21

Dynamic Simulation – Part Two

Wan31B – (Formula - Aero)

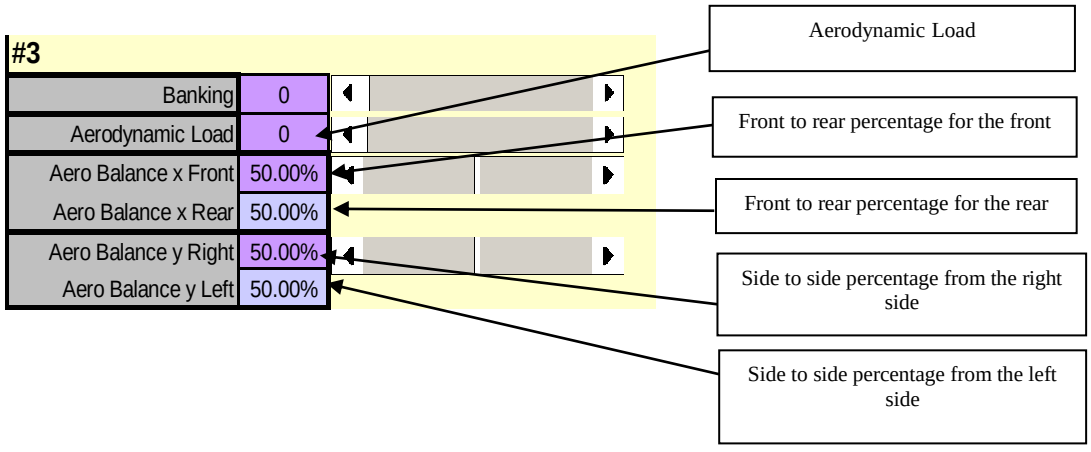
(*It's just not this simple!)*

Note: Despite its title, Chapter 21 is just as important for **Oval Course** only race engineers as it is for road course racers. Most of the material discussed in this chapter is not addressed in any other chapter.

Note: Calculating the resultant acceleration forces with the addition of aerodynamic loads is far from straightforward. Throughout Book One, we are simply taking the forces the tires are able to develop with the addition of aerodynamic loading and dividing that number by the weight seen at each corner as the result of mechanical load transfer only. *As always, it's just not that simple*. The mechanical corner loads need to be adjusted in relation to the various spring, damper and bar wheel rates and motions. Several currently used simulation programs take the percentage of final load seen at each corner (see the Splits and Changes worksheet) and then multiply that percentage by the chassis' total curb weight. However, this method seems to have a lower correlation between actual on track acceleration forces than simply using the pre aero loads. Accurately calculating the resultant acceleration forces seen at each tire requires quite a number of subroutines and closed loop iterations which are not easily programmed in Excel. The good news is that simply using the pre aero corner loads ends up being fairly close and the trends are quite accurate. Numerous simulation programs use the pre aero corner loads and then add one or more correction factors. For the purposes of Book One, we will not include the correction factors, but, if the user is comparing the Wan31B model with on track data, he/she should feel free to add a correction factor(s).

Note: As was the case in Chapter 20, Chapter 21 simply lays the groundwork for a great deal of additional work. The serious race engineer will want to spend at least several hundred hours working with the various Wan31B components *(This is definitly not an overstatement)*.

The Wan31B simulation model allows the user to enter a given amount of total aero load in addition to its front to rear and side to side balance (Box #3). The aerodynamic load is entered via the second slider in Box #3. The aero balance is entered as a percentage through the two lower sliders. The model then converts this percentage into an x and y distance from the center point of the chassis as shown



in the A3 aero cells in the Wan31A worksheet. These balanced percentages and related distances from the center of the chassis represent the aero **pressure center** i.e. the point at which the aero load is applied to the chassis.

Mechanical versus Aerodynamic Balance

Note: Throughout Chapter 21, the amounts of added aero loads and their pressure center co-ordinates are simply a figment of the author's imagination. Once the reader has initially gone through the material presented in Chapter 21, he/she should run through the same types of exercises using aero map data as used in Chapter 18, or, if available, actual data for the particular chassis with which he/she is currently working. Remember that any change in the chassis platform will have an effect on the amount and pressure center co-ordinates of the aerodynamic loads.

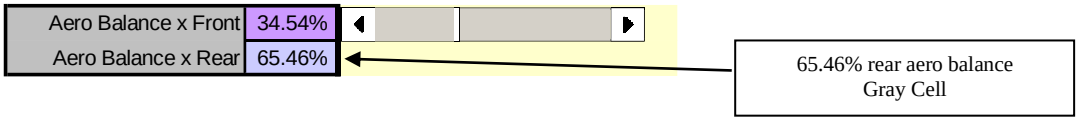
Important Note: Just as in Chapter 20, the user **first** defines the optimum **non-aero** chassis performance (non-aero acceleration rates). Once the optimum **mechanical** balance is found, the user **adds** the aero load and aero load balance. **Once the mechanical balance is set, the sliders in Box 1# are not readjusted**.

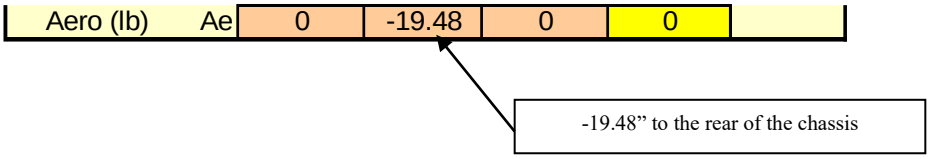
Lateral Acceleration

- Load the Wan31B Formula High Downforce model
- 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 aero balance cells should read 50%
- **Add** 1.695g of left turn acceleration in Box #1. This matches the maximum left turn performance the chassis can produce. In this case, the rear of the chassis shows the lowest lateral acceleration rate.
    - The corner loads are LF = 91.00 lb., RF = 565 lb., LR = 70.00 lb. and RR = 844 lb.
    - The front lateral acceleration force = 1.878g while the rear = 1.695g.
    - The ride heights are LF = 0.808", RF = 0.717", LR = 0.843" and RR = 0.762"
- **While maintaining** the 50% front to rear and side to side aero balance, add 500 lb. of aero load using the aerodynamic load slider in Box #3.
- In this case, the rear of the chassis shows the lowest lateral acceleration rate. Front = 2.523g, Rear = **2.125g**.
    - The new corner loads are LF = 216 lb., RF = 690 lb., LR = 195 lb. and RR = 969 lb.
    - The front lateral acceleration force has moved from 1.878g to 2.523g while the rear has moved from 1.695g to 2.125g (**Rear** maximum capacity). Though the rear of the chassis still controls the maximum lateral acceleration, the chassis is capable of achieving the chassis' overall lateral acceleration performance has improved by 0.430g.

- The ride heights are LF = 0.713”, RF = 0.623”, LR = 0.780” and RR = 0.700”

- **Maintaining** the 500 lb. of aero load, move the front to **rear** aero pressure center from 50% rear to 65.46% rear. This moves the pressure center co-ordinate from the center of the chassis to 19.480” rearward of the chassis centerline, as seen in the A3 box of Wan31A.





  - As a result of moving the aero pressure center 19.480” rearward, the new lateral acceleration rates are now 2.331g front and 2.248g rear. Though the chassis is still not laterally balanced, the oversteer condition has improved considerably.

  - The new corner loads are LF = 178 lb., RF = 650lb., LR = 232 lb. and RR = 1109 lb.

  - The ride heights are LF = 0.734”, RF = 0.644”, LR = 0.765” and RR = 0.684”

  - *Reset the aero loads to zero and the front to rear balance to 50%*

- **While maintaining** the 50% front to rear and side to side aero balance, add 1500 lb. of aero load using the aerodynamic load slider in Box #3.

  - The corner loads are now LF = 466 lb., RF = 940 lb., LR = 444 lb. and RR = 1220 lb.

  - The front lateral acceleration force has moved from 1.878g to 3.634g while the rear has moved from 1.695g to 2.2.866 (**Rear** maximum capacity). Though the rear of the chassis still controls the maximum lateral acceleration the chassis is capable of achieving, the overall lateral acceleration performance has improved by 1.171g.

  - The ride heights are LF = 0.523”, RF = 0.435”, LR = 0.655” and RR = 0.577”

- **Maintaining** the 1500 lb. of aero load, move the front to rear aero pressure center from 50% rear to 67.43% rear. This moves the pressure center co-ordinate from the center of the chassis to –21.962” rearward of the chassis centerline.

  - As a result of moving the aero pressure center 21.962” rearward, the new lateral acceleration rates are now 3.084 front and 3.196 rear.

  - The new corner loads are LF = 339 lb., RF = 805 lb., LR = 571 lb. and RR = 1354 lb.

  - The ride heights are LF = 0.594”, RF = 0.507”, LR = 0.601” and RR = 0.524”

- **Maintaining** the 1500 lb. of aero load and the front to rear aero pressure center at 67.43% rear, move the side to side aero balance 54.86% to the left side of the chassis. This moves the lateral pressure center 3.00154” to the left side of the chassis.

- As a result of moving the aero pressure center 21.962” rearward and 3.00154” to the left, the new lateral acceleration rates are 3.104g front and 3.225g rear. The front of the chassis is now the controlling factor governing the chassis’ lateral performance. From the previous example, the chassis’ lateral acceleration rate has improved from 3.084g in the previous example to 3.104g.

- The new corner loads are LF = 366 lb., RF = 778 lb., LR = 614 lb. and RR = 1311 lb.

- The ride heights are LF = 0.588”, RF = 0.511”, LR = 0.596” and RR = 0.528”

- *Reset the aero loads to zero and the front to rear balance to 50%*

- **While maintaining** the 50% front to rear and side to side aero balance, add 3000 lb. of aero load using the aerodynamic load slider in Box #3.

  - The corner loads are now LF = 842 lb., RF = 1314 lb., LR = 818 lb. and RR = 1596 lb.

  - The front lateral acceleration force has moved from 1.878g (no aero) to 4.938 while the rear has moved from 1.695g (no aero) to 3.735 (**Rear** maximum capacity). Though the rear of the chassis still controls the maximum lateral acceleration the chassis is capable of achieving, the overall lateral acceleration performance has improved by 2.040g.

  - The ride heights are LF = 0.237”, RF = 0.153”, LR = 0.466” and RR = 0.391”

- **Maintaining** the 3000 lb. of aero load, move the front to rear aero pressure center from 50% rear to 66.79% rear. This moves the pressure center co-ordinate from the center of the chassis to –21.155” rearward of the chassis centerline.

  - As a result of moving the aero pressure center 21.155” rearward, the new lateral acceleration rates are now 4.111 front and 4.187 rear. The chassis is laterally balanced.

  - The new corner loads are LF = 597 lb., RF = 1055 lb., LR = 1063 lb. and RR = 1855 lb.

  - The ride heights are LF = 0.374”, RF = 0.290”, LR = 0.364” and RR = 0.289” – the ride heights are almost balanced L to R.

  - *Reset the aero loads to zero and the front to rear balance to 50%*

Table 21-1 shows the changes in corner load and ride height for each of the previous examples. Remember, that changes in the chassis platform, pitch, roll, droop, etc., can have a **major** effect on the amount and position of the aero loading a chassis produces at any given speed.

Corner Loads & Ride Heights	Load	Ride	Load	Ride	Load	Ride	Load	Ride
Left Turn	LF	LF	RF	RF	LR	LR	RR	RR
Mechanical only (1.695g)	91.00	0.808"	565.00	0.717"	70.00	0.843"	844.00	0.762"
500 aero with 0/0 balance (2.125g)	216.00	0.713"	690.00	0.623"	195.00	0.780"	969.00	0.700"
500 aero with 65.46% rear (2.248g)	178.00	0.73	650.00	0.644"	232.00	0.765"	1009.00	0.684"
1500 aero with 0/0 balance (2.866g)	466.00	0.523"	940.00	0.435"	444.00	0.655"	1220.00	0.577"
1500 aero with 67.43% rear (3.084g)	339.00	0.594"	805.00	0.507"	571.00	0.601"	1354.00	0.524"
1500 aero with 67.43% rear/54.86 left (3.104)	366.00	0.588"	778.00	0.511"	614.00	0.596"	1311.00	0.528"
3000 aero with 0/0 balance (3.735g)	842.00	0.237"	1314.00	0.153"	818.00	0.466"	1596.00	0.391"
3000 aero with 66.79% rear (4.111g)	597.00	0.374"	1055.00	0.290"	1063.00	0.364"	1855.00	0.289"

Table 21-1

Note: The user now needs to relook at lateral acceleration while changing the various tire factors in conjunction with a myriad of different set up scenarios.

Longitudinal Acceleration - Braking

- Load the Wan31B Formula High Downforce model
- 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%

Note: **Do not** readjust the Box #1 sliders after the initial mechanical loads are fixed.

- Move the Box #2 slider all the way to the left so its accompanying cell reads zero.
- **With** the Box #2 cell reading **zero**, move the Box #1 brake slider to 1.927 so that it matches the 1.927g braking force seen in Box #4.
    - 1.927g is the maximum mechanical braking force the chassis can produce with the current chassis set up.
    - The corner loads are LF = 508 lb., RF = 508 lb., LR = 277 lb. and RR = 277 lb.
    - The ride heights are LF = 0.680”, RF = 0.680”, LR = 0.852” and RR = 0.852”
- **Add** 500 lb. of aero load.
    - The rate of braking acceleration has moved from 1.927g to 2.431g
    - The corner loads are LF = 633 lb., RF = 633 lb., LR = 402 lb. and RR = 402 lb.
    - The ride heights are LF = 0.586”, RF = 0.586”, LR = 0.789” and RR = 0.789”

Note: Remember that the maximum amount of braking force can only be achieved if the brake bias is set to match the front to rear load percentage.

- **Add** 1500 lb. of aero load.
    - The rate of braking acceleration has moved from 1.927g to 3.301g
    - The corner loads are LF = 883 lb., RF = 883 lb., LR = 652 lb. and RR = 652 lb.
    - The ride heights are LF = 0.396”, RF = 0.396”, LR = 0.665” and RR = 0.665”
    - Changing the front to rear pressure center co-ordinate will only improve the braking performance if the brake bias is set to reflect the changes in corner loads.
    - Offsetting the side to side pressure center for a chassis with equal left to right mechanical loads will degrade braking performance while the chassis is inline braking. This is not always the case when the chassis is seeing combined acceleration.

- **Add** 3000 lb. of aero load.

    - The rate of braking has moved from 1.927g to 4.323. A braking rate as high as this is well into the land of extreme **fiction** because no matter how much the driver adjusts the brake balance, the split between the front and rear loads cannot be matched.

    Remember that aero dynamic downforce (loading) is always accompanied by aerodynamic drag. During the various braking phases, aero drag can actually improve the chassis' braking performance level. Also, remember that aero drag decreases as speed decreases.

Longitudinal Acceleration – Forward Acceleration

- Load the Wan31B Formula High Downforce model

- 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%

Note: **Do not** readjust the Box #1 sliders after the initial mechanical loads are fixed.

- Move the Box #2 slider all the way to the left so its accompanying cell reads zero.

- **With** the Box #2 cell reading zero, move the Box #1 acceleration slider to 1.347 so that it matches the 1.347g forward acceleration force seen in Box #4.

    - 1.347g is the maximum mechanical forward acceleration force the chassis can produce with the current chassis set up.

    - The corner loads are LF = 202 lb., RF = 202 lb., LR = 583 lb. and RR = 583 lb.

    - The ride heights are LF = 0.833", RF = 0.833", LR = 0.770" and RR = 0.770"

- **Add** 500 lb. of aero load

    - The forward acceleration force has increased from 1.347g to 1.563g

    - The corner loads are LF = 327 lb., RF = 327 lb., LR = 708 lb. and RR = 708 lb.

    - The ride heights are LF = 0.738", RF = 0.738", LR = 0.708" and RR = 0.708"

- **Maintaining** the 500 lb. of aero load, move the aero pressure center 60% to the rear. This moves the pressure center y co-ordinate to -12.6".

    - The forward acceleration force is increased to1.604g

    - The corner loads are LF = 302 lb., RF = 302 lb., LR = 733lb. and RR = 733 lb.

    - The ride heights are LF = 0.751", RF = 0.751", LR = 0.697" and RR = 0.697"

- *Reset the aero loads to zero and the balance to 50%*

- **Add** 1500 lb. of aero load

  - The forward acceleration force has increased from 1.347g to 1.936g

  - The corner loads are LF = 577 lb., RF = 577 lb., LR = 958 lb. and RR = 958 lb.

  - The ride heights are LF = 0.549", RF = 0.549", LR = 0.583" and RR = 0.583"

- **Maintaining** the 1500 lb. of aero load, move the aero pressure center 60% to the rear. This moves the pressure center y co-ordinate to -12.6".

  - The forward acceleration force is increased to 2.034g

  - The corner loads are LF = 502 lb., RF = 502 lb., LR = 1033 lb. and RR = 1033 lb.

  - The ride heights are LF = 0.589", RF = 0.589", LR = 0.552" and RR = 0.552"

  - *Reset the aero loads to zero and the balance to 50%*

Note: Aero drag with a high downforce chassis can have a considerable effect on a chassis' forward acceleration rate in addition to the chassis' terminal speed.

> **Note**: The user now needs to relook at longitudinal acceleration while changing the various tire factors in conjunction with a myriad of different set up scenarios.

Combined Acceleration with Aero Loads

Corner entry

- Load the Wan31B Formula High Downforce model

- 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%

- **Set** the Box #2 slide at 0.8, the Box #1 left turn slider at 1.485 and the braking slider at 1.087.

  - The front lateral acceleration rate is 1.485g while the rear is 1.407

  - The left turn acceleration is 1.407g (**rear** maximum capacity). The lateral acceleration rate at the **rear** of the chassis is the controlling factor in the chassis ultimate lateral performance i.e. the **rear** has a lower lateral acceleration rate than the front.

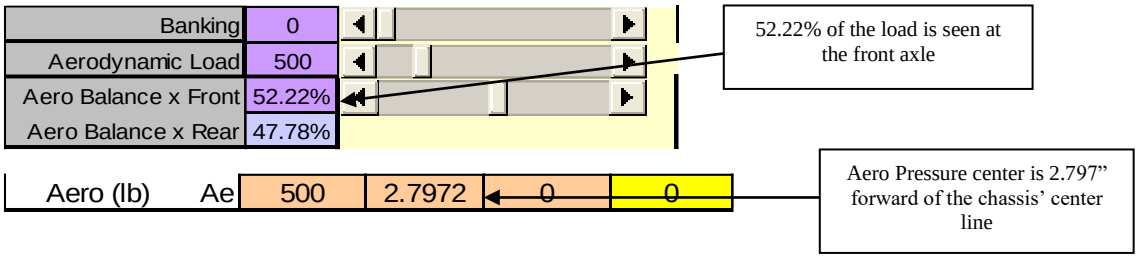
  - The braking capacity is 1.087g

  - The corner loads are LF = 219 lb., RF = 640 lb., LR = 19 lb. and RR = 692 lb.

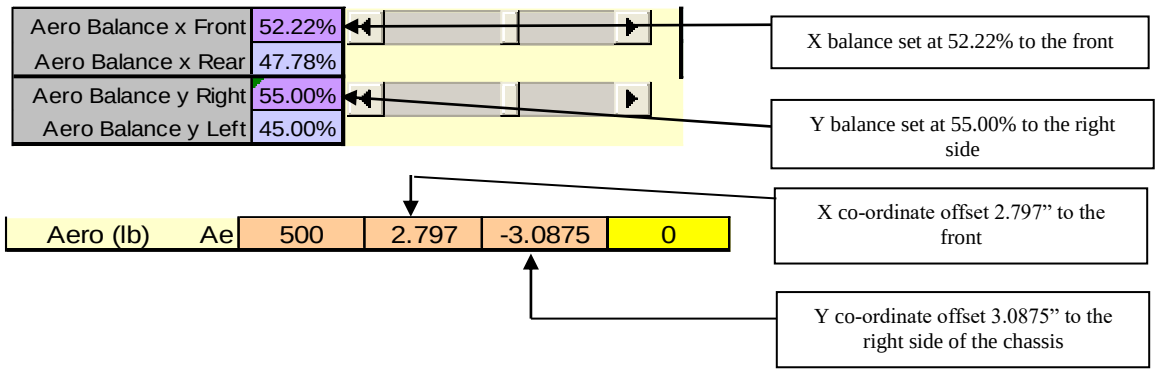
- The ride heights are LF = 0.758”, RF = 0.678”, LR = 0.868” and RR = 0.797”

Note: Remember not to readjust the Box #1 sliders after the initial mechanical loads are fixed.

- **Add** 500 lb. aero load
  - The front lateral acceleration rate is 1.846g while the rear is 1.881g
  - The left turn acceleration is 1.846g (**front** maximum capacity). The lateral acceleration rate at the **front** of the chassis is **now** the controlling factor in the chassis ultimate lateral performance i.e. the front has a lower lateral acceleration rate than the rear.
  - The braking capacity is 1.396g
  - The corner loads are LF = 344lb., RF = 765 lb., LR = 144 lb. and RR = 817 lb.
  - The ride heights are LF = 0.663”, RF = 0.584”, LR = 0.806” and RR = 0.735”
- **Maintaining** the 500 lb. aero load, move the aero pressure center forward to 52.22% front. This moves the y co-ordinate in Wan31A forward 2.797”.



  - The front and rear lateral acceleration rates are now balanced, at 1.861g while the braking rate is 1.396g
- **Maintaining** the 500 lb. aero load and 55.22% front balance set the side to side balance at 55.00% **right**. The side to side co-ordinate is now 3.0875” to the right of center.



  - The front lateral acceleration rate has dropped to 1.857g while the rear rate has dropped to 1.847g
  - The left turn acceleration is 1.847g (**rear** maximum capacity). The lateral acceleration rate at the **rear** of the chassis is **now** the controlling factor in the chassis ultimate lateral performance i.e. the rear has a lower lateral acceleration rate than the front.

- The braking capacity has dropped to 1.389g
- The corner loads are LF = 340lb., RF = 780 lb., LR = 124 lb. and RR = 826 lb.
- The ride heights are LF = 0.662", RF = 0.578", LR = 0.810" and RR = 0.736"

Note: During cornering, the aero pressure center often moves laterally in the direction of the mechanical load transfer.

Notice that the end of the chassis controlling the ultimate lateral acceleration moved to:

- The rear when only mechanical grip was considered
- The front when 500 aero load was added at the x and y center point of chassis
- An equal front and rear rate when the aero pressure center was moved forward 2.797"
- The rear when the pressure center was moved forward and to the right side of the chassis by 3.0875".

- *Reset the aero loads to zero and the balance to 50%*

Corner Apex –Trail Braking

- Load the Wan31B Formula High Downforce model
- 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%
- **Set** the Box #2 slide at 0.960, the Box #1 left turn slider at 1.644 and the braking slider at 0.500.
  - The front lateral acceleration rate is 1.792g while the rear is **only** 1.644g
  - The left turn acceleration is 1.644g (**rear** maximum capacity). The lateral acceleration rate at the **rear** of the chassis is the controlling factor in the chassis' ultimate lateral performance i.e. the rear has a lower lateral acceleration rate than the front.
  - The braking capacity is 0.500g
  - The corner loads are LF = 143 lb., RF = 606 lb., LR = 36 lb. and RR = 784 lb.
  - The ride heights are LF = 0.787", RF = 0.698", LR = 0.856" and RR = 0.777"
- **Add** 500 lb. aero load
  - The front lateral acceleration rate is now 2.313g while the rear is at 2.120g

    - The left turn acceleration is 2.120(**rear** maximum capacity). The lateral acceleration rate at the **rear** of the chassis is **now** the controlling factor in the chassis ultimate lateral performance i.e. the rear has a lower lateral acceleration rate than the front.

    - The braking capacity is 0.645

    - The ride heights are LF = 0.691", RF = 0.604", LR = 0.793" and RR = 0.715"

    - The percentage of front lateral acceleration is 52.18% while the percentage of rear lateral acceleration is 47.82%, a 4.37% difference

- **Add** 1000 lb. aero load

    - The front lateral acceleration rate is now 2.785g while the rear is still less at 2.550g

    - The percentage of front lateral acceleration is 52.20% while the percentage of rear lateral acceleration is 47.80%, a 4.41% difference

- **Add** 2000 lb. aero load

    - The front lateral acceleration rate is now 3.599g while the rear is still less at 3.292g

    - The percentage of front lateral acceleration is 52.23% while the percentage of rear lateral acceleration is 47.77%, a 4.46% difference

Notice that as the aero load increases, the split between the front and rear acceleration forces also increases.

- **Add** 500 lb. aero load and move the front to rear balance to 60.25% **rear**

    - The front to rear lateral acceleration rate is now balanced at 2.211g

- **Add** 500 lb. aero load and move the front to rear balance to 65.00% rear

    - The front lateral acceleration rate is now 2.163g while the rear is 2.252g. With a **rear** aero load percentage of 65.00% the chassis lateral acceleration rate has dropped to only 2.163g compared to the 60.25% rear rate of 2.211g.

- **Add** 500 lb. aero load and move the front to rear balance to 55.00% front

    - The front lateral acceleration rate has moved up to 2.362g while the rear has dropped to 2.074g. With a front aero load percentage at 55.00%, the chassis' ultimate lateral performance is considerably less than when the aero pressure center is located at the center of the chassis.

Corner Apex –Heavy Trail Braking

- Load the Wan31B Formula High Downforce model
- 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%
- **Set** the Box #2 slider at 0.687, the Box #1 left turn slider at 1.254 and the braking slider at 1.341
    - Because of the higher rate of braking, the front now sees a higher percentage of load, but, because of the extreme rear lateral split, the front lateral acceleration performance is still higher than the rear lateral acceleration rate. The front lateral acceleration rate is 1.278g while the rear is 1.255g. Both the front and rear lateral acceleration rates are considerably lower than when the chassis was only braking at 0.500g

Note: A higher percentage of **mechanica**l load transfer **decreases** acceleration performance.

- **Keeping** the same Box #1 and #2 settings as in the previous example, add 500 lb. of aero load
    - Adding 500 lb. of aero load with the pressure center located at the center point of the chassis improved the lateral and longitudinal performance as well as changing the front to rear lateral acceleration balance. At this point, the rear has a higher lateral acceleration rate of 1.695g compared to the front = 1.566g.
    - Remember that when lower braking rates are used as in the "Corner Apex –Trail Braking" example, the lateral acceleration rates are always going to be higher.
- **Keeping** the same Box #1 and #2 settings as in the previous example, add 500 lb. of aero load and move the front to rear balance 59.35% to the front
    - The front and rear lateral acceleration rates are now the same at 1.616g

Note: Normally the end and/or side of the chassis that sees the greatest increase in **aero** loading sees the highest **increase** in acceleration performance.

Corner Exit

- Load the Wan31B Formula High Downforce model
- 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%

- **Set** the Box #2 slider at 0.514, the Box #1 left turn slider at 0.917 and the acceleration slider at 1.090

    - With mechanical grip only, the chassis is capable of laterally accelerating at 0.917g (rear maximum capacity) and forward accelerating at 1.090g

- **Adding** 1000 lb. of aero load improves both the lateral and longitudinal acceleration rates but the rear of the chassis is still the limiting factor for lateral acceleration.

- Placing 75% of the 1000 lb. aero load at the rear tires helps both lateral and longitudinal acceleration. The front to rear lateral split has decreased but the rear is still the limiting factor in regards to lateral acceleration. The chassis would need to see 83.11% of the aero load at the rear tires before the front and rear lateral acceleration rates would match – 1.396% g's at front and rear.

Note: Increasing the percentage of forward longitudinal acceleration degrades the rear tire's lateral acceleration potential.

Looking at the previous example before the 1000 lb. aero load was added, the front lateral acceleration was 1.042g while the rear was only 0.917g. The combined front corner load was 452 lb. while the combined rear corner load was 1118 lb. The rear was 666 lb. heavier than the front. The difference between the front and rear lateral acceleration rates is 0.125g.

With 1000 lb. of aero load with its pressure center located at the center of the chassis, the front lateral acceleration rate is 2.021g while the rear rate is 1.224g, or, a difference of 0.797g. The front combined corner load is 953 lb. while the rear combined corner load is 1618 lb., a difference of 665 lb. The addition of 1000 lb. of aero load did improve lateral acceleration but because the front to rear load and acceleration rate splits were even greater than with no aero load, the chassis is not operating as efficiently, particularly when the aero drag is included in the equation.

Unless the chassis CG, track and/or wheelbase is changed, there is not a great deal the race engineer can do about the **amount** of load transfer. The two things a race engineer can do, by changing the mechanical set up and/or the aero pressure center co-ordinates, is control **how** the load is transferred.

Moving the aero pressure center rearwards does help this particular cornering phase but the aero load would need to be at 83.11% before the front and rear lateral acceleration rates would balance out.

Back to the Mechanical Set Up

There is no question that aero balance can affect overall chassis balance but aero loads and balance cannot overcome a less than optimum mechanical set up. The mechanical set up **always** needs to be perfected before the race engineer begins playing with the aero balance.

Note: Changing the mechanical set up is much less straightforward than shown in the following examples, particularly when running a high downforce aero car. Any mechanical set up change needs to be made with an understanding of how the dynamic ride heights will change the aero loads and balance. Remember that changes in the chassis dynamic platform affect the chassis' **kinematics** and **aero** loads and balances. Dynamic platform changes (ride height changes) are a **major** consideration when making mechanical set up changes with a high downforce chassis.

- Load the Wan31B Formula High Downforce model

- 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 the base Wan31B formula high downforce set up and the Box #2 slider set at 0.514, the chassis saw 0.917g lateral acceleration (rear maximum capacity) and 1.090g forward acceleration. The front split = –254.0 and rear split = -422. As previously stated, the race engineer can't change the amount of load transfer but he/she can change the front and rear splits.

- **Wan31A Set Up Change #1** – Lower the rear spring rates from 2500 lb. to 2000 lb. Leave the rear preloads unchanged. For this particular cornering phase, the change helped forward acceleration slightly, which is now 1.095 compared to the base set up of 1.090g while the lateral acceleration only improved from 0.917g to 0.921g. However, if the chassis only needs to see the original amount of 1.090g forward acceleration, the rear lateral acceleration can be increased to 0.931g – (the Box #2 slider is moved to 0.520). Front split = -292.0 while the rear split = -391. The front and rear splits have improved.

- *Reset chassis to base set up*

- **Wan31A Set Up Change #2** – Add an 800 lb. front bar. Keeping the forward acceleration at 1.090g (Box #2 at 0.534), the rear lateral acceleration rate has increased to 0.962g. The bad news is that the LF to RF split has increased. Front split = -367 while the rear split = -332. Adding a front bar will help the rear lateral acceleration rate but the bar rate cannot be so large that it will burn off the front tires. Working the front tires too hard will quickly degrade their coefficient of friction resulting in the chassis moving from an oversteer condition to an understeer condition causing a much lower lateral acceleration potential.

- **Wan31A Set Up Change #3** – Add a 200 lb. front bar, increase the front spring rates to 2200 lb. and decrease the rear spring rates to 2200 lb. Don't change the spring preloads. Keeping the forward acceleration at 1.090g (Box #2 at 0.525), the rear lateral acceleration rate has increased from the base set up to 0.943g. Front split = -324 while the rear split = -365. This set up, compared to the 800 lb. bar set up, will slow down the front tire wear. Though the chassis' initial performance will not be as high, its performance level over a long run will be considerably better.

- **Wan31A Set Up Change #4** – Keeping the same mechanical set up as in the previous example, add 1000 lb. of aero load with its pressure center at the chassis' center point. While maintaining 1.090g of forward acceleration (Box#2 slider set at 0.768), the rear lateral acceleration rate has moved to 1.836g. The front split = 322 while the rear split = -367.

Note: Remember once the mechanical load transfer factors are set (Box #1), they **remain** unchanged as the aero load is added. The percentage of lateral versus forward/braking acceleration can be changed if the user wants to see what would happen if less than maximum lateral or longitudinal acceleration is used by the driver.

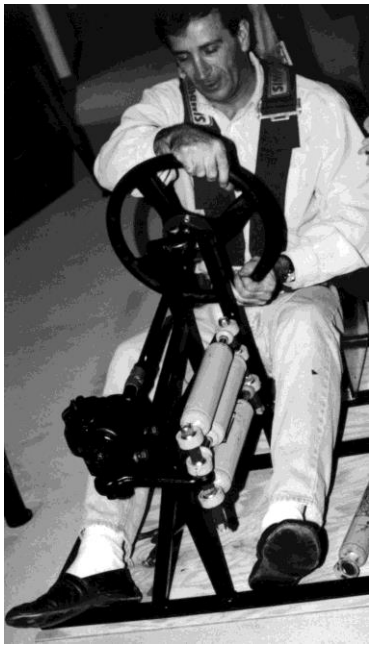
- **Wan31A Set Up Change #5** – Keeping the set up and aero load from the previous example, move the aero balance to 65% rear. While maintaining 1.090g of forward acceleration (Box #2 slider set at 0.799), the rear lateral acceleration rate has moved to 2.035g. The front split = -320 while the rear split = -370. The rear of the chassis is still the determining factor controlling the chassis' ultimate lateral acceleration performance with front lateral acceleration at 2.694g and the rear at 2.035g. The difference between the front and rear lateral acceleration rates is 0.661g. This split is considerably less than the 1.164g difference seen with the original mechanical set up and 1000 lb. of aero load with its pressure center at the center point of the chassis.

Basic Truth – As is the case with mechanical set up changes, the best aero set up for one on track phase is seldom right for many of the other on track phases.

Groundwork - Always remember the words of the ancient Chinese philosopher: "*He who has the highest level of intestinal fortitude wins*".

Homework - Now that the basic Tire and WinGeo3 kinematic concepts have been introduced in Chapters 2 through 14 and the basic Wan31A and Wan31B dynamic concepts in Chapters 15 through 21, it is left to the reader to enlist his/her intestinal fortitude in support of many hundreds of hours studying the wonderful world of vehicle dynamics. Actually the study of vehicle dynamics is a life long endeavor.

THE END



Thanks Paul