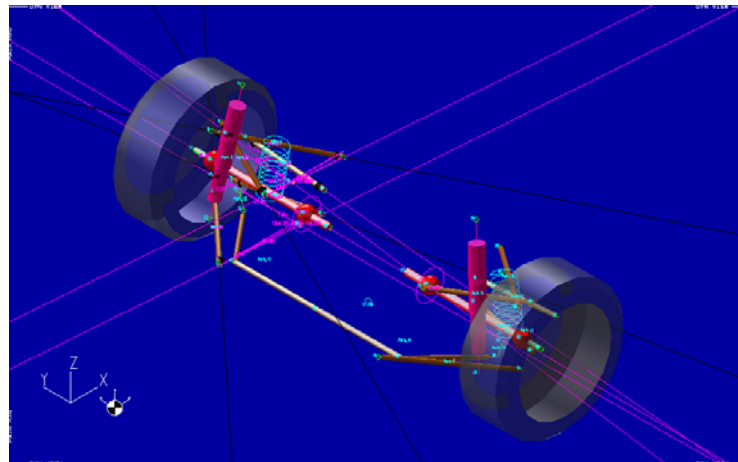# Suspension Topology for maximized Control of Traction Power

Magnus Roland,
President & CEO Swedish Advanced Automotive Business AB

Dr. Armin Zuber,
Manager Advanced Chassis Benteler Automobiltechnik GmbH

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14 June 2012

Vehicle Dynamics is a reality which by theory goes beyond Newtonian Mechanics

Vehicle Dynamics is a reality
which by theory goes beyond
Newtonian Mechanics

Closed Loop Control Mechanization
by New Theory
goes beyond
Electronic Intervention
in Vehicle Control

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Mind and Consciousness

are the major operators in Vehicle Dynamics

#1: Blomqvist/Cederberg

Source: Audi AG

Stig Blomqvist;   World Rally Champion in 1984

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Mind and Consciousness

are the major operators in Vehicle Dynamics

Source: Audi AG

Consciousness is the term that refers to the relationship between the Mind and the Physical Reality with which it interacts!

Mind is synonymous with the conscious or subconscious metaphysical process we have "inside our heads" in order to control the Physical Reality we are part of!

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Mind and Consciousness

are the major operators in Vehicle Dynamics

Source: Audi AG

The Concept of Mind has been an issue of dispute in Physics since the earliest days of Quantum Physics as Niels Bohr and Albert Einstein had their debate whether the Mind and Consciousness are parts of Physics.

Advanced levels of Vehicle Dynamics may bring clarity into this dispute.

Momentum and Inertia are States of Physical Memory and Intention!

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Mind and Consciousness

are the major operators in Vehicle Dynamics

340 m/s

Supersonic Quantum States

http://de.wikipedia.org/w/index.php?title=Datei:FA-18_Hornet_breaking_sound_barrier_(7_July_1999)_-_filtered.jpg&filetimestamp=20080416100616

http://de.wikipedia.org/w/index.php?title=Datei:F18%C3%9Cberschallflug.jpg&filetimestamp=20080821235630

Supersonic Quantum States are effects in "Free Space" when the Speed of the Driving Force of Action is faster than the Natural Wave Propagation.

The Driver's Mind with an Active Intention is always preceding Physical Action.
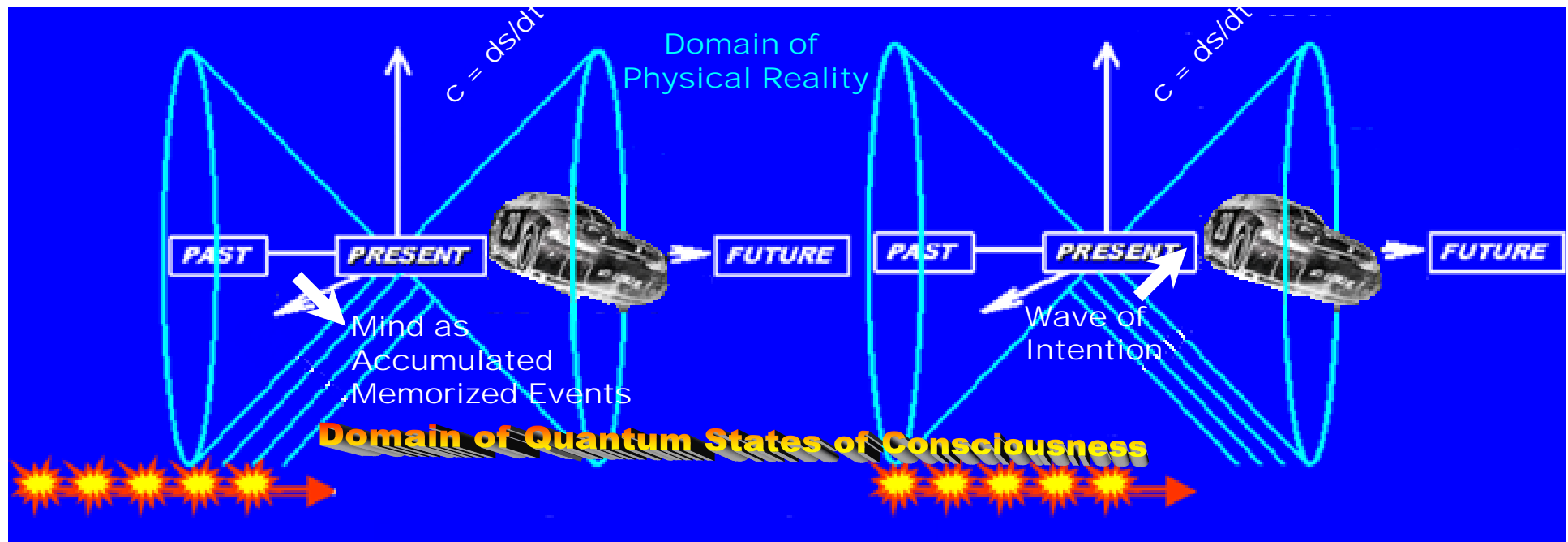
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Mind and Consciousness

are the major operators in Vehicle Dynamics

The physicist David Bohm interpreted the Schrödinger wave function in the Quantum Theory to contain information acting upon particles and that the wave function is analogous to "Mind" forming a common process with matter.

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VEHICLE DYNAMICS BEYOND NEWTON

Mind and Consciousness

are the major operators in Vehicle Dynamics

gif&filetimestamp=20070105133013

Dynamic stability builds upon an operation of a closed loop control!
A Spin Vector connected to Memory (Past) and Intention (Future) and orthogonal to Geometric Time provides a view of Mind as a closed loop Operator in the Present.
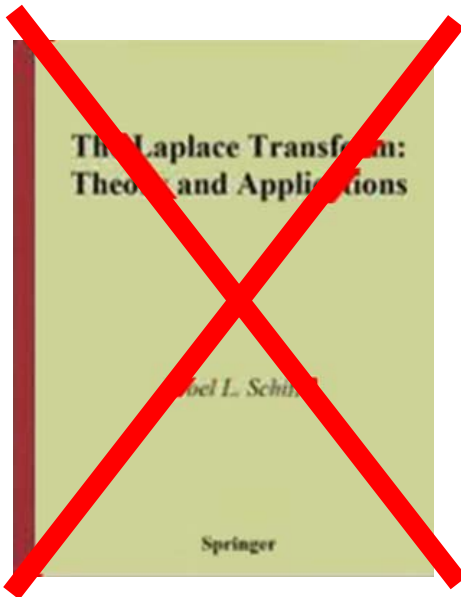**A "Linear World View" with no possibility to go back in time does not provide a closed loop operation in the Present in order to achieve Robust Control of Future States.**

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Mind and Consciousness

**are the major operators in Vehicle Dynamics**

Source: Audi AG
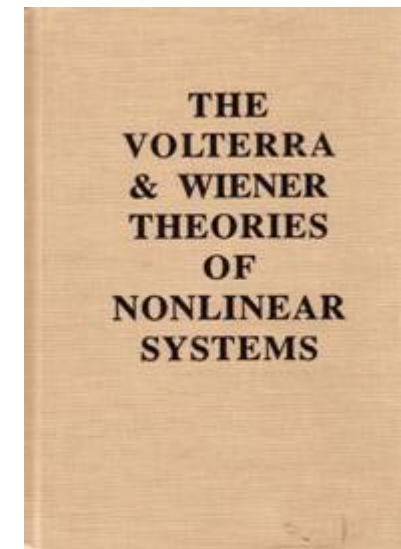
Vehicle Dynamics at Advanced Levels is an <u>Art</u> of Control of Non Linear Systems.

The Operation in Narrow Corridors at the Border of the Possible is a Contribution to <u>Science</u> to Observe Phenomena of Hidden Characteristics.

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Suspension Topology should orchestrate Road Noise into Harmony

Chaotic White Noise
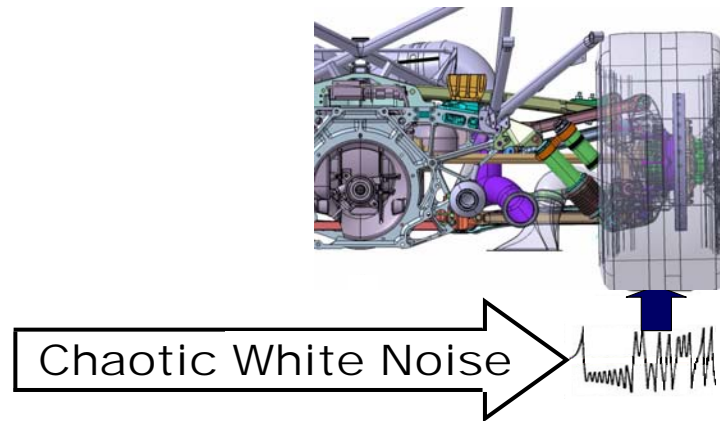
Chaotic white road noise is transformed to human compatible harmony by the suspension plant operator with very special implicit characteristics.
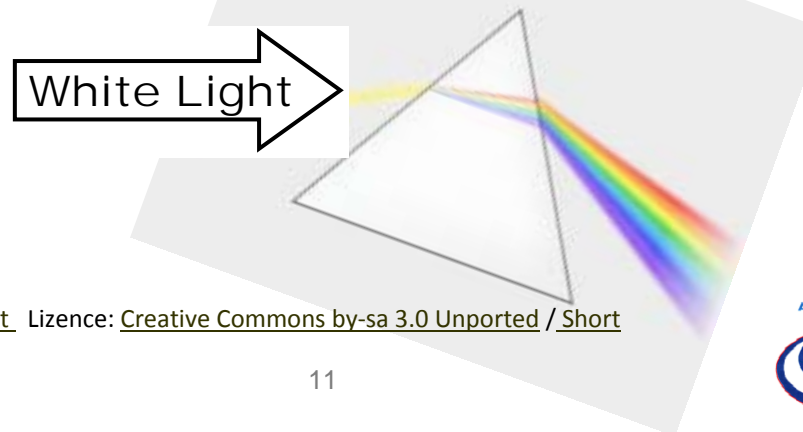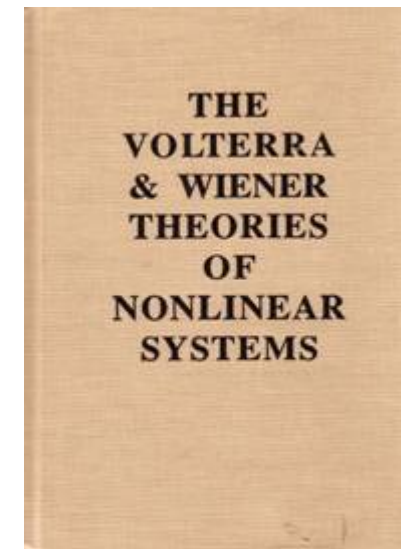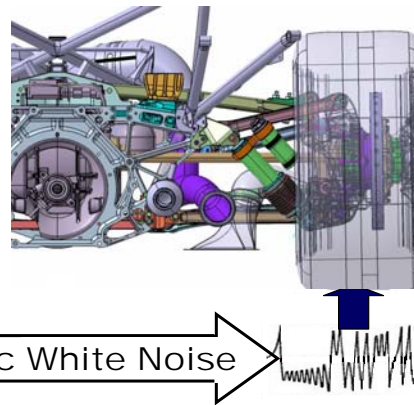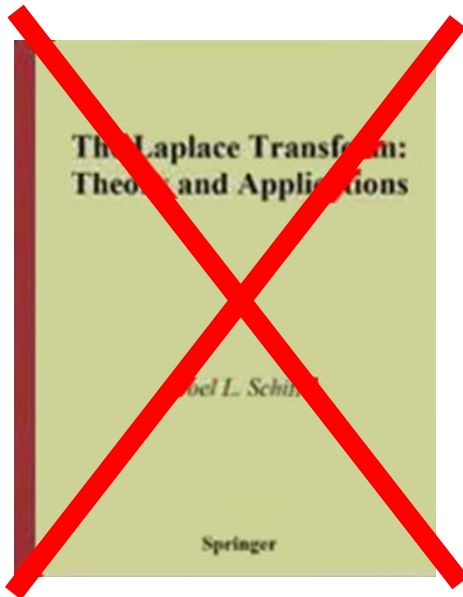
White Light

Photo: Suidroot Lizence: Creative Commons by-sa 3.0 Unported / Short

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Suspension Topology should orchestrate Road Noise into Harmony

The Laplace Transform: Theory and Applications

Springer

THE VOLTERRA & WIENER THEORIES OF NONLINEAR SYSTEMS

Chaotic White Noise

Real Life Closed Loop Control from Suspension Mechanization is experienced to outperform Electronic Intervention from certain ESP-systems when exposed to stochastic road input.

Tuned for predictable proving ground conditions (also on frozen lakes) the choice of control algorithms for linear control theory may enter into unstable modes for stochastic road input

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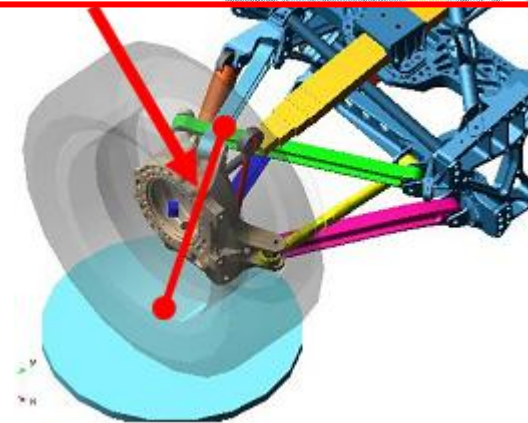Automobiltechnik
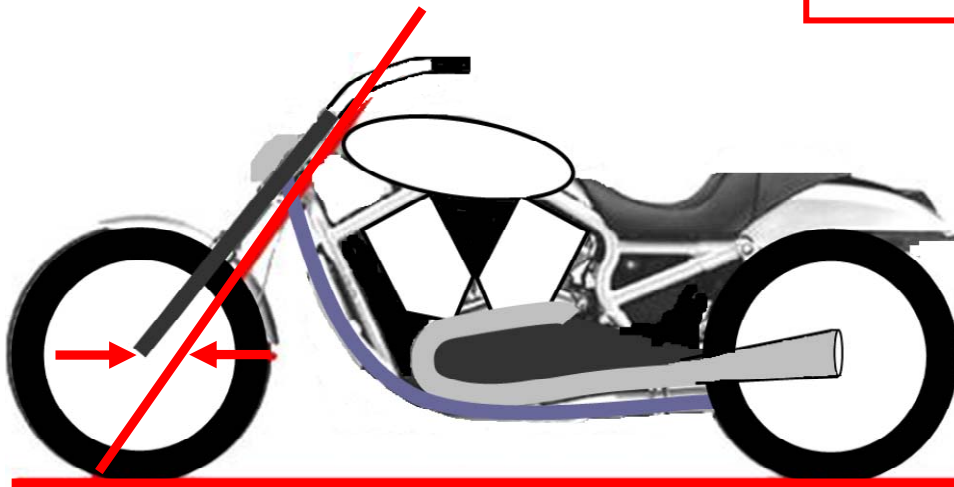
VEHICLE DYNAMICS BEYOND NEWTON

The free space dynamics of Earth has Precession as slow angular change when moving forward and Polar Motion Variations of Nutation as fast angular change.

The Earth "Nutation" being perpendicular to the Earth spin axis compares to the cross-coupled sequential pattern of motion of toe- and camber-change.
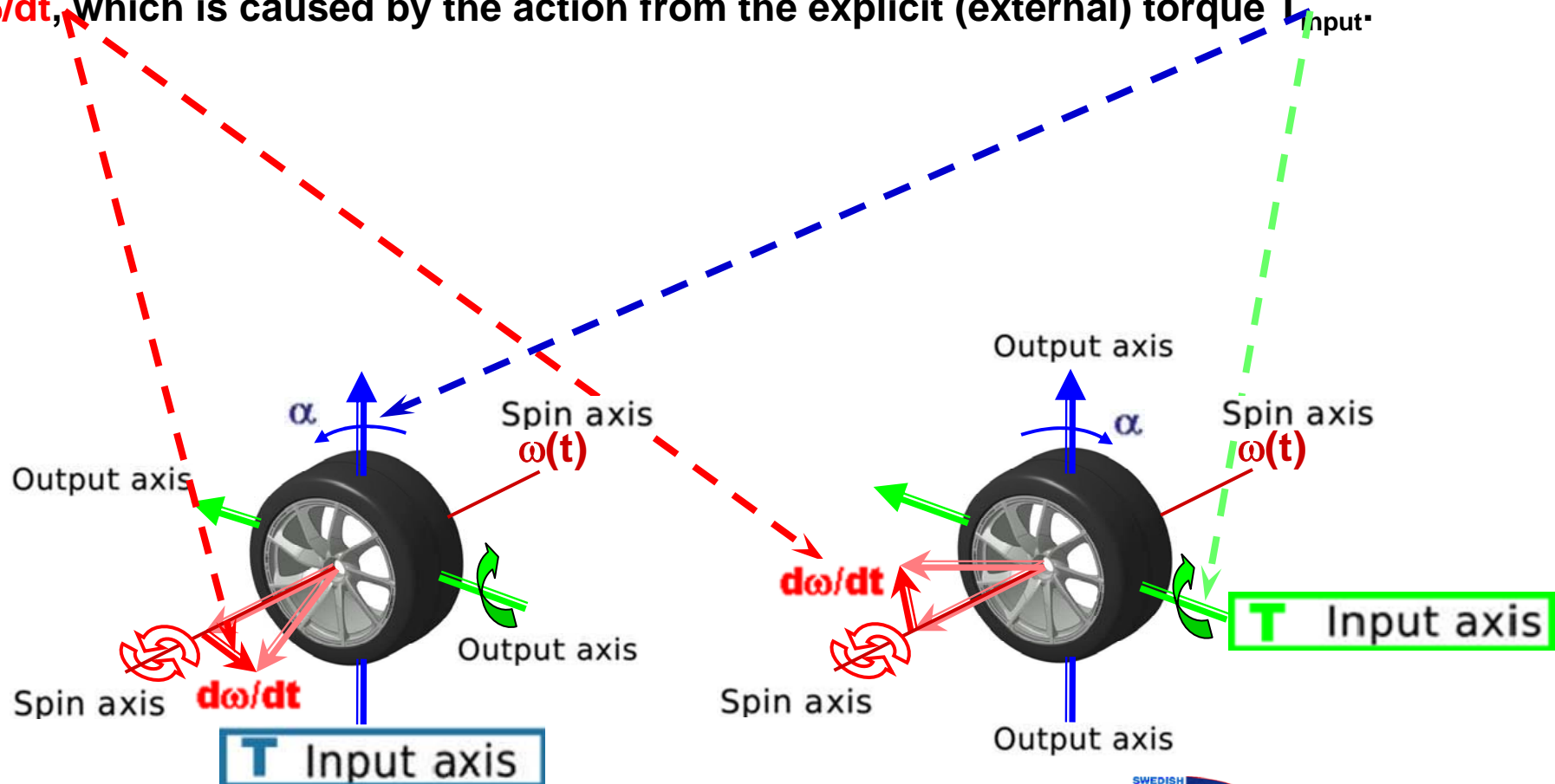
Gravity controlled Earth "Nutation" could give guidance to suspension topology how to operate the sequence of elasto-kinematic toe vs. camber perturbation.
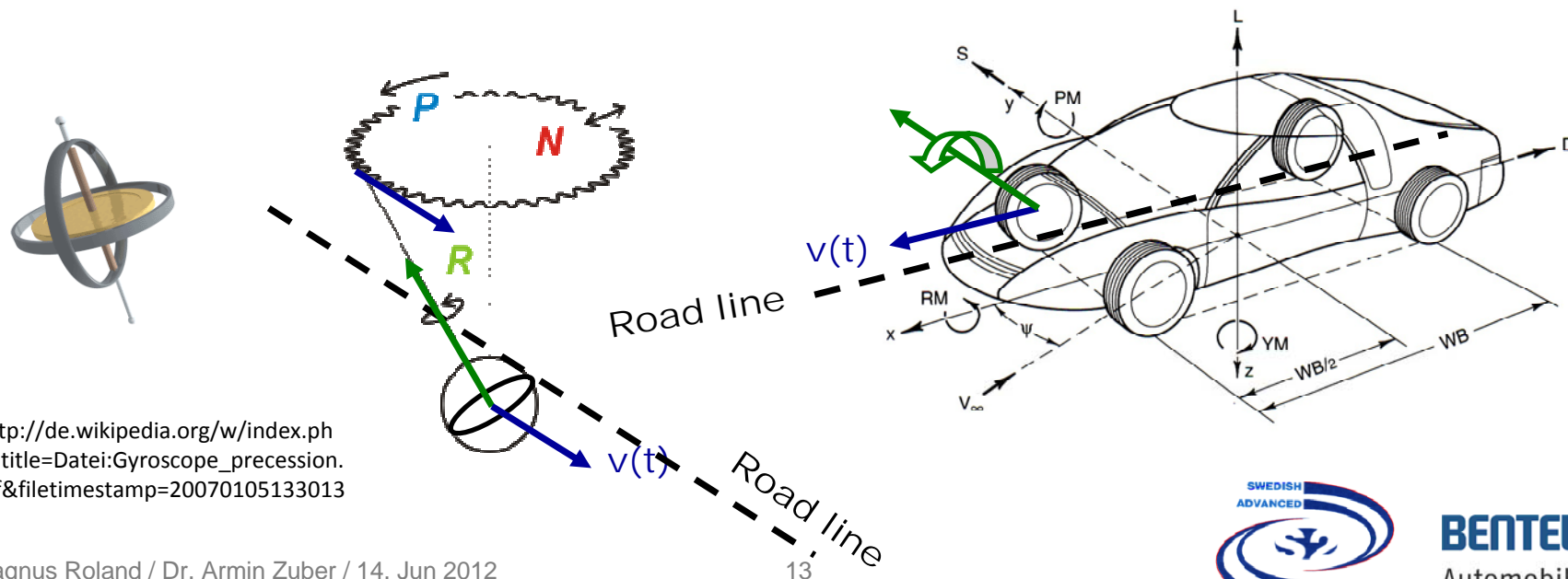
http://de.wikipedia.org/w/index.php?title=Datei:Gyroscope_precession.gif&filetimestamp=20070105133013

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Gravity controlled Earth "Nutation" could give guidance to suspension topology how to operate the sequence of elasto-kinematic toe vs. camber perturbation.

Dynamics are robust if virtual king-pin axis is located behind the spin-axis of the wheel & tire with a sequence where toe-change is preceding camber-change.

virtual king-pin axis behind wheel center

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A spinning wheel with an angular momentum of $L = J\omega$ and obeying the principle of "conservation of momentum" will see a **counter-operation** of the change of $d\omega/dt$, which is caused by the action from the explicit (external) torque T_{Input}.
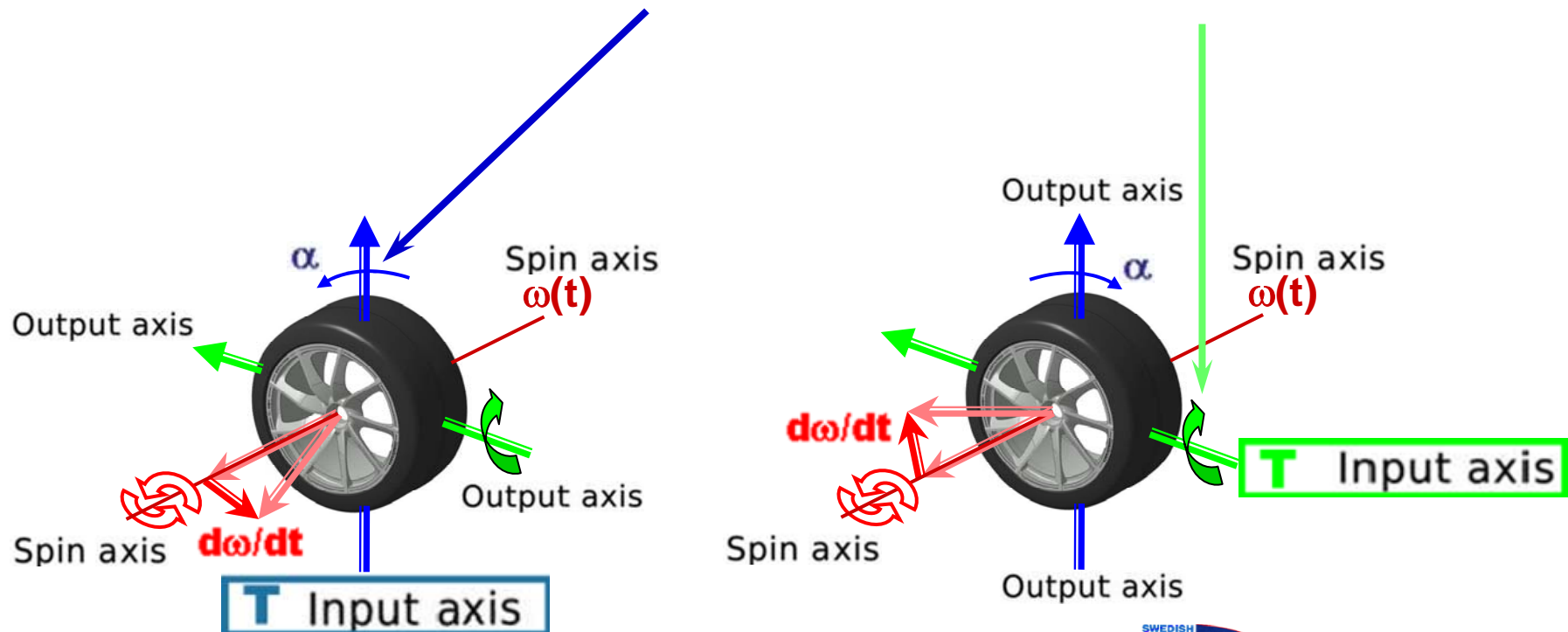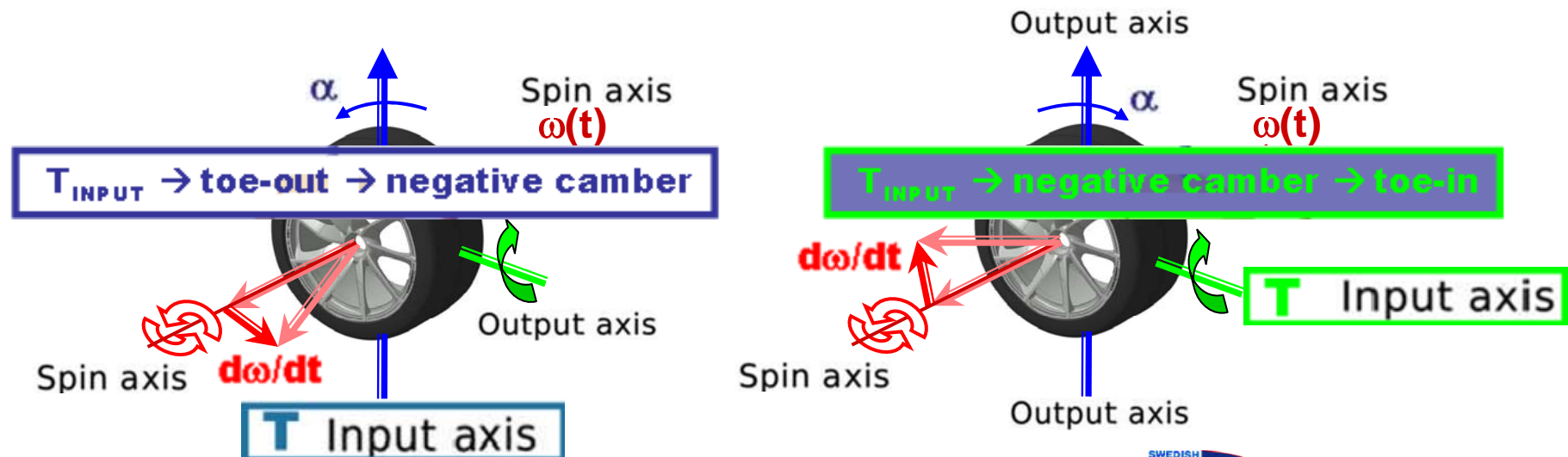
BENTELER
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A spinning wheel with an angular momentum of $L = J\omega$ and obeying the principle of "conservation of momentum" will see a counter-operation of the change of $d\omega/dt$, which is caused by the action from the explicit (external) torque T_{input}.

The counter-operation $T_{response} = L*d\alpha/dt$ or $T_{response} = L*d\gamma/dt$ is different dependent upon whether T_{input} is an action of <u>toe-steer</u> ($d\alpha/dt$) or <u>camber-change</u> ($d\gamma/dt$).
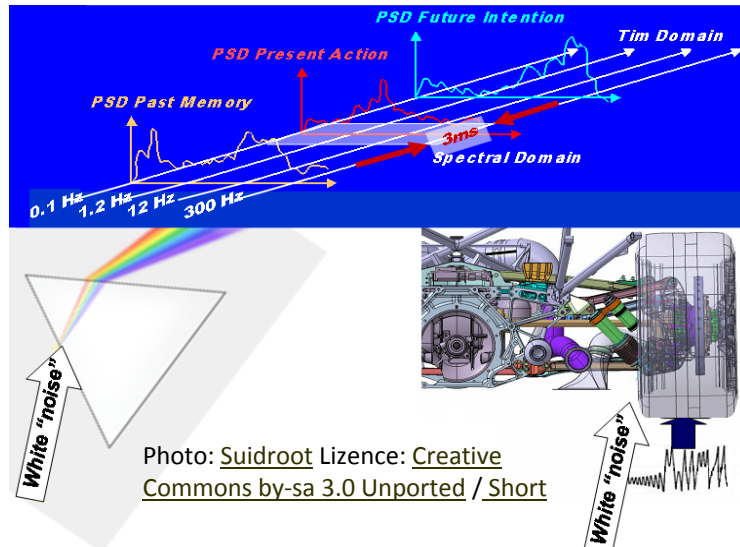
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Robust dynamic control of a front wheel on a motor bike shows the importance of king-pin axis behind wheel center and how counter steer compares to toe-out action as input for robust gyroscopic dynamics if toe-out is preceding camber-change.

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VEHICLE DYNAMICS BEYOND NEWTON

virtual king-pin axis behind wheel center

PSD Future Intention

PSD Present Action

Tim Domain

PSD Past Memory

3ms

Spectral Domain

0.1 Hz 1.2 Hz 12 Hz 300 Hz

White "noise"

White "noise"

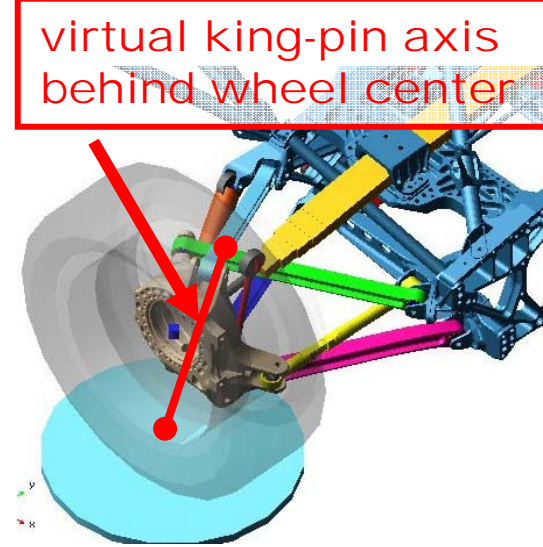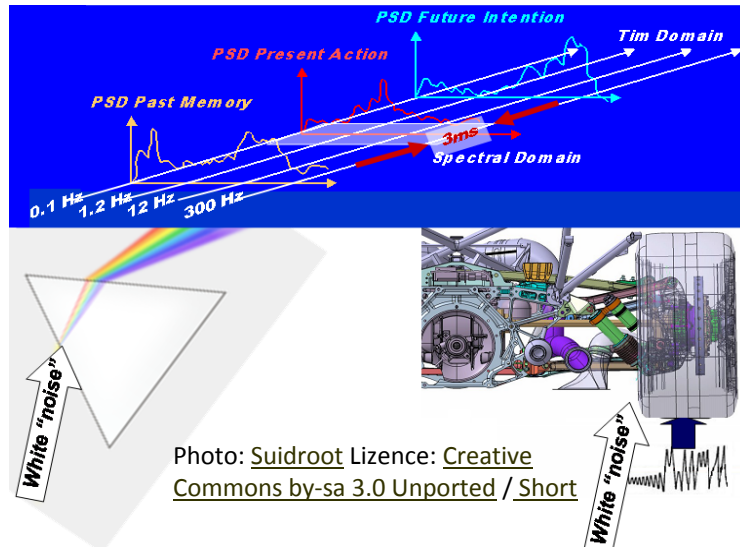Photo: Suidroot Lizence: Creative Commons by-sa 3.0 Unported / Short
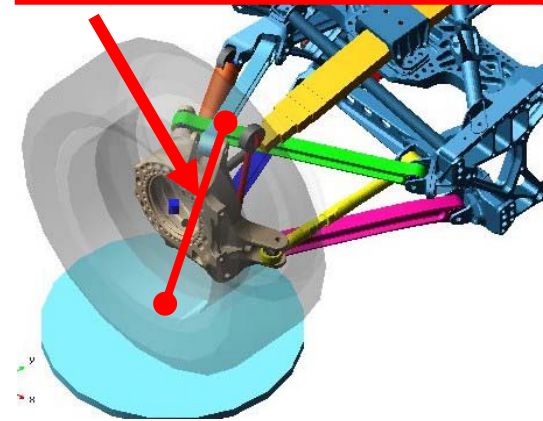
Toe- and camber-change for kinematics and very stiff uni-balls coupled with common bump and rebound are simultaneous in their modes of change.
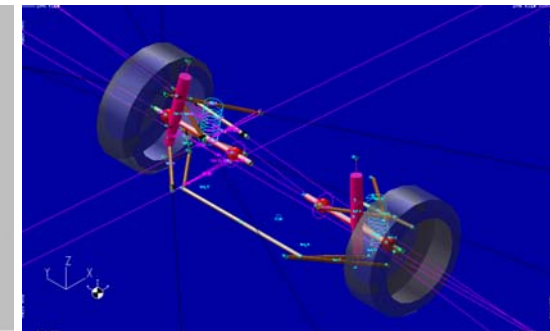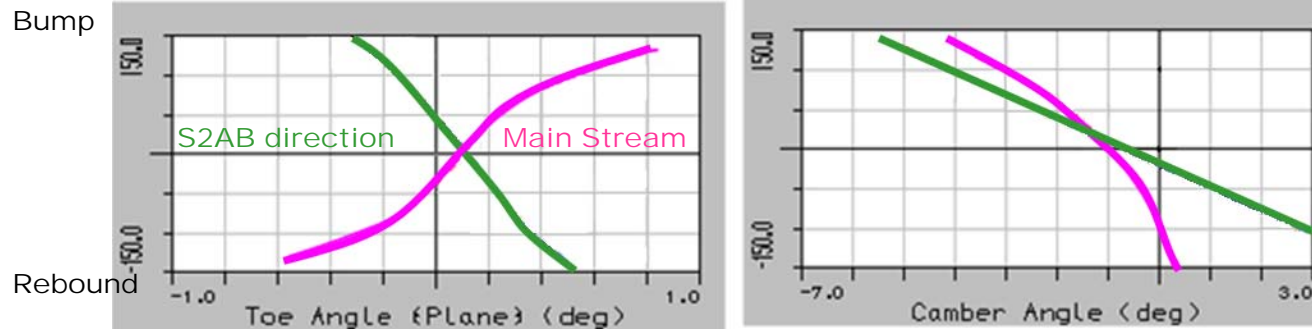
Bump

150.0

S2AB direction   **Main Stream**

-150.0

Rebound

-1.0   Toe Angle (Plane) (deg)   1.0

150.0

-150.0

-7.0   Camber Angle (deg)   3.0

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Photo: Suidroot Lizence: Creative Commons by-sa 3.0 Unported / Short

virtual king-pin axis behind wheel center

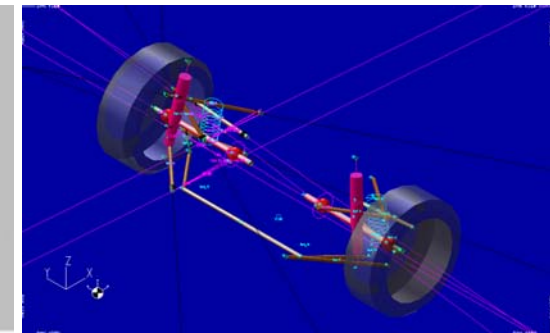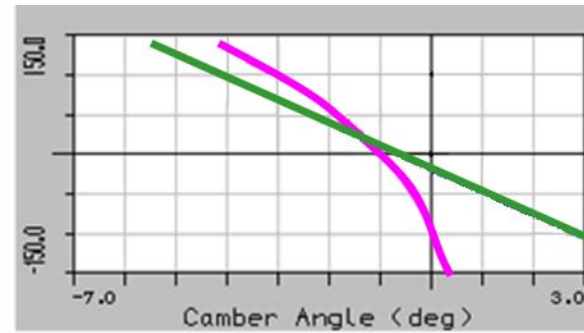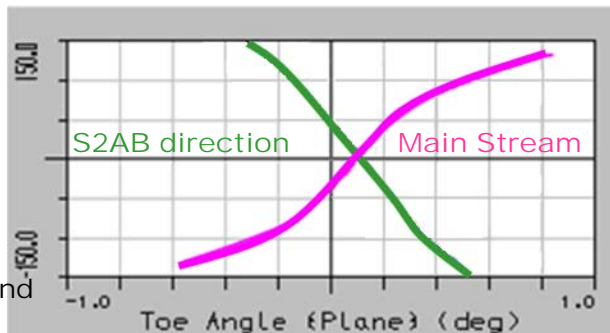**Stochastic road input transformed into harmony demands toe-out at bump to precede camber change from different elasto-kinematics as prerequisite for gyroscopic order!**


Bump

Rebound

S2AB direction   Main Stream

Toe Angle (Plane) (deg)

Camber Angle (deg)

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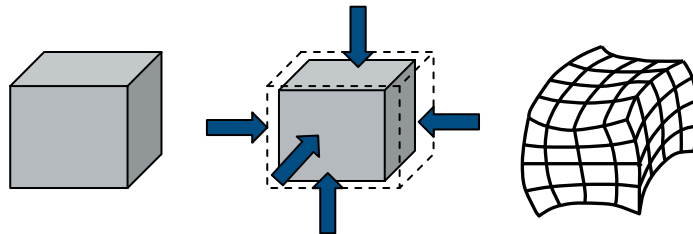
Power operates reciprocally in the short moments of the present!

Traction Power compares to Engine Indicated Power to be controlled within milliseconds and with precision on nano-levels!
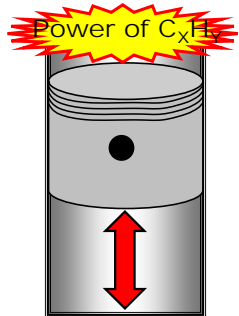
Power of C_XH_Y

Power of C_xH_y

virtual king-pin axis

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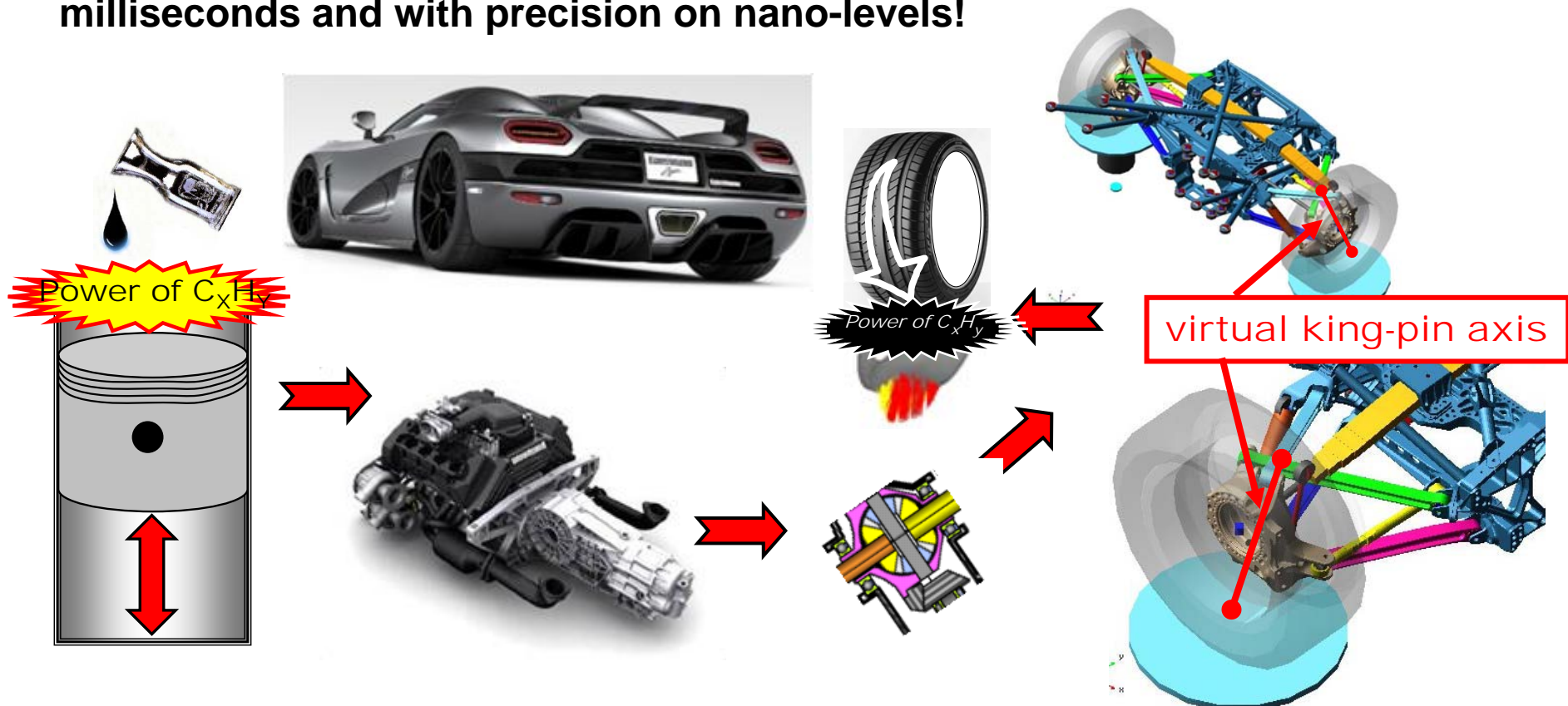
Local States of Finite Elements defined by Stress-Energy-Tensors is a Method of Defining Parameters Inaccessible to Direct Measures

Hooke's law
Quasi Steady State derived from Direct Measures

Power of C_xH_y

Engine Indicated Power as Compression [N/m^2] under motion [m/s] is a Physical Pulse (or Wave) propagation over space and time [Ns/m^3]. In steel the propagation is 6000 m/s, which is inaccessible to direct measures
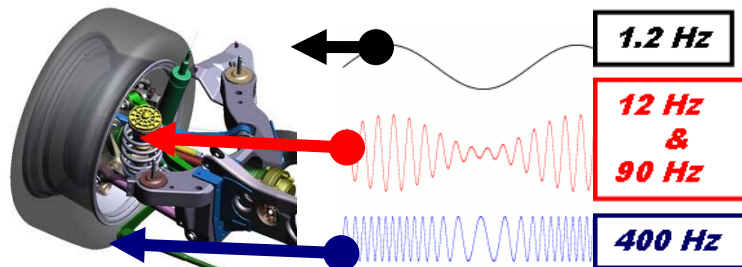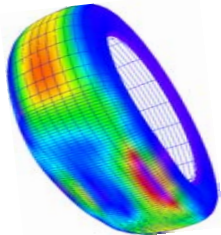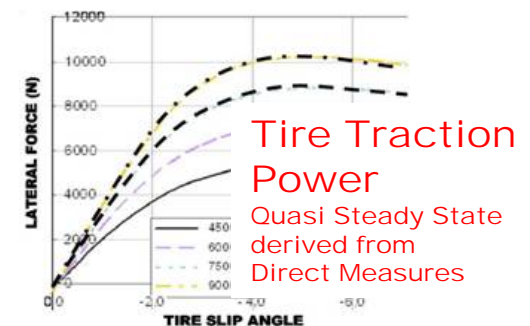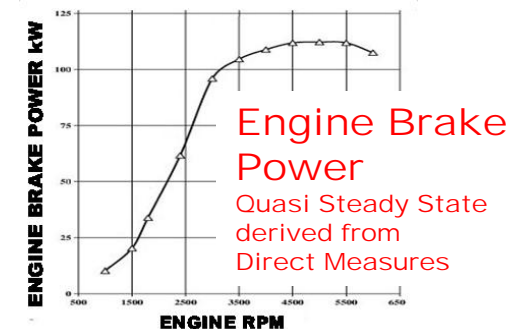
Engine Brake Power
Quasi Steady State derived from Direct Measures

1.2 Hz

12 Hz & 90 Hz

400 Hz

Photo: Berserkerus Licence: Creative Commons 2.5

Tire Traction Power
Quasi Steady State derived from Direct Measures

Tire Traction Power defined by Stress [N/m^2] under motion [m/s] is as well an effect of a Physical Wave propagation, which in rubber is 50 m/s!
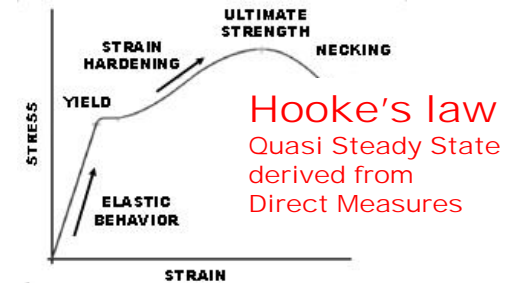
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Traction Power compares to Engine Indicated Power to be controlled within milliseconds and with precision on nano-levels!

Three variables, i.e. toe-, camber- and halftrack-variation cause multi-directional stresses in the tire to road interface. The sum (Σ) of power contributions should generate minimum internal power losses providing maximized external traction

$$\Sigma \Pi_y = f \text{ (toe-variation} \quad , \quad \text{camber-variation} \quad , \quad \text{half-track variation)}$$
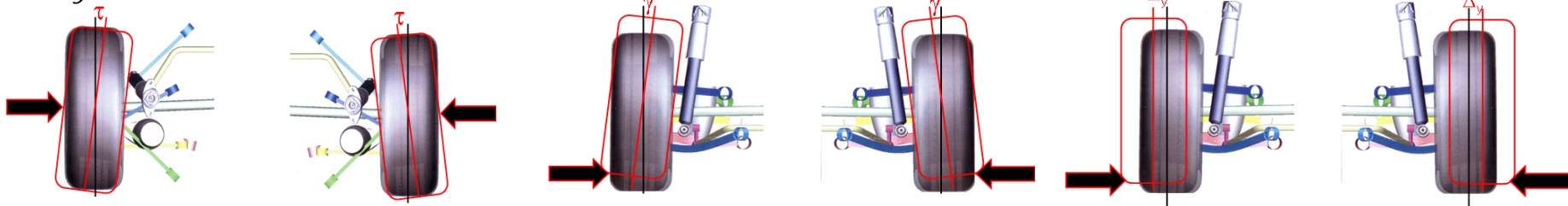
The "Power Loss Function" is a simplified mathematical formula with focus on the sum (Σ) of the lateral effects in the tire to road interface from the more complex product of interaction (Π_y) of all the local <u>stress-energy-tensors.</u>
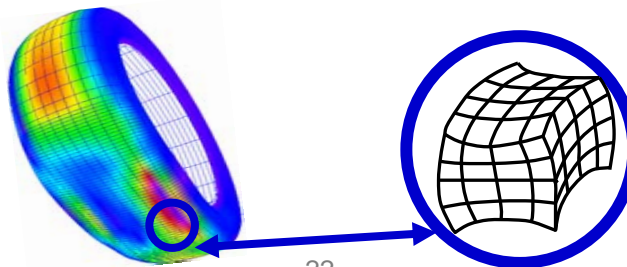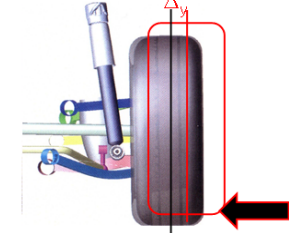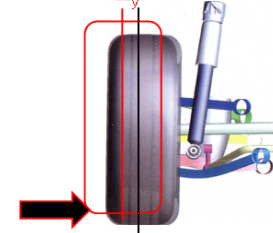
Finite Element virtual work principle

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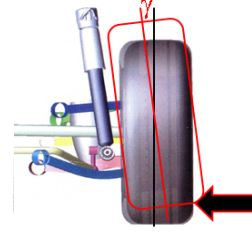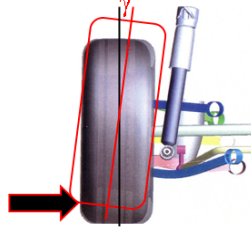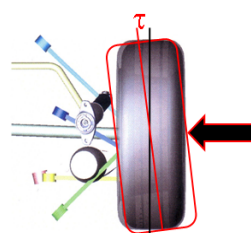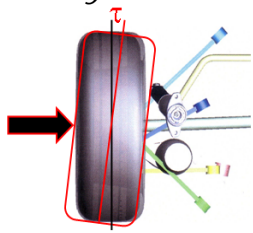
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The „Power Loss Function" is a simplified mathematical formula.

$$\sum \Pi_y = C_\alpha \cdot R \cdot \left|\left(T_{\tau/t} - \frac{1}{20} \Gamma_{\gamma/t} + 2\frac{d\alpha_{\Delta/v}}{dt} \right)\right| \quad \text{Nm/s}$$

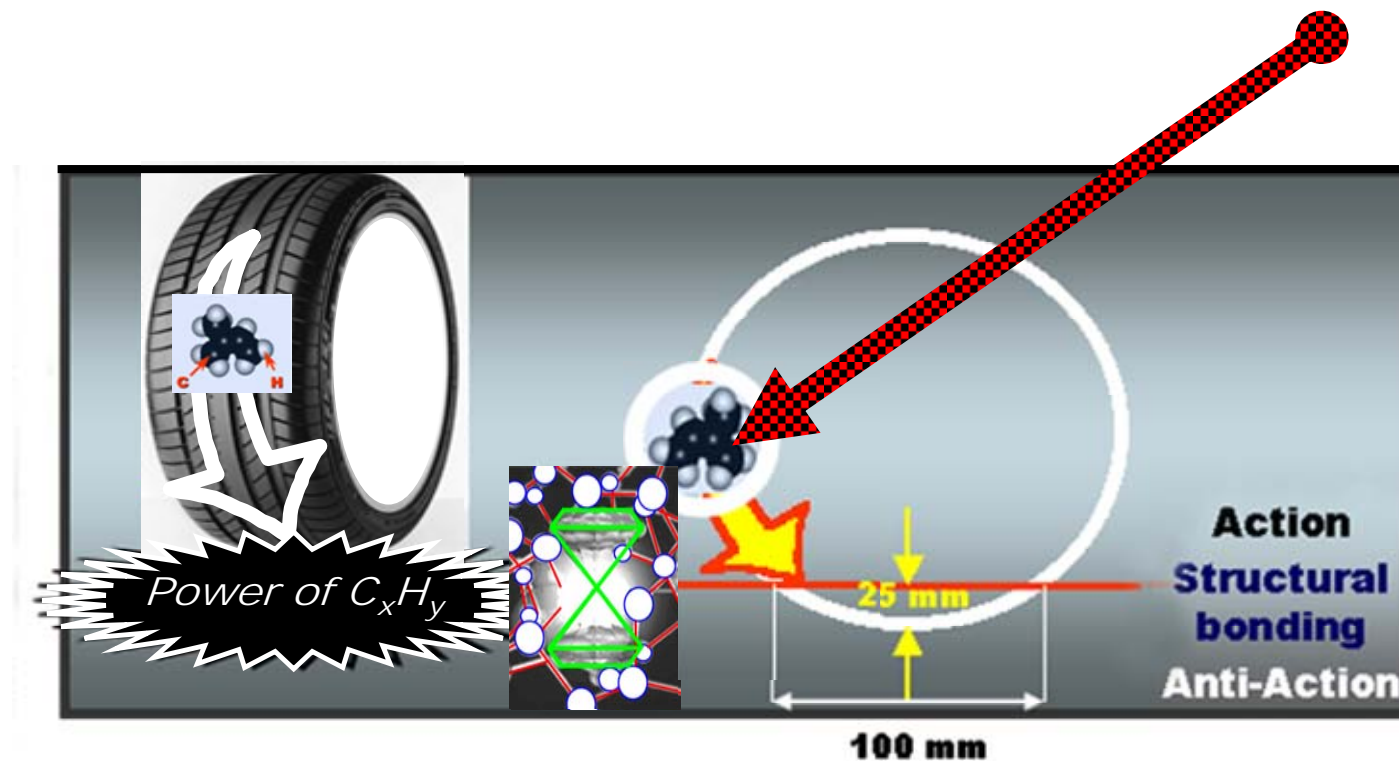| tire-index	toe-kinematic	camber-gradient	half-track impacts	dimension of power

$\sum \Pi_y$ = f (toe-variation   ,   camber-variation   ,   half-track variation)
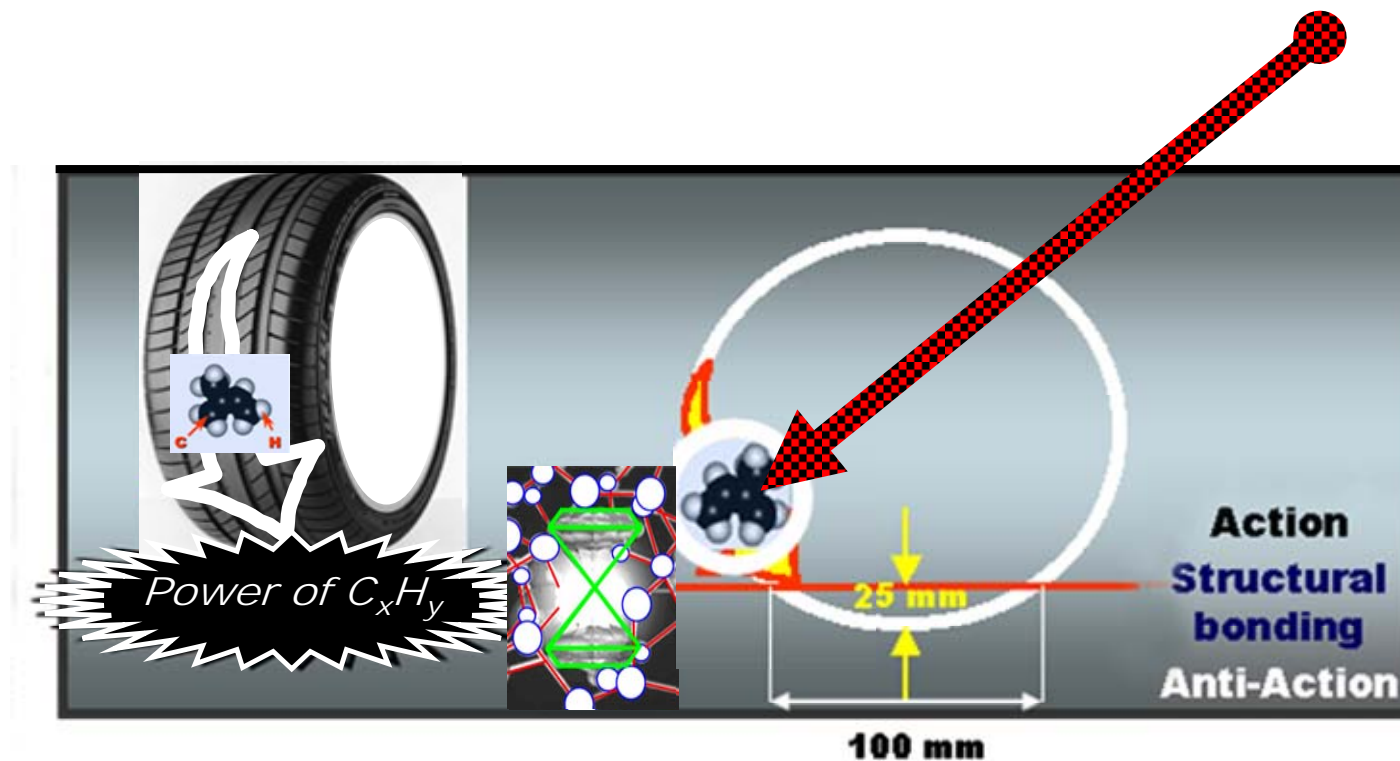

Numerators and denominators to normalize kinematic gradients of toe-, camber- and half track change into traction power in the tire foot print are derived from reverse engineering of validated desired function of operation as well as from valid tire data.

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Let us follow a molecule of rubber at the periphery of the tire!

Power of C_xH_y

Action
Structural
bonding
Anti-Action

25 mm

100 mm

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Let us follow a molecule of rubber at the periphery of the tire!

Power of C_xH_y

25 mm

Action
Structural
bonding
Anti-Action

100 mm

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VEHICLE DYNAMICS BEYOND NEWTON

Let us follow a molecule of rubber at the periphery of the tire!

Power of C_xH_y

Action
Structural
bonding
Anti-Action

25 mm

100 mm

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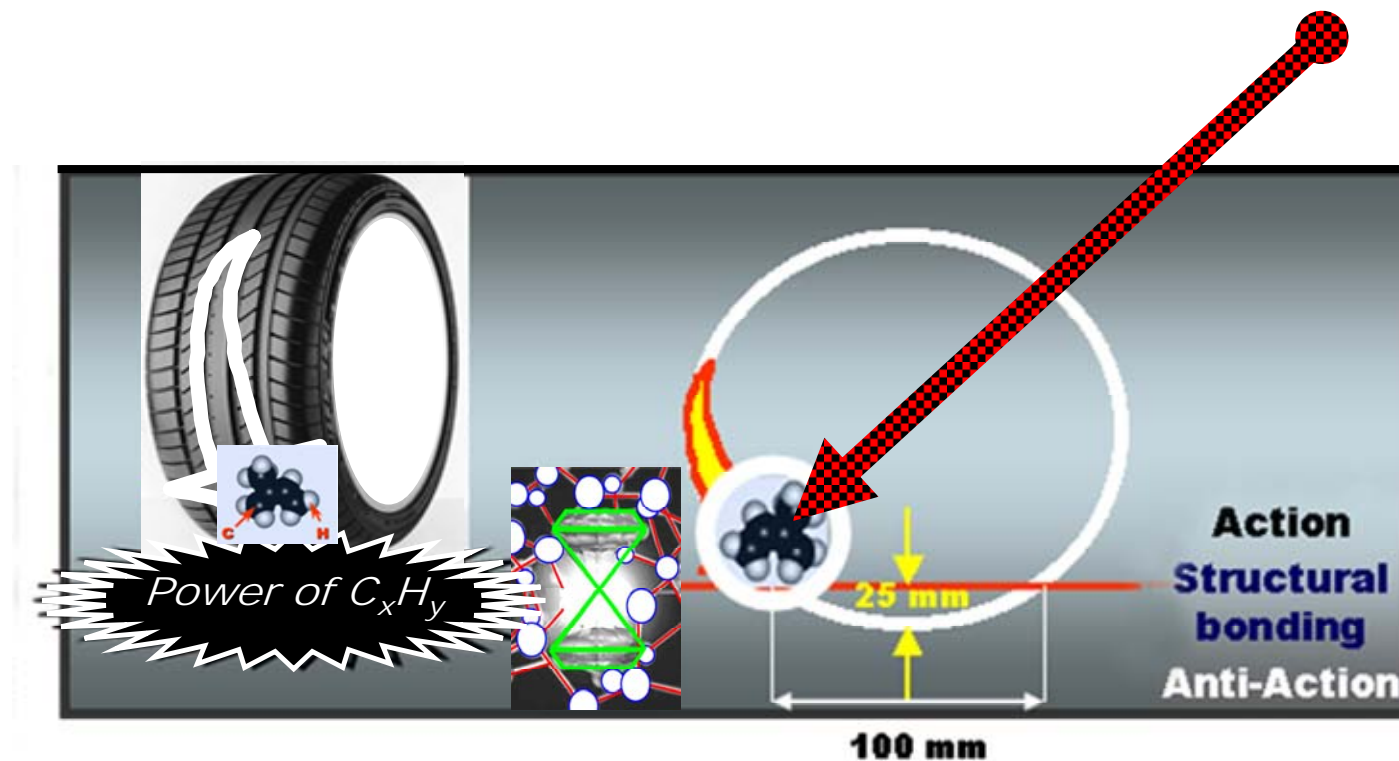
Let us follow a molecule of rubber at the periphery of the tire!

The schoolbook equations $s=\frac{1}{2}at^2$ or $a=2s/t^2$ with $\Delta Z \sim 25$ mm and $\Delta t \sim 0.64$ milliseconds at a speed of 280 km/h (Formula One) provides a d^2z/dt^2 in vertical direction of **13000 g!**
(Koenigsegg Agera at Nürburgring at a speed of 402 km/h → 26 000 g!)
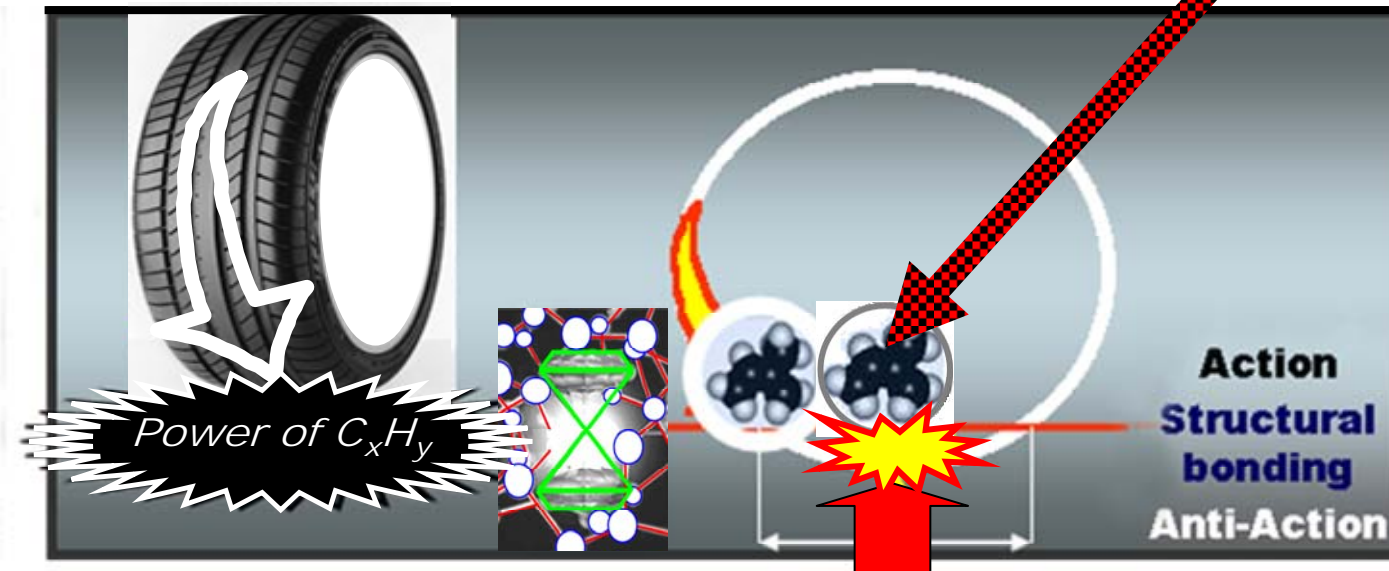
Power of C_xH_y

Action
Structural bonding
Anti-Action

13000 g!

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STRESS / STRAIN curve:
ULTIMATE STRENGTH, STRAIN HARDENING, NECKII, YIELD, FRACTIRE STRESS, ELASTIC BEHAVIOR

Rubber tire exposed to stress under motion.

$I\omega \neq 0$ — **True!**

False!

$I\omega = 0$ — **True!**

The Tire/Wheel Assembly Angular Momentum [L=Iω] as the physical "Mind" has impact on interaction.

Normalized Longitudinal Force (F_x/F_y) vs Longitudinal Slip

Braking / Deceleration   Propulsion / Acceleration
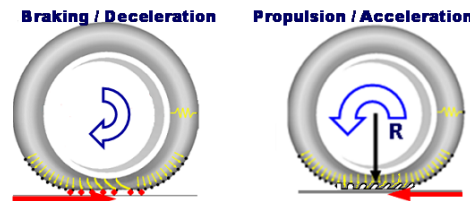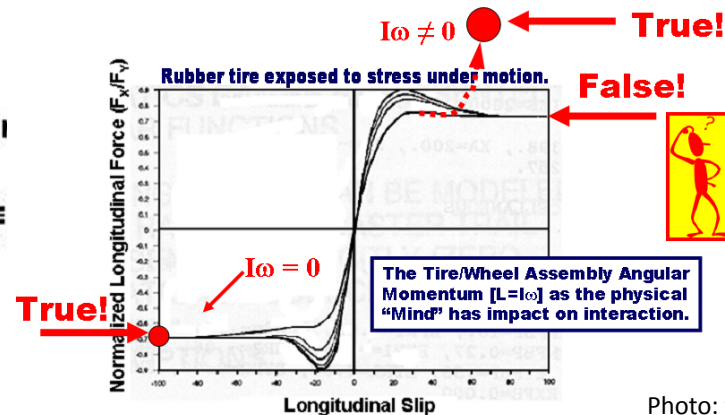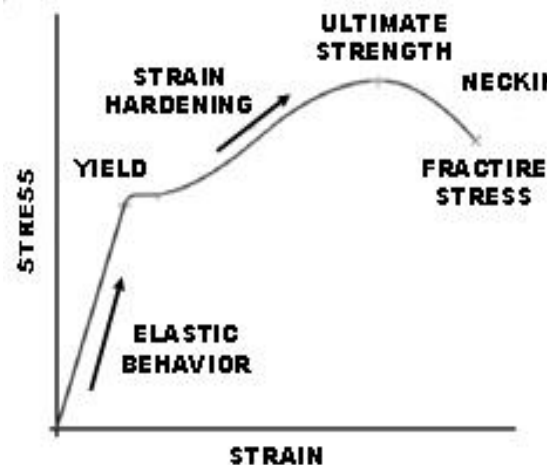
Photo: twm1340 Licence: Creative Commons by-sa 2.0 / Short

Top Fuel Dragster Asphalt & Slicks!
Tire/Wheel L=I$\omega \neq 0$
8000 Hp → 5.2g

Power of C_xH_y

Action Structural bonding Anti-Action

Chaotic White Noise

13000g!

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VEHICLE DYNAMICS BEYOND NEWTON

13000g!
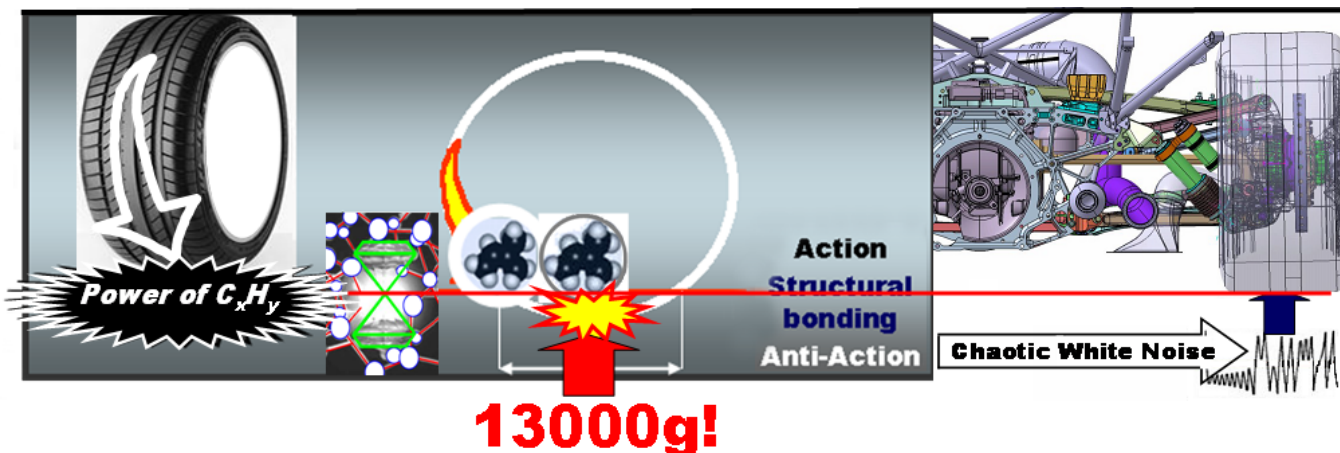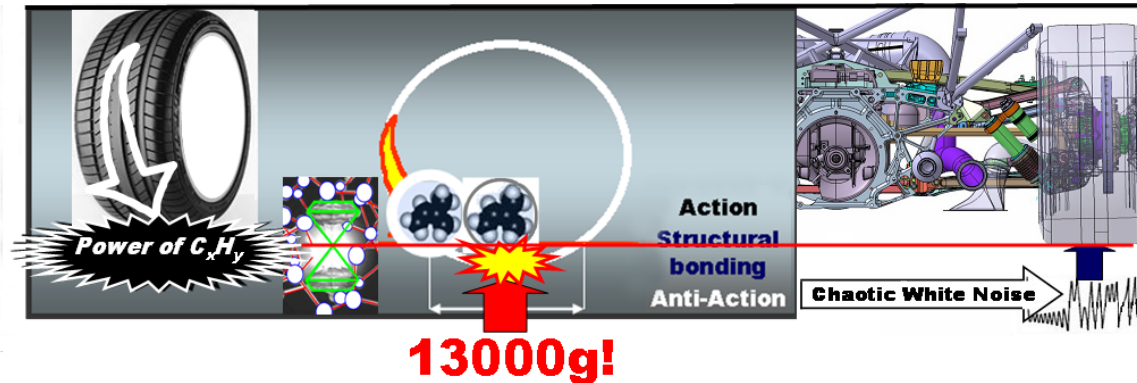
The impact speed of 80 m/s in the tire foot print compares to a "supersonic bang" in rubber since the natural wave propagation is 50 m/s in rubber. Local cones of propagating waves in the structure on atomic level of the rubber would have a similar pattern as diamond-anvil cells creating exceptional physical high pressure material properties of structural bonding.
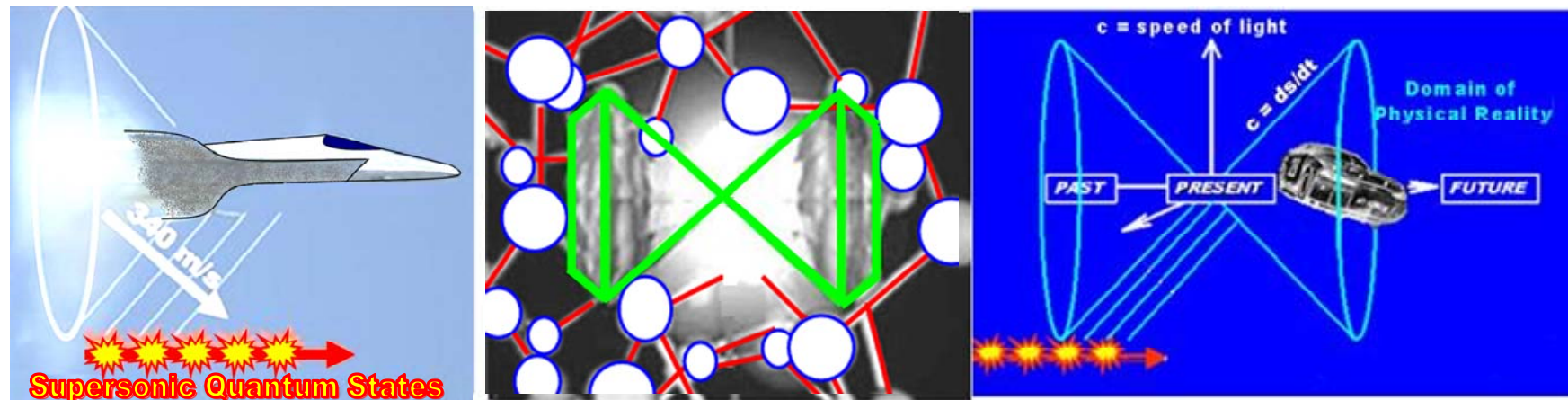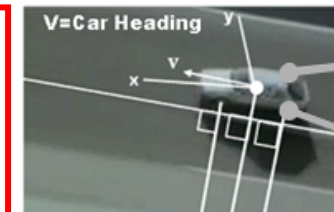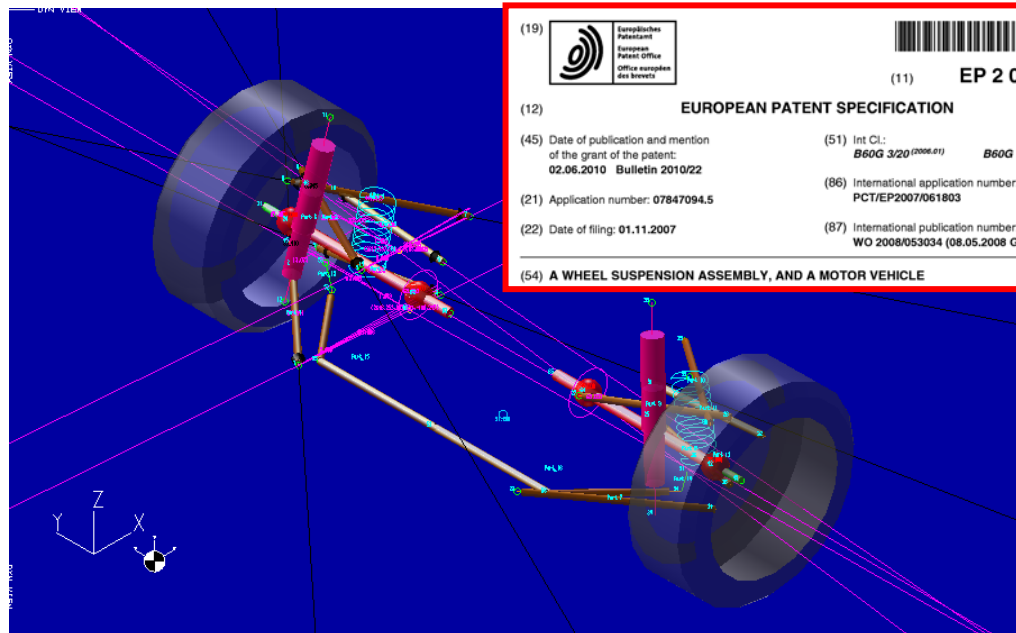
Summary of Theory

Matter has "mind" defined by momentum and inertia of power quanta propagating in space-time, where implicit characteristics are defined by system topology.
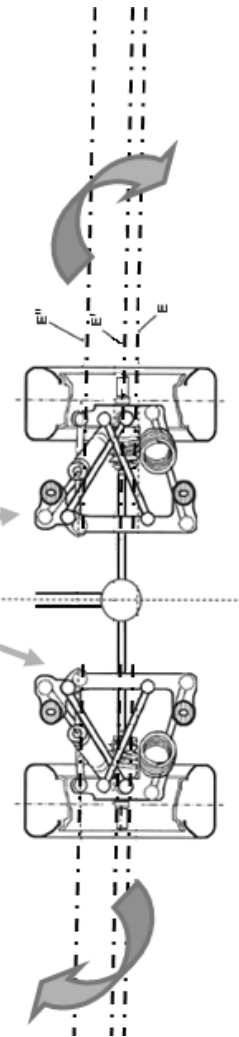
A spinning gyro with counter-intuitive dynamics provides a closed loop operator controlling power action on nano-level although defined at a macro-system level.

Power propagation for lateral control should comply with lowest possible implicit lateral power losses from kinematic control as well as converge towards an instantaneous center of action synchronous with the instantaneous turn center.

Kinematic gradients provide amplitude modulation (AM) and properties of springs and masses provide frequency modulation (FM). Propagation in steel is 6000 m/s.


(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

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(87) International publication number: WO 2008/053034 (08.05.2008 Gazette 2008/19)

(54) A WHEEL SUSPENSION ASSEMBLY, AND A MOTOR VEHICLE

V=Car Heading

Instantaneous Turn Center
Instantaneous Center of Action

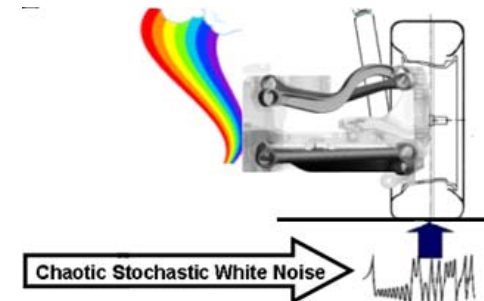SWEDISH ADVANCED AUTOMOTIVE BUSINESS
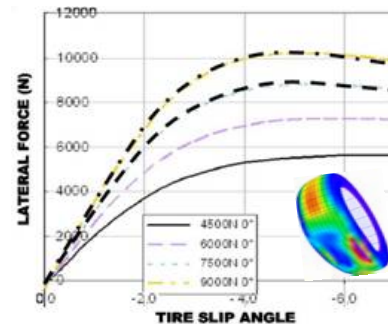
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BENTELER VEHICLE DYNAMICS
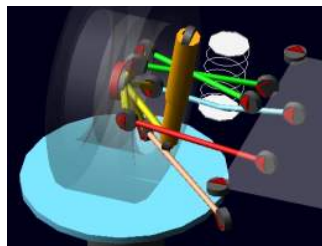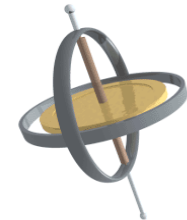## Das Fahrwerk mit Mehrwert

From THEORY to REALITY
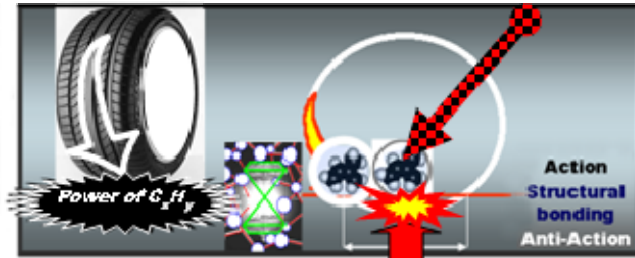
13000 g!
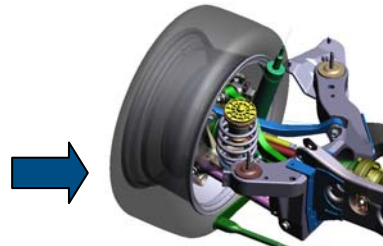
5,2 g!

„Power Loss Function"

$$\sum \Pi_y = C_\alpha \cdot R \cdot |(T_{\tau/t} - \frac{1}{20}\Gamma_{\gamma/t} + 2\frac{d\alpha_{\Delta/v}}{dt})|\ \text{Nm/s}$$

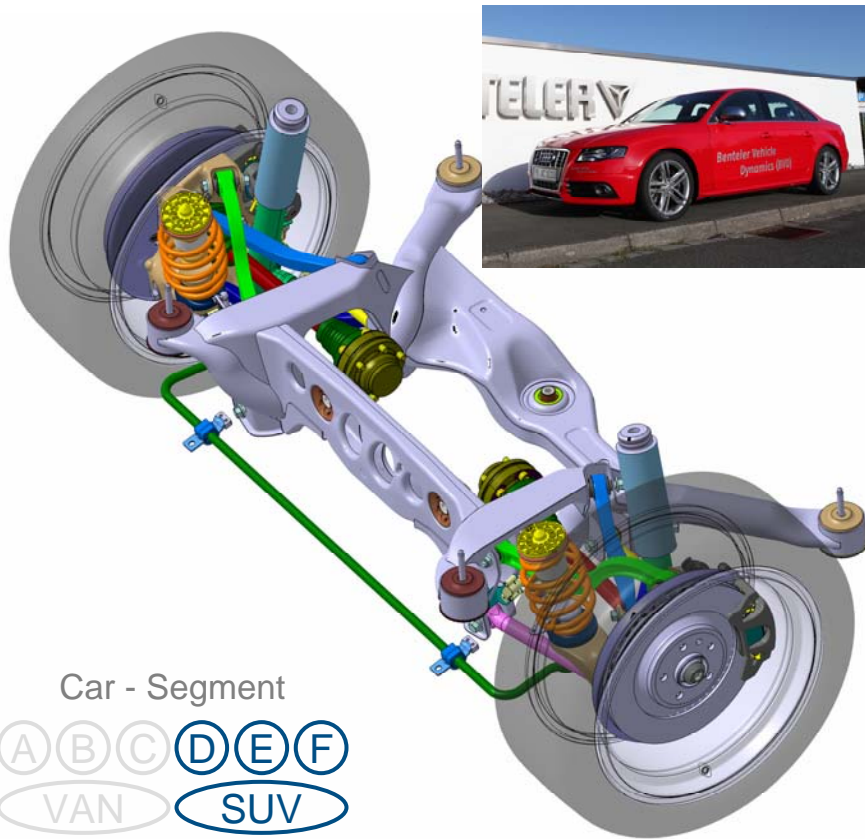**Kinematics & Elastokinematics** → **Design** → **Prototype** → **Testing**

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BENTELER VEHICLE DYNAMICS
Das Fahrwerk mit Mehrwert
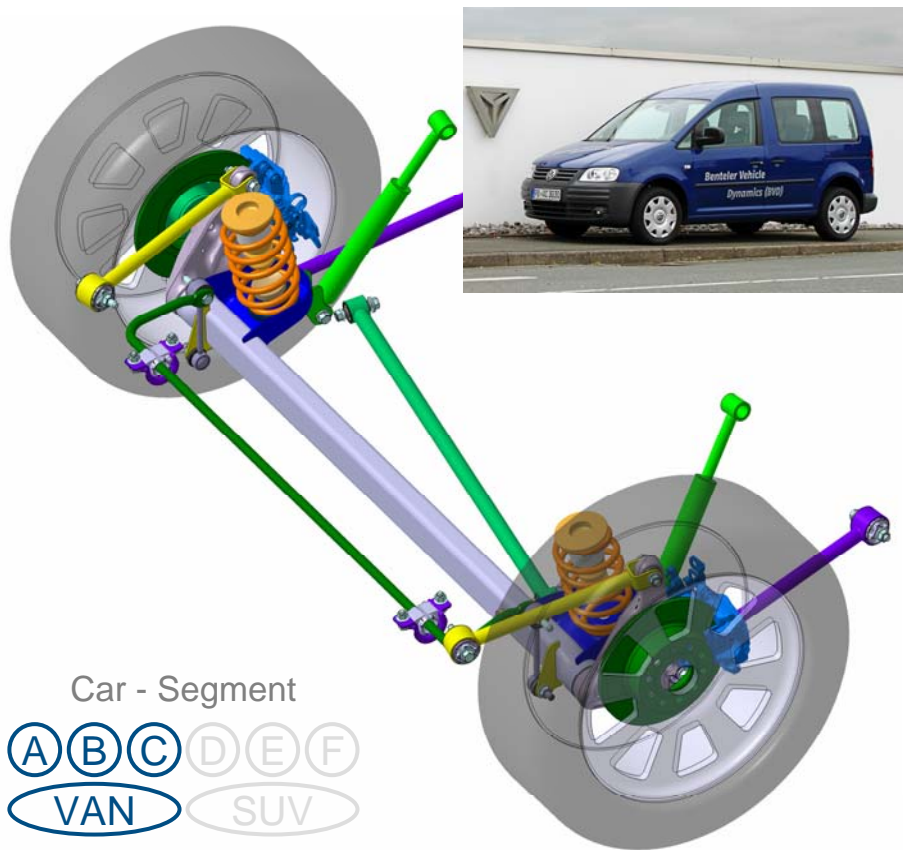
Benteler Premium Suspension

Car - Segment

The **Benteler Premium Suspension** is the ideal solution for vehicles in the **D/E/F segments and SUV - 2WD and 4WD**.

- purely mechanical-kinematical solution
- excellent on center feeling
- impressive driving experience
- high precision achieved in the tread shuffle
- exceptionally reduction of the tire wear by up to **40 percent**

BENTELER VEHICLE DYNAMICS
Das Fahrwerk mit Mehrwert
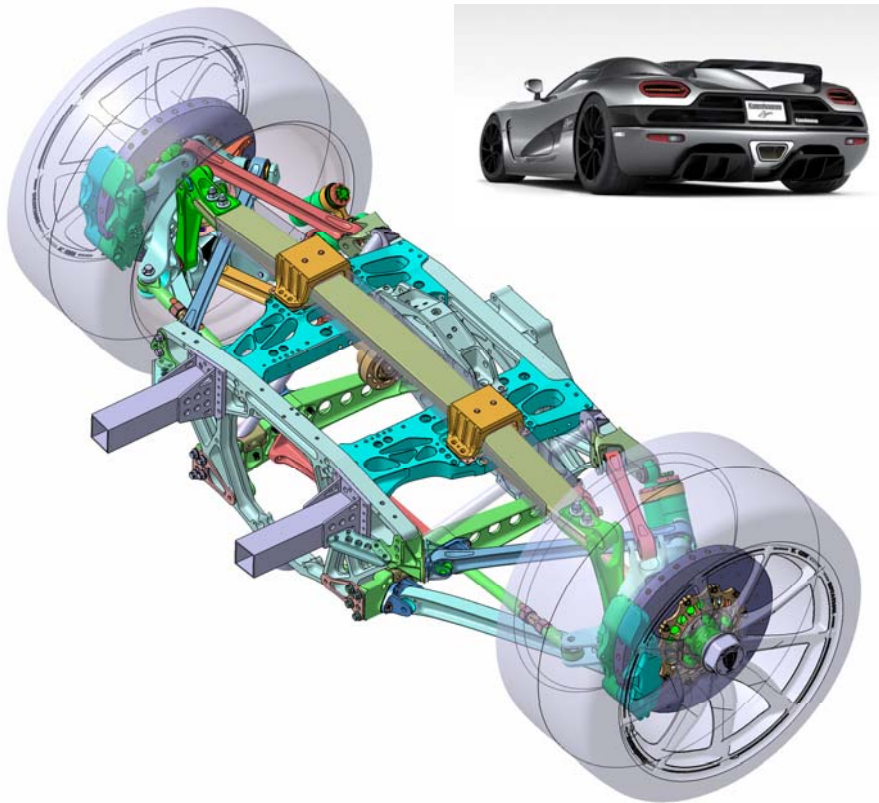
Benteler Compact Suspension

The **Benteler Compact Suspension** is the ideal solution for vehicles in the **A/B/C segments and Vans – 2WD and 4WD**.

- purely mechanical-kinematical solution
- high precision achieved in the tread shuffle
- direct vehicle response
- impressive cornering stability
- Excellent track stability

Car - Segment

Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ Ⓕ

VAN   SUV

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Benteler Premium Suspension Sport

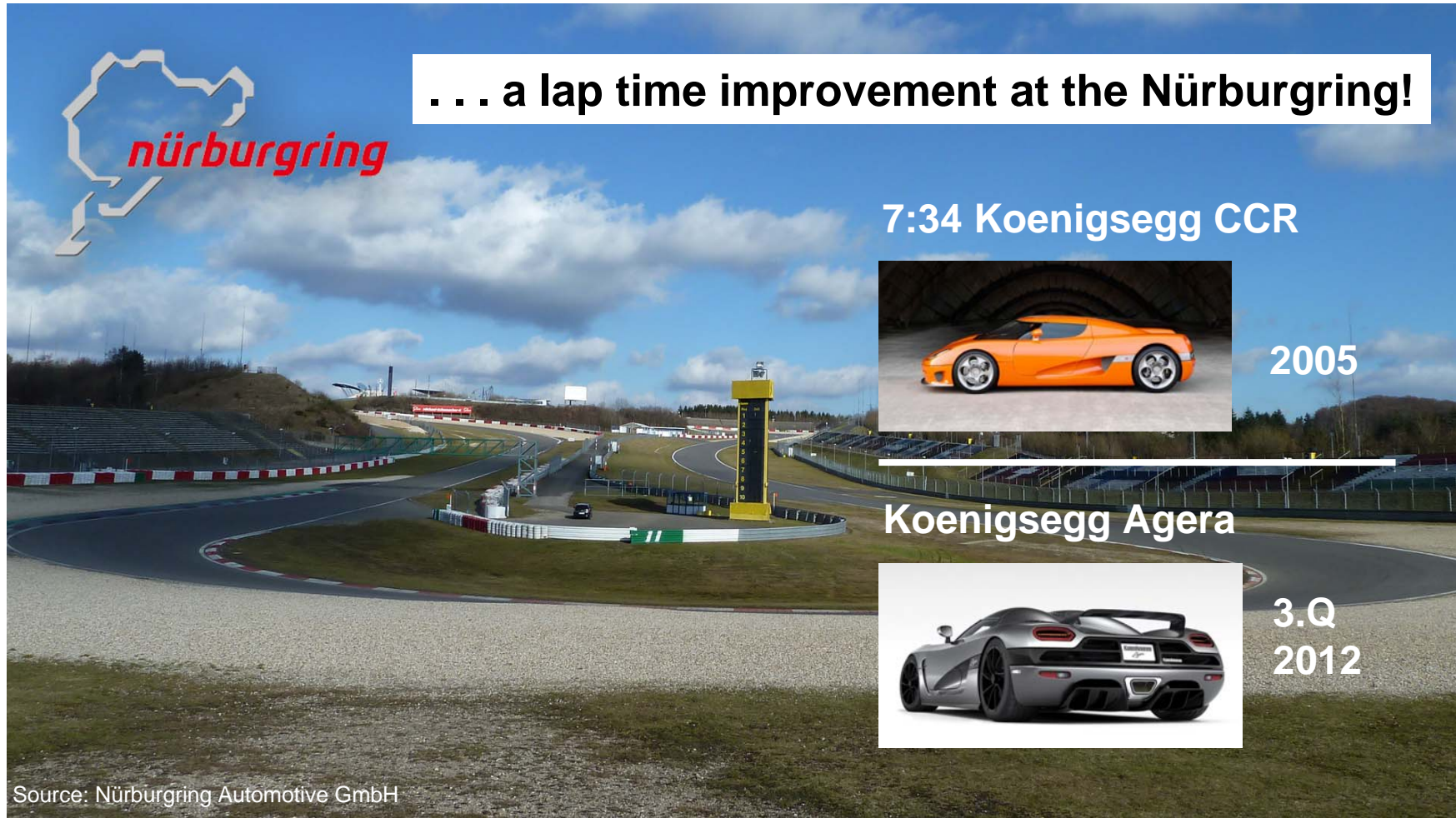The **Benteler Premium Suspension Sport** is designed for supercar applications.

- purely mechanical-kinematical solution
- five straight links
- lateral composite leaf spring

We expect

- exceptionally driving stability
- less tire wear
- precise steering behavior

and . . .

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BENTELER VEHICLE DYNAMICS
Das Fahrwerk mit Mehrwert

. . . a lap time improvement at the Nürburgring!
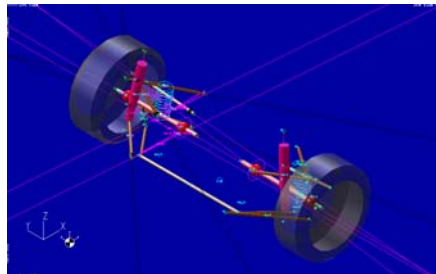
7:34 Koenigsegg CCR

2005

Koenigsegg Agera

3.Q 2012

Source: Nürburgring Automotive GmbH

Thank you for your attention!

Magnus Roland,
President & CEO Swedish Advanced Automotive Business AB

Dr. Armin Zuber,
Manager Advanced Chassis Benteler Automobiltechnik GmbH