard to steering angle. This is a measure of the yaw moment control that the driver has.
- Lateral acceleration generated at 1° of steering shows the derivative of lateral acceleration (Y) with regard to steering angle. This is a measure of the lateral-acceleration control that the driver has.

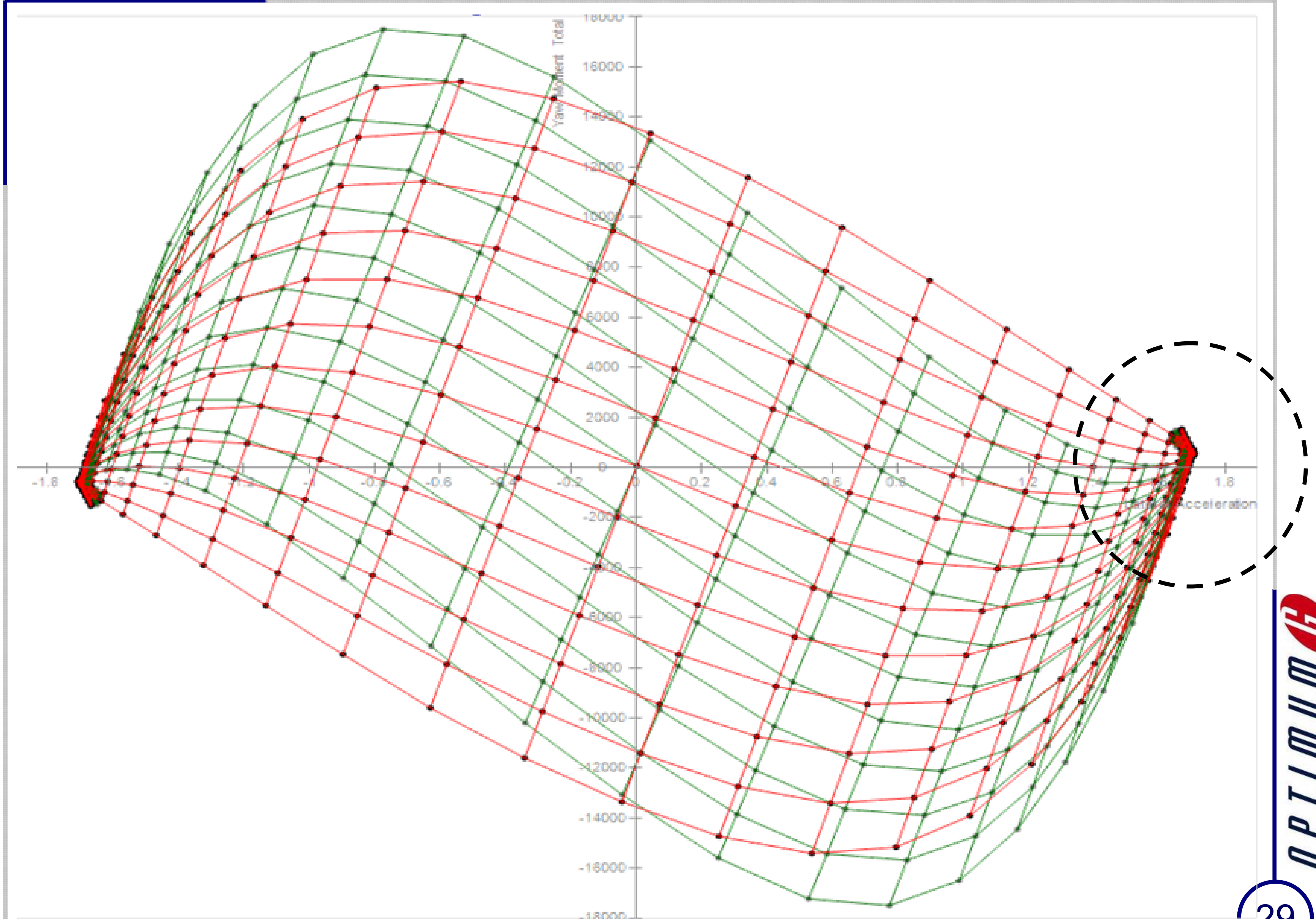
OPTIMUM G

Yaw Moment Diagram – How to use it? (2)

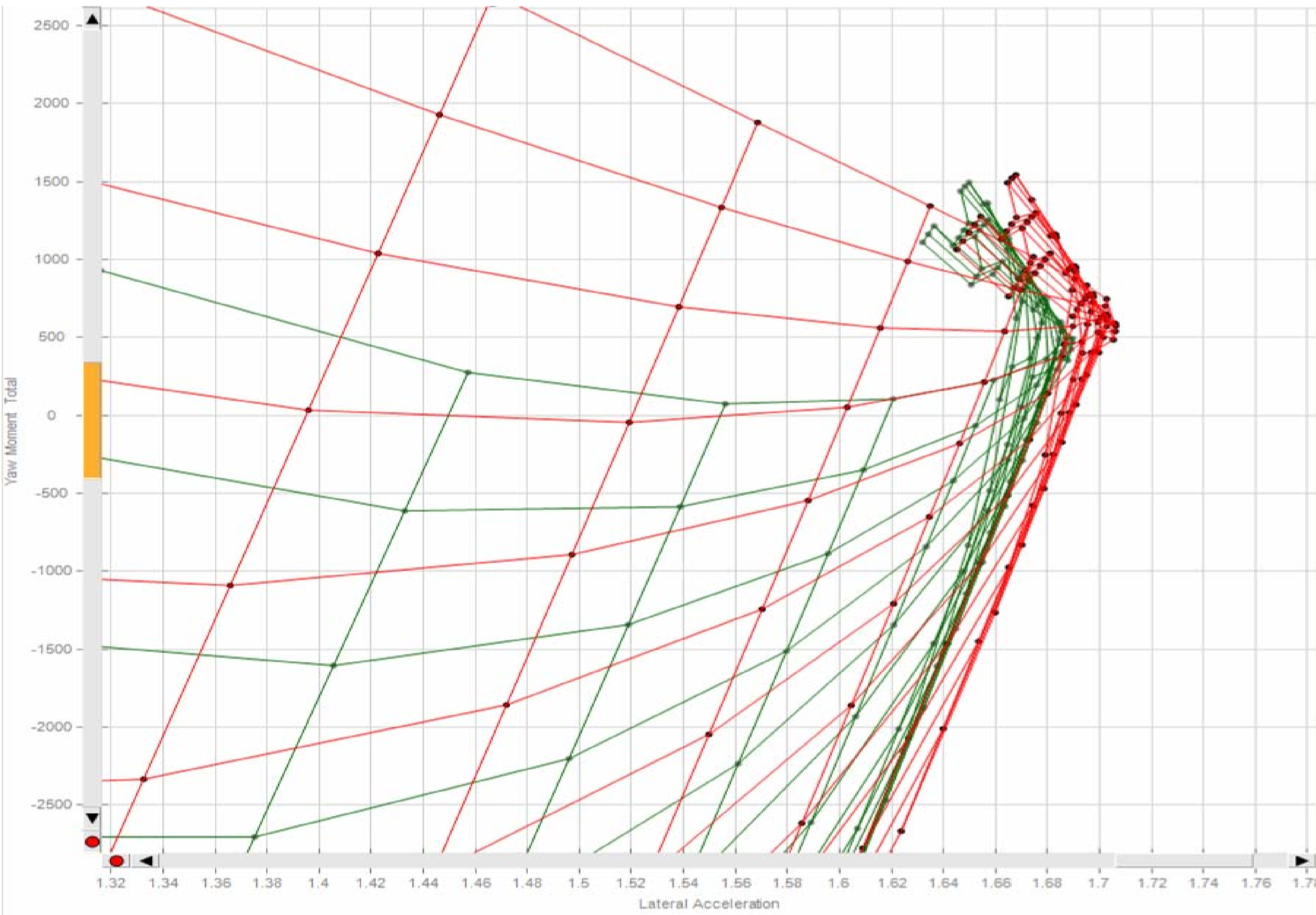
Limit Behavior

- **LIMIT BEHAVIOR:** If the tip of the diagram is above the line yaw moment (N) = 0 for positive lateral accelerations, then the car is limit oversteer (spin).
- If the tip of the diagram is below the yaw moment (N) = 0 for positive lateral accelerations, the car is limit understeer (plow).
- Note that a car can be limit oversteer but understeer in terms of trim behavior.

Yaw Moment Diagram – Overlay



Yaw Moment Diagram – Overlay (2)

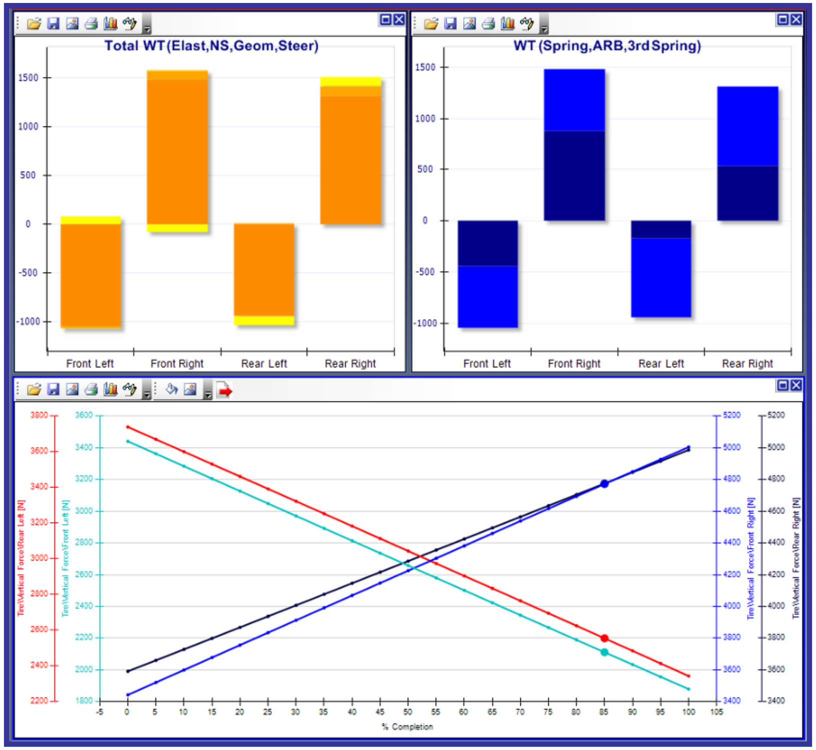


Analysis – QSS Simulation

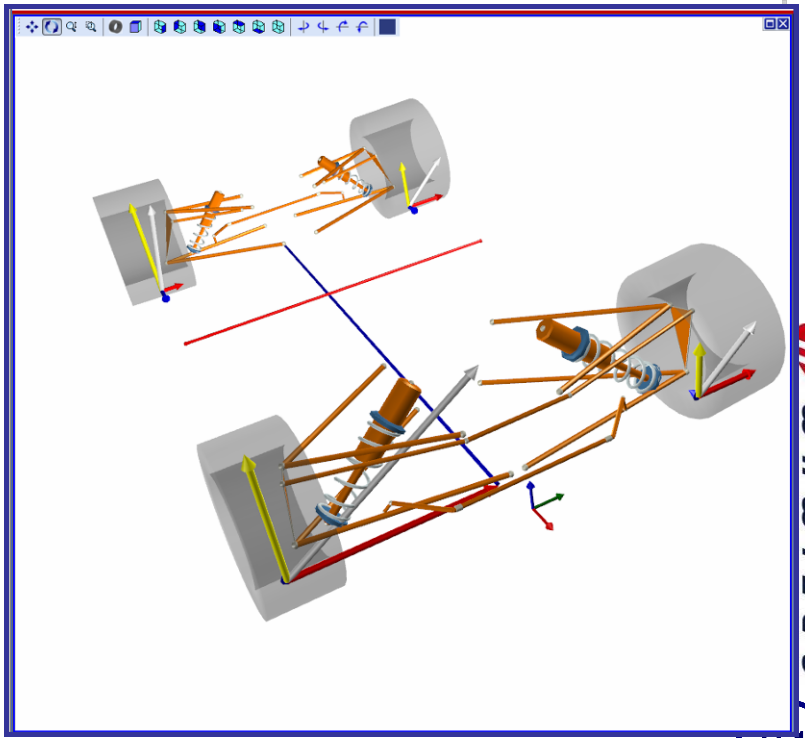
Motion:

- **Lateral Acceleration : ramp from 0 to 1 G**
- **Speed : 200 Km/h**
- **Steering angle : 0 to 60 Deg**

Weight Transfer

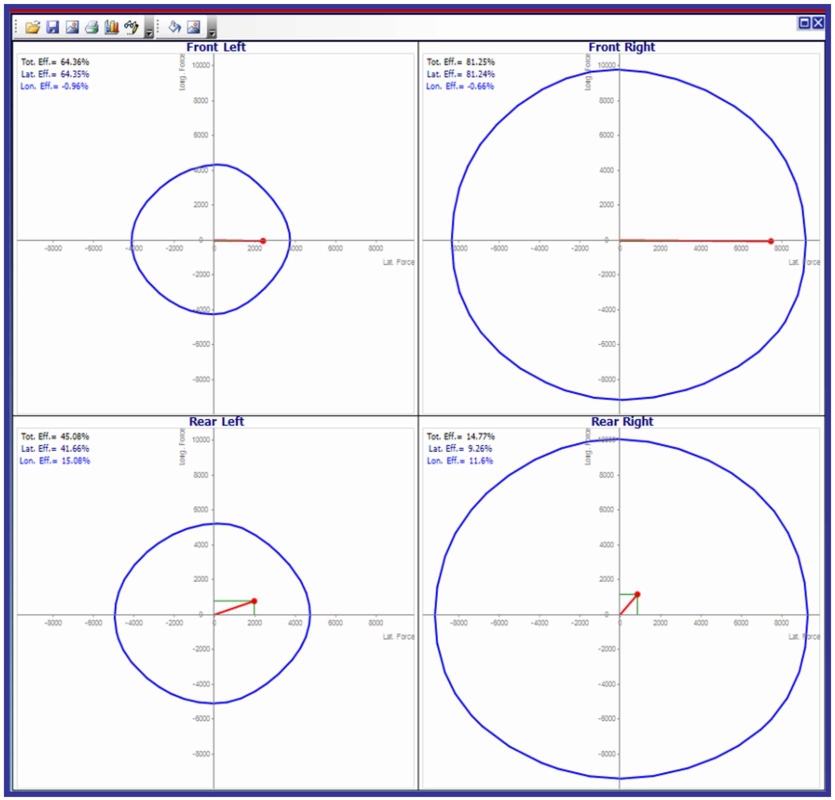


Visualization of forces

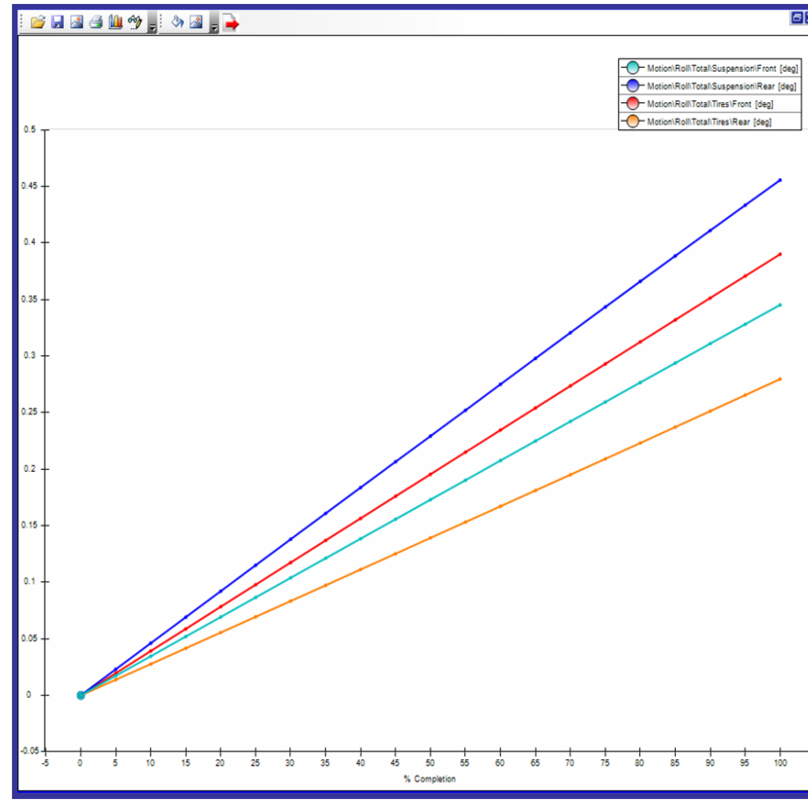


Analysis – QSS Simulation (2)

Friction Ellipse



Roll in suspension and tires



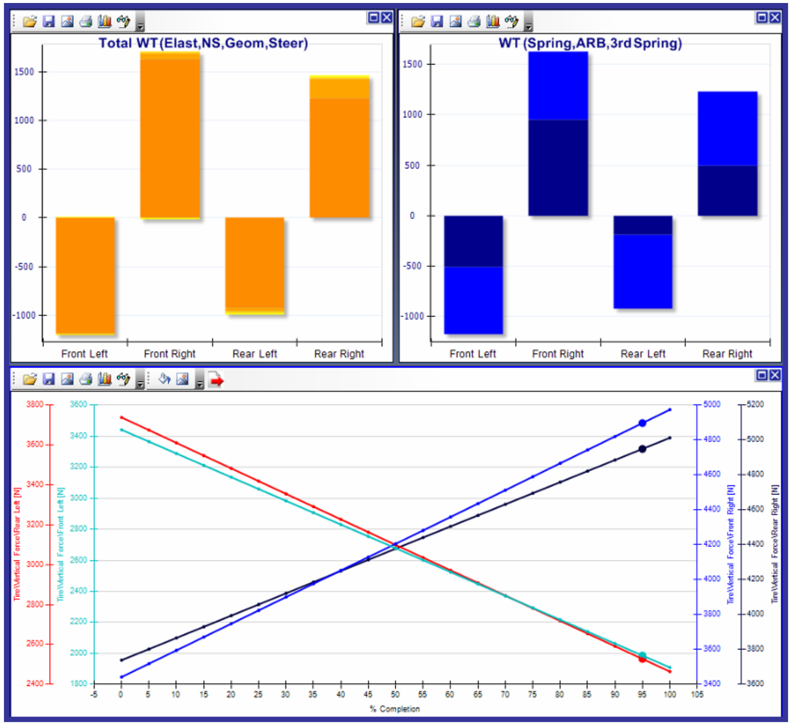
OPTIMUM G

Analysis – PSS Simulation

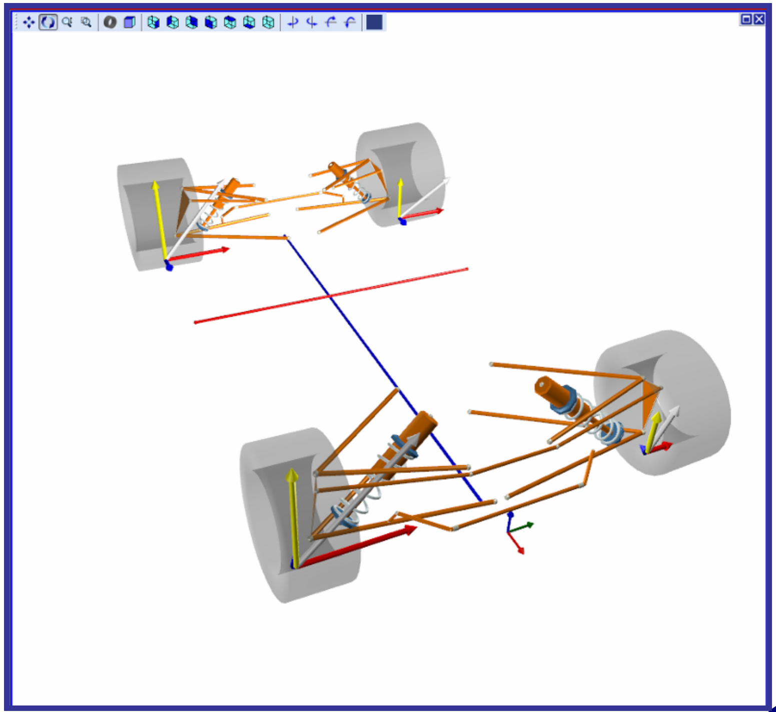
Motion:

- Same motion as QSS
- Calculating the steering wheel angle

Weight Transfer

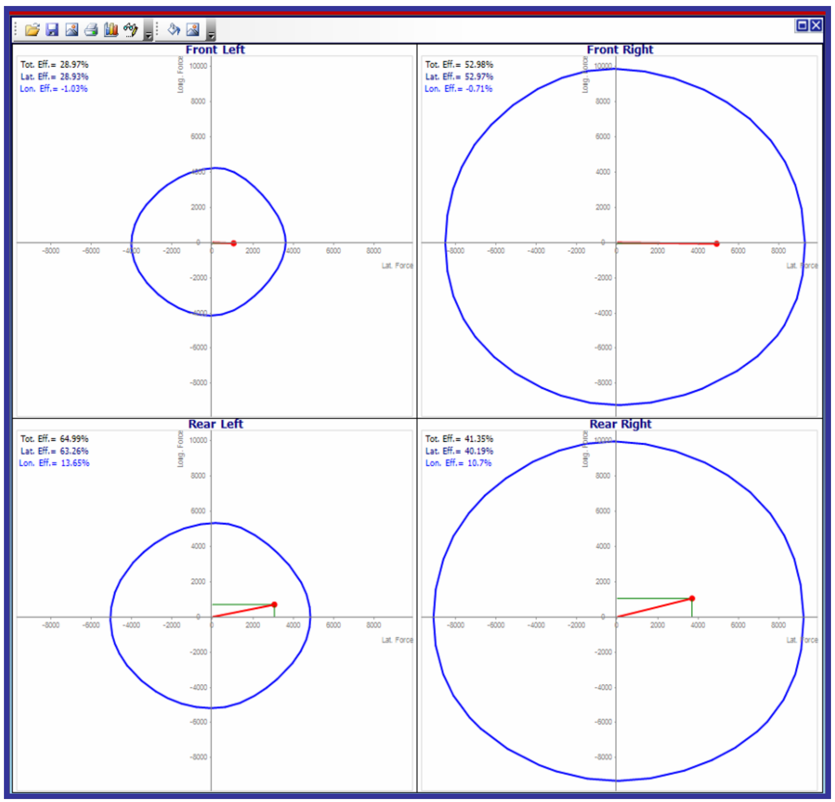


Visualization of forces

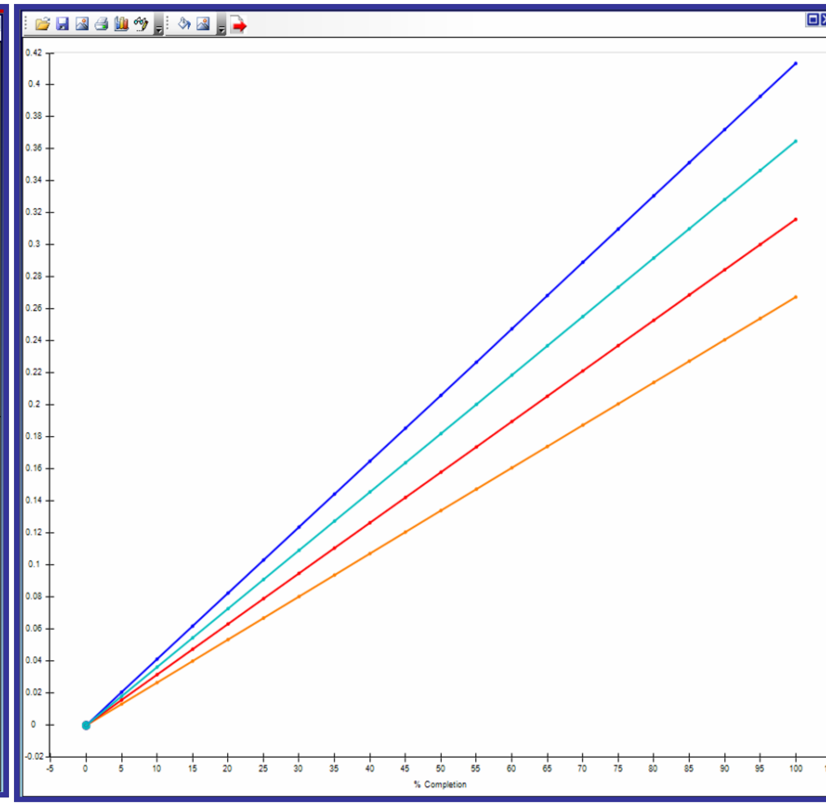


Analysis – PSS Simulation (2)

Friction Ellipse



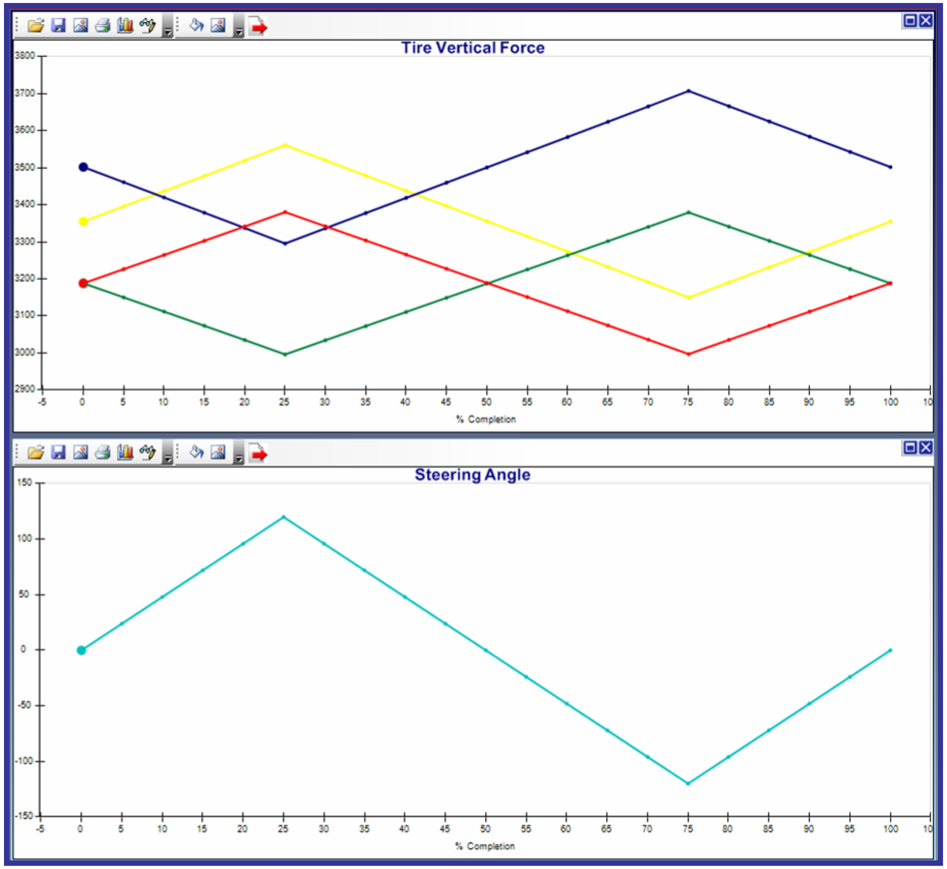
Roll in suspension and tires



Analysis – Steering Simulation

Motion:

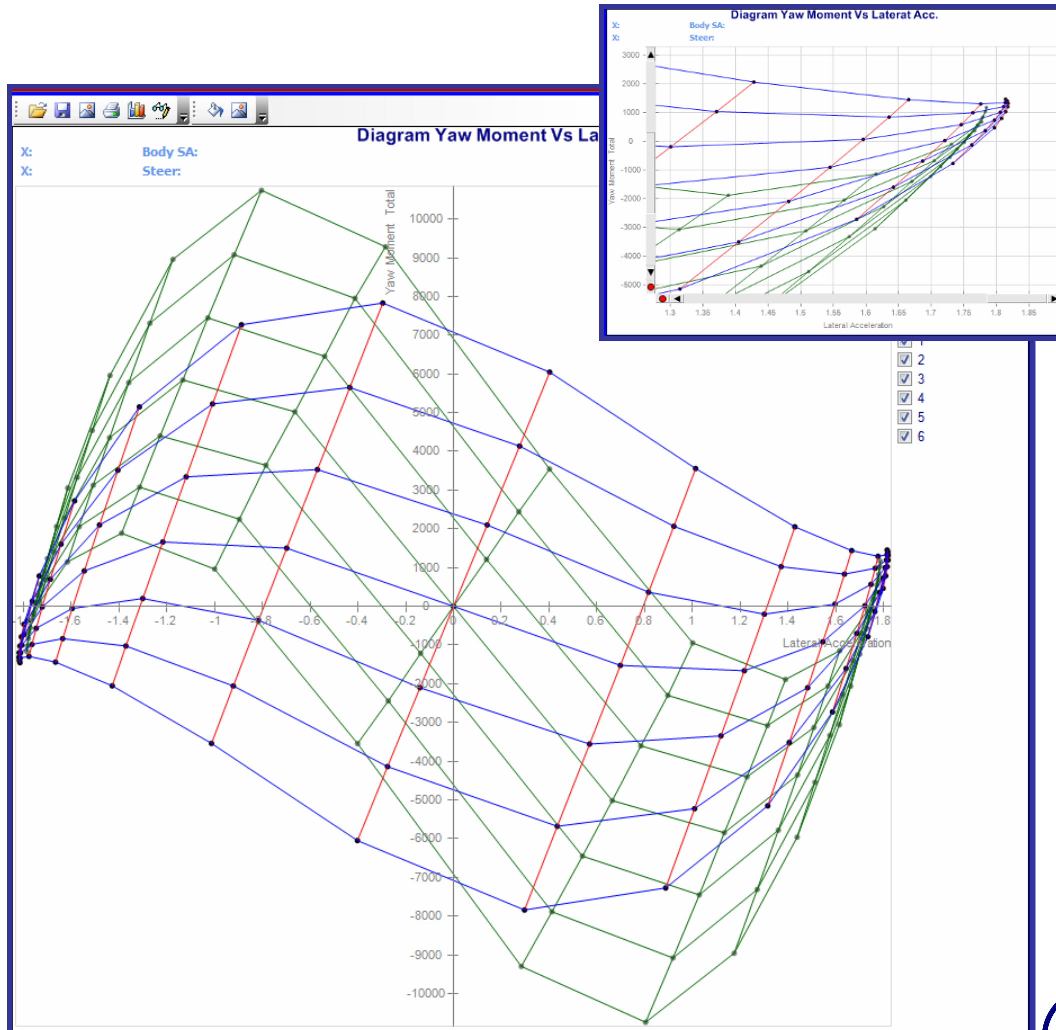
- **Sweep of steering angle**
- **Analyze weight transfer due to steering geometry**



Analysis – Yaw Moment Diagram

Motion: Sweep of the steering angle only to analyze the weight transfer due to the steering geometry

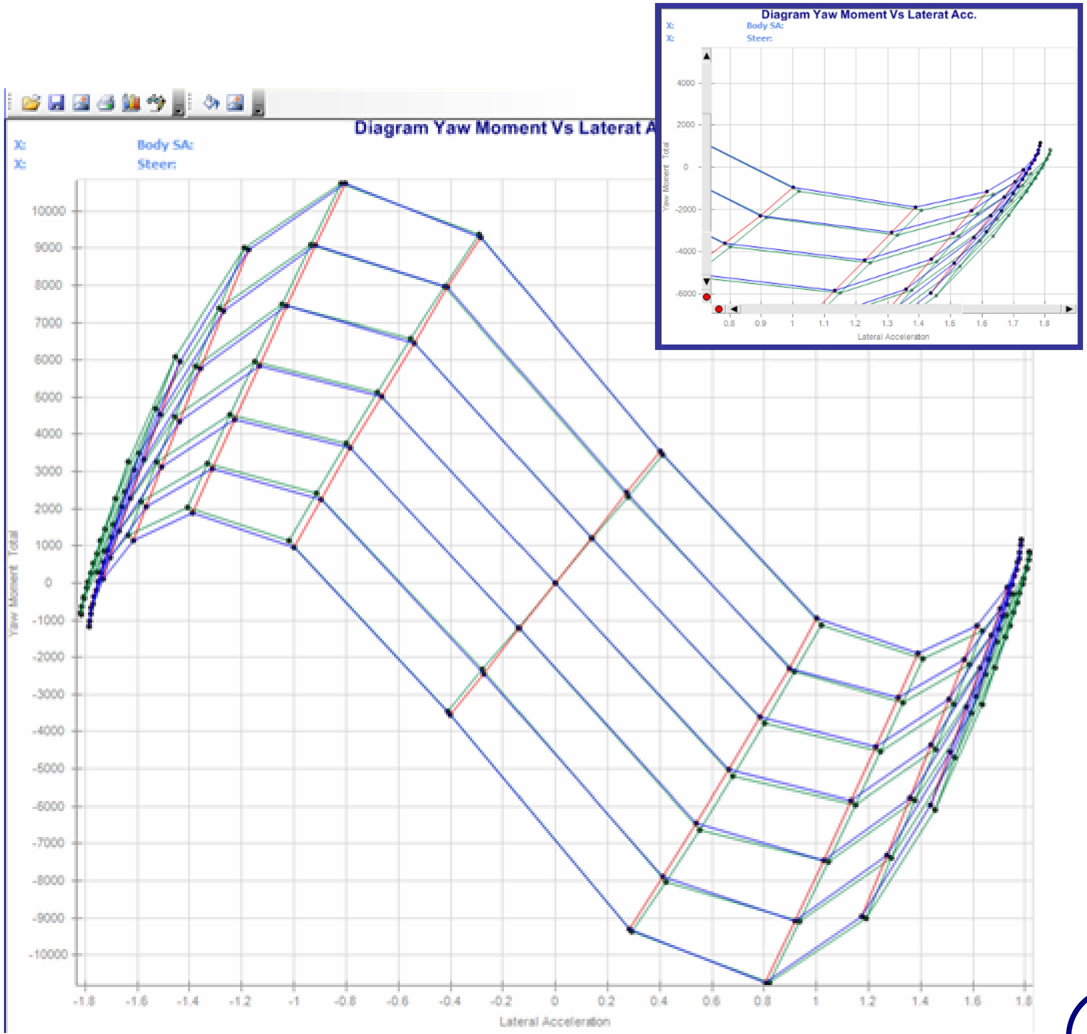
- **More Oversteer and lateral acceleration and higher speed**
- **More corner entry understeer at lower speed**
- **Less control at 100 km/h but more stability.**



Analysis – Yaw Moment Diagram (2)

Baseline Configuration, 100 Km/h and 150 km/h

- **Understeer tendency at the limit for stiffer front suspension**
- **Same corner entry behavior**
- **Less control with stiffer springs in the front**

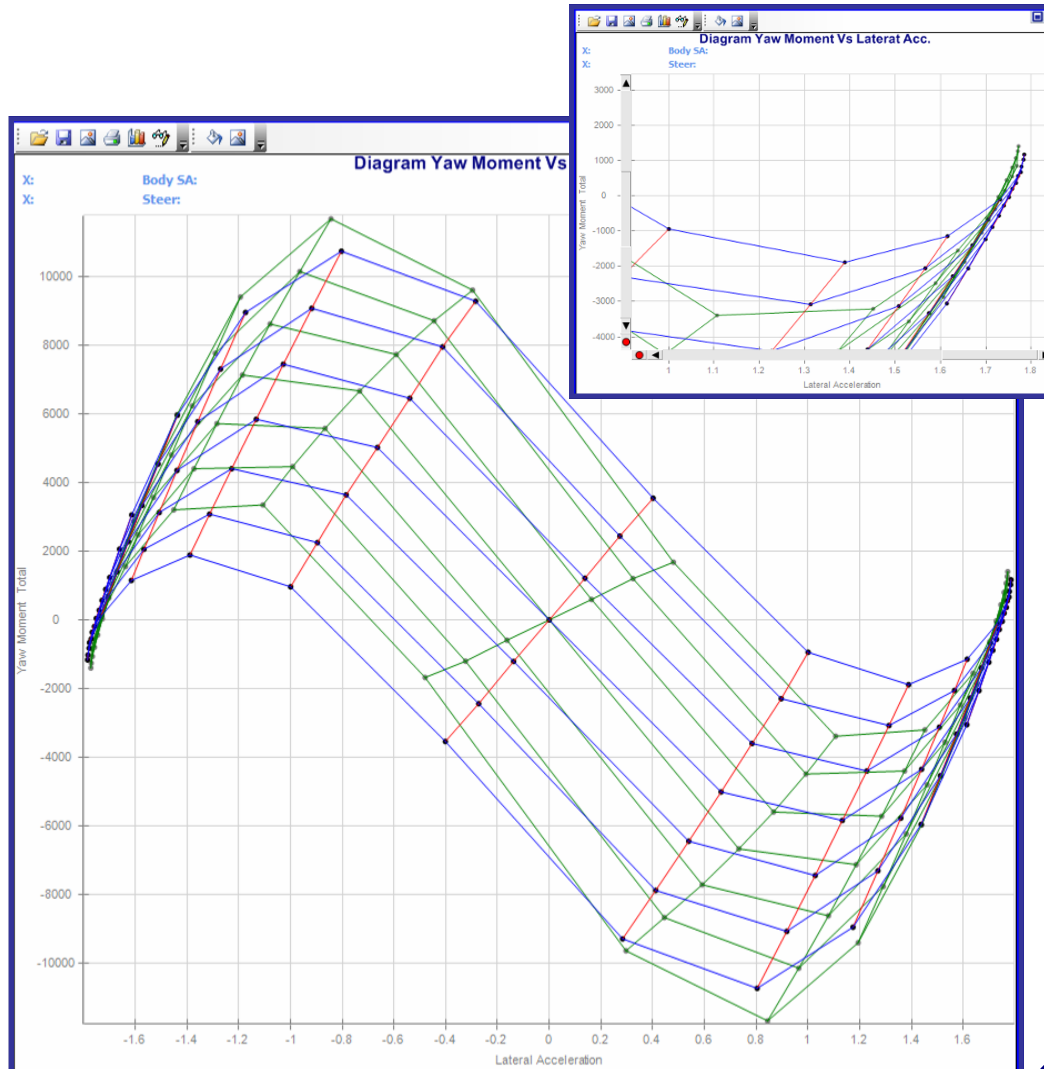


OPTIMUM G

Analysis – Yaw Moment Diagram (3)

Baseline Configuration, Stiff Spring in the front

- **Understeer tendency at the limit for stiffer front suspension**
- **Same corner entry behavior**
- **Less control with stiffer springs in the front**



Questions? - Contacts

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Denver, CO 80231

engineering@optimumg.com
www.optimumg.com

"There is no such thing as understeer or oversteer: there is only under-yaw or over-yaw moment"