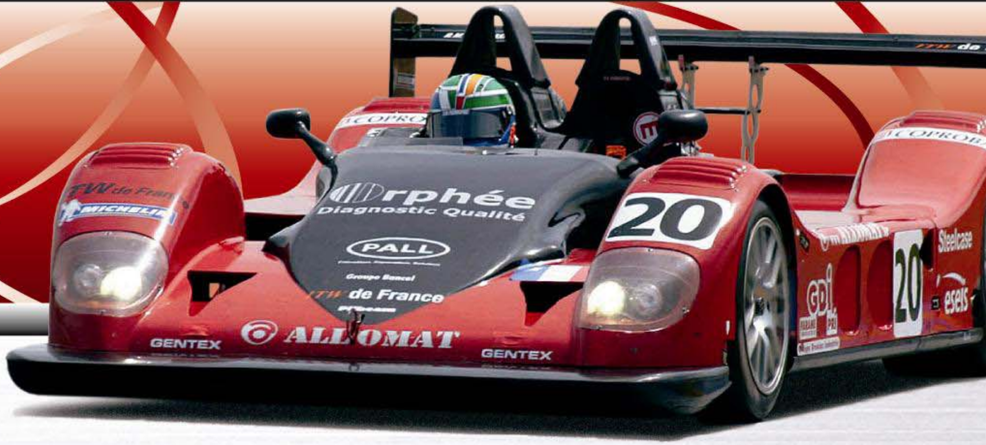
The use of data acquisition & simulation in racecar design and engineering.



ChassisSim
The Winner's Edge

Presented by Danny Nowlan and Mike Pilbeam

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Workshop Goals

- Introduce Data acquisition tools and Laptime simulation tools
- Show what to look for in logged data and what to focus on.
- Discuss the appropriate use of racecar simulation tools.
- Present a number of case studies to show the application of these tools.
- These slides are talking points as opposed to a manual
- Don’t hesitate to comment our ask questions
- The goal is to understand both the how and the why.

Data acquisition and analysis tools

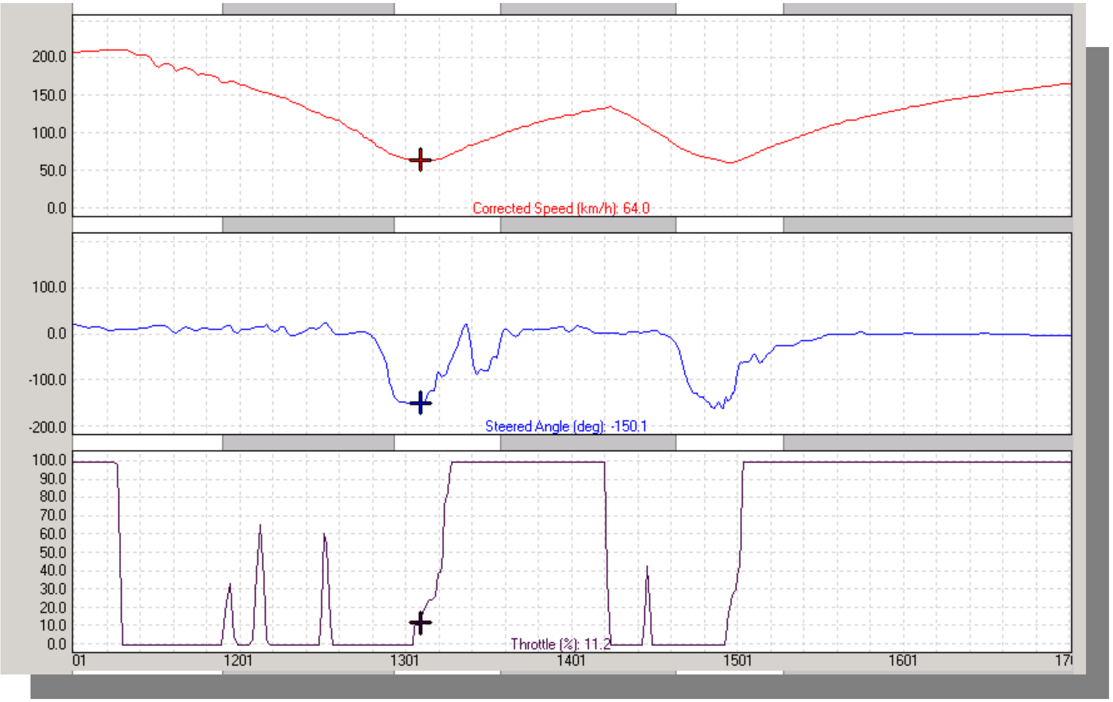
- **Data acquisition and analysis software come from a wide variety of distributors**
  - Most systems come with highly advanced analysis software.
- **For the purposes of this workshop we will be using Motec Interpreter**
  - This is for convenience.
  - The principles shown here can be applied to **Pi Toolbox, I2, WinDarab** or any other data analysis package.
- **The goal is to show what to look for in the data and why.**

Suggestions on data to be reviewed

- **Speed, RPM, steer and throttle and driver brake inputs.**
  - Tells you how the car is performing.
  - Is an indication of how the car is being driven.
- **Suspension movements and if available tyre loads**
  - Tells you what the Chassis is doing.
- **Lateral, longitudinal and, if available, vertical acceleration**
  - It quantifies what the Chassis is doing.

What to look for in the Data.

- Look for common trends in the data.
- **If something happens repeatedly, the car is telling you something.**



- When there are too many lines break up the data and refocus.
- Always make notes.
- Always ask the question why and don't just look at the fastest lap.

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Data acquisition – Math channels.

- Maths channels are a very powerful way of looking at data.
- Some suggestions for Maths channels are,
- Curvature – Inverse corner radius. This is very useful in identifying the driving line a driver uses.

$$iR = \frac{1}{R} = cv\_sign \cdot 127.008 \cdot \frac{a_y}{V^2}$$

Lateral acceleration a_y in g, V in km/h

- Neutral steer – This indicates the steering angle at the wheel if the steering was completely neutral.

$$\delta_{S-NEUTRAL} = iR \cdot wb \cdot \frac{180}{\pi}$$

wb = wheelbase in m.

Ride heights

- Ride height –ride heights can be approximated by,

$$rh_f = rh_{f0} - \left(mr_f \cdot \left(\frac{fl\_damp + fr\_damp}{2} \right) + \frac{(Load_{FL} + Load_{FR}) \cdot 9.8}{2 \cdot ktf} \right)$$

$$rh_r = rh_{r0} - \left(mr_r \cdot \left(\frac{rl\_damp + rr\_damp}{2} \right) + \frac{(Load_{RL} + Load_{RR}) \cdot 9.8}{2 \cdot ktr} \right)$$

→ rh_f = Front ride height in mm.

→ rh_f0 = Initial front ride height in mm

→ rh_r = Rear ride height in mm

→ rh_r0 = Initial rear ride height in mm.

→ mr_f and mr_r Wheel to damper ratio at the front and rear respectively

→ fl_damp,fr_damp,rl_damp and rr_damp are the damper movements at the damper in mm. These are zeroed on the ground.

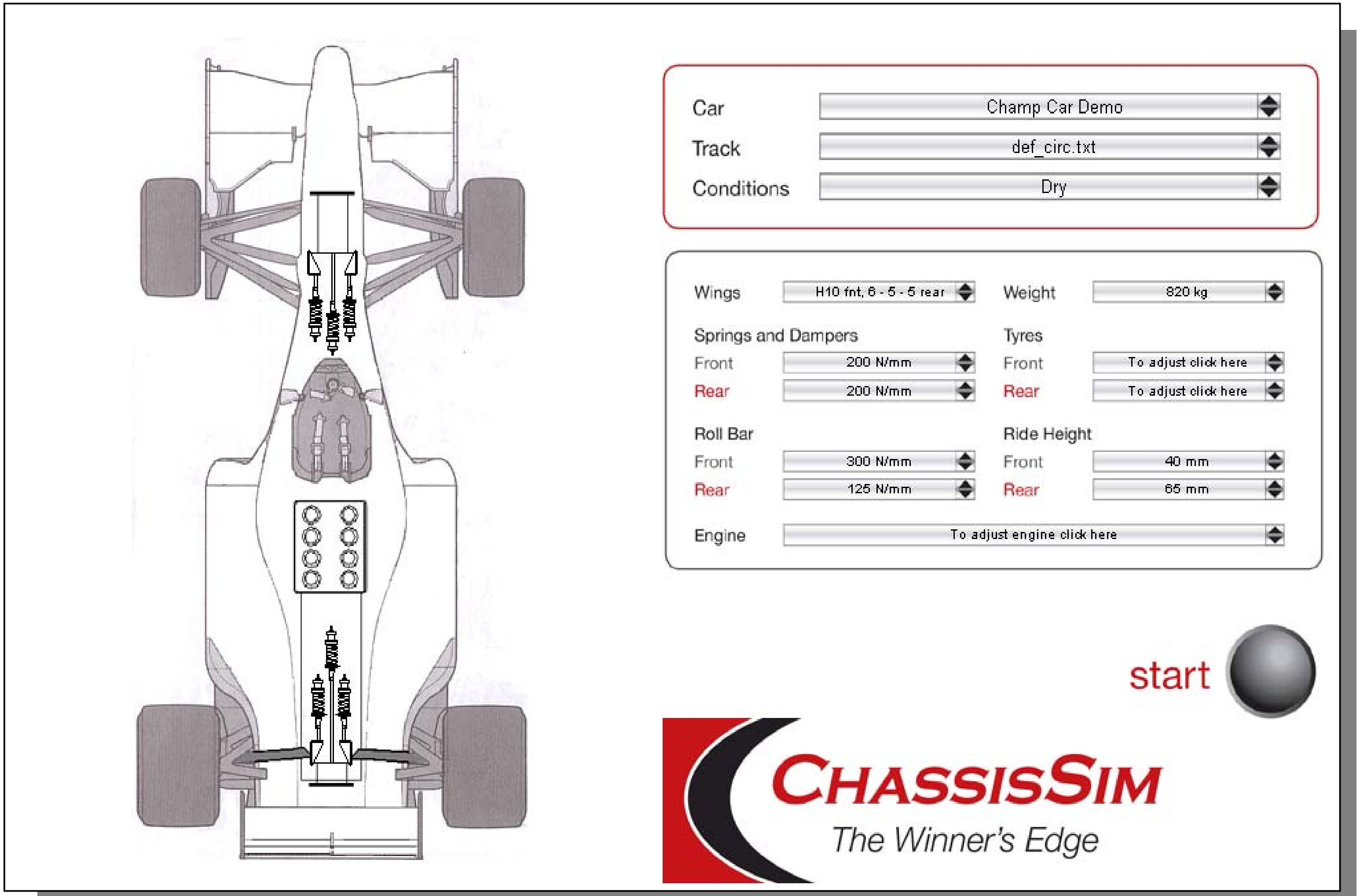
→ Load_FL, Load_FR, Load_RL and Load_RR are the tyre loads in kg zeroed on the ground.

→ ktf and ktr are the tyre spring rates in N/mm.

LapTime simulation tools: ChassisSim

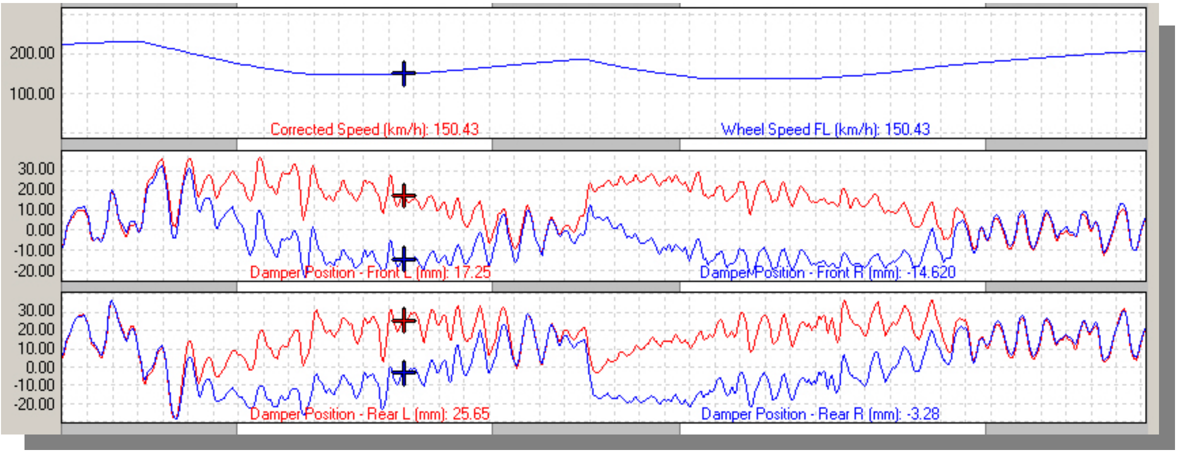
- Full transient simulation
- Track model includes road surface variation.
- Car model includes dampers and aerodynamic maps
- Calculation is less than real-time lap duration
  - ChassisSim simulates all the time-dependant effects
  - Particularly relevant when looking at damper rates and control of tyre loads
- ChassisSim interfaces with several analysis packages one of which is Motec Interpreter

LapTime simulation tools: ChassisSim



Don’t look at a simulation at face value.

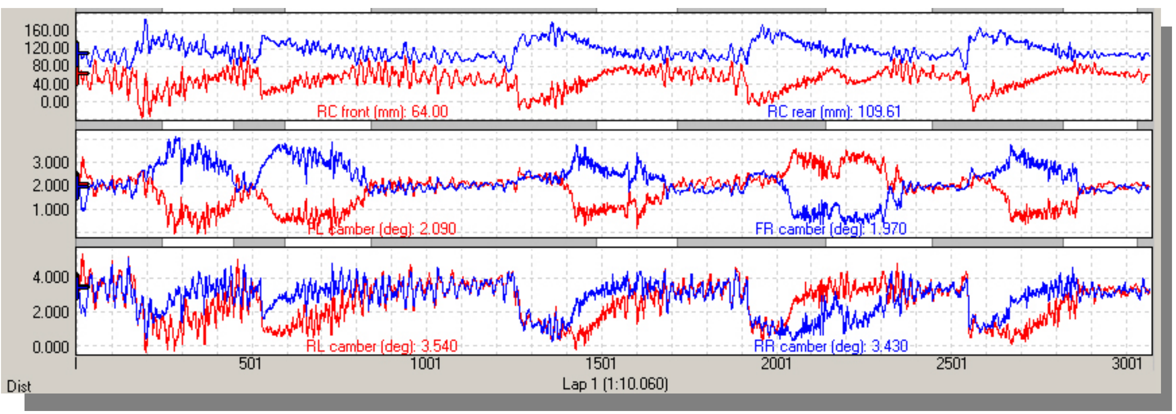
- The following can be seen from a simulation
- It will yield the tyre loads that can be expected.
- It will tell you what the suspension is doing.
- A simulation run gives you a picture of what to expect with the car.



Simulation suggestions.

Remember simulators are tools, they will help you if used correctly!

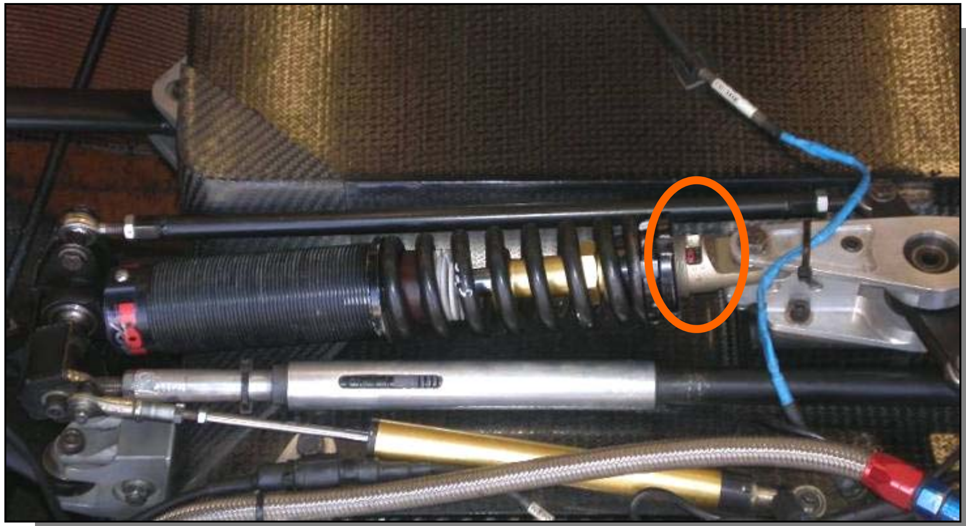
- When simulating, direct the attention to what you are trying to improve.
- Log every simulation run and scrutinise it as if it is actual logged data.
- With every simulation run, ask the question **why?**



Case Study 1:
MP93 LMP2 - Damper settings

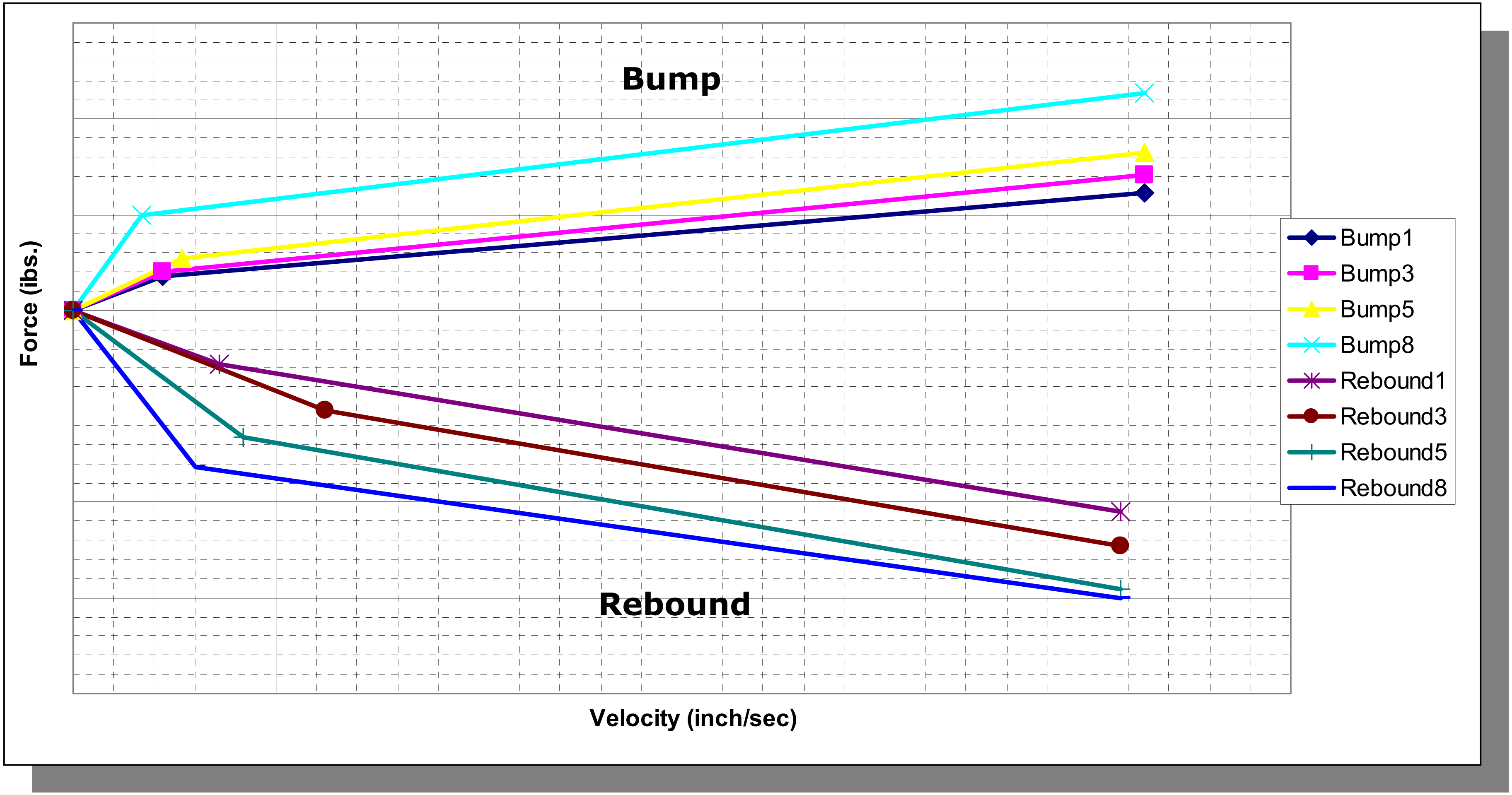
- 8 settings in Bump
- 8 settings in Rebound

Testing at Le Mans began with very stiff settings, especially in bump.



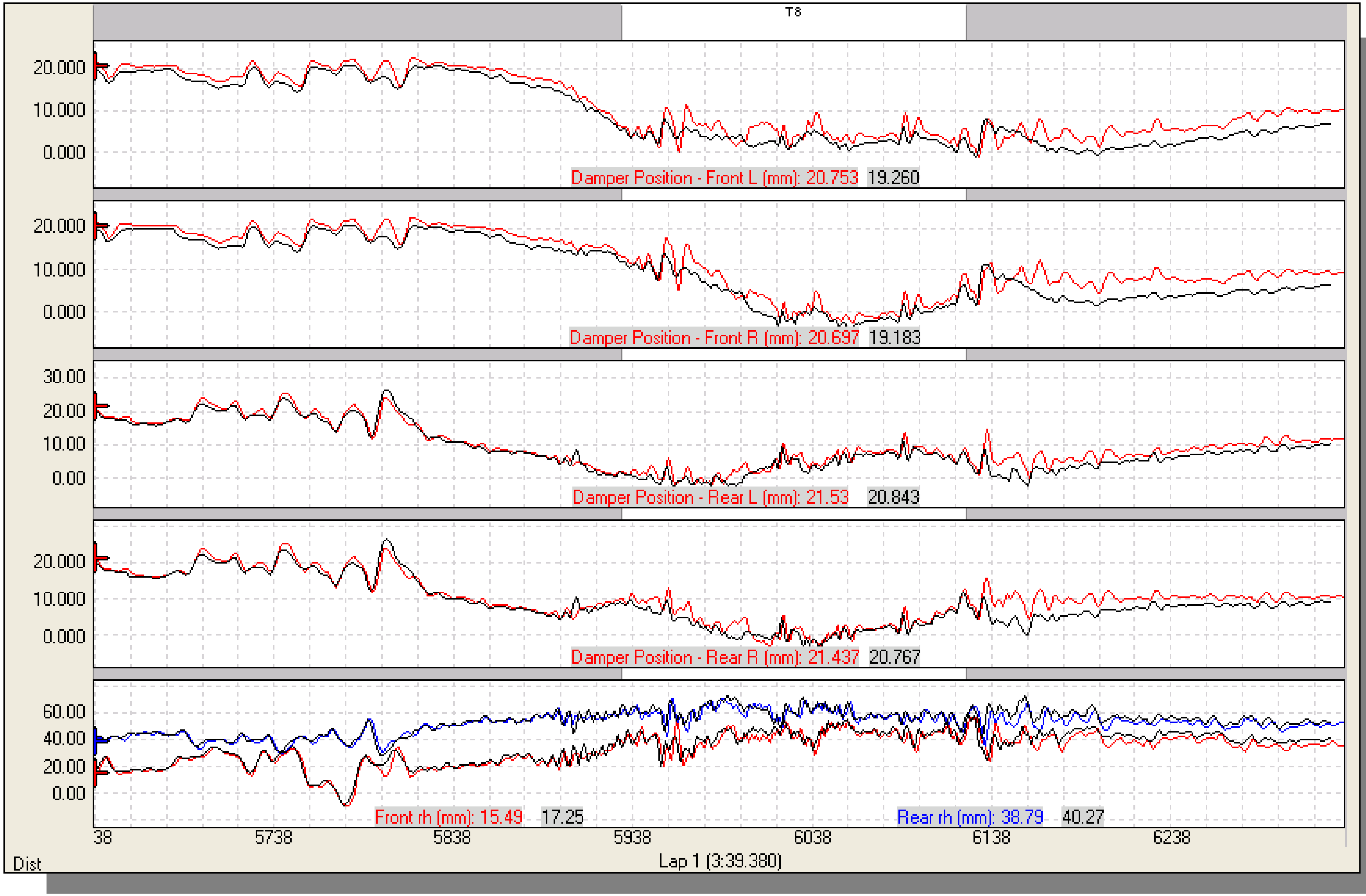
However, driver feedback showed:

- very “bumpy” behaviour
- abnormal understeering


Bump
Rebound
Force (ibs.)
Velocity (inch/sec)
Bump1
Bump3
Bump5
Bump8
Rebound1
Rebound3
Rebound5
Rebound8

Results of using simulation.

- **Simulating the effect of a much softer damper setup revealed a huge gain**
  - The data showed that the bump movements transferred back to the dampers.
  - The data showed more constant tyre loads.
- **When this was applied**:
  - understeering in the chicanes was solved
  - The drivers reported the car was much “easier” to drive.
- **All of this was reflected in the pre-simulated data**.

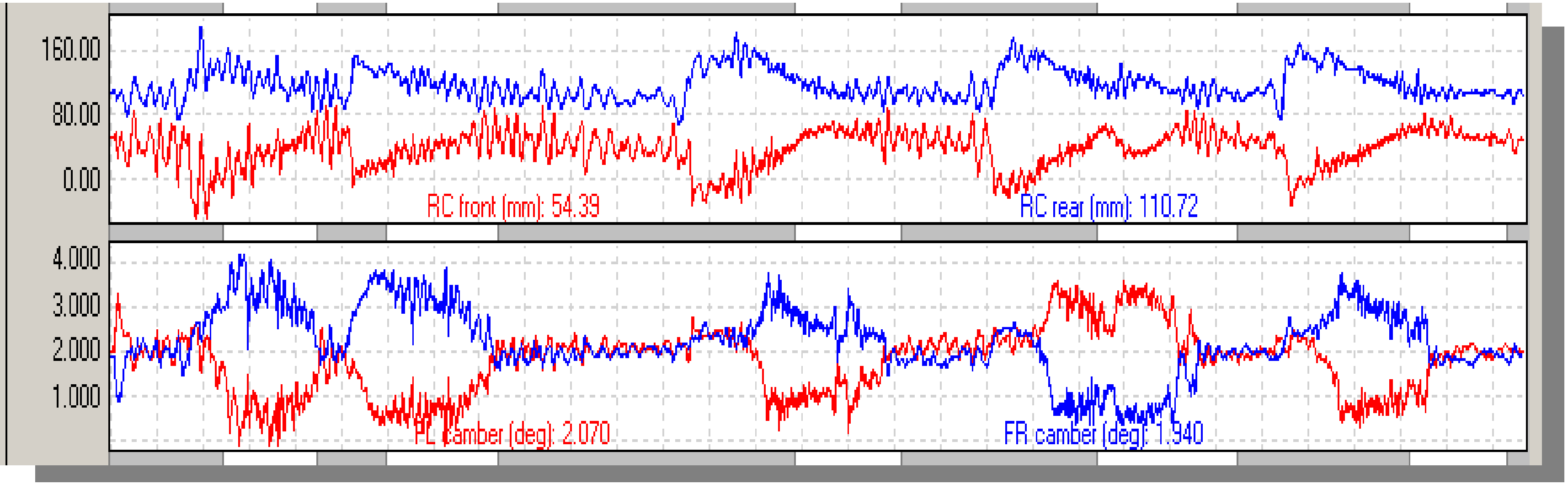

T8
20.000
10.000
0.000
Damper Position - Front L (mm): 20.753
19.260
20.000
10.000
0.000
Damper Position - Front R (mm): 20.697
19.183
30.00
20.00
10.00
0.00
Damper Position - Rear L (mm): 21.53
20.843
20.000
10.000
0.000
Damper Position - Rear R (mm): 21.437
20.767
60.00
40.00
20.00
0.00
Front rh (mm): 15.49
17.25
Rear rh (mm): 38.79
40.27
38
5738
5838
5938
6038
6138
6238
Dist
Lap 1 (3:39.380)

Case Study 2:
Using simulation to design a front suspension

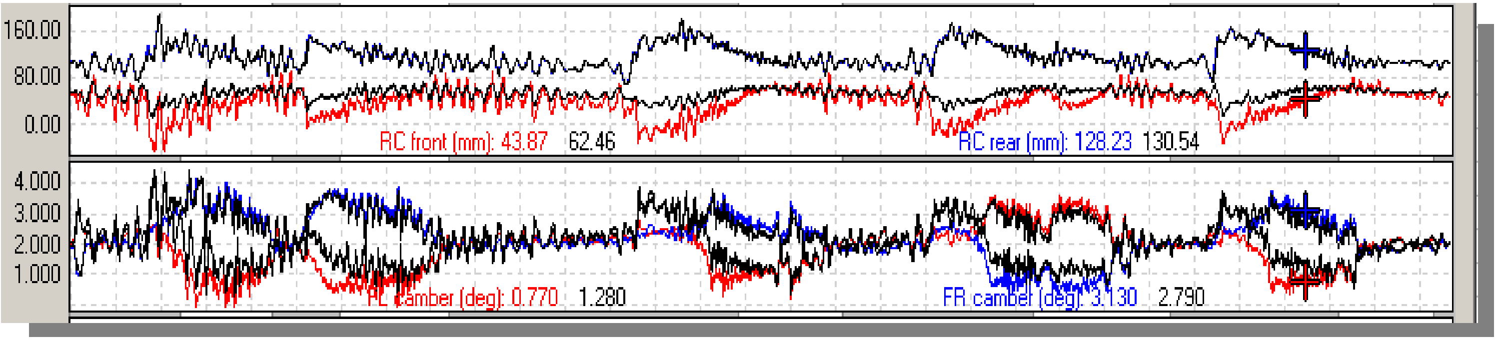
- The project brief is to produce a no compromise race car from a road car shell.
- The target car had a McPherson front suspension, and MultiLink rear suspension.

Design approach using simulation

- The base car was simulated using a representative setup.
- The focus of the analysis was,
  - Camber gain.
  - Roll centre variation.
- It was found the front end of the car suffered from,
  - Excessive camber gain
  - High roll centre variation.



- A front double wishbone suspension system was examined.
- A number of different geometries where tried. The focus for the design was:
  - Minimise camber gain and roll centre variation.
- The final design showed a gain of nearly 0.6 sec, however it was selected because:
  - Camber gain at the front matched that at the rear.
  - Roll centre variation showed considerable improvement and matched the rear.
  - This ensured the suspension geometry would form a stable platform.

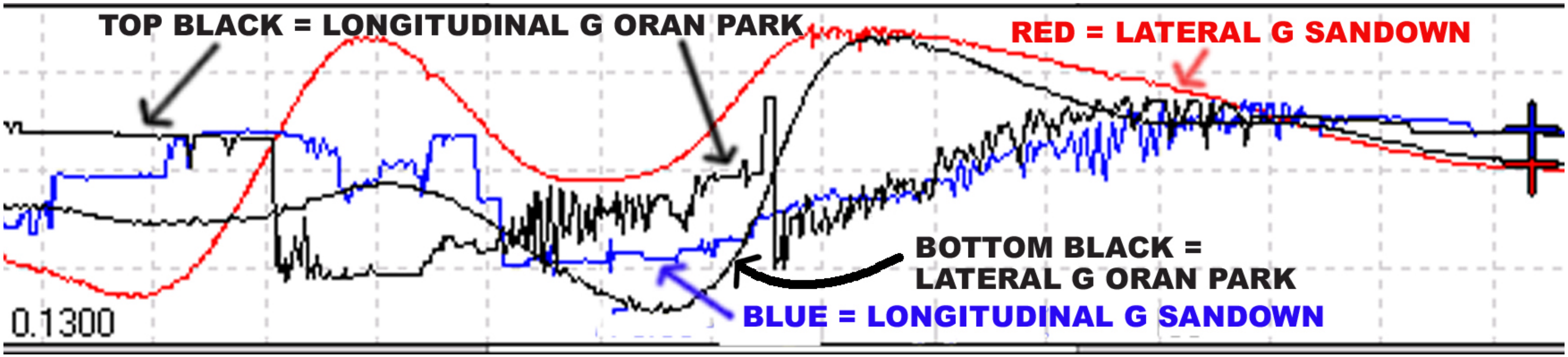


Case Study 3:

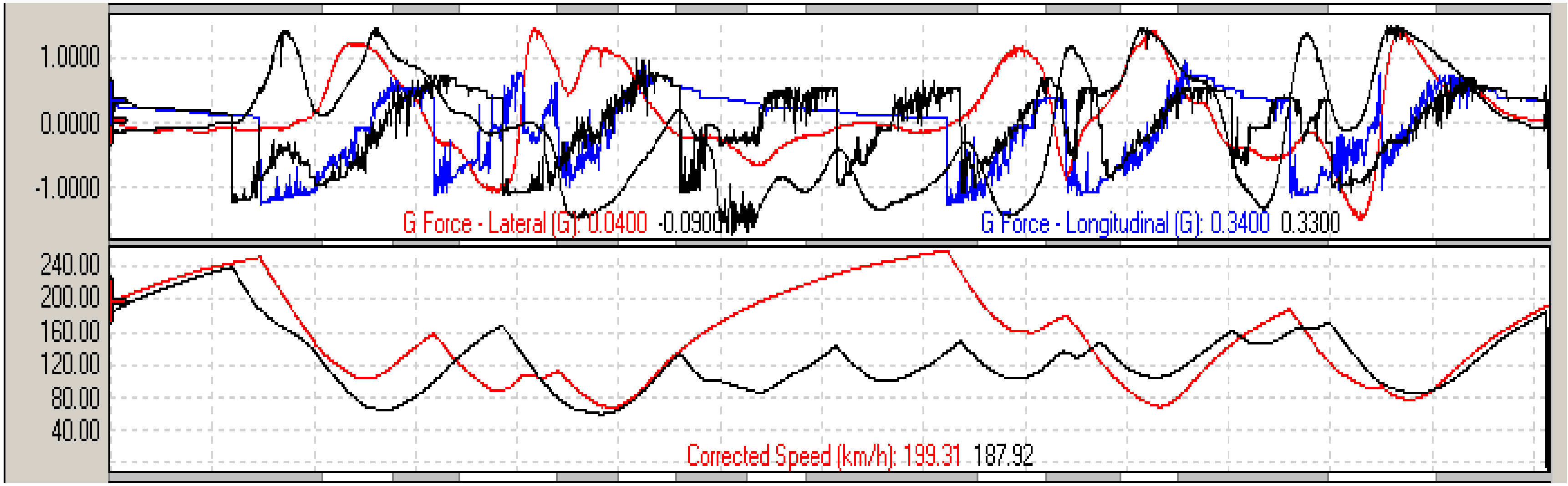
Using logged data to predict a setup for Carrera Cup.

- The only practice session was washed out.
- The data from the previous year was unreliable.
- The only option was to compare data from other cars.
- Lateral and Inline acceleration was compared.
- This will indicate whether the setup is appropriate.

Enlarged view of last turn at Oran park and Sandown tracks



Complete view of Oran park and Sandown tracks



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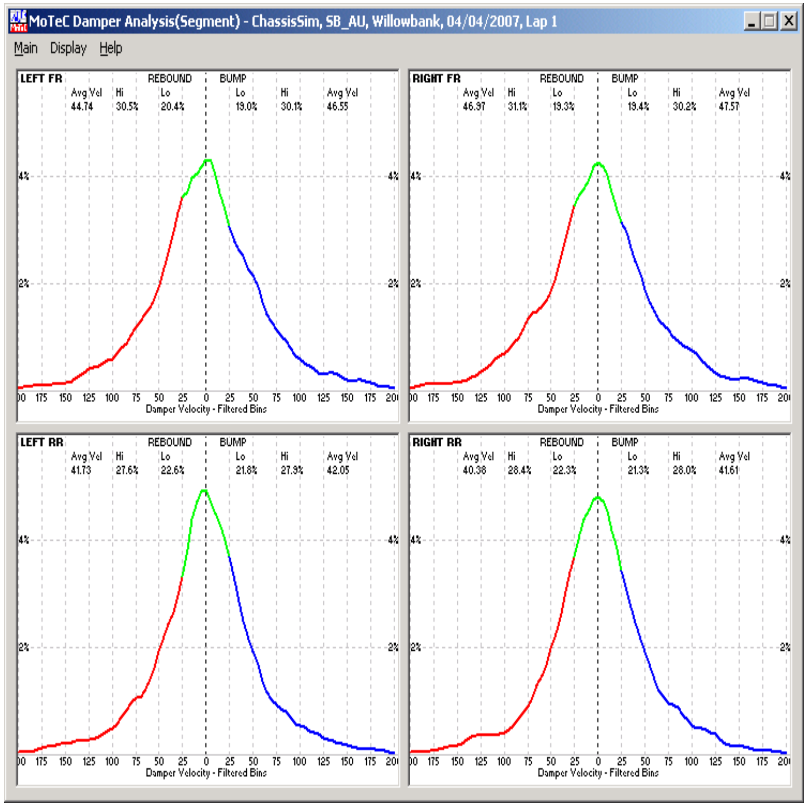
- It was found the **lateral** and **longitudinal** G correlated.
- This meant the grip factors where the same.
- The previous qualifying setup could be used.
- We achieved placed 3rd in qualifying.

Case Study 4:
Using damper histograms for damper setup.

- The damper histogram is a powerful tool in evaluating damper behaviour
- The ideal bell curve is desired
- This is for all 4 dampers
- The distribution is about 20/80 ratio
- The key to adjustment is to increase the damper rate in an area that is flat.
- Alternatively if there is too much of a peak reduce the appropriate sector of the damper.
- This analysis is used extensively in V8 Supercars



Screen from MoTec

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Conclusion

- **When using data acquisition**
  - Look for patterns that repeat.
  - Look at the data in groups.
- **When using simulation**
  - Focus on the area that needs to be examined
  - Just don't focus on the lap time.
  - Investigate the data that is returned.
- **Simulation and data analysis are tools**
  - they will help you if used correctly.
  - These tools help you understand what makes the car work.
- **Used in this manner simulation and data acquisition are indispensable.**