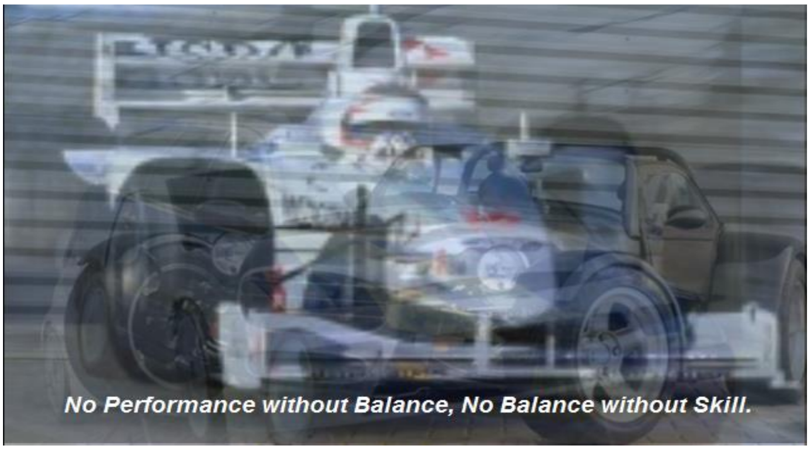
DYNATUNE-XL SIMULATION TOOL SUITE

THE 5 "MUST KNOW" FUNDAMENTALS OF VEHICLE DYNAMICS

"No Performance without Balance, No Balance without Skill"



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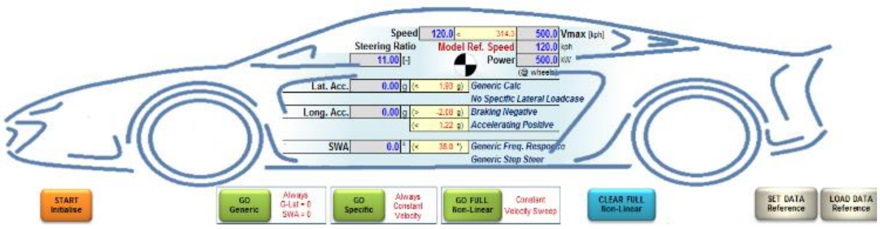
The following list of 5 Basic Fundamentals come with the **DYNATUNE-XL RIDE & HANDLING MODULE**. Although this document has been specifically written with the **DYNATUNE-XL** User Community in mind, these 5 Basic Fundamentals will greatly enhance the understanding of Vehicle Dynamics of anyone who is interested in the topic.



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THE 5 FUNDAMENTALS

- **1: FUNDAMENTALS OF MECHANICS & STATIC ANALYSIS**
- **2: FUNDAMENTALS OF LINEAR & NON-LINEAR SYSTEMS**
- **3: FUNDAMENTALS OF LOAD TRANSFER**
- **4: FUNDAMENTALS OF THE TIRE**
- **5: FUNDAMENTALS OF VEHICLE DYNAMICS BALANCE ANALYSIS**

This document is building up on articles from the **DYNATUNE-XL FAQ** webpage for customers:

http://www.dynatune-xl.com/support-rh.html

1: FUNDAMENTALS OF MECHANICS & STATIC ANALYSIS

- The above picture does show in essence the All Governing - but unfortunately also the most overlooked & forgotten - Fundamental of Vehicle Dynamics. Most of you have certainly experienced the fact that a table with 4 legs does always “wobble” on a non-perfectly flat underground and a 3-legged table does not. The correct physical description for such a 4-legged table/device is a “Statically Over-Constrained System” whereas the 3-legged table is a so called “Statically Free System”.

  Statically Over-Constrained Systems do have the following Key Characteristics:

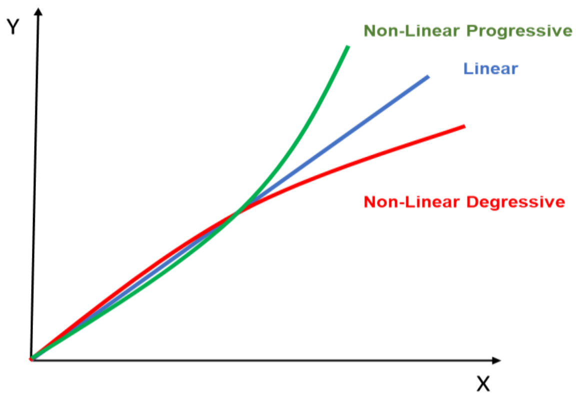
  1) The reaction forces can typically not be calculated without specific boundary conditions, assumptions and/or material data.

  2) More importantly: The reaction force in one leg of the table is dependent on the reaction forces & **STIFFNESS** of the other legs (!) .

  3) Anything, that does affect the instantaneous condition of the two participating materials creating those reaction forces - like for instance temperature or adhesion - can/will affect/change those reaction forces - at any given time and/or at any given location.

- This does also mean, that there is a fundamental difference between a car with 3 wheels and a car with 4 wheels. Only on a car with 4 wheels the reaction force at one corner can be “tuned” by changing the STIFFNESS of one of the other/all of the remaining legs - aka Suspension & Tire Vertical Stiffness! In extreme essence, the balance of a three wheeled vehicle can only be tuned via changes in static weight distribution and/or tire characteristics.

2: FUNDAMENTALS OF LINEAR & NON-LINEAR SYSTEMS



- The above picture does show the difference between a Linear and a Non-Linear System. A Linear System is characterized by a linear (=straight line) relationship between two (operating) points, whereas a Non-Linear System does typically provide a (to some or more extend) “curved/polynomial” relationship between those points.

  The following system characteristics are vital for proper understanding of Vehicle Dynamics:

  1) Non-Linear Systems can be “Progressive” or “Degressive” – See picture.

  2) If two conditions in a Linear System are known, any other condition of that system can be immediately calculated/predicted by linear extrapolation.

  3) As Non-Linear System conditions cannot be calculated by linear extrapolation, typically, in order to predict any other condition some kind of numerical iteration or curve fitting has to be applied.

  4) A typical example for a Linear Vehicle Component is a Coil Spring.

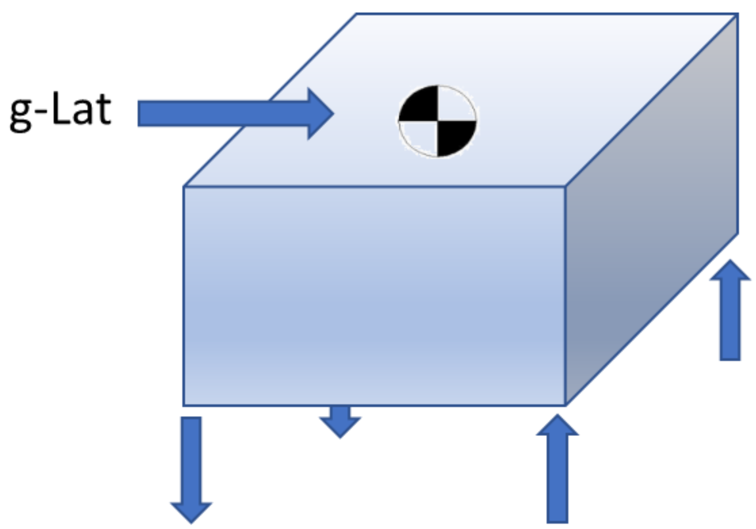
  5) A typical example for a Non-Linear “Progressive” Vehicle Component is a Bump Rubber.

  6) A typical example for a Non-Linear “Degressive” Vehicle Component is the Tire.

3: FUNDAMENTALS OF LOAD TRANSFER

3.1: LOAD TRANSFER ON RIGID BODY

- In order to understand the Fundamentals of Load Transfer it is important to start looking at the the principle of EXTERNAL Lateral Load Transfer on a rigid body with 4 “contact” points to ground. It is called EXTERNAL Load Transfer as there is no internal movement in a Rigid Body (like there is on a vehicle where the Body can roll on the Axles). We do assume that the rigid body does have 4 Contact Points to Ground.



- The above picture does show in extreme essence the principle of EXTERNAL Lateral Load Transfer (assuming as mentioned a rigid body with 4 "contact" points to ground). A Lateral Acceleration acting on the Centre of Gravity of the Rigid Body will cause a leverage moment to ground which must be counter-acted by an increased vertical load on the outside and a reduced vertical load at the inside "contact" points.

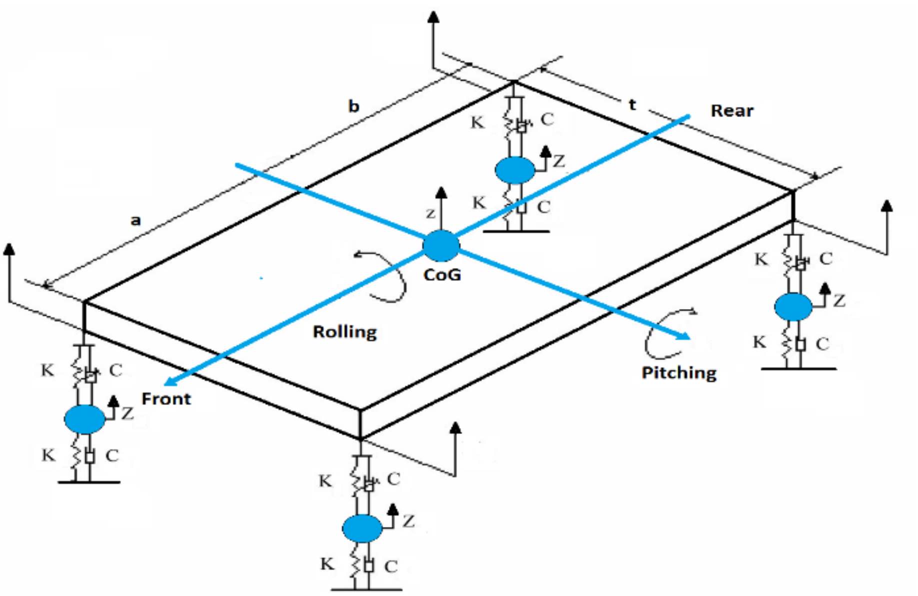
- It is Fundamentally Important to understand that for any object (whether this is a table or a car), the TOTAL amount of Lateral Load Transfer is SOLELY defined by the amount of Lateral Acceleration, Centre of Gravity Height and the corresponding "Trackwidth" of the contact points to ground.

- For a GIVEN Lateral Acceleration the TOTAL Amount of Lateral Load Transfer does ALWAYS remain CONSTANT.

- The same principle is of course valid for Longitudinal Load Transfer Analysis.

3.2: LOAD TRANSFER ON FLEXIBLE BODY

- As a vehicle is not a single Rigid Body, it is necessary to make a second step to analyse the Load Transfer in a Flexible Body (in the sense of a Non-Rigid Body). In order to differentiate from the Rigid Body analysis, the nomenclature does change to INTERNAL Lateral Load Transfer and the 4 "contact points" become Suspension & Tire System



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- The above picture does show a 6 Degree of Freedom Model which on the contrary to the rigid body model does exist out of Sprung & Unsprung Masses connected to each other by a Suspension & flexible Springs/Anti-Roll Bars allowing thus additional "internal" Roll & Pitch Motion and as such this simulation model is commonly used to calculate the INTERNAL Load Transfer on Springs & Anti-Roll Bars.

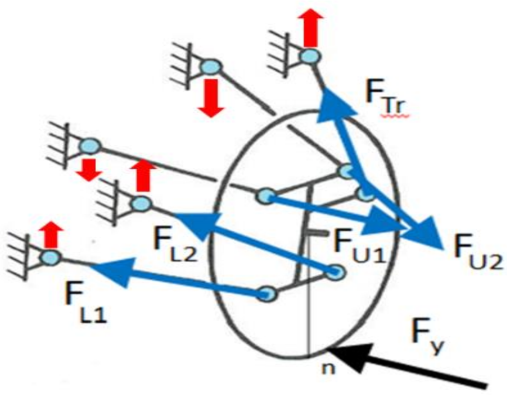
- The Roll Motion does usually take place around the Roll Centre Axis which is being defined by Roll Centre Heights at the Front and Rear Suspension.

- Front & Rear Suspension Pitch Centres do likewise define the resulting Pitch Motion of the Vehicle Body under Longitudinal Accelerations.

- In difference with the EXTERNAL Load Transfer, the INTERNAL Load Transfer can be separated into 2 Contributing Mechanism:

    - Elastic Load Transfer: Elastic Load Transfer is referring to the amount of Load going into "Elastic" Components like Springs and Anti-Roll Bars & Tires.

    - Geometric (Link-) Load Transfer: Geometric (Link-) Load Transfer is addressing the part of the Load Transfer caused by the 3-Dimensional Position of the Suspension Links in the Vehicle:



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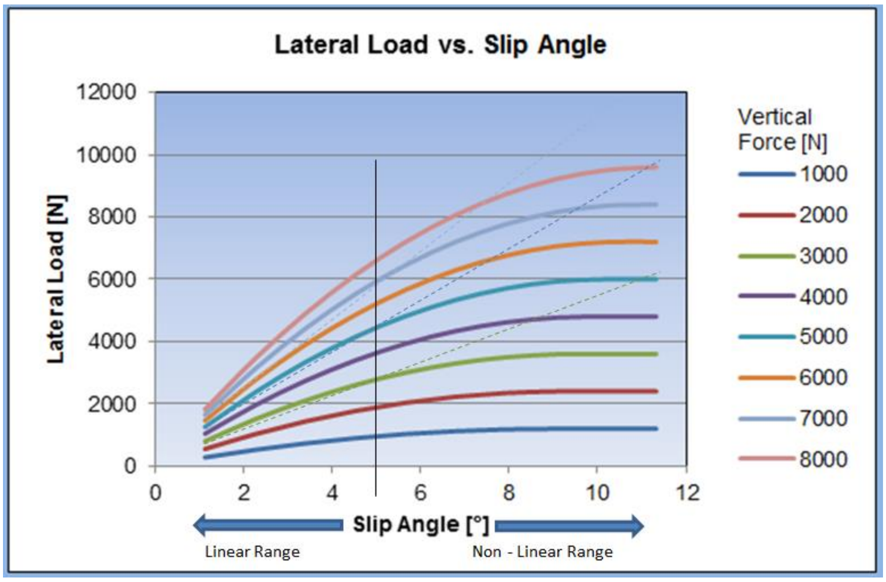
    Any Lateral (or Longitudinal) Force at the Contact Patch will create (**in blue**) reaction forces in the Suspension Links. These Link Forces can from their side create at their respective chassis attachments (**in red**) Vertical Force omponents which will influence the amount of load that at the end must be provided by the Springs and Anti-Roll Bars.

    - In fact, Geometric Link Load Transfer and Suspension Roll Centres / Pitch Centres are equivalent. The lower the RCH, the lower the Link Load Transfer and vice versa.

- **The TOTAL Sum of Front & Rear Axle INTERNAL Lateral Load Transfer MUST ALWAYS be EQUAL to the TOTAL EXTERNAL Lateral Load Transfer.**

4: FUNDAMENTALS OF THE TIRE

- As the following raph does clearly show, the Tire is a rather complex Non-Linear Degressive System. Up to a certain Slip Angle the correlation between Vertical and Lateral Force is fairly Linear (i.e. Linear Range of the Tire) whereas above that Slip Angle, the relationship does become increasingly more Non-Linear (i.e. Non-Linear Range of the Tire). More information can be found on the **DYNATUNE-XL** FAQ Website.



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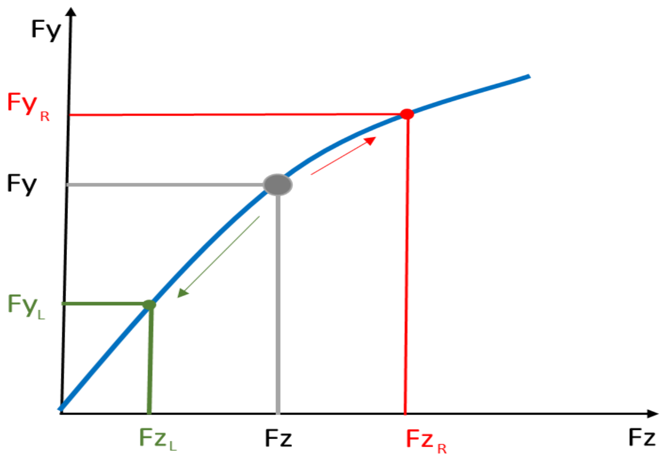
- This above shown rather complex Tire Behaviour can be hugely simplified with the help of the following graph, describing what will happen on the Axle-Tire System when the vehicle does make a (left-hand) turn:



1) When running on a straight line both Tires on an Axle will see the same vertical Force Fz, which will provide for each Tire the same (theoretical) Lateral Force Capability Fy.

2) Entering into a left-hand turn will mean that the Right Tire will see – due to the Load Transfer – more Vertical Load (FzR) and the Left Tire will see an equally lower Vertical Load (FzL).

3) According to these new Vertical Loads the Tires will be able to provide different Lateral Forces (FyR & FyL). However, knowing that the Tire is a degressive component, the amount of gain of Lateral Force on the outside Tire will be less than the amount of Lateral Force which is lost on the inside Tire and thus overall leading to a REDUCED TOTAL AXLE LATERAL FORCE:

FyL + FyR < 2 x Fy

- In fact, the equation **FyL + FyR < 2 x Fy** does describe the Key Performance Behaviour of any Axle – Tire system on a vehicle. In words:

  "The sum of both Left and Right Tire Lateral Forces on one Axle during cornering is always LOWER than the potentially available total Lateral Force when running in a straight line".

- The Key Tuning Objective in Vehicle Dynamics will be to minimize and balance the Front and Rear Axle Deterioration during cornering. More Deterioration at the Front Axle will lead to a more Understeering behaviour whilst more Deterioration at the Rear Axle will lead towards a more Oversteering Vehicle Balance.

5: FUNDAMENTALS OF VEHICLE DYNAMICS BALANCE ANALYSIS

- Due to the nature of statically over-constrained systems the analysis and prediction /interpretation of to be expected vehicle behaviour does often provide significant problems to many engineers. A proven analysis method/prediction technique is to "look at what happens at the other end of the car which has not changed".

- The following example will provide a clear detailed answer to an often-posed question using the above-mentioned principle whilst rigorously applying all previously explained fundamentals:

  Will lowering the Front Roll Centre Height create more or less Understeer ?

  1. Lowering the RCH at the Front Axle will also lower the Roll Axis Height at the x-position of the Centre of Gravity of the Sprung Mass.

  2. This will effectively increase the lever arm of the Centrifugal Force (induced by Lateral Acceleration) and as a physical consequence, the Roll Moment of the sprung mass around the roll axis must increase.

  3. This increased Roll Moment will need to be counteracted by the Springs and Anti-Roll Bars.

  4. As we did not change anything on the springs nor the anti-roll bars on the vehicle, the Roll Angle of the sprung body on the chassis must increase due to the increased Roll Moment.

  5. Now, as we did either make any modifications to the Rear Suspension, the increased Roll Angle must effectively lead to a higher INTERNAL (elastic) load transfer of the Springs and Anti-Roll Bars at the Rear Axle. In fact, more Roll-Angle = More Spring Deflection Change = More Spring Force Change.

  6. Using this knowledge and the fact that the TOTAL INTERNAL Lateral Load Transfer for a Given Lateral Acceleration must be ALWAYS CONSTANT, we can only conclude that the INTERNAL Lateral Load Transfer on the Front Axle has to diminish.

  7. As we do know that the Axle – Tire System is degressive, we can safely assume that the increased Lateral Load Transfer on the Rear Axle will deteriorate the Lateral Force Capability of the Rear Axle whilst the reduced Lateral Load Transfer on the Front Axle will increase the Front Axle Lateral Force Capability. The outcome of this Analysis must be a vehicle balanced towards less Understeer.

DYNATUNE – XL

DYNATUNE-XL is the registered name of a suite of core skill **MS EXCEL ®** based Engineering and Simulation Tools.

The **DYNATUNE-XL** Tool Suite does provide Professional Engineering Tools covering the most Important Aspects of Vehicle Dynamics. All Tools aim to achieve a Maximum of Results with a Minimum of Input Data allowing quick Setup Checks or - if wanted - more complex Generic Parameter Studies. Being a fully **MS EXCEL ®** based Tool does significantly reduce the application threshold for many engineers and technicians. MS Excel is available on most computers as part of **MS OFFICE ®** and widely supported in business applications**.**

SOFTWARE REQUIREMENTS & LICENSE MANAGEMENT

Software requirements for **RELEASE 8.0** are **Full** Versions (incl. latest updates) of **MS EXCEL ® 2007, 2010, 2013, 2016** or **2019** or **Office/365** with a **MS Windows ® XP, Windows Vista, Windows 7 Starter, Windows 7, Windows 8** or **10 Operating System**.

All Modules of **DYNATUNE-XL** come as a compiled executable (*.exe) binary file which will call **MS EXCEL®** as a separate stand-alone instance. Source code is copyright protected and safe data handling is guaranteed through secure binary files.

Standard Customer Licenses are typically valid for the use of the workbooks (and ALL user-saved variants) on 1 computer and for 1 user only without a timing constraint.

The protection software does offer to the customer next to the security of encoded binary data handling also - by means of a unique License Key Verification Procedure - a state–of-the-art data protection.

License support is available for the latest releases only and as there is no annual maintenance fee existing clients with older product releases can acquire "upgrading" licenses to the latest version release at special client rates.

Recommended minimum hardware configuration for the **DYNATUNE-XL** Tools are Intel Core i5/i7 CPU (or similar) with 4GB Ram.

All Units in **DYNATUNE-XL** are SI.

DYNATUNE-XL DEMO VERSIONS

DEMO Versions of the following DYNATUNE-XL Modules can be downloaded here:

- DYNATUNE Ride & Handling Module: http://www.dynatune-xl.com/download-demo-rh.html
- DYNATUNE Suspension Design Module: http://www.dynatune-xl.com/download-demo-sdm.html
- DYNATUNE Suspension Tuning Module: http://www.dynatune-xl.com/download-demo-stm.html

DYNATUNE-XL STORE

B2C customers can acquire the various **DYNATUNE-XL** Modules online in our webstore:

http://www.dynatune-xl.com/store/c1/Featured_Products.html

B2B customers are kindly requested to contact us directly.

DYNATUNE-XL CONTACT

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