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G-Force Longitudinal - Braking

When a driver is braking rather than accelerating, G Force Long goes negative. The quicker the vehicle slows down, the more negative G Force Long becomes. Therefore G Force Long is great at determining the effectiveness of braking. While Brake Pressure traces are more useful for driver analysis, the G Force Long channel can still provide lots of information about the car's ability or the driver's ability to use it. Note there is a direct relationship between speed and G Force Long. Either of these channels can be used to verify the other's validity. Therefore it helps to graph both on the same screen.

Low Downforce Braking

Once weight transfer has occurred in the transition to straight line braking, a relatively flat plateau of G Force Long should appear. Hopefully at the vehicle's maximum rather than the driver's maximum! Then at the turn in point, steering angle is added as the driver starts to trail brake. Because the front tires will be forced to give up some braking grip to steer the car, the negative value of G Force Long should rise back up.

△ *Warning:* The maximum amount of G Force from one corner to another will not always be the same due to many influencing factors seen with acceleration.

Figure 6.11 *Graph for a sedan type low downforce race car at Mid-Ohio showing the braking forces from the G Force Long channel.*

A summary of the graph above in ***Figure 6.11***:

- This vehicle can brake around a maximum of -1.3 G's.
- Typical for low downforce cars, G Force Long for Turns 2 and 3 are similar, yet the entry speed into Turn 3 is much higher than Turn 2.
- The cursor sits at the point where turn in begins. Turns 1 and 3 have very little trail braking as the trace goes up sharply. Turn 2 has more trail braking and the trace curves up while the pedal is released slowly.

High Downforce Braking

Race cars with high amounts of downforce won't have a flat plateau of G Force Long when braking. Rather they will have a varying amount of G's even while braking in a straight line. Aerodynamic downforce increases with vehicle speed. The faster a car travels the more downforce it creates. Because downforce increases the grip level of tires, higher speeds will allow drivers to brake harder. Then as the speed decreases, so does downforce and the braking ability of the race car. Hence a rise in G Force Long. Then at the start of trail braking the trace will rise up even more sharply. Analyzing ***Figure 6.12***, notice the following:

- The cursor location sitting in Turn 1 points to the moment in the braking zone where straight line braking ends and trail braking begins. Notice how the slope of the trace directly after the cursor rises more quickly than before the cursor. This knee in the slope can be used to identify the start of trail braking and should correspond to when the steering wheel starts to move. The Steering Wheel Angle trace is on the bottom for reference. This location is also easily noticed in Turn 5.
- The maximum G's in each braking zone change based on the entry speed. The first and last braking zones which are Turns 1 and 5 have the greatest negative G forces. Those corners in the middle have less. Notice the maximums are proportional to entry speed.
- The entry speed of Turns 3 and 4 are similar as pointed out by the green arrows, but the maximum G was slightly less in Turn 4. Many factors are at play here. Shorter braking zones have less optimal bias as there is not enough time and forces to achieve complete weight transfer. But the main factor here in Turn 4 is the trail braking where less tire grip is available for breaking due to the added steering input.

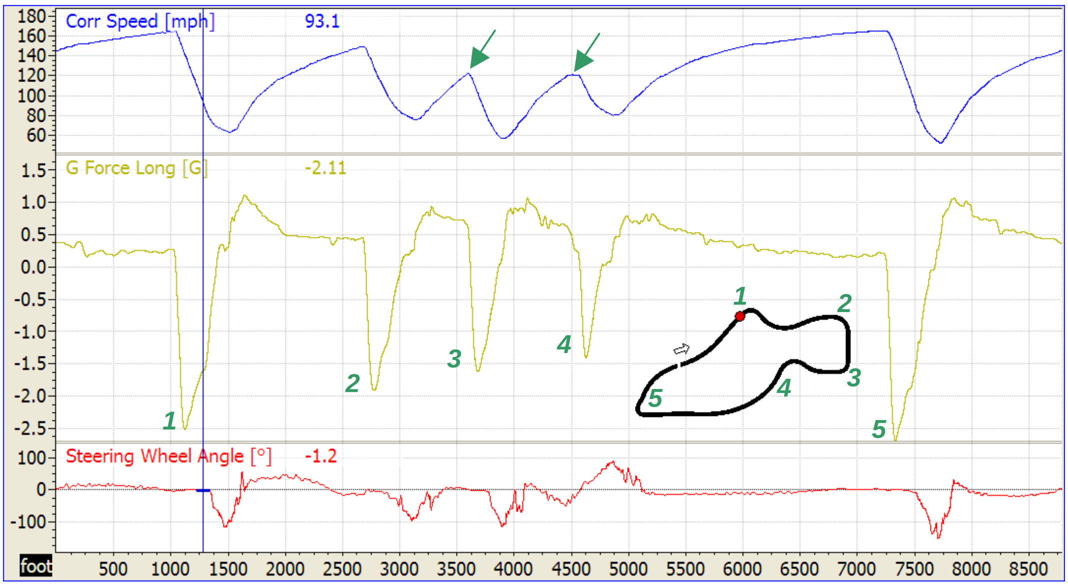

Figure 6.12 *Maximum braking forces achieved before each corner varies with speed on this high downforce formula car on the short Sebring course.*

Braking Point

The trace of G Force Long is great for comparing and measuring the braking points between laps. Remember to verify the graph is in distance mode first. Then use the cursor to measure differences in the lap distance where the G Force Long trace first takes a sudden drop. The distance in ***Figure 6.13*** is found to be 64 feet or about three car lengths. This might seem like a large difference, but to the driver in the car it's not. Remember that when traveling at 140 mph, braking 64 feet later corresponds to only 0.3 seconds. Hardly more than a blink of an eye!

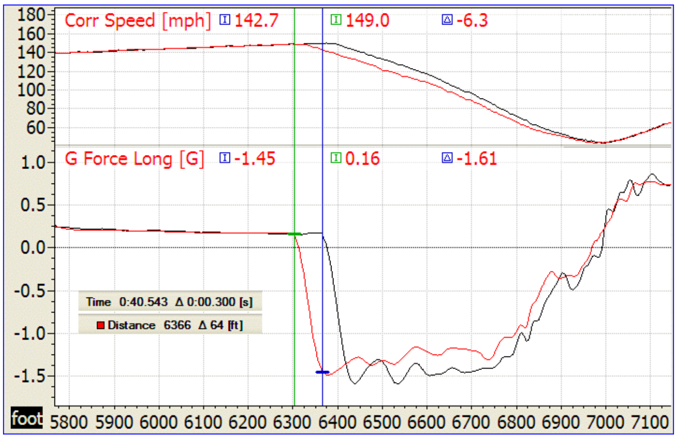

Figure 6.13 *Braking points are easy to see with G Force Long. Distance can be measured where the traces drop to find the difference in braking points.*

More importantly the variance channel can be used to find how much time is gained by this later breaking. While the act of braking later is known to produce faster lap times, it's the increase in speed throughout the entire braking zone which lowers the lap time. The graph below of ***Figure 6.14*** is an expanded view of the lap in ***Figure 6.13***. The two cursors which surround the first braking zone, show a net time gain of 0.371 seconds from the mere 64 feet of braking later. Notice the variance channel moves down throughout the entire braking zone, not during the actual 64 feet of braking later.

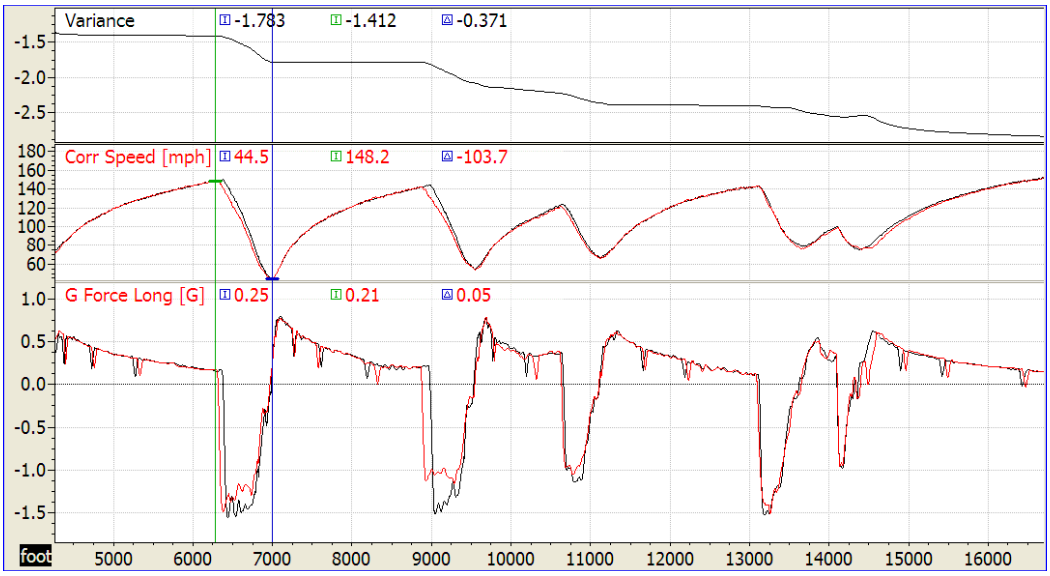

Figure 6.14 *The Variance channel allows for time gained or lost in the braking zone to be accurately measured.*

During a qualifying session, the majority of lowered lap times come from later braking points. A lighter car with less fuel and fresh tires are the perfect conditions for a fast lap. The two laps shown in ***Figure 6.14*** are what you might see as the differences between a race lap and a qualifying lap.

△ *Warning:* Trying to braking later can cause driver error. Often a driver is overwhelmed by the increase in speed when entering a corner. Because it feels too fast some drivers will mistakenly over slow for the corner. Other times drivers will over shooting the corner, removing any advantage gained from braking later. Over shoots can also cause the lap of data to shift over in distance, resulting in the rest of the lap not lining up.

In ***Figure 6.15***, when braking for Turn 1 the red trace brakes 70 feet deeper, but then over slows the car by 8.4 mph. This results in a slower exit and the time gained by braking later was lost when exiting the corner. Always use the variance and compare braking zones, corners and their following straight sections together. Such differences could be the result of driving a different line or over slowing for the corner. Verifying with video and GPS are the only ways to be sure of the reason.

Looking at Turns 2 & 3, the red trace does exactly the opposite from Turn 1 and brakes early yet carries more speed through and after the corner. Obvious from the G Force Long trace, we see the black lap which was faster out of Turn 1 might have been too fast entering Turn 3. There is a major lift right before the turn where the black trace drops off. It could be caused from the driver feeling unstable or running out of talent. Notice the driver lifting off the throttle, then back on when he or she realized their braking point was further ahead. Giving the driver the benefit of the doubt, perhaps there was another car in their way causing the lift? Or they were trying a different line through the corner? Verify with video and GPS.

Turn 5 looks similar between both laps and shows good consistency.

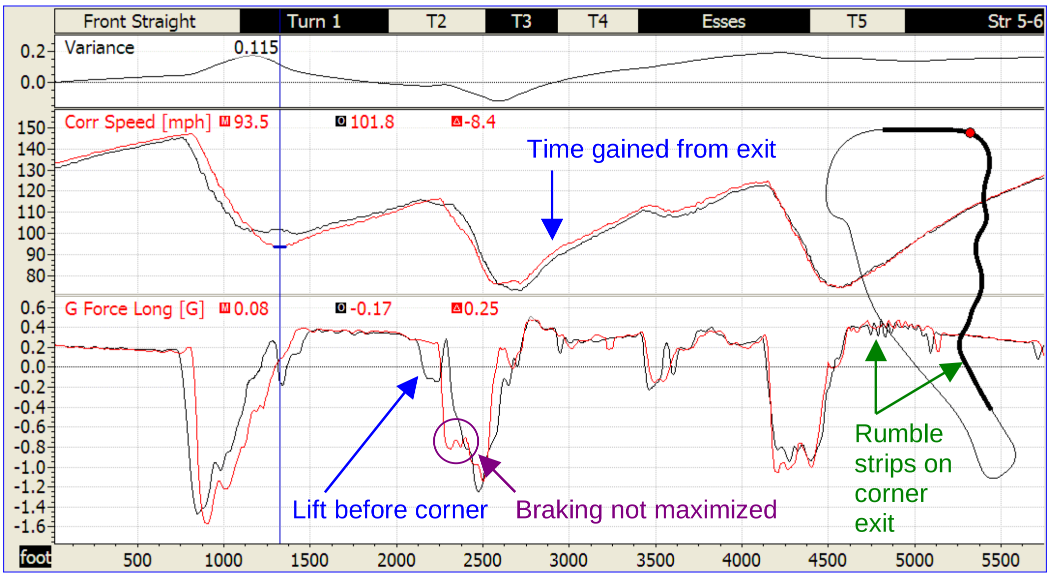

Figure 6.15 *Three corners where the first two have different braking points between the laps while the last braking point is the same.*

Application of Brakes

Race cars with stiff suspension can transfer weight more quickly, handling quick and hard applications of the brake pedal with ease. Those with a lot of aerodynamic downforce can also tolerate quick and hard applications of braking.

Race cars with soft suspension require patience and sensible applications of the brakes. Stepping too hard too quickly can lock up the front tires before weight has transferred to the front which helps keep the tires rolling.

△ Warning: Inexperienced drivers might try to move the bias knob more rearward to prevent lockups when applying the brakes too quickly. This will decrease overall braking ability. Brakes should be balanced and optimized during the period after weight transfer. This is the longest portion of braking, and should be in a steady state which means no movement in weight balance. During braking there could be as much as 75% of the vehicle's weight on the front and only 25% on the rear. That is why the front brakes are larger than the rear, they do more!

As weight is transferring or moving forward, it has momentum. This momentum increases the weight transfer before leveling off. On loose gravel and dirt, rally drivers perfect their skill of braking and un-braking at the natural frequency of the car, using this momentum to transfer more and more weight onto the front with each press and release cycle of the brake pedal. This helps the tires dig into the loose ground and results in quicker stops.

Note: With the exception of rally driving, braking should always be done with one consistent application for optimal results.

If the G Force Long has a double peak, then maximum braking ability wasn't accomplished and needs analysis. Often this could be the result of any one of the following reasons:

- A driver realizes they started braking too early and won't reach their turn in point for the corner. So the driver releases some braking force to drive further into the corner, then presses hard again just before turning.
- A driver notices one or more of the wheels have locked up. So the driver attempts to modulate the brake pedal force in hopes of preventing damage done to the tire. A quick check of wheel speed traces will verify this cause.
- Sometimes the peak will move up and down when the driver tries to blip the throttle on down shifts. More common is the release of pressure on the brake pedal when reaching for the throttle. But don't rule out an increase in pressure when blipping the throttle because the driver wasn't braking hard enough to begin with and the blip increased brake pedal pressure.

Braking Effort

Braking effort should only be studied in a straight line which is the only place where maximum negative G Forces are possible. As soon as a driver starts the turn in process, tire grip must be used for cornering so G Force will rise back up. Short braking zones should also be ignored because drivers are being smooth and to minimize weight transfer they don't brake as hard. Therefore these such braking areas don't offer much to analyze.

While the slope of the speed trace can used to estimate braking effort, with G Force Long an actual number can be logged to measure stopping ability directly. Higher braking forces result in more negative G Forces.

Before making any conclusions from looking at G Force Long, always have a quick look at the individual wheel speed traces for any lockup. If the tires aren't locking up anywhere on any lap, then the driver should be braking harder. Another reason why two front wheel speed sensors is highly recommended.

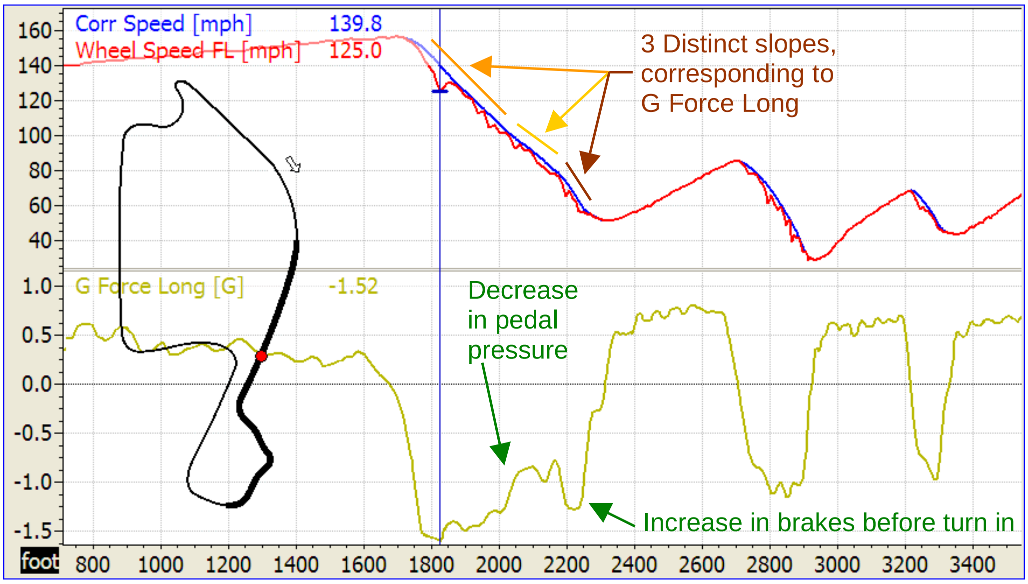

Figure 6.16 *Here heading into Turn 1 at Long Beach, braking too early leads the driver into adjusting the brake pedal pressure. The hard braking early on has a little tire lockup, which is good to see the driver finding the tire's limit.*

One of the biggest improvements to lap time is often helping a driver to brake at the maximum ability of the race car. This cannot be over emphasized. Drivers often brake at what they feel is the maximum, but until a tire gets locked up no one will ever know. Traction sampling (testing the limits) and partial lock ups are the only way to find that limit. Newer cars with ABS are a great training aid for drivers to keep braking harder until ABS activates.

Braking Release

The release of the brakes should not be as abrupt as the application of brakes. This can be a sensitive area for the race car as it transitions from braking to cornering. Weight is transferred off the front tires and onto the rear, while at the same time the addition of steering transfers weight from the inside to the outside tires. Abrupt movements can upset the car and cause handling issues induced by the driver.

While the release of the brake pedal can effect handling, its speed of release is often governed by trail braking. The technique called trail braking requires a slow release of the brake pedal, timed correctly with feeding in steering angle. As more and more braking power is released, more and more steering can be added.