20

Dynamic Simulation – Part One

Wan31B – (Stock Car)

(*It's just not this simple!)*

Note: Despite its title, Chapter 20 is just as important for **Road Course** only race engineers as it is for oval track racers. Most of the material discussed in this chapter is not addressed in any other chapter.

Important Note: The accuracy of any simulation program is only as good as the accuracy and complexities of the model and the input data. The Wan31 models are intended as a teaching tool and not a fully developed simulation program used by professional race teams. Having said that, we have been rather taken aback at how accurate this very simple program has turned out to be, particularly in the area of trends. Further to that point, we know of no commercially available software or team-developed software packages that are fully sorted.

Take a Deep Breath

As in the case of Wan31A, Wan31B may seem a bit daunting to begin with but once the reader navigates his/her way through the first few examples, working with the Wan31B model becomes quite intuitive. Wan31B consists of the Wan31B worksheet plus 23 additional worksheets including a slightly modified Wan31A. The good news is that 15 of the worksheets are the same as seen in Wan31A. The heart of Wan31B is contained within the first three worksheets.

- Load Wan31B Short Track Stock Car B

First Worksheet - Wan31B

Inputs

- **Important Note**: All inputs on the first worksheet are via the use of the sliders. Do not enter numbers directly into the cells.

- Worksheet One (Wan31B) is utilized by the user to enter load transfer factors (Box #1), the amount of currently used lateral acceleration (Box #2), the amount of banking and aero load (box #3) and the amount of engine torque (Box #6).

- Most user inputs on Worksheet One are through the use of sliders. Remember that only one turn direction can be used at a time. Similarly, either braking or forward acceleration can be entered but not both. Sliders for Box #1 and #2 move in increments of 0.001 while the sliders in Box #3 and #6 move in increments of 1.

    - The load transfer factors are used to change the amounts of combined or individual lateral and/or longitudinal load transfer. The numbers to the left of the sliders represent the amount of load transfer in g. The inputs from the #1 **Load Transfer Factor** Box are automatically entered into the A5 Inertial Forces Box in Wan31A (third worksheet). The Wan31A and B models see this input as amounts of lateral and longitudinal load transfer which subsequently changes the chassis corner loads, ride heights, pitch and roll. Wan31B then calculates the

amounts of **individual** maximum lateral and longitudinal acceleration force that each tire can produce with its resultant normal load. Just because the user enters 1.25 into the L Turn Load Factor cell does not necessarily mean the chassis will then produce 1.25g of lateral acceleration. The higher the number entered into this cell, the more lateral load transfer the Wan31A chassis will see, and, as we already know, a higher amount of load transfer almost always leads to a lower acceleration force i.e. unbalanced splits. However, as we will soon see, if we have been able to develop accurate tire maps, the numbers entered into the optimum Load Transfer Factor Box should match the acceleration forces quite closely.

- The maximum amount of lateral acceleration force displayed in both pounds and g is shown in the right-hand calculator named **Lateral versus Longitudinal (Box #4)**.

Outputs – Lateral versus Longitudinal Box #4

- The **Lateral versus Longitudinal** calculator allows the user to see the amount of longitudinal acceleration available for any current amount of lateral acceleration.
    - The user alters the lateral versus longitudinal acceleration percentages by entering a factor between 0 and 1 in the **Lateral Acceleration Factor (#2)** Box. Once the user enters the lateral acceleration factor, the **current** amount of lateral acceleration is shown together with the available longitudinal acceleration force. The **available longitudinal** acceleration is shown as both force in pounds and g. Entering 1 in Box #2 results in the **maximum** amount of lateral acceleration but no longitudinal acceleration while entering 0 results in **no** lateral acceleration but the maximum amount of longitudinal acceleration.
    - The change in tire contact patch size can be observed in the green cells. The contact patch size shown as square inches is a basic calculation which divides the load by the tire psi. The Wan31B model does not recalculate the tire psi factor through these changes in contact patch size and psi setting. Many of our software packages that we are currently developing for individual teams constantly updates the psi factor.
- The **Lateral versus Longitudinal** Box (#4) shows, in order:
    - Front lateral g – top pink cell
    - Front longitudinal g – top blue cell
    - Front corner loads (including aero and banking loads) – brown cells
    - Front corner loads (not including aero and banking loads) – brown cells
    - Current lateral force shown in lb. and g – light blue Box
    - Current longitudinal force shown in lb. and g – light green Box
    - Maximum lateral acceleration – upper middle pink Box
    - Maximum forward acceleration – middle blue Box
    - Maximum braking acceleration – lower middle blue Box
    - The same order is repeated for the rear corners

Output – Splits Box #5

The **splits** calculator allows the user to examine:

- Left to right and rear to front force splits
- Percentages of lateral and longitudinal forces
- Corner ride heights
- Angle of pitch and roll

Input – Thrust Box #6

The **Thrus**t calculator allows the user to enter the chassis' final gear ratio, drive line efficiency and the engine torque in order to find the maximum amount of forward thrust the individual and combined driven tires can produce.

Second Worksheet – Tires

From the user's standpoint, the **Tires** worksheet is primarily used to modify each tire's performance level.

- The F_{max}, a and L_o factors in each lateral and longitudinal Box control the base map load versus forces configuration. These factors are manipulated until the simulation performance level closely matches the recorded on track performance. If all four corners use the **same** tire, **all** lateral and longitudinal base factors are normally changed by the same amount.

- The performance factors such as steer angle, temperature, etc. are adjusted individually for each corner as well as for differences in lateral and longitudinal performance levels. Changing the performance factors can dramatically alter a chassis balance and ultimate performance. Therefore, developing accurate tire performance factors are extremely important for accurate simulation results. With the models we provide to individual race teams, all of the tire factors are tied to best fit equations based on the tire map graphs.

Third Worksheet – Wan31A

The Wan31A worksheet, as before, is used to modify the chassis set up.

- **Important Note**: The Wan31A worksheet is not used to enter acceleration or aero load data. Those changes are made in the first worksheet and then automatically linked to the appropriate Wan31A cells. Then the values from the Wan31A cells are displayed directly or via the tire worksheet. As an example, once the user inputs a change in the #1 load transfer factor in Wan31B, the LF tire load is computed by Wan31A as shown in cell W14, and this is transferred to the tires' C5 cell, then to Wan31B M34 cell and finally displayed in the #4 Lat. vs long. Box of Wan31B in the H6 cell and #5 splits box of Wan31B in the P4 cell. All of these sheets are linked together so if you make an individual change, just reload the original Wan31B model. The worksheets are set up this way to display the most relevant information in one Wan31B screen.

Using Wan31B

Wan31B is simply a continuation of Wan31A. Wan31B looks at the resultant corner loads from the Wan31A set up and then calculates the actual amount of lateral and longitudinal acceleration force each tire is producing. The race engineer can then determine the chassis, overall performance level and balance.

A chassis balance is often viewed as a chain which is only as strong as its weakest link. For example, the combined front and rear lateral acceleration force may be shown as 1.062g but with a rear lateral force of 1.177g and a front lateral force of 1.002g, the chassis' actual performance level will only be as great as its weakest link of 1.002g. Beyond a lateral acceleration force of 1.022g, the car will begin to understeer/push. If the optimum steer angle has not been reached, the driver can add steer angle. Past the optimum steer angle, the driver will either have to increase the radius of the turn or slow down. The front to rear balance will hardly ever be perfectly matched, so, providing the driver is pushing the chassis hard enough, one end will always reach its maximum level of acceleration before the other end. A driver that tells you the chassis is perfectly balanced is not taking it to the limit.

Important Note - Three primary concepts the race engineer needs to understand about chassis performance and balance:

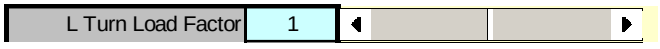
- Front to rear lateral balance is affected by a change in acceleration rate increments as small as 0.001g while 0.01g represents a large set up change.
- The heaviest end of the chassis will most often see the lowest lateral acceleration rate. This is dependent on the tire performance profile.
- A change in one tire factor often results in a greater change in performance and balance than a set up change.

Adjusting the Computer Screen Size - As in the case of Wan31A, the user will need to adjust the screen zoom size to fit his/her particular screen configuration.

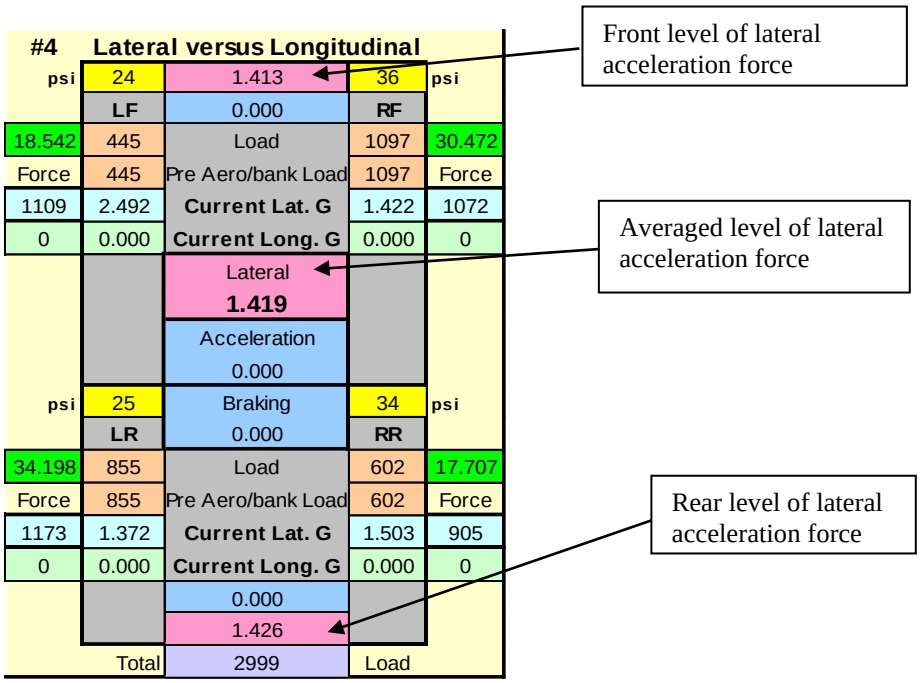
- Load Wan31B Short Track Stock Car B
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%

Lateral Acceleration

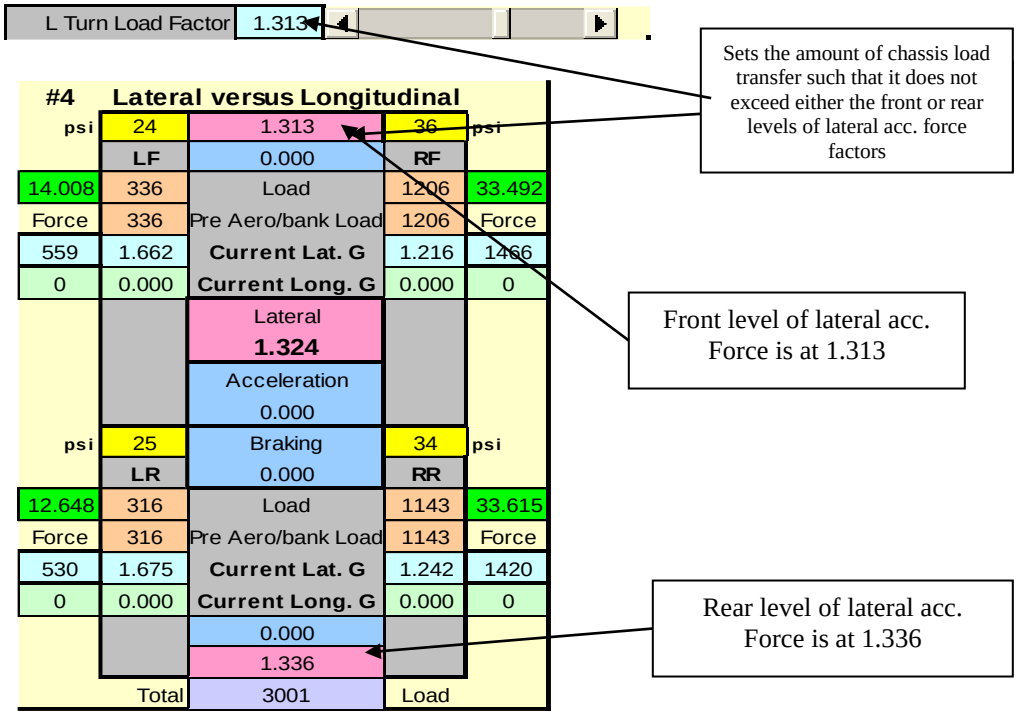
- Move the left turn slider to the right until the cell to the left of the slider shows 1.



  - With the corner loads at LF = 445 lb., RF = 1097 lb., LR = 444 lb. and RR = 1015 lb., the front lateral acceleration force is 1.357g while the rear lateral acceleration force is 1.388g. All longitudinal acceleration forces are shown as zero. Notice that the front lateral acceleration force is less than the rear force.



- We next want to begin to match the acceleration forces with the load transfer. Remember that when moving the Box #1 load transfer sliders, we are, in fact, adding an amount of load transfer to the chassis which is equivalent to a g force as shown in the cells to the left of the slider. A 1 in the left turn cell indicates that the chassis is seeing the equivalent of 1g of left turn load transfer. We now need to match the amount of load transfer with the acceleration forces the chassis is producing. By slowly moving the left turn slider to the right, we find that at 1.313, the amount of load transfer and acceleration force the chassis is capable of producing matches. Remember the amount of acceleration a chassis can produce is restricted to the least balanced end of the chassis, which, in this case, is the front. Achieving a slightly better LF to RF load balance would improve the front left turn factor.

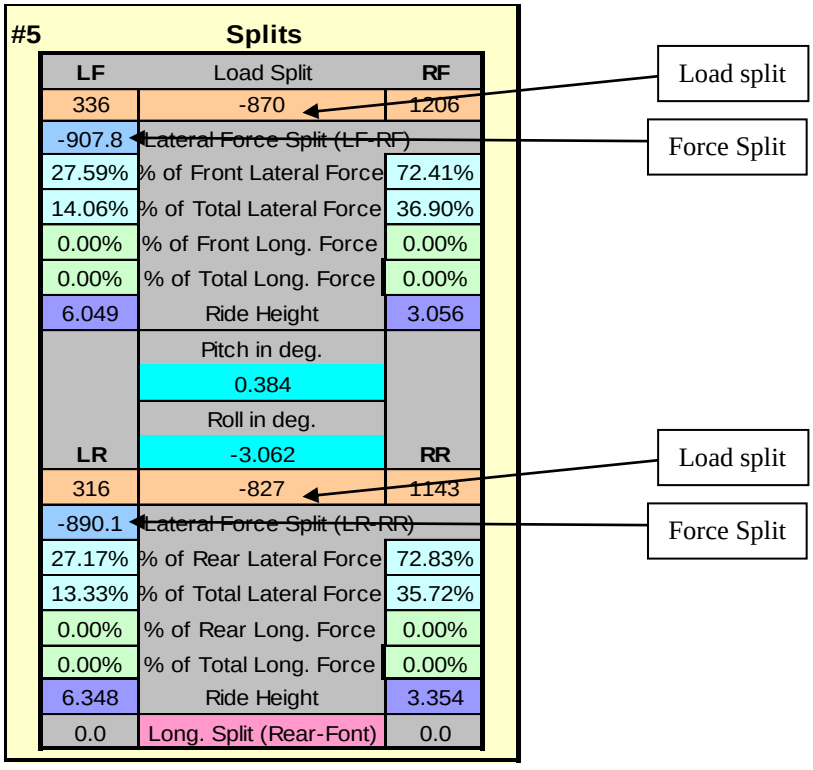


- With 1.313g of lateral load transfer, the chassis is producing a left turn acceleration force of 1.313g at the front and 1.336 at the rear. The corner loads are LF = 336 lb., RF = 1206 lb., LR = 316 lb. and RR = 1143 lb. If we now look at the individual corner acceleration numbers, we see that the more lightly loaded inside corners show a much higher lateral acceleration potential than the more heavily loaded outside corners. The total rear acceleration force is found by combining the two rear acceleration forces and dividing by the combined rear normal load, which, in this case, results in 1.336g. *It's not as simple as just combining the inside and outside acceleration forces*.

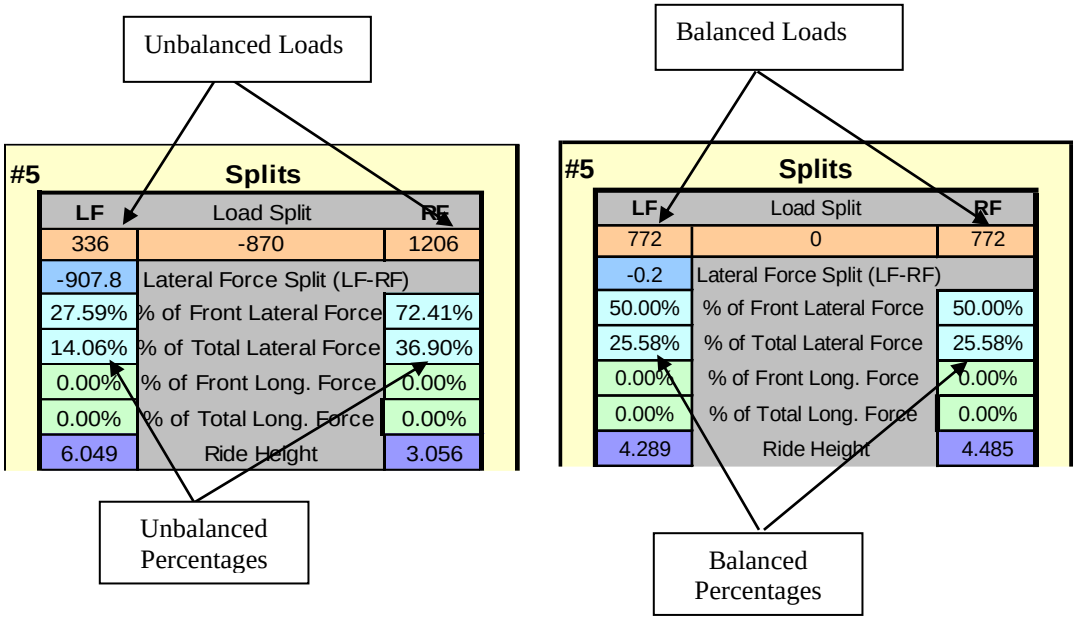
    - The corner lateral acceleration forces are LF = 559 lb., RF = 1466 lb., LR = 530 lb. and RR = 1420 lb. but even though the outside tires are producing a higher level of lateral acceleration force, they are not producing it as efficiently as the more lightly loaded inside tires. This is illustrated at the current lateral g force seen at each tire - LF = 1.662g, RF = 1.216g, LR = 1.675g and RR = 1.420g. Notice that the most lightly loaded LR corner also has the highest level of lateral acceleration (corner acceleration force/corner normal load = g).

    - To illustrate this point, move the left turn load factor slider all the way to the left so the corner loads are the same as when the chassis is sitting on the scale pads (zero inertial forces). Notice that both the front and rear lateral acceleration forces are now considerably higher at 1.413g front and 1.426g rear. These show potential acceleration forces at the highest level of tire balance.

- Notice that as shown in the **Splits** Box #5, the amount of load split, lateral force split and the amount of lateral acceleration each end of the chassis can produce are all tied together. The greater the load split is, the greater the force split will be, and, as a result, the combined acceleration force will be lower. Return the left turn load factor slider to 1.313.

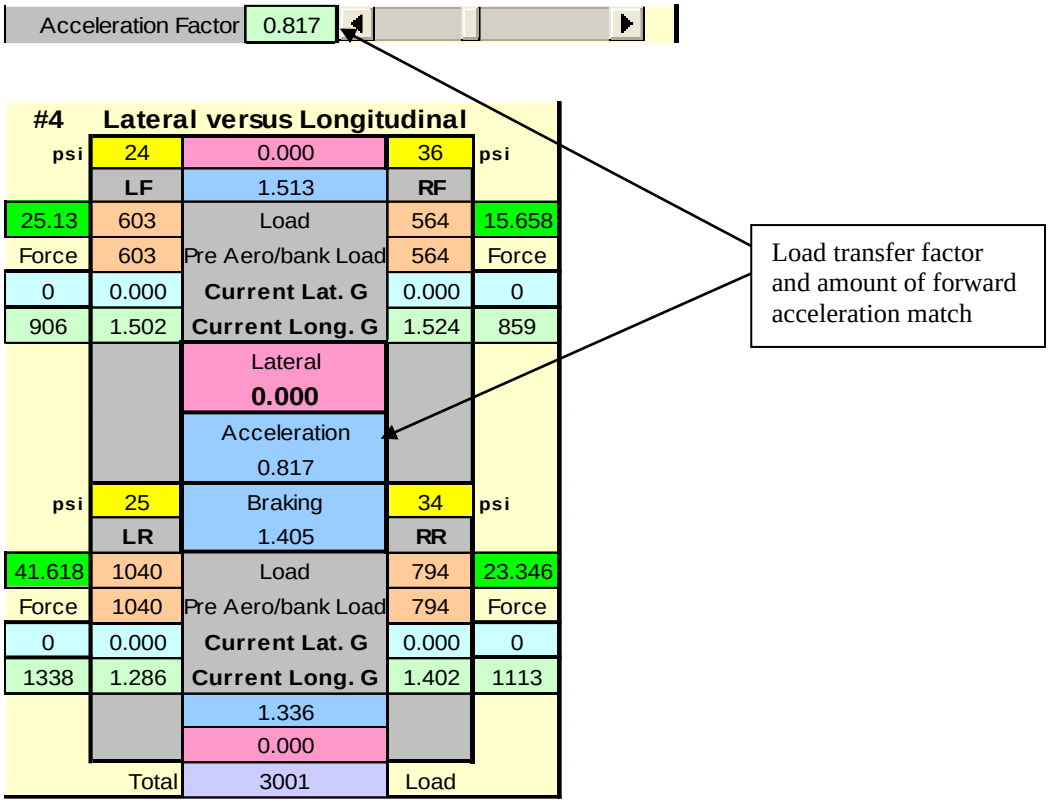


- Comparing the percentages of corner force a tire is producing in relation to the combined front/rear acceleration force and total chassis acceleration force can give the race engineer considerable insights into how hard a tire is working. Remember, the harder a tire works, the higher its temperature, internal psi and wear factor will be.



Longitudinal Acceleration Forces – Forward Acceleration

- Load Wan31B Short Track Stock Car B
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - Move the Box #2 slider all the way to the left until the current lateral factor in the cell to the left of the slider equals zero.
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%
- Move the acceleration slider in Box #1 to the right until the load transfer number to the left of the slider matches the amount of forward acceleration as shown at the center of Box #4. The value of the Acceleration Factor in Box #1 should not exceed the total acceleration value in the center of Box #4. In this case, the amount of load transfer seen by the chassis and the amount of forward acceleration the rear tires are producing are the same. The rear tires are producing 0.817g of forward acceleration.



- Moving the slider in Box #6, set the engine torque at 500 lb./ft. The calculator shows that at 500 lb./ft the engine is only able to produce 0.728g of forward acceleration. At this point the rear tires can handle more acceleration force than the engine can provide. In this first example, the differential has a 5:83 ratio, the transmission is 1:1 and the drive line efficiency is 85%. The rear tire loaded radius from Wan31A is automatically included in the calculations

    - Using the **Acceleration Force** worksheet, we see that if we change the transmission ratio to 1.23, our final ratio becomes 7.1709. If we enter this new ratio into Box #6, the engine at 500 lb./ft of acceleration can now produce 0.896g of forward acceleration and because the tires can only handle a combined acceleration force of 0.817g, the driver will only be able to apply 456 lb./ft of engine torque. In this case, because the chassis is set up with a higher LR load bias and there is no lateral load transfer to offset this LR to RR bias, the LR tire is seeing a much higher normal load, and, as a consequence, is operating at a reduced efficiency. If the two rear tires saw a more balanced load, the chassis would be able to accelerate at a higher rate. If the rear tires saw a balanced load of 908 lb., the chassis would be able to accelerate at 0.821g which is better than the unbalanced loads but still below the 0.896g the engine can produce at 500 lb./ft of torque.

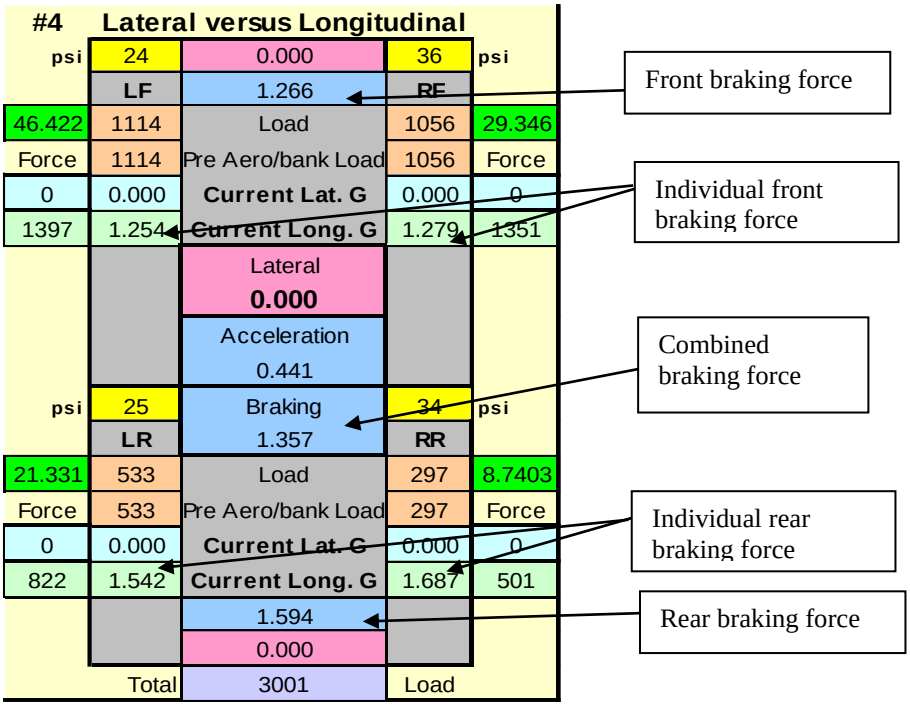
- During all acceleration conditions, the amount of acceleration a tire is able to produce is dependent on the acceleration factors such as temperature, wear, internal psi/air pressure, etc. When a locked differential is used in conjunction with a left to right difference in tire circumference (stagger), the difference in each tire's shear/slip percentage under forward acceleration can play a considerable role in determining the chassis' ultimate performance level. We will look at this condition shortly.

Longitudinal Acceleration Forces – Braking

- Load Wan31B Short Track Stock Car B
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - Move the Box #2 slider all the way to the left until the current lateral factor in the cell to the left of the slider equals zero.
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%

- Braking acceleration forces are determined through a combination of individual tire forces and the combined front and combined rear braking forces. As in the case of left to right and front to rear lateral acceleration force, a chassis front and rear braking forces will seldom, if ever, be at the same level. Each tire's acceleration factors in conjunction with the brake torque bias will play a considerable role in determining the chassis' ultimate braking performance. Book One will use the combined front and rear braking forces; however, after on track testing, a small factor normally needs to be included in the braking calculations to bring the calculated forces in line with on track performance. This factor will be quite small – somewhere in the 0.9989 range.
  - Move the brake slider in Box #1 to the right until the Brake Factor (load transfer) equals the chassis' combined level of braking force as shown in the middle of Box #4. For this particular set up, the load transfer and maximum braking force is at 1.357g. As will be discussed shortly, once the tire factors are included for each individual tire, the actual level of braking performance may well be considerably less.

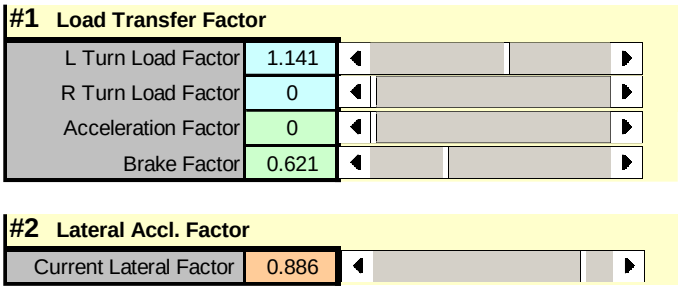


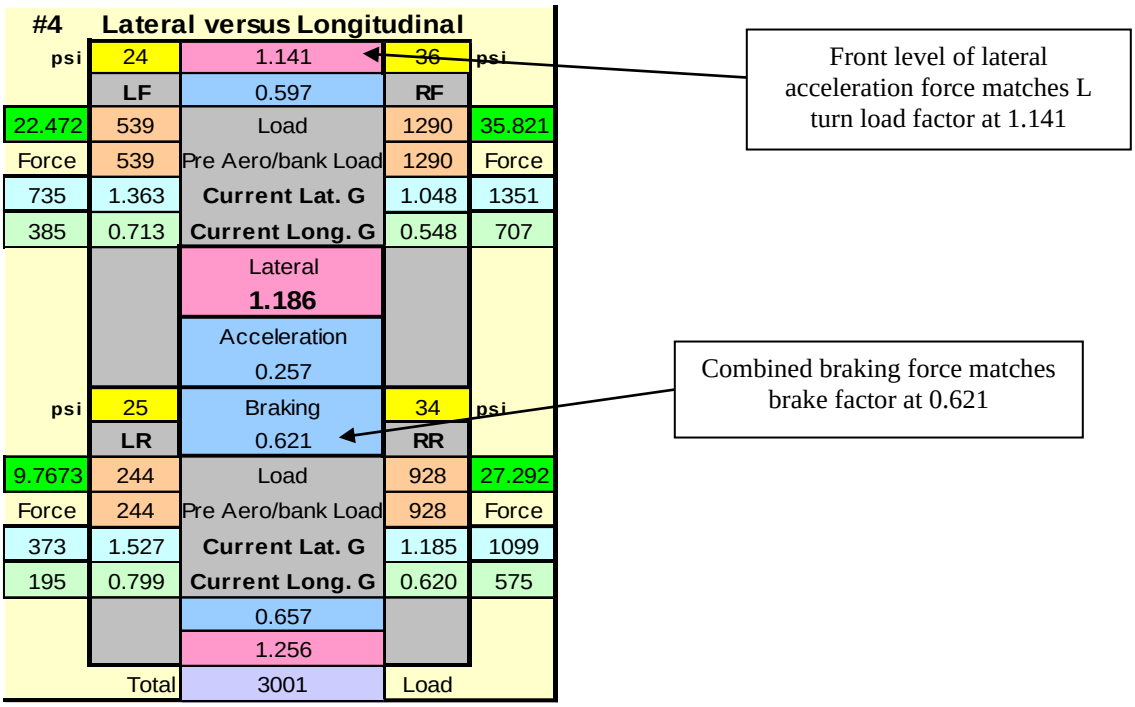


Combined Acceleration Forces

Finding the correct amount of combined acceleration for any particular cornering iteration is a matter of experimenting with the load transfer factors in Box#1 and the lateral versus longitudinal splits (Lateral Factor) in Box #2. The race engineer will begin with either a ballpark lateral and longitudinal number or a minimum lateral or longitudinal number and then experiment with the various sliders to find the final g forces.

- Load Wan31B Short Track Stock Car B
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%
- To find the maximum amount of available left turn lateral acceleration force when at least 0.621g of braking force is required:
  - Set the brake factor in Box #1 to 0.621g
  - Move the Box #2 slider to the left until the braking force is fairly close to 0.621g.
- It is now simply a matter of moving the Box #1 left turn slider and Box #2 lateral slider back and forth until the braking and turn g forces in Box #4 match the load transfer numbers in Box #1 – match but do not exceed either the front or rear level of lateral acceleration. For the set up in this example and with a braking force of 0.621g, the maximum left turn acceleration force is 1.141g. Though it may take the user some time to initially balance the acceleration forces for any particular set up, this procedure quickly becomes quite straightforward.





- As in the case of many Wan31A operations, the problem of finding the optimum combined forces can be easily solved by building Excel's closed loop solvers. However, even for users with sufficient Excel skills to do so, it is highly recommended that they first spend some considerable amount of time working through the various combined acceleration iterations by using the sliders before building in a series of solvers. Working through this type of problem by hand will teach you far more than building a solver. Obviously, once the race engineer is using this type of dynamic model for at shop and at race track set ups, he/she will want to use built in solvers but remember, computer calculated answers of this type do little to help the race engineer understand the process.

Adding the Tire Factors

A chassis' performance level is continuously changing as the result of changes in the tire factors. Notice that an optimum setting for lateral acceleration may not be the optimum setting for longitudinal acceleration. For example, for the factors used in the Wan31B map, the optimum lateral camber angle is 4° while for longitudinal acceleration it is 0°.

Note: The tire factors used in Wan31B can be found by scrolling below the tire calculators on the second worksheet (**Tires**). The user may want to print out these factors as a reference while working with Wan31B. Each tire type will have its own set of factors which are discerned through on track testing.

- Increased steer angle only increases lateral performance up to the point of optimum steer. Past that point, lateral performance decreases with each increase in steer angle.

- Increased camber only increases lateral performance up to the point of optimum camber. Past that point, lateral performance decreases with each increase in camber angle. Camber, particularly with an independent suspension system, may move below and/or above the optimum camber angle many times a second.

- Tire performance is slightly increased below the optimum tire pressure but it heats the tire at a faster rate and increases tire drag. Tire pressure above the optimum pressure degrades tire performance but decreases tire drag.

- Tire wear degrades tire performance at a rapid rate. Tires normally begin to give up their optimum performance level after only a few laps and continue to do so throughout the run.

- Tire temperature below or above the tire's optimum temperature degrades tire performance. As a tire enters a corner, its temperature can quickly move from optimum to considerably above optimum in less than a second. As tire temperature continues to rise throughout the corner, the tire's performance level will continue to deteriorate.

- Increased shear/slip percentage only increases longitudinal performance up to the point of optimum shear/slip percentage. Past that point, longitudinal performance decreases with each increase in shear/slip percentage. A chassis under forward acceleration with a locked differential and rear wheel stagger will never see an optimum level of shear/slip percentage at both wheels while the chassis is operating at a turn radius less than the designed stagger turn radius. As the turn radius decreases to zero, the forward acceleration performance level will continue to decrease. Under inline forward acceleration, the smaller inside tire will always be running at a lower shear/slip percentage (locked differential). If the inside tire is at its optimum shear/slip percentage, the larger outside tire will be past its optimum shear/slip percentage.

Note: If the user has sufficient programming and mathematical skills he/she may want to convert the various tire factors into best fit algorithms from the tire factor maps.

Corner Entry Examples

- Load Wan31B Short Track Stock Car B

- Check to see that:

  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero

  - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00

  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%.

Base Example:

- All tire factors in the tires worksheet set at 1 except the wear factors which are all set at 0.99437.

- Box #2 slider set at 0.389

- Box #1 left turn slider set at 0.494

- Box #1 braking slider set at 1.256

Base - Looking at Box #4, we see the **left turn** acceleration is **0.494g** (**front** maximum capacity) and **braking** acceleration is **1.256g**.

Example #1 – Camber Change:

Note: When using the Wan31B tire maps, a positive camber number indicates that the camber angle is set for increased performance. For example, a positive camber factor for an outside corner would indicate the tire is leaned in at the top while a positive camber factor at an inside corner would indicate the tire is leaned out at the top.

- Set front camber factors for 4º – Lateral = 1.0041, Longitudinal = 0.9982

LF Tire - Lateral		LF Tire - Longitudinal	
F_{max}	2500	F_{max}	2500
a	1.8	a	1.8
L_o	750	L_o	750
Normal Load	916	Normal Load	916
Base Lateral Force	1280	Base Longitudinal	1280
Shear/Silp Factor	1	Shear/Silp %	1
Camber Factor	1.0041	Camber Factor	0.9982
Temp. Factor	1	Temp. Factor	1
psi Factor	1	psi Factor	1
Speed Factor	1	Wear Factor	0.99437
Wear Factor	0.99437		

#1A - Without changing the Box #1 and #2 sliders, we see that the lateral acceleration capacity has increased to 0.501g (**front** maximum capacity) while the braking, capacity has decreased to 1.249g. In order to maintain 1.256g of braking, a larger proportion of the tires total capacity will need to be used in braking.

- Realigning the Box #1 and Box #2 sliders – Moving the Box#1 left turn slider to 0.486 and Box #2 slider to 0.377 realigns the load transfer numbers with the acceleration numbers.

#1B – Changing the front camber angle from 2º to 4º actually degraded chassis performance because the new camber angle hurt **braking** acceleration more than it helped lateral acceleration. We still have 1.256g of braking but in order to maintain that level of braking, the left turn acceleration was degraded from 0.494g to 0.486g.

Example #3 – Temperature Change:

- Return all factors to their base setting.
- Return sliders to base setting – left turn = 0.494, braking = 1.256 and Box #2 slider = 0.389
- Change the RF lateral and longitudinal temperature factors from 1 to 0.9846.

#2A - Without changing the Box #1 and #2 sliders, we see that the lateral acceleration capacity has decreased to 0.466g (**front** maximum capacity) while the braking capacity has decreased to 1.209g. In order to maintain 1.256g of braking, a larger proportion of the tires total capacity will need to be used for braking.

- Realigning the Box #1 and #2 sliders – Moving the Box #1 left turn slider to 0.363 and Box #2 slider to 0.302 realigns the load transfer numbers with the acceleration numbers.

#2B – The increase in RF tire temperature degraded both the lateral and longitudinal tire performance levels. In order to maintain 1.256g of braking, the cornering capacity was reduced from 0.494 to only 0.363 (front maximum capacity). A change in left turn acceleration force of 1049-771 = 278 lb – "Combined Front Lateral" cell. If the driver needed to maintain the original 0.494g of lateral

acceleration, he/she would need to reduce the braking acceleration force from 1.257g to 1.200g. A change in braking force of 3770 – 3602 = 168 lb – "Total Longitudinal Acceleration Force" cell.

Corner Apex Examples

- Load Wan31B Short Track Stock Car
- Check to see that:
    - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
    - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00
    - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%

Base Example:

- All tire factors set at 1 except the wear factors which are all set at 0.99437.
- Box #2 slider set at 1.00
- Box #1 left turn slider set at 1.368
- Box #1 braking slider set at 0.00

Base – Looking at Box #4 we see that **left turn** acceleration is **1.304g** (**Front** maximum capacity) while the longitudinal acceleration is 0.0g. The corner loads are LF = 317 lb., RF = 1225 lb., LR = 294 lb. and RR = 1165 lb.

Example #1 – Changing the Front Lateral Shear/Slip Factor

- Increase the front lateral shear/slip factor from 1 to 1.003 on both front tires. This represents a **very** small increase in steer angle.

#1 - Readjusting the Box #1 left turn slider, the load transfer and lateral acceleration numbers align at **1.332g** (**Rear** maximum capacity). At this point the chassis is virtually balanced with the front lateral acceleration force at 1.338g.

- Return all tire factors to their base setting.

Example #2 - Changing the RF psi Factor (pressure):

- Change the RF tire psi factor from 1 to 1.003. This represents a decrease in tire pressure of approximately 2 lb.

#2 - Readjusting the Box #1 left turn slider, the load transfer and lateral acceleration numbers align at **1.332g** (Both Front and Rear Maximum capacity). Decreasing the RF air pressure resulted in the front and rear lateral acceleration rates matching. The new corner loads are LF = 330 lb., RF = 1212 lb., LR = 309 lb. and RR = 1150lb. As a result of lowering the RF tire pressure the RF lateral acceleration rate changed from 1.216g to 1.241g.

Corner Exit Examples

- Load Wan31B Short Track Stock Car B
- Check to see that:
    - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
    - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00
    - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%

Base example:

- All tire factors set at 1 except the wear factors which are all set at 0.99437.
- Box #2 slider set at 0.432
- Box #1 left turn slider set at 0.584
- Box #1 acceleration slider set at 0.722

Base - Looking at Box #3 we see that **rear** left turn acceleration is **0.582g** (**rear** maximum capacity) while the forward longitudinal acceleration is **0.725g**. The corner loads are LF = 427 lb., RF = 783 lb., LR = 775lb. and RR = 1016 lb.

Example #1 – Rear longitudinal shear/slip percentage

If we set the engine torque to 505 lb./ft in Box #6, we see the engine is capable of producing 0.736g of forward acceleration. Providing 0.582g of lateral acceleration is sufficient to maintain the proper turn radius we will want to find a way to improve our rear tire performance so that the driver can use all of the available engine torque.

- Change the rear longitudinal shear/slip percentage factor from 1 to 1.003 on both rear tires.

#1 – When the driver adds more engine torque the rear tires will have moved from 4% to 5% shear/slip. In doing so, the forward acceleration performance level has moved from 0.725g to **0.747g** while the turning capacity has remained more or less constant at 0.581. Because the engine can only produce 0.736g of forward acceleration, there is a slight excess of forward acceleration performance capacity. If we adjust the rear forward acceleration level down to 0.736g, we see that the chassis can now laterally accelerate at 0.613g (Rear maximum capacity) – Left turn at 0.613, Acc. At 0.736 and Lateral Factor at 0.456. Generally speaking, this would mean the driver could get on the power slightly sooner.

Example #2 – Asymmetrical rear tire shear/slip percentages

For a chassis running with a locked differential under forward acceleration and using a larger amount of rear stagger than required by the chassis path, the driven tires will see different amounts of shear/slip percentage.

- Change the LR rear longitudinal shear/slip percentage factor to 0.995 and the RR to 0.971

#2 – With Box #2 slider set at 0.436, the **rear** lateral acceleration rate is 0.601g while the maximum lateral acceleration rate drops to 0.593g at the rear. The **rear** lateral acceleration rate is the determining factor controlling the amount of possible lateral acceleration.

Example #3 – Bolting on a set of stickers

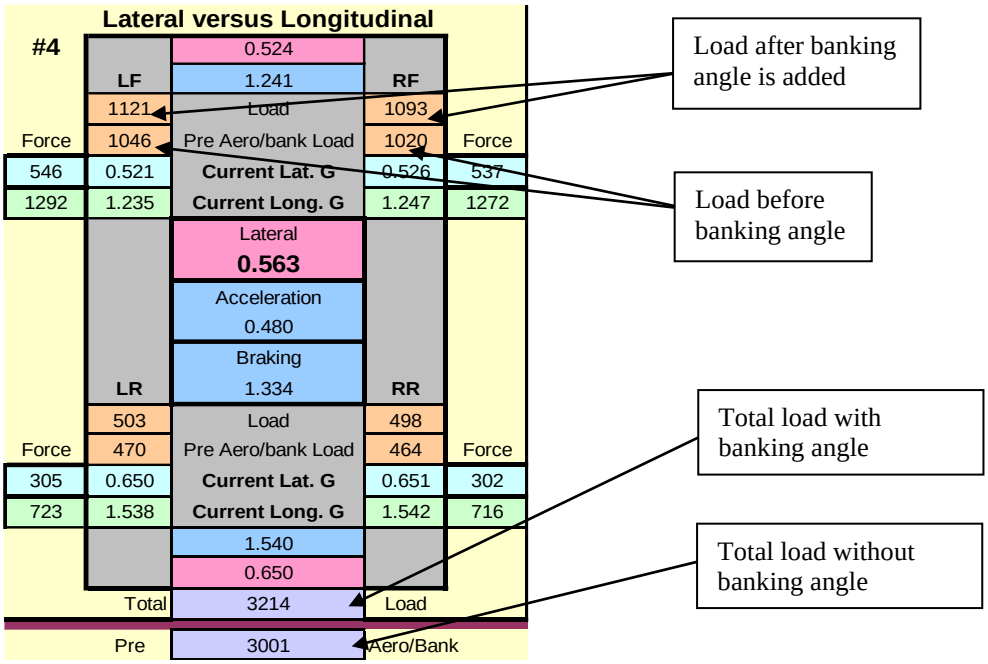
- Change the rear longitudinal shear/slip percentage factors to 1.003
- Change the front and rear lateral and longitudinal wear factors from 0.99437 to 1.0028 i.e. replacing the worn tires with stickers.

#3 – Now that's a serious performance increase. Keeping the forward acceleration at **0.736g,** the chassis is now capable of turning left at **0.768g** (**rear** maximum capacity – Box #2 at 0.542). If the turn radius only requires a lateral acceleration of 0.582g, the driver will be able to get on the power considerably sooner.

Banking

Banking is the closet the racer is ever going to get to something for nothing. As we learned in the Wan31A chapters, banking not only increases the amount of **dynamic** normal loading on the tires without increasing the weight of the chassis but also tends to improve the inside to outside balance.

Wan31B allows the user to see the changes in load as the result of adding banking angle.



- Load Wan31B Short Track Stock Car
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%

Base Example:

- All tire factors set at 1 except where indicated
    - All wear factors set at 0.99437
    - Both front lateral camber set at 1.004 and front longitudinal camber set at 0.9986
    - Both front lateral shear/slip set at 1.0028
- Box #2 slider set at 0.887
- Box #1 left turn slider set at 1.200
- Box #1 braking slider set at 0.520

Base – With a banking angle of zero and the load transfer factors aligned with the acceleration forces, Box #4 indicates the chassis has a left turn acceleration rate of **1.200g** (Front Maximum) and a braking acceleration rate of **0.520g**.

- Using the Box #3 banking slider, increase the banking angle from zero to 10^{o}.

Example #1A – Maintaining the same percentage of lateral versus longitudinal acceleration as in the previous example - Box #2 slider set at 0.887, the readjusted left turn acceleration rate is now at **1.363g** (Front maximum capacity) and the new braking acceleration rate is now **0.610g**.

Example #1B – With braking at approximately **0.520g** and #2 set to 0.908, the new lateral acceleration rate is **1. 411g** (Front maximum).

Example #1C – With left turn acceleration maintained at approximately **1.200g** and #2 set to 0.804**,** the new braking acceleration rate is **0.848g**.

Banking is Not Quite Free

As the chassis rolls in and out of the banking, the wedge percentage tends to change - sometimes considerably. For the base, zero banking example the wedge was **51.0%** while in the #1A 10^{o} banking example the wedge percentage dropped to **50.0%**. If the banking angle is increased to $20^{o,}$ the lateral acceleration rate increases to **1.502g**, the braking acceleration rate increases to **0.694g**, #2 = 0.887 while the wedge percentage drops to **48.9%.** The de-wedging of the chassis as it enters the turn can be quite useful but the chassis needs to be set up with this in mind.

Dynamics and Chassis Set Up Changes - Combining Wan31A & Wan31B

The groundwork has now been laid for the reader to begin the real work - - to combine the myriad of possible Wan31A set up changes with the dynamic Wan31B tire mapping model. This type of exploration leads to a much greater understanding of how a race car actually works. Though a number of examples will be included to get the reader started, the amount the race engineer is able to glean from reading and studying this first book and its accompanying software is wholly dependent on how much work the individual is willing to put in on his/her own.

The user needs to go through all ten cornering phases a number of times with different set up combinations.

As discussed in Chapter 1 you can not develop this type of knowledge by simply reading a textbook. It is paramount that the race engineer develop his/her knowledge base while working with models such as Wan31 A & B in conjunction with actual on track race cars.

Chapters 20 and 21 are simply outlines to a virtually endless quest. Remember there are no generic answer leading to the hot set up. *Be assured that Book 2 through 5 don't get any simpler*.

Now for the good news. If a race engineer puts in the time to truly understand race car dynamics, he/she will be in a very elite class.

Looking at Set Up Changes

While working with Wan31A, we experimented with various set up changes to help the left to right and rear to front load balance (load splits). Often a small set up change will result in a fairly large change in the load split balance. It would therefore stand to reason that these changes would also result in an equally large change to the front to rear lateral acceleration balance but it turns out that this is not the case. If, for example, the front end of the chassis has a much lower lateral acceleration rate than the rear end of the chassis, it is quite difficult to find a set up that will perfectly rebalance the two ends of the chassis. That is not to say that making a set up change can not dramatically change the chassis overall balance because it most certainly can.

Lateral versus Longitudinal

#4		1.640	
	LF	0.000	RF
	370	Load	370
Force	370	Pre Aero/bank Load	370 Force
607	1.640	**Current Lat. G**	1.640 607
0	0.000	**Current Long. G**	0.000 0
		Lateral **1.568**	
		Acceleration 0.000	
		Braking 0.000	
	LR		RR
	570	Load	570
Force	570	Pre Aero/bank Load	570 Force
867	1.521	**Current Lat. G**	1.521 867
0	0.000	**Current Long. G**	0.000 0
		0.000	
		1.521	
	Total	1880	Load
	Pre	1880	Aero/Bank
	Total Lateral Acceleration Force		2947
	Combined Front Lateral		1214 740
	Combined Rear Lateral		1734 1140

As previously discussed, even if the left to right splits are equal as shown in the accompanying graphic, the heaviest end of the chassis is **most often** going to see the lowest lateral acceleration rate because of the tire profile slope.

Remember, the acceleration rate is calculated as (lateral force/load = g). As the normal load increases, the load versus force coefficient is going to decrease. Balancing the left to right split will always improve the acceleration rate but it **can't** always make up for that end of the chassis being heavier. This last point is illustrated in the accompanying graphic where both the front and rear left to right loads are balanced but because the rear loads are greater than the front loads, the rear is going to have a lower acceleration rate. The chassis will not be able to

laterally accelerate at a rate greater than 1.521g because that is the minimum value of the front (1.640) and the rear (1.521). The exception to this rule is with a chassis that runs different tires front and rear i.e. wider tires, vastly different tire factors or tires with a higher coefficient of friction run at the heaviest end of the chassis.

While running the same tire at all four corners and without the effects of aerodynamic loads, the yaw center will move away from the heaviest end of the chassis i.e. increasing the rear load moves the yaw center toward the front of the chassis.

What the race engineer must always remember is that a driver can easily feel a change in lateral acceleration as **small** as 0.001g and altering the acceleration rate by 0.01g will result in a considerable change in the chassis' overall balance. Of course, the closer we are able to get the front to rear acceleration rates to balance, the higher the overall performance level of the chassis will be. In most cases, as just discussed, balancing the front to rear acceleration rates is simply not possible. If we make a radical chassis set up change to balance one cornering phase it will almost always bite us in another cornering phase. The profile of the tire's performance curve has a great deal to do with how closely the front to rear acceleration balances can be matched. *It is **FAR** from this simple.*

Note: To cloud the issue still more, there are numerous factors affecting chassis acceleration rates that won't be introduced until Book Two. Though the Wan31B model will most definitely help the race engineer understand dynamic set up and chassis performance, it's not that simple. You really wanted to hear that!

- Load Wan31B Short Track Stock Car B
- Check to see that:
    - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
    - The slider in Box #2 is moved all the way to the right and its accompanying cell reads 1.00
    - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%

Base Set Up:

- Box #2 slider =0.887
- Box #1 left turn = 1.142
- Box #1 braking = 0.618
- Wan31A remains as loaded with base set up

Base Set Up – Left turn = 1.142g, braking = 0.618g. With this set up, the front end of the chassis is the limiting factor controlling the lateral acceleration rate – front = 1.142g, rear = 1.257g. The corner loads are LF = 538 lb., RF = 1289 lb., LR = 244 lb. and RR = 929 lb.

Note: The lateral versus longitudinal split of 0.887 in Box #2 is, unless otherwise indicated, maintained throughout the set up changes for this cornering phase.

Adding a 200 lb. front anti roll bar - In Wan31A, add a 200 lb. front bar and adjust Box #1 factor.

- Left turn Front = 1.123g, Rear = 1.292g

- Braking = 0.619g
- A front bar decreases front performance while increasing rear performance

Soften the Front Bar – In Wan31A, change the front bar rate from 200 lb. to 100 lb.

- Left turn Front = 1.130g, Rear = 1.280g
- Braking = 0.619g.
- *Return Wan31A to its base setting*

Changing the Wedge – Changing the LF preload.

- **Add 200 lb. front bar**
- Adding a 200 lb. front bar and increasing LF preload from 0.17 to 0.6 moves the static wedge from 53.6% to 52.4% with load factors in Box #1 set at 0.
- Left turn Front = 1.128g, Rear = 1.284g
- Braking = 0.619g.
- The corner loads are LF = 489 lb., RF = 1339 lb., LR = 305 lb. and RR = 869 lb.
- With this set up the front end of the chassis is the limiting factor controlling the lateral acceleration rate.
- *Return Wan31A to its base setting*

Adding a Front & Rear Bar – Add a 200 lb. **front** and **rear** bar

- Left turn Front = 1.126g, Rear = 1.287g
- Braking = 0.619g.
- With this set up the front end of the chassis is the limiting factor controlling the lateral acceleration rate.
- The corner loads are LF = 483 lb., RF = 1345 lb., LR = 312 lb. and RR = 861 lb.
- Notice that running equal front and rear bars increases the roll rate while also increasing the lateral acceleration performance by 0.003 with just the front bar. However, it is less than the 1.142g for the base set up with no bars.
- *Return Wan31A to its base setting*

Adding a Rear Bar – Add a 200 lb. **rear** bar (no front bar)

- Left turn Front = 1.146g, Rear = 1.248g
- Braking = 0.617g
- Dynamic Wedge = 50.0%

- Adding a rear bar increases front performance while degrading rear performance and we now have increased the lateral g's from the 1.142 g's in the base case to 1.146 g's. Increasing the rear bar to 400 lb. will increase the lateral acceleration to 1.150 g's, up 0.008 from the base case.

Adding a front or rear bar has little effect on any proportion of load transfer that is purely longitudinal if the side to side suspension kinematics are symmetrical. The greater the side to side suspension asymmetries are, the greater the effects of longitudinal load transfer will be.

- Load Wan31B Short Track Stock Car
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - The slider **in Box #2** is moved all the way to the right and its accompanying cell reads **1.00**
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%
- With no anti roll bar installed, the lateral acceleration is Front = 1.313, Rear = 1.336g
- With a 200 lb. front bar installed, the lateral acceleration is Front = 1.278, Rear = 1.377g
- With a 200 lb. rear bar installed, the lateral acceleration is Front = 1.321, Rear = 1.325g

Change Track Bar Angle – Raise both sides of the track bar to 14.543".

Axle y	Axle z	Frame y	Frame z
18.063	14.543	21.063	14.543

- Load Wan31B Short Track Stock Car
- Check to see that:
  - All sliders in Box #1 are moved all the way to the left and their accompanying cells read zero
  - The slider in **Box #2** is moved all the way to the right and its accompanying cell reads **1.00**
  - The banking and aero load sliders in Box #3 are moved all the way to the left and their accompanying cells read zero. All balance cells should read 50%
  - Left turn Front = 1.343g, Rear = **1.304g** – Lower than base
- **Add 200 lb. front bar**
  - Left turn Front = **1.312g**, Rear = 1.338 – Same as base
- **Acceleration** - Set #2 lateral acceleration factor at 0.900
  - Left turn Front = 1.218g, Rear = **1.199g**
  - **Forward** acceleration = 0.309g

- **Braking** - Set #2 Lateral Factor at 0.9 – Reset Acc. Factor to 0.0
    - Left turn Front = **1.159g**, Rear = 1.271
    - **Braking** = 0.583g
- **Acceleration** - Set #2 lateral acceleration factor at 0.8
    - Left turn Front = 1.108g, Rear = **1.070g**
    - **Forward** acceleration = 0.443g
- **Braking** - Set #2 lateral acceleration factor at 0.8
    - Left turn Front = **1.025g**, Rear = 1.168g
    - **Braking** = 0.808g
- **Acceleration** - Set #2 lateral acceleration factor at 0.8
- **Replace** the front bar with a 200 lb. rear bar
    - Left turn Front = 1.132g, Rear = **1.054g**
    - **Forward** acceleration = 0.433g
- **Braking** - Set #2 lateral acceleration factor at 0.8
    - Left turn Front = **1.037g**, Rear = 1.134g
    - **Braking** = 0.804g
- *Return Wan31A to its base setting*

Lower the Track Bar – Lower both sides of the track bar by 2".

Axle y	Axle z	Frame y	Frame z
18.063	8.860	21.063	9.543

- Set #2 lateral acceleration factor at 1.000
    - Left turn Front = **1.298g**, Rear = 1.356g
- **Acceleration** - Set #2 lateral acceleration factor at 0.887
    - Left turn Front = 1.190g, Rear = 1.190g – Lateral Balance
    - **Forward** acceleration = 0.333g
- Raising both sides of the track bar helps front performance more than just raising the frame side of the bar and degrades the rear performance more than just raising the frame side.
- *Reload Wan31B*

Stiffer RR Spring – Change the RR spring to 350 lb. and readjust the preload to -0.454.

- Add 200 lb. front bar
- **Acceleration** - Set #2 lateral acceleration factor at 0.887
  - Left turn Front = **1.185g**, Rear = 1.194g
  - **Forward** acceleration = 0.334g
- **Braking** - Set #2 lateral acceleration factor at 0.887
  - Left turn Front = **1.125g**, Rear = 1.289g – No change from base RR spring setting
  - **Braking** = 0.619g
- With this set up, the front end of the chassis is the limiting factor controlling the lateral acceleration rate.
- Increasing the RR spring rate to 350 lb. slightly decreased the front performance and slightly helped the rear performance. The resultant corner loads achieved from adding a 350 lb. RR spring may well not have been what the reader would have intuitively expected from this change. If so, the users should try the same change without the front anti roll bar.
- The corner loads are LF = 480 lb., RF = 1348 lb., LR = 316 lb. and RR = 857 lb.

Much Stiffer RR Spring – Change the RR spring to 500 lb. and readjust the preload to –0.823.

- Add 200 lb. front bar and set #2 Lateral Acceleration Factor at 0.887.
- Left turn = **1.127g**, Rear = 1..287
- Braking = 0.619g.
- Changing the RR spring to 500 lb. slightly increased the front performance and slightly decreased the rear performance.

Note: When measuring the ride heights from points well inside the wheelbase as is often done with stock cars, be careful not to confuse the direction the ride heights are changing with the amounts the springs are moving. When adding a stiffer RR spring the dynamic RR ride height may well be lower even though the springs motion is decreased as shown in Table 20-1 (The following table is not taken from the current Wan31 Short Track Chassis).

From Stock Car chassis 350 = 0.318, 1000 = -0.578, 5000 = -0.9635

With 200 front anti roll bars

CG = 18"

Static	790	4.262	754	4.51	855	4.535	602	4.783	
	LF Load	LF Ride	RF Load	RF Ride	LR Load	LR Ride	RR Load	RR Ride	
Base Set Up @ 1g	603.3	4.837	1241.3	4.139	356.8	5.374	799.6	4.677	B @ 0.6
350 RR @ 1g	597.3	4.838	1247.3	4.118	362.8	5.360	793.6	4.640	B @ 0.6
1000 RR @ 1g	589.4	4.838	1255.1	4.091	370.6	5.340	785.8	4.593	B @ 0.6
5000 RR @ 1g	584.9	4.838	1259.6	4.076	375.1	5.329	781.3	4.566	B @ 0.6
Spring Motion		LF		RF		LR		RR	
Base Set Up @ 1g		1.367		1.947		2.334		2.265	B @ 0.6
350 RR @ 1g		1.359		1.953		2.36		1.277	B @ 0.6
1000 RR @ 1g		1.348		1.961		2.395		0.439	B @ 0.6
5000 RR @ 1g		1.342		1.965		2.415		0.087	B @ 0.6

Table 20-1

- *Reload Wan31B*

Stiffer LR Spring - Change the LR spring to 350 lb. and readjust the preload to 0.352

- Add 200 lb. front bar and set #2 Lateral Acceleration Factor at 0.887.
- Front = **1.130g**, rear = 1.280g
- Braking = 0.619g.
- With this set up, the front end of the chassis is the limiting factor controlling the lateral acceleration rate.
- Increasing the LR spring to 350 lb. and a 200 lb. front bar slightly improved the front performance and slightly decreased the rear performance.
- The corner loads are LF = 496 lb., RF = 1332 lb., LR = 296 lb. and RR = 878 lb.
- *Reload Wan31B*

As can be seen from the normal loads shown in Table 20-2, changing spring rates is about more than an immediate change in chassis performance and balance. The more normal load a tire sees, the faster it will build air pressure, which, in turn, will lead to a delayed performance change. Also, remember that the harder an individual tire is worked, the faster it will wear out.

Normal Loads for Rear Spring Iterations

With 200 lb front bar - #2 Lat. Accl. Factor @ 0.887

	LF	RF	LR	RR
Base Set Up	538	1289	244	929
350 RR	480	1348	339	839
350 LR	496	1332	296	878

Table 20-2

The following four examples show the difference in potential acceleration forces for a stock car chassis - static on scale readings, base dynamic set up, 350 RR spring and 350 lb. LR spring (The following examples are not taken from the current Wan31 Short Track Chassis). Take considerable time to compare each part of the four examples. How hard each particular tire is working will provide a considerable number of clues on how the chassis balance will change over a longer run.

Static

Lateral versus Longitudinal

#4

		1.253		
	LF	0.652	RF	
	790	Load	754	
Force	790	Pre Aero/bank Load	754	Force
984	1.245	**Current Lat. G**	1.261	951
512	0.648	**Current Long. G**	0.657	495
		Lateral **1.259**		
		Acceleration 0.320		
		Braking 0.655		
	LR		RR	
	855	Load	602	
Force	855	Pre Aero/bank Load	602	Force
1040	1.217	**Current Lat. G**	1.333	802
542	0.633	**Current Long. G**	0.694	418
		0.658		
		1.265		
	Total	3001	Load	

#5 **Splits**

LF	Load Split	RF
790	36	754
32.6	Lateral Force Split (LF-RF)	
50.84%	% of Front Lateral Force	49.16%
26.04%	% of Total Lateral Force	25.18%
50.84%	% of Front Long. Force	49.16%
26.04%	% of Total Long. Force	25.18%
4.262	Ride Height	4.510
	Pitch in deg. 0.351	
	Roll in deg. 0.254	
LR		RR
855	253	602
237.9	Lateral Force Split (LR-RR)	
56.46%	% of Rear Lateral Force	43.54%
27.54%	% of Total Lateral Force	21.24%
56.46%	% of Rear Long. Force	43.54%
27.54%	% of Total Long. Force	21.24%
4.535	Ride Height	4.783
29.5	Long. Split (Rear-Font)	-77.4

Pre	3001	Aero/Bank			
Total Lateral Acceleration Force	3778			Total Longitudinal Acceleration Force	1967
Combined Front Lateral	1935	1544	Load	Total Front Longitudinal	1007
Combined Rear Lateral	1843	1457	Load	Total Rear Longitudinal	959

Dynamic Base

Lateral versus Longitudinal

#4

		1.165		
	LF	0.606	RF	
	628	Load	1195	
Force	628	Pre Aero/bank Load	1195	Force
829	1.320	**Current Lat. G**	1.083	1294
432	0.687	**Current Long. G**	0.564	673
		Lateral **1.215**		
		Acceleration 0.264		
		Braking 0.633		
	LR		RR	
	333	Load	845	
Force	333	Pre Aero/bank Load	845	Force
492	1.476	**Current Lat. G**	1.221	1032
256	0.768	**Current Long. G**	0.636	537
		0.673		
		1.293		
	Total	3001	Load	

#5 **Splits**

LF	Load Split	RF
628	-567	1195
-464.3	Lateral Force Split (LF-RF)	
39.06%	% of Front Lateral Force	60.94%
22.74%	% of Total Lateral Force	35.48%
39.06%	% of Front Long. Force	60.94%
22.74%	% of Total Long. Force	35.48%
4.805	Ride Height	4.187
	Pitch in deg. 0.641	
	Roll in deg. -0.633	
LR		RR
333	-511	845
-539.6	Lateral Force Split (LR-RR)	
32.29%	% of Rear Lateral Force	67.71%
13.49%	% of Total Lateral Force	28.29%
32.29%	% of Rear Long. Force	67.71%
13.49%	% of Total Long. Force	28.29%
5.303	Ride Height	4.685
-175.6	Long. Split (Rear-Font)	-136.4

Pre	3001	Aero/Bank			
Total Lateral Acceleration Force	3647			Total Longitudinal Acceleration Force	1898
Combined Front Lateral	2123	1823	Load	Total Front Longitudinal	1105
Combined Rear Lateral	1524	1178	Load	Total Rear Longitudinal	793

350 RR

Lateral versus Longitudinal

#4				
		1.164		
	LF	0.606	RF	
	624	Load	1199	
Force	624	Pre Aero/bank Load	1199	Force
825	1.322	**Current Lat. G**	1.081	1296
430	0.688	**Current Long. G**	0.563	675
		Lateral		
		1.215		
		Acceleration		
		0.265		
		Braking		
	LR	0.633	RR	
	339	Load	839	
Force	339	Pre Aero/bank Load	839	Force
499	1.472	**Current Lat. G**	1.224	1027
260	0.766	**Current Long. G**	0.637	534
		0.674		
		1.295		
	Total	3001	Load	

#5	**Splits**	
LF	Load Split	RF
624	-575	1199
-471.1	Lateral Force Split (LF-RF)	
38.90%	% of Front Lateral Force	61.10%
22.62%	% of Total Lateral Force	35.54%
38.90%	% of Front Long. Force	61.10%
22.62%	% of Total Long. Force	35.54%
4.805	Ride Height	4.169
	Pitch in deg.	
	0.625	
	Roll in deg.	
LR	-0.650	RR
339	-500	839
-527.1	Lateral Force Split (LR-RR)	
32.73%	% of Rear Lateral Force	67.27%
13.69%	% of Total Lateral Force	28.14%
32.73%	% of Rear Long. Force	67.27%
13.69%	% of Total Long. Force	28.14%
5.290	Ride Height	4.655
-169.6	Long. Split (Rear-Font)	-140.4

Pre	3001	Aero/Bank				
Total Lateral Acceleration Force	3648			Total Longitudinal Acceleration Force	1899	
Combined Front Lateral	2121	1823	Load	Total Front Longitudinal	1104	
Combined Rear Lateral	1526	1178	Load	Total Rear Longitudinal	794	

350 LR

Lateral versus Longitudinal

#4				
		1.170		
	LF	0.609	RF	
	654	Load	1168	
Force	654	Pre Aero/bank Load	1168	Force
856	1.308	**Current Lat. G**	1.092	1276
445	0.681	**Current Long. G**	0.569	664
		Lateral		
		1.214		
		Acceleration		
		0.262		
		Braking		
	LR	0.632	RR	
	306	Load	873	
Force	306	Pre Aero/bank Load	873	Force
456	1.492	**Current Lat. G**	1.209	1055
237	0.777	**Current Long. G**	0.630	549
		0.668		
		1.282		
	Total	3001	Load	

#5	**Splits**	
LF	Load Split	RF
654	-514	1168
-420.7	Lateral Force Split (LF-RF)	
40.13%	% of Front Lateral Force	59.87%
23.48%	% of Total Lateral Force	35.03%
40.13%	% of Front Long. Force	59.87%
23.48%	% of Total Long. Force	35.03%
4.694	Ride Height	4.180
	Pitch in deg.	
	0.547	
	Roll in deg.	
LR	-0.526	RR
306	-567	873
-599.6	Lateral Force Split (LR-RR)	
30.16%	% of Rear Lateral Force	69.84%
12.51%	% of Total Lateral Force	28.97%
30.16%	% of Rear Long. Force	69.84%
12.51%	% of Total Long. Force	28.97%
5.118	Ride Height	4.605
-208.1	Long. Split (Rear-Font)	-115.0

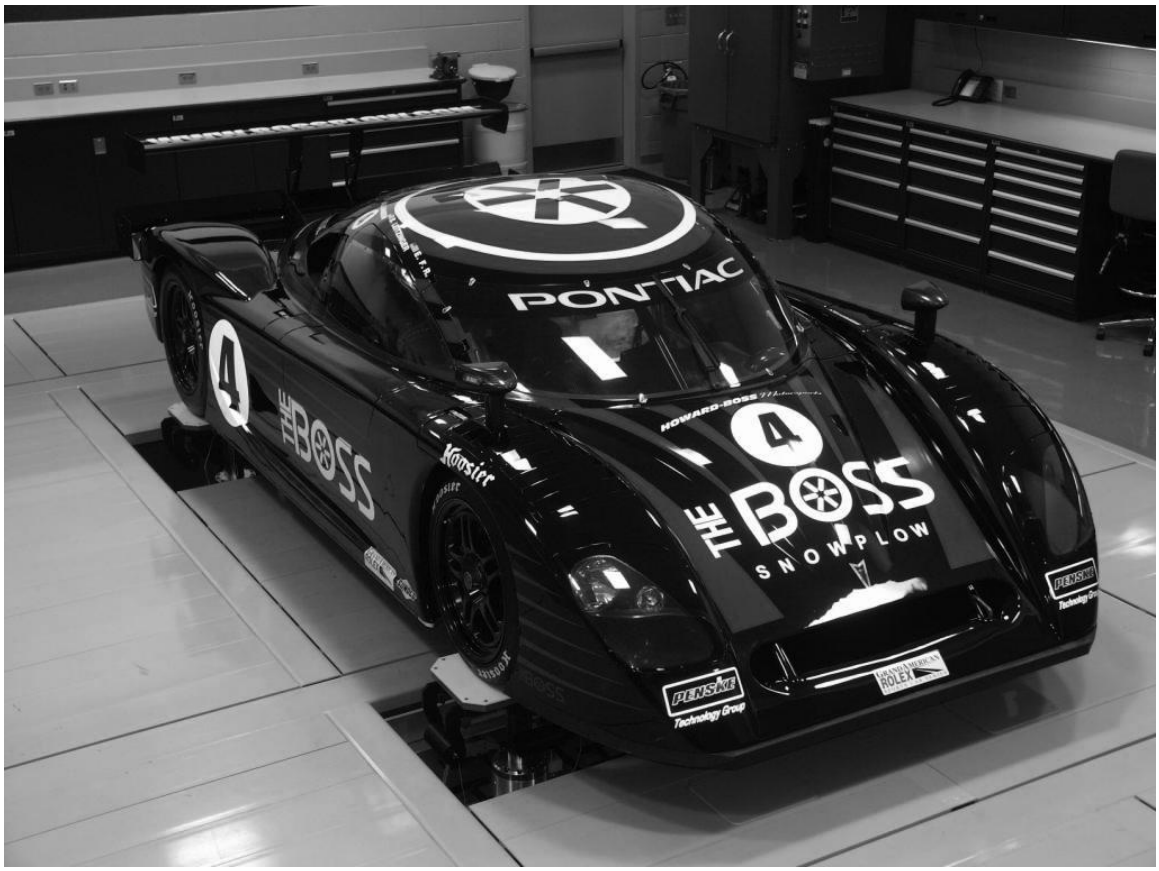
Pre	3001	Aero/Bank				
Total Lateral Acceleration Force	3643			Total Longitudinal Acceleration Force	1897	
Combined Front Lateral	2132	1823	Load	Total Front Longitudinal	1110	
Combined Rear Lateral	1511	1178	Load	Total Rear Longitudinal	787	

Changes in Balance versus a Tire's Profile

Though the changes in chassis balance and performance levels were less than dramatic for the tire profile used in Chapter 20, the resultant trends are common for all tires. Remember, it takes very little change in acceleration force to result in a considerable change in chassis balance.



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