13

Static Loads Mass Centers of Gravity

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

Static Loads - A chassis' static loads are those loads seen at the scale pads during set up. These static corner loads are affected by any asymmetric offsets such as front to rear and/or left to right biases, differences in side to side and/or front to rear track asymmetries, wheel base asymmetries, etc. Scale pad set up is extremely important as it has a major influence on a chassis' ultimate dynamic track performance.

Note: From this point on through to the end of the book, the Excel Mathematical Models provided on the Excel CD are used extensively. As is the case with the WinGeo3 software, the material in this book can not be thoroughly learned and understood without spending considerable time working with all of the provided models.

Open the Excel "Kinematic Calculators", select tab for sheet "Bias-Load- Split"

Static Corner Load Calculator #1 "LF load given" - This first calculator allows the user to **input** total weight, left side and rear bias plus **load one corner**. The calculator outputs the remaining corner loads, corner load percentages, combined loads and side to side, end to end and diagonal weight (wedge) load splits. Load splits are calculated by subtracting the right side loads from the left side loads, the rear loads from the front loads and the LR load from the RF load (wedge split). The user can choose which corner load to input. Learning how static loads are changed due to a change in one corner load or bias is the first fundamental step in being able to set up a chassis in the shop and/or the track. I am continually dumbfounded by how few racers understand this first basic step. Be sure to work with this calculator until you fully understand how changing a corner load and/or a bias affects the resultant loads and percentages. It is as important to be able to predict the percentage changes as it is to be able to predict the load changes. The user also needs to be able to accurately predict the changes in load splits. Static splits are a very good indicator of what the chassis' dynamic performance and balance will be.

Changing Static Corner Loads - As previously discussed static corner loads can be changed by moving the spring perch up or down, lengthening or shortening the push rods on a formula car or screwing the load bolts in or out on a stock car. Notice that adding ten pounds to the left front also adds ten pounds to the right rear while removing ten pounds from the right front and left rear. This happens whether the chassis is symmetrical or asymmetrical because even a symmetrical chassis, under dynamic conditions, is almost always operating with some form of asymmetry. Everyone should spend time working with the various bias iterations.

- While maintaining the total weight plus the left side and rear bias, experiment with changing the individual corner loads. Knowing how much changing one corner load affects the three remaining corners will speed up shop and track set up immeasurably. In subsequent Dynamics chapters, we will also look at the resultant ride height changes.

- While maintaining the rear bias and total weight, experiment with changing the individual corner loads and left side bias.

- While maintaining the left side bias and total weight, experiment with changing the individual corner loads and rear bias.

- While maintaining the total weight, experiment with changing the individual corner loads in conjunction with the left side and rear biases.

Notice that changing the left side bias while maintaining the same left front load does not change the right front load or the front side to side split.

The only change in the following three calculators is a change in left side bias - 55%, 54% and 50% respectively. Notice the major change in the splits as the result of changing the bias by only one percent. As we will see in subsequent chapters, this small change in bias will have a major effect on dynamic performance.

ALL INPUT CHANGES DONE IN YELLOW CELLS ONLY

LF Load Given

		27.8%	50.0%	22.2%	
LF-RF Split	170	835	1500	665	
	55.0%	1650	3000	1350	45.0%
LR-RR Split	130	815	1500	685	
		27.2%	50.0%	22.8%	
	Rear Split	-20.0	49.3%	20	Rear Split
		Wedge Split	150		

LF Load Given

		27.8%	50.0%	22.2%	
LF-RF Split	170	835	1500	665	
	54.0%	1620	3000	1380	46.0%
LR-RR Split	70	785	1500	715	
		26.2%	50.0%	23.8%	
	Rear Split	-50.0	48.3%	50	Rear Split
		Wedge Split	120		

LF Load Given

		27.8%	50.0%	22.2%	
LF-RF Split	170	835	1500	665	
	50.0%	1500	3000	1500	50.0%
LR-RR Split	-170	665	1500	835	
		22.2%	50.0%	27.8%	
	Rear Split	-170.0	44.3%	170	Rear Split
		Wedge Split	0		

Even a change of one tenth of one percent can quite significantly change chassis performance - - hence the need to ever so carefully set up both road course and oval track cars. It is also pretty easy to see why any form of friction and/or stiction can dramatically affect both static and dynamic loads.

LF Load Given

		27.8%	50.0%	22.2%	
LF-RF Split	170	835	1500	665	
	54.9%	1647	3000	1353	45.1%
LR-RR Split	124	812	1500	688	
		27.1%	50.0%	22.9%	
	Rear Split	-23.0	49.2%	23	Rear Split
		Wedge Split	147		

Static Corner Load Percentage Calculator "Bias-Load-%" tab - This second calculator allows the user to **input** total weight, left side and rear bias plus **one corner percentage**. The calculator outputs the remaining corner percentages, corner loads, combined loads and side to side, end to end and wedge load splits. The user can choose which corner load to input. In subsequent chapters, it will become evident that when we combine tire coefficient data with corner loads, knowing what the corner percentages and combined side and/or rear loads are will help the engineer predict the chassis dynamic balances.

	LF% Given			
		32.0%	52.0%	20.0%	
LF-RF Split	360	960	1560	600	
	55.0%	1650	3000	1350	45.0%
LR-RR Split	-60	690	1440	750	
		23.0%	48.0%	25.0%	
	Rear Split	-270.0	0.430	150	Rear Split
		Wedge Split	90		

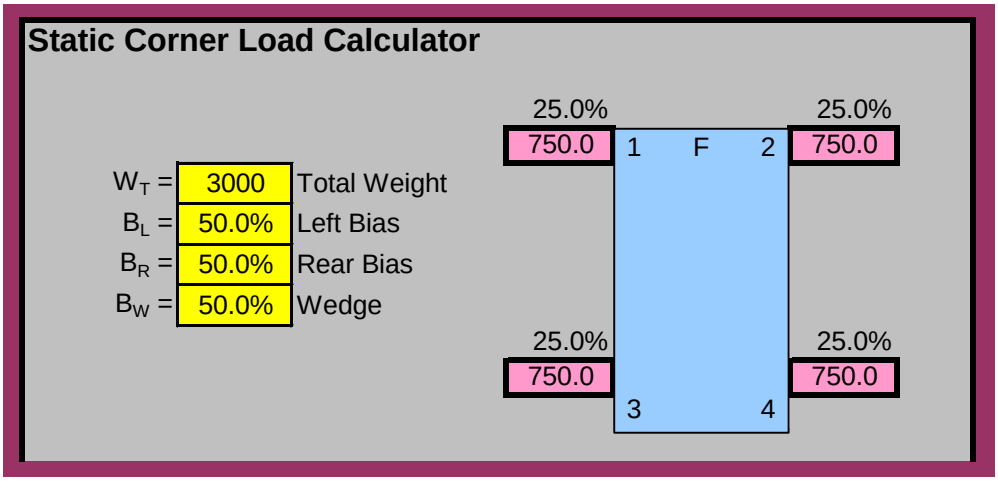
As in the case of a corner load change, an increase in a corner percentage results in the same increase at the diagonal corner and a similar decrease at the opposite corners. For a chassis weighing 3000 lb., a one percent change represents a change of 30 lb. at the scale pad. For a 1500 lb. chassis, it is 15 lb. etc. This relationship is the **same** whether the chassis is **symmetric** or **asymmetric**. Change a corner by one percent with a 3000 lb. chassis increases or decreases all of the splits by 60 lb. A one percent change with a 1500 lb. chassis increases or decreases all of the splits by 30 lb. etc. **Increasing** the left front corner percentage by **one** percent will **decrease** the **wedge** by **two** percent. This is true, irrespective of the chassis' weight or biases.

If the biases are kept constant, changing the load or percentage at one corner will change all of the corner loads and percentages but the left side/right side and front/rear combined loads will not change. The left side/right side or front/rear loads will only change if a bias is changed (static weight is added, removed and/or moved around) at least for a chassis without friction and stiction. *It's just not quite that simple.*

Static Corner Load Calculator "Pad Load" tab – This calculator allows the race engineer to enter:

- Total chassis load
- Left side bias
- Rear bias
- Wedge/Diagonal percentage (RF+LR)/W_T

The calculator then finds the individual corner loads and percentages.



Center of Gravity - A center of gravity is the point at which a body or series of bodies moves as though the entire system's mass existed at one point and as if all external forces and loads were applied at that point. It is assumed that this fixed location within the body is a point where all the weight is concentrated. It is the point in a body through which the resultant force of gravitational attraction acts, which, for a race car, is normal to the earth's surface.

The center of mass of a body or series of bodies does not change as the result of external forces acting on that body. What does change is the **kinetic** center which is discussed in the following chapter.

The center of gravity location is **fundamental** to the chassis' performance envelope. As we have previously discussed, the vertical or normal load applied to each tire plays a major role in determining the resultant lateral and/or longitudinal acceleration performance. In turn, how acceleration loads are proportioned and transferred between the four tires is greatly influenced by the center of gravity co-ordinates.

The Three Mass Centers of Gravity - A race car is generally broken down into three primary types of mass:

- Total mass of the car
- Sprung mass
- Unsprung mass

The remainder of this chapter is primarily concerned with finding the x, y and z co-ordinates of these mass centers of gravity. How these centers affect chassis performance is discussed in subsequent chapters.

Total Center of Gravity (CG) - This is the center of gravity of the entire or combined chassis. The total center of gravity determines the amount of load transferred during lateral and/or longitudinal acceleration. If a racecar had no suspension system we would only be concerned with the total center of gravity.

Sprung Mass Center of Gravity - This includes any part of the chassis that is suspended via the springs, bars and dampers, including the weight of the springs and dampers on a push rod inboard system, half the weight of the spring and damper on a coil over system and half the weight of the damper on a stock car system. *It's not that simple*.

The sprung mass center of gravity plays a major role in determining the sprung mass overturning moment as the result of lateral and/or longitudinal acceleration (forces applied at the springs, bars and dampers). Total sprung weight is found by subtracting the total overall chassis weight from the total unsprung weight.

Unsprung Centers of Gravity - This includes all non-suspended components such as the tires, rims, hubs, uprights and spindles plus approximately one half the weight of components that are jointly suspended between the chassis/tub and the uprights/spindles such as the upper and lower control arms. On a coil over system, half the weight of the dampers and springs is unsprung weight while on a stock car system, one half the damper weight is calculated as unsprung weight. On the coil over and stock car system, half the weight of the anti roll bar arms are also included. *It's not that simple.*

The easiest way to determine the amount of unsprung weight at each corner is to set the chassis on scale pads, support the chassis with adjustable stands at ride height, replace the dampers with dummy dampers of the same weight proportions but with no preload or stiction, back off the spring perches so there is no preload on the springs and then record the scale reading at each corner. The scale reading indicates the amount of unsprung weight. *As always, it's not quite that simple but these numbers will be close*.

As discussed in previous chapters, “x” represents the longitudinal co-ordinates while “y” represents the lateral co-ordinates. The center of gravity co-ordinates are indicated by yR (lateral) and xR (longitudinal). A **positive longitudinal** number indicates the center of gravity is offset **ahead** of the lateral center line of the chassis while a **positive lateral** number indicates that the center of gravity is offset to the **left** of the longitudinal center line. The distance from the center line of the rear wheels to the CG is “b” while the distance from the center line of the front wheels to the CG is “a” - Figure 13-1.

Total Mass X and Y Co-ordinates - If the left and right side tracks are not equal, the center of gravity co-ordinates **can not** be determined by simply using front to back and left to right wheel load percentages.

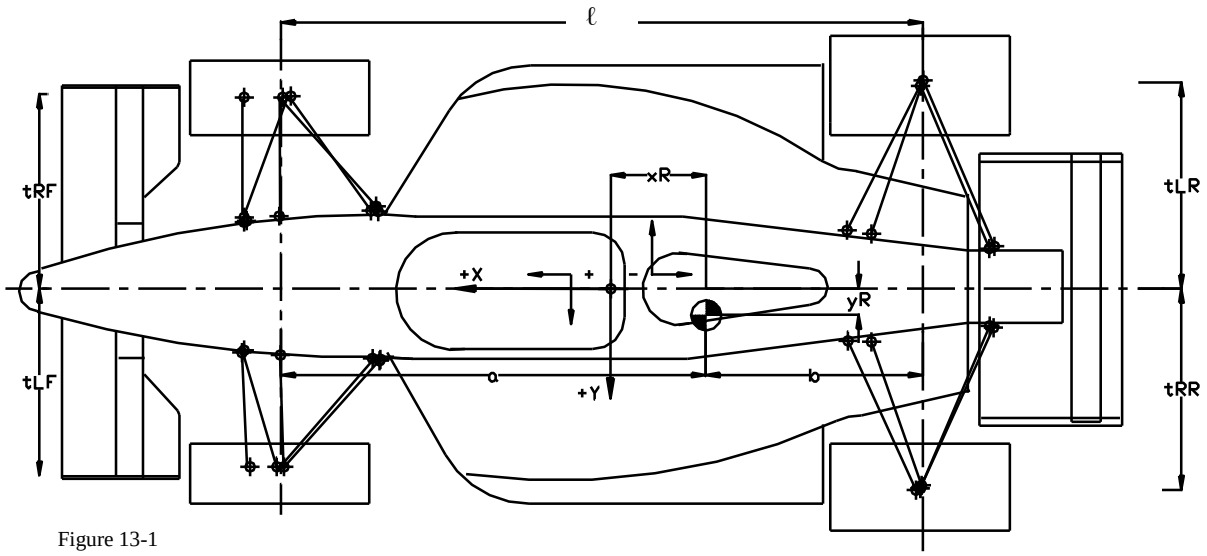


Figure 13-1

One of several formulas that can be used to determine the x and y CG co-ordinates is shown in Formula 13-1. This formula assumes that the left and right side wheel bases are the same. If the left and right side wheel bases are not the same, a mean average will need to be calculated when using this basic formula. We will see in Chapter 14 in the model Wan31A that it calculates the cg based on left and right side wheel bases separately. Spend a considerable amount of time looking at the various co-ordinate changes as the result of changing tire loads and/or track widths. The calculator also shows the changes in wedge (diagonal load, offset or split) - $(L_{RF} + L_{LR})/W_T$. An Excel total mass and sprung mass xR and yR center of gravity calculator is included on the Excel disc (xR & yR Center of Mass). For a more complete analysis of the equations used in the dynamic sections of the book, see Chapter 15.

Total Load CG Offset

b =	$(L_{LR}+L_{RR})*(\ell/W_T)$
a =	ℓ - b
xR =	$(\ell/2)$-b
yR =	$(L_{LF}*t_{LF}+L_{LR}*t_{LR}-L_{RF}*t_{RF}-L_{RR}*t_{RR})/W_T$
B_W% =	$(L_{RF}+L_{LR})W_T$
W_T =	$L_{LF}+L_{LR}+L_{RF}+L_{RR}$

Formula 13-1

The Sprung Mass x and y Co-ordinate - The sprung corner loads are calculated by subtracting the original corner loads from the unsprung corner loads. The total sprung load is a combination of all four sprung corner loads. Formula 13-2 is used to calculate the sprung mass x and y co-ordinates.

Sprung Load CG Offset

$$\mathbf{b_S} = (L_{LRS}+L_{RRS})*(\ell/W_T)$$

$$\mathbf{a_S} = \ell - xb_S$$

$$\mathbf{xR_S} = (\ell/2) - xb_S$$

$$\mathbf{yR_S} = (L_{LFS}*t_{LF}+L_{LRS}*t_{LR}-L_{RFS}*t_{RF}-L_{RRS}*t_{RR})/W_S$$

$$\mathbf{W_S} = L_{LFS}+L_{LRS}+L_{RFS}+L_{RRS}$$

Formula 13-2

Notice that the total and sprung centers of gravity will not be at the same position if the chassis is asymmetric in any way – Figure 13-2.

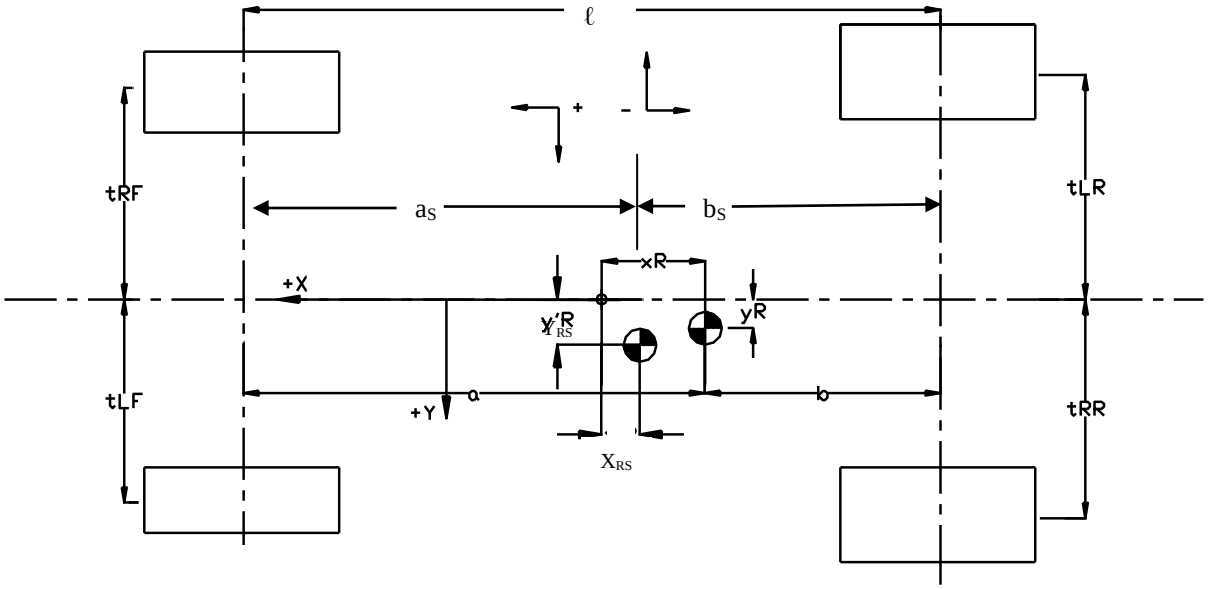
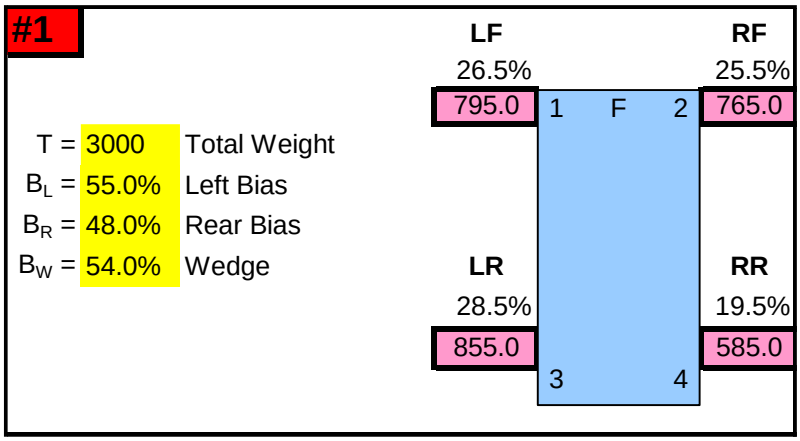


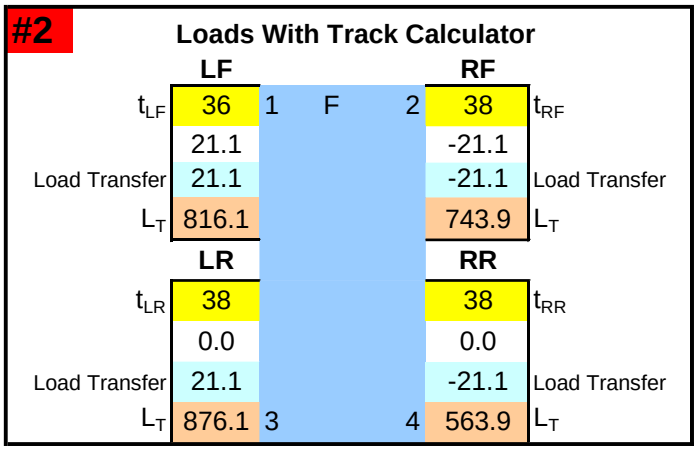
Figure 13-2

The basic Center of Mass calculator is broken into three components. Using the "Center of Mass" tab the first **component #1** is used to find the corner loads and percentages when the total weight, left side bias, rear bias and diagonal weight (wedge) are given.

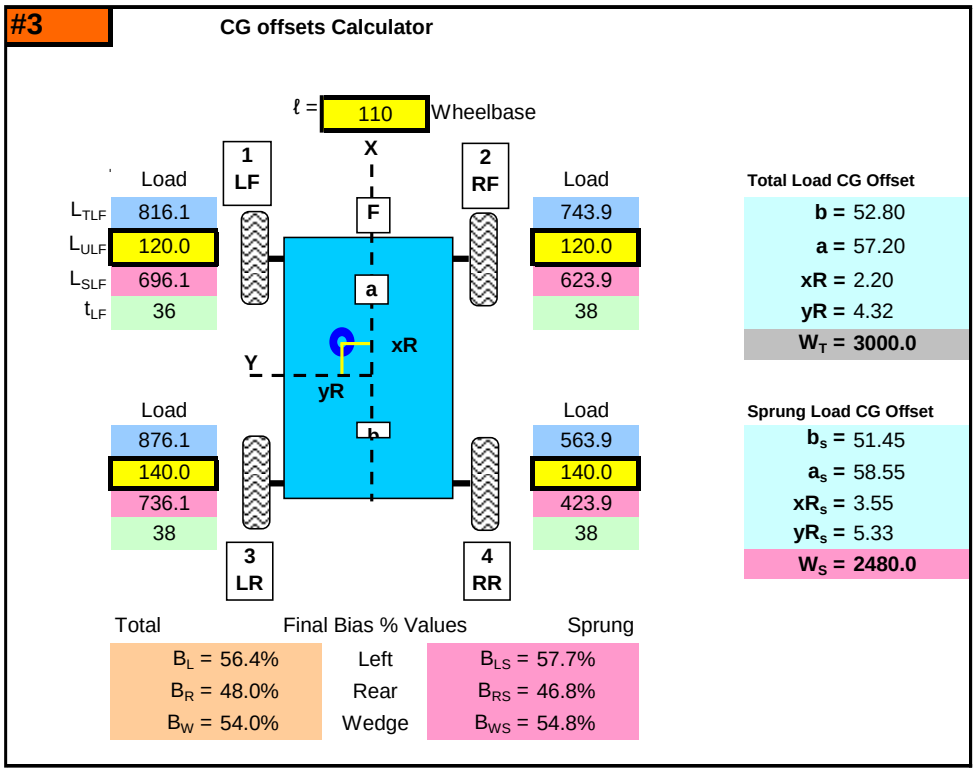


Formula for finding corner percentages:
Given - Total weight - Left side% - Front% - Wedge%
LR%=(wedge%+left%-front%)/2
RF%=(wedge%-LR%)
LF%=(left%-LR%)
RR%=(100%-LR%-RF%-LF%)

The second **component #2** is used to calculate the change in corner load when one or more of the tracks are asymmetric. This component is necessary for oval track cars which can run a different track width at each corner.



The third and primary **component #3** calculates the X & Y co-ordinates, distance from the front and rear wheelbase to the CG and the wedge (diagonal weight) of both the total mass and the sprung mass. The user inputs the unsprung weight and the wheelbase.



These three component models are the **main building blocks** used when working out a chassis set up. The reader needs to spend considerable time working with the components individually and in combination with each other. The Wan31 models used in the dynamic section of the book calculates both asymmetric tracks and wheelbases.

Working with the various bias and track offsets is as useful for the **road course** race engineer as for the **oval track** race engineer.

Examples

Model #1: "Pad Load" tab

- For a 1500 lb. symmetric car (combined left side and right side corner loads are equal) with a 60% rear bias, a RF to LR diagonal weight offset of one percent will result in a rear split (bias) of 15 lb. to the LR while the front sees a split (bias) of 15 lb. to the RF.

- For a 3000 lb. chassis with a 55% left side bias, 50% rear bias and 55% diagonal weight (wedge), the front split is zero. In fact, irrespective of the chassis' overall weight, if the rear bias is 50% and the left side and wedge bias is 55%, both front corners will each carry 25% of the load while the left rear will carry 30% and the right rear 20%. If the rear bias is increased by 1%, both rear corner load percentages will increase by 0.5% while the front corner percentages will decrease by 0.5%. If $B_L = B_W$ then front split = 0. If $(1\text{-}B_L) = B_W$ then rear split =0.

- If the wedge is decreased by 1%, the LF and RR% will increase by 0.5% while the LF and RR% will decrease by 0.5%. This relationship is constant no matter what the rear bias is.

Model #2: "Center of Mass" tab

- For a 1500 lb. asymmetric chassis with a rear bias of 60%, if the rear tires are moved 1/10" to the right, the left side corners will see an increased load of 1.2 lb. while the right side corners will see a decrease of 1.2 lb.

- For a 3000 lb. chassis with a left side bias of 55%, rear bias at 51% and a wedge bias of 56% if the rear tires are moved 0.3" to the right, the left side corner loads will increase by 6 lb. and the right side corner loads will decrease by 6 lb. If the front tires are also moved to the right by 0.4", the load change becomes 13.8 lb. For a stock car using a live axle and track bar at the rear and short control arms at the front, this much scrub movement is common.

- If only the left front track is shortened, both the left side corners will see an equal increase in load and the right side corners will each see an equal decrease in load.

- For a 3000 lb. chassis with 55% left, 60% rear and 54 wedge bias, moving the LF track in 1" increases the left side corner loads by 8 lb. each and decreases the right side loads by 8 lb. each. If the LR is moved in 1" rather than the LF, the load change is now 12 lb. The amount of front to rear load bias affects the amount of load due to track width change(s).

- For a 3000 lb. chassis with 55% left, 60% rear and 54 wedge bias, moving the front and rear left side tracks in 1" increases the left side corner loads by 20 lb. each and decreases the right side loads by 20 lb. each.

Model #3: "Center of Mass" tab

- If the total corner loads remain unchanged, changing the amount of unsprung weight at all four corners changes the sprung load at each corner but it does not affect either the total or sprung mass X & Y offsets or the axle center line to the CG distances.

- Changing the unsprung weight at only one corner changes the unsprung load at that corner and affects the **sprung X** & **Y** offset. For example, if the LF unsprung weight was increased, the sprung mass center co-ordinates would be moved rearward and to the left. The total axle center line to the CG distances do not change but the sprung axle center line to the CG distances does. In this case, the distance from the sprung CG to the rear axle center line will increase while the front distance decreases. The X & Y CG co-ordinates play a major role in determining the amount of lateral and/or longitudinal load transfer and resultant roll and pitch angles.

- Changing the wheel base will affect both the total and sprung mass axle center line to CG distances. This, in turn, affects longitudinal load transfer and pitch angles.

Total Mass Center of Gravity Height (CGz) - It is **very** difficult to accurately determine the z co-ordinate of the chassis' total mass (extreme understatement). Even though the CG height is one of the most important numbers the race engineer needs when calculating chassis dynamics, it remains one of the most difficult numbers to accurately obtain, and, as we will see in subsequent chapters, a small change in CG height can have a profound effect on chassis performance. Everyone agrees on how important this number is, but if you ask ten people or groups of people to calculate the CG height for a particular chassis, you will invariably get ten different answers.

The first problem is what formula to use. Of the twenty or so books I have on the subject, there are at least six different formulas and every one of those formulas result in a different answer. After considerable testing, both theoretically and in the lab (R&D shop), the one formula I am willing to live with is presented by Dave Segal in "Race Car Vehicle Dynamics"[1].

W_T = Load

$L_F{}^1$ = Front load measured at θ

R_{LCG} = Left side unsprung radius – height of line between front & rear wheels at the CG location

a = y distance from rear axle center line to CG

b = y distance from rear axle center line to CG

xR = is the resultant longitudinal position of the CG in relation to the lateral center line of the chassis. A positive number indicates that the CG is offset towards the front of the chassis as seen from the plan view.

yR = is the resultant lateral position of the CG in relation to the longitudinal center line of the chassis. A positive number indicates that the CG is offset towards the left of the chassis as seen from the plan view.

θ = angle of chassis after it is lifted at the rear axle center line

ℓ = length of wheel base

r_{LF} = radius of left front wheel

r_{LR} = radius of left rear wheel

$$(1) \quad h1 = \frac{\Delta L_F{}^1 * \ell - W_T * b}{W_T * \tan\theta}$$

[1] Race Car Vehicle Dynamics, William F. Milliken and Douglas L. Milliken, SAE International

(2) $$R_{LCG} = r_{LF} * (b/\ell) + r_{LR} * (a/\ell)$$

(3) $$h = h_1 + R_{LCG}$$

Sprung center of Gravity (CG_{SZ}) Formula

$CG_{SZ} = ((W_T*CG_Z)-(L_{ULF}*r_{ULF})-(L_{URF}*r_{URF})-(L_{ULR}*r_{ULR})-(L_{URR}*r_{URR}))/W_S$

This calculation involves first determining the chassis', total load and its "a" and "b" longitudinal co-ordinates. The chassis is next lifted at the rear of the car to a prescribed angle and the total front load is remeasured. All other things being equal, the higher the angle of lift, the more accurate the final calculations will be – Figure 13-3.

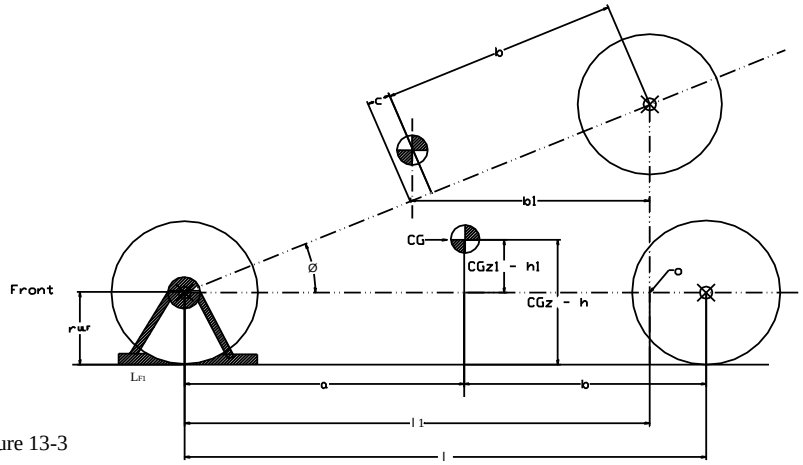


Figure 13-3

The Excel mathematical Model (CG Height) calculates the center of gravity height of both the total and sprung mass. Spend considerable time working with this calculator in order to understand why a small error of any type can drastically change the calculated center of gravity height (CG_Z). For example, if the resultant front load is changed one pound from 1152.0 to 1153; the CG height moves from 17.639" to 17.872", a difference of 0.233". Additionally, if the angle of lift is changed one degree from 11.60^0 to 12.60^0, the CG height moves from 17.639" to 17.123", a difference of 0.516". These are **not** small numbers when it comes to how they affect load transfer and overturning moments as discussed in Chapter 15.

Excel file Chpt 13 – CG Height tab

W_T =	3000.0	a =	42.00
Raised L_F =	1746.0	h_1=	6.986
b =	54.00	R_{LCG} =	11.33
ℓ =	96.00	$(CG_Z)h$ =	18.311
θ =	15.00	Δ θ F% =	58.2
L_{ULF} =	120	W_S =	2480.0
r_{ULF} =	10.80	CG_{SZ} =	19.751
L_{URF} =	120		
r_{URF} =	10.80		
L_{ULR} =	140		
r_{ULR} =	12.00		
L_{URR} =	140		
r_{URR} =	12.00		

The "h_1" number (distance between the CG_Z and a line drawn longitudinally between the front and rear hub centers) allows the race engineer or DAG (data acquisition guy) to write math channel software for the data system which will tie the CG height to changes in ride and pitch.
L_F[1]

Figure 13-4 illustrates a test model used to confirm the accuracy of the Segal formula. When a light test model is used, as shown in the accompanying picture, you need to use electronics and software that can achieve accurate three decimal point readings. Most scales pads sold for setting up race cars don't have this level of accuracy



Figure 13-4

Measuring Procedures for Center of Gravity Height (CG_Z) - Developing the apparatus for measuring chassis CG height is not a one day project. Everything needs to be accurate to within a few thousandths of an inch - no exceptions. If time and care is not taken to do it right, you might as well pick a CG_Z number out of the air and save yourself some time and a whole lot of aggravation. I have fabricated entire stock car and GT tube frame chassis in less time than it takes to build the necessary equipment, calibrate it and perform the CG_Z measurement procedures. The entire process is discussed in some detail in Book Two but a brief outline is as follows:

- The scale pads used to find a chassis' CG_Z need to be extremely accurate and repeatable. The load cells need to be accurate to three decimal places and the software accurate to at least two decimal places. Your typical set up scales are **not** good enough.

- Suspension needs to be locked in place at ride height. Rods affixed with left and right hand rod ends in place of the dampers will work but make sure the original damper weight and weight proportioning is kept intact. The lighter the car, the more important this is. Changing the damper weight by a few pounds does make a difference.

- Test procedures for each change in ride height setting need to be run at least twice, and preferably three times, particularly if the numbers are not matching within a few thousandths.

- Tests need to be run with the chassis set up flat (no ride difference left to right and no pitch difference front to back) in addition to several set ups the team will use at the track. We need this information to confirm the accuracy of "h_1" (the distance from the CG to a line drawn between the front and rear hub centers), particularly with chassis that run a different front and rear wheel radius. Remember, as a tire's radius changes due to squish and/or psi changes (primarily bias ply

tires), this change will affect the CG height (CG_Z). The Segal formula does not take right to left radius differences (stagger) into consideration. These combined differences need to be calculated using the lateral offset percentage. It's not just the mean difference between the right and left tire unless the CG_Y is on the center line of the chassis.

- Tests are run with the fuel tank completely empty as well as completely full in order to prevent any shift in fuel load (make sure all the vents are closed when running full tank tests. The CG_Z can then be calculated for various partial load calculations. *It's not that simple*.

- No matter how stiff you make the tires by adding inordinate amounts of air pressure and how well you think you have the front tires chocked, lifting the chassis with the front tires sitting on the scale pads will not result in repeatable numbers.

I can not guarantee that the method I use results in the absolute correct number but it will be very close and it is repeatable to within plus or minus a few thousandths, including taking the car off the jig, remounting it and retesting.

The method I use to find the overall chassis' load/weight by lifting the rear of the chassis to remeasure the front load/weight is:

- Affix the scale pads to the scale cradles.

- Affix the front cradles to the set up pad - the rear cradles need to be left free so they can slide ahead slightly as the chassis is raised at the rear.

- Affix the front and rear hub fixtures to the scale pads and zero the scales The front and rear hub fixture heights need to reflect the difference in the front and rear tire radius (very important). The rear hub fixture height is adjustable (telescoping legs) see Figure 13-6.

- With the scales prezeroed, attach the chassis, tires on, to the hub fixtures and record the total load/weight.

- Disconnect the rear hub fixture telescoping locks and then using an air over hydraulic jack or ram, lift the rear of the chassis to the prescribed angle. The distance the chassis needs to be lifted is dependent upon the prescribed angle i.e. height = ℓ *tan angle. Adjust the rear hub fixtures to the correct height and lock the telescoping joints and then release the lift mechanism.

- Record the new combined front weight.

- In theory, one should be able to first weigh the chassis on the scale pads to determine the total load/weight and then affix the fixtures to the hubs; however, theory and practice don't always match.

- When possible and if practical, I like to run this test using three angles: 10^0, 15^0 and 20^0. Always use the same prescribed angles and adjust the amount the rear needs to be lifted accordingly. Always using the same angles allows the race engineer to compare different files and chassis.

Figure 13-5 illustrates the chassis before it is raised at the rear while Figure 13-6 shows the chassis after it has been raised. Once the rear hub fixtures have been set at **exactly** the correct height, the jack or ram is disconnected from the chassis. Stock cars and GT cars use the same procedures but are often lifted via overhead cables and fixtures that attach to the top of both rear hub fixtures. This sounds simple, but it isn't.

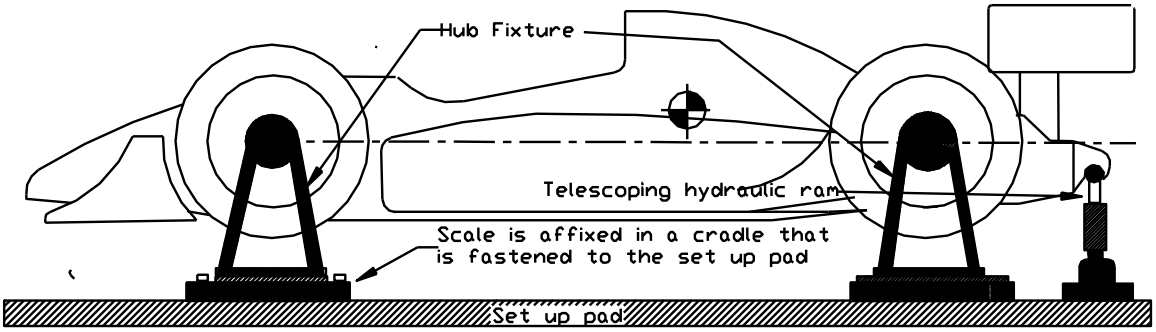


Figure 13-5

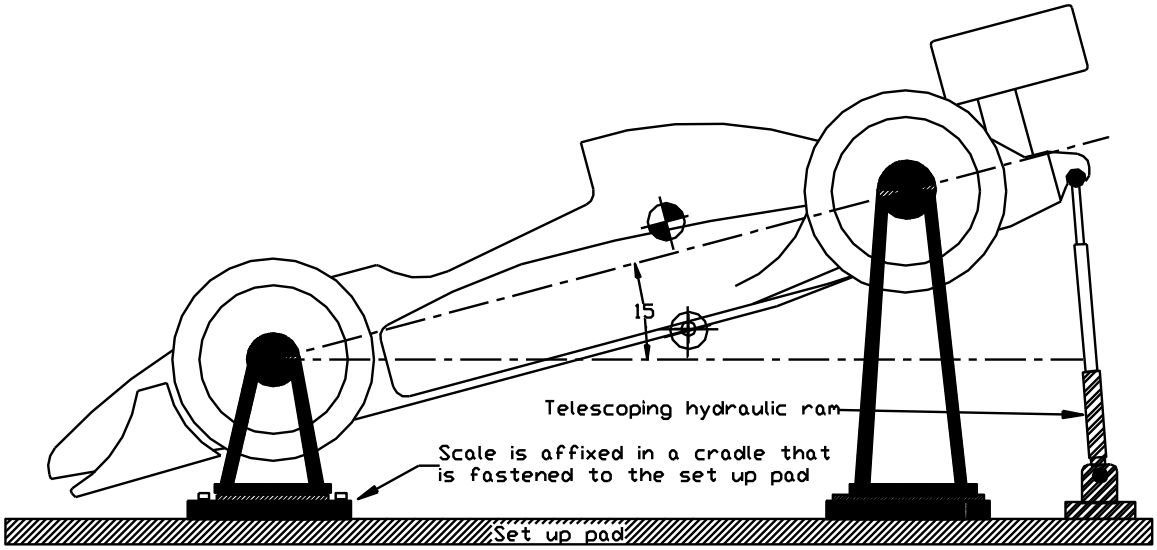
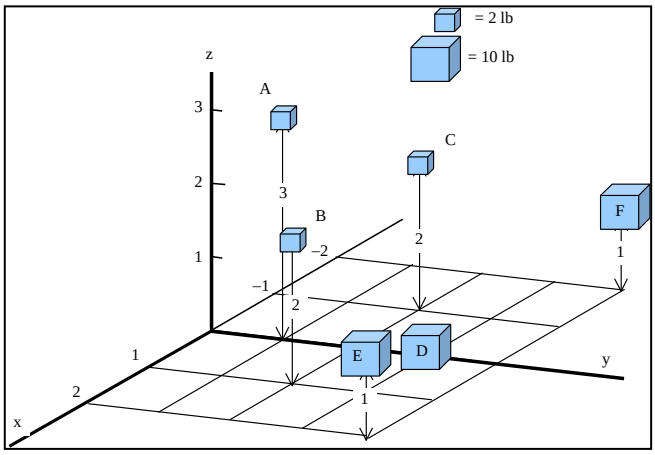
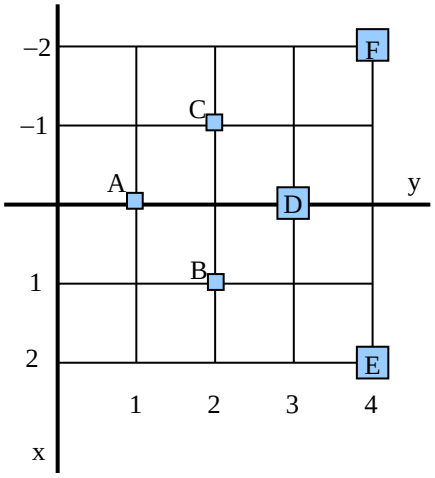


Figure 13-6

Unsprung Mass Center of Gravity Height CG_{USZ} - There are two methods used to determine the unsprung center of gravity height. The first is to simply measure the distance from the set up pad to the center line of the hub at the point where the rim attaches to the hub (mounting surface of the hub).

The second method which can also be used to locate the CG co-ordinate of all parts of the chassis requires the race engineer to locate the position of each component on a three dimensional grid normally by using a digital measurement device, and then entering each items mass into the three x, y and z equations. The following pages provide an example problem and solution. This may seem extreme but manufacturers and teams often do this type of calculation when looking at ways to lower the CGz and overall chassis mass. It is relatively easy when the whole vehicle is in a CAD file, and one can just enter the densities of the various bits and leave the hard work to the computer.





$$(1)\ CGx = \frac{\Sigma Wx}{\Sigma W}$$

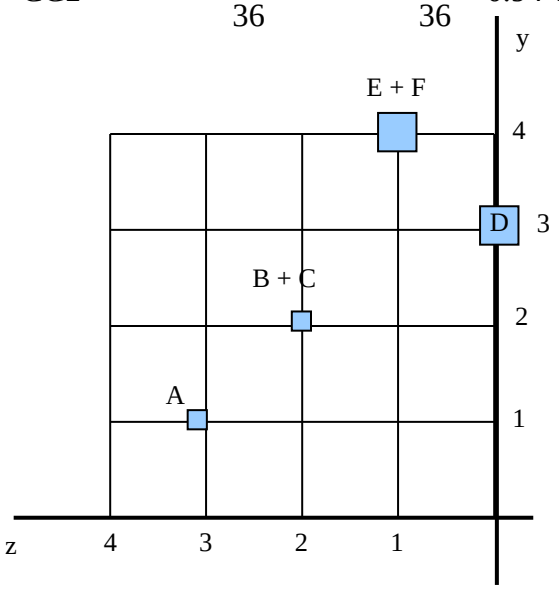
$$(2)\ CGy = \frac{\Sigma Wy}{\Sigma W}$$

$$CGy = \frac{A(1)*B(2)+C(2)+D(3)+E(4)+F(4)}{A+B+C++D+E+F} = \frac{2(1)+2(2)+2(2)+10(3)+10(4)+10(4)}{2+2+2+10+10+10}$$

$$CGy = \frac{2+4+4+30+40+40}{36} = \frac{120}{36} = 3.33\ \text{ft}$$

$$CGz = \frac{A(3)+B(2)+C(2)+D(0)+E(1)+F(1)}{A+B+C++D+E+F} = \frac{2(3)+2(2)+2(2)+10(0)+10(1)+10(1)}{2+2+2+10+10+10}$$

$$CGz = \frac{6+4+4+0+10+10}{36} = \frac{34}{36} = 0.94 \text{ ft}$$



(3) $CGz = \frac{\Sigma Wz}{\Sigma W}$

$$CGz = \frac{A(3)+B(2)+C(2)+D(0)+E(1)+F(1)}{A+B+C++D+E+F} = \frac{2(3)+2(2)+2(2)+10(0)+10(1)+10(1)}{2+2+2+10+10+10}$$

$$CGz = \frac{6+4+4+0+10+10}{36} = \frac{34}{36} = 0.94 \text{ ft}$$