Fuel for thought for Le Mans 2014

What can we expect to come out of the innovative regulations for next year?

BY CHRIS VAN RUTTEN

Last June, the ACO released a concept of the future regulations for the Le Mans race. The organisers' stated aim is to challenge the entrants to develop a more efficient car. So, instead of imposing restrictions to the engine, in order to keep the power under control, they limited the amount of fuel which may be used. Since power is relative to the fuel used, multiplied by engine efficiency, this simple rule limits the engine power as well. In return the entrants are granted more technical freedom to design their power plant.

It could have been an option to limit the amount of fuel for the complete race, which, contrary to the amount of fuel per lap, would lead to an even more complicated puzzle. The design would have to take many irregularities into account which might occur during the race, such as yellow flag periods, and rain. Next to that, it could open possibilities for teams running faster than they could continue for a complete race, just for the sake of extra attention of leading in the early stages. It would be quite confusing for the spectators. The choice of specifying an amount of fuel per lap is much more straightforward and will guarantee that there is still a race for the drivers.

Based on this regulation, what is there to expect? By using a simulation package, such as LapSim, an estimate can be made in which direction the LMP cars will develop. How will the fuel limit influence lap times and top speeds? What kind of engine may we expect? Will the trend go to low drag vehicles? How sensitive is the fuel limit to parameter changes of the vehicle?

> **"Specifying an amount of fuel per lap will guarantee that there's a race for the drivers"**

AS THINGS STAND

As a reference, we have a model of a current LMP1 petrol car that we've made in LapSim. Main chassis specifications are vehicle weight including driver 1000kg, and an aerodynamic efficiency of 4.37. Other main parameters of the chassis can be seen in the setup overview in **Figure 1**.

With the engine simulation in LapSim, a power curve can be generated for the current engine of an LMP car, a 3.4-litre V8 with a 43.4mm restrictor. Optimising the engine parameters results in the power graph as shown in **Figure 2**.

The advantage of the engine simulation is that not only is a power curve generated, but also the efficiency of the engine in the complete power band is calculated. Thereby combining the power curve of the engine simulation with the lap simulator, the software will also simulate the fuel consumption over a lap. The results of simulating a lap at the Le Mans track can be seen in **Figure 3**. The lap time of the model is 3:32.81.

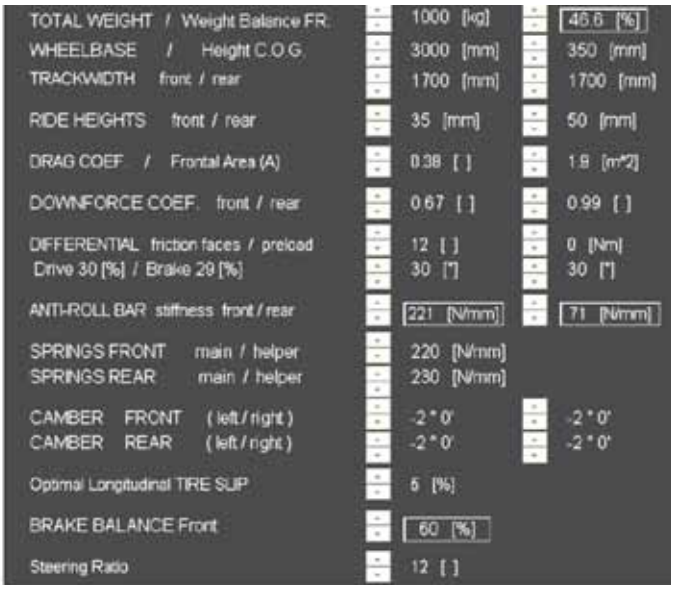

Figure 1: overview of chassis parameters in a 2012 LMP

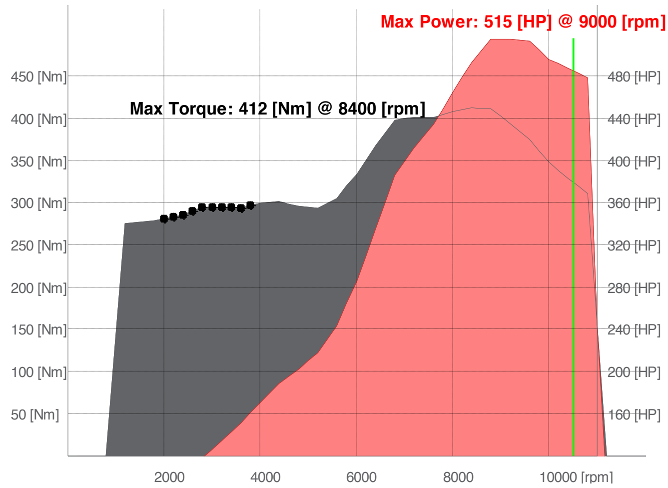

Figure 2: power curve for a 2012 LMP

The model reaches a top speed of 311km/h, as can be seen in the top figure. Below the speed graph, the engine rpm, throttle and selected gear are shown. The bottom three figures show the fuel flow in ml/sec, middle figure the accumulated fuel over the lap (6.18-litre total) and the bottom figure shows the theoretical efficiency of the engine.

This model is used as a reference to view the implications to the 2014 regulations.

THE 2014 EFFECT

In a first attempt to reach the fuel limits of 2014, a smaller engine is simulated. With a 2.8-litre, 6 cylinder engine with 84mm bore and 86mm stroke engine, the model seems capable

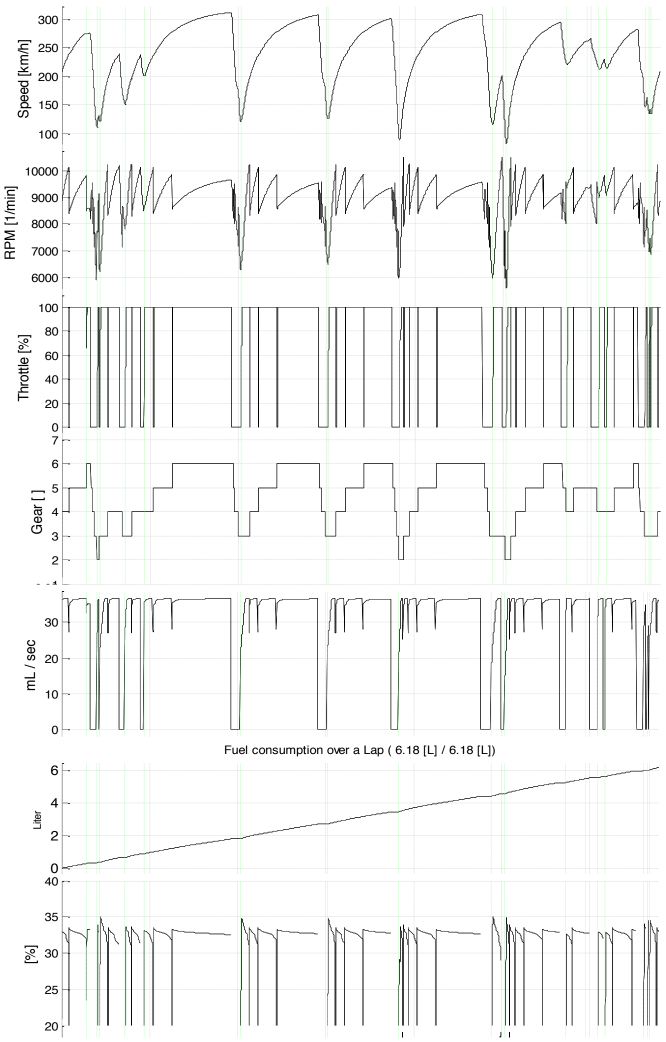

Figure 3: simulation results for a 2012 LMP

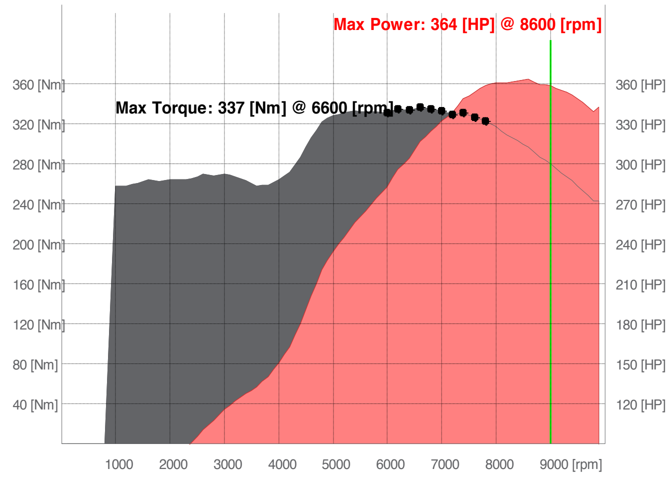

Figure 4: a 2.8 litre 6 cylinder engine for a 2014 LMP

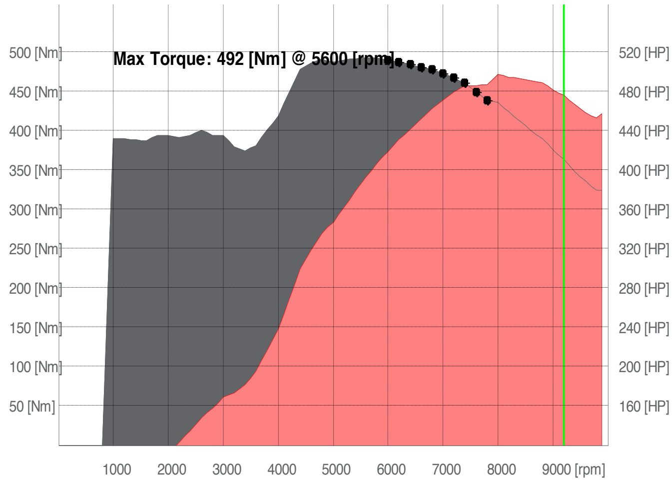

Figure 5: option 2; a 4-litre V8 for a 2014 LMP

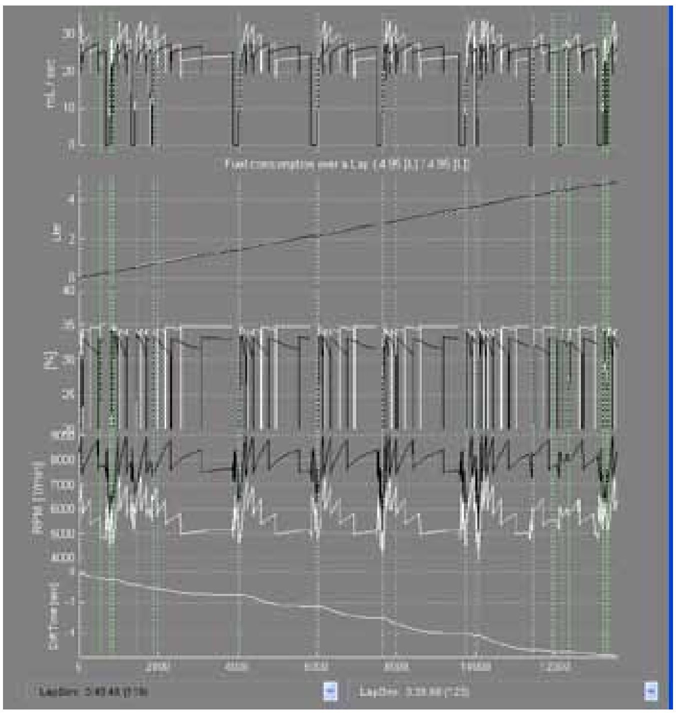

Figure 6: comparison between a 2.8-litre and 4-litre engine

of reaching the fuel limits. Combined with appropriate valves and camshaft timing, it develops 364hp between 8000 and 8800rpm **(Figure 4)**.

The engine is combined with an appropriate 7 speed gearbox to suit the 2012 chassis. However, for fuel economy reasons, sixth and seventh gears are chosen longer compared to those used for the fastest lap time. Chassis parameters are kept the same, just the total weight is reduced to 930kg. This combination results in a lap time of 3:45.46, a top speed of 276km/h and a fuel consumption of 4.95-litres over a lap. In order to reach this fuel limit, the higher gears needed to be short shifted, otherwise the fuel consumption would be more. When it comes to lap time, short shifting the higher gears is the most effective way of reducing the fuel consumption.

This would be the classic approach when running an engine more or less on full power, as would reducing the engine size in order to reach the fuel limits. A second option would be running a "too powerful" engine in a torque range where it is most effective. As a comparison to the 2.8-litre 6 cylinder, a 4-litre V8 with 86mm bore and 86mm stroke is simulated. The camshaft timing has been changed in favour of more low end torque. This engine delivers 497hp and 492Nm of torque, as can be seen in **Figure 5**.

In order to reach the fuel targets, the gearbox ratios have been chosen way too long from a classic setup perspective, as

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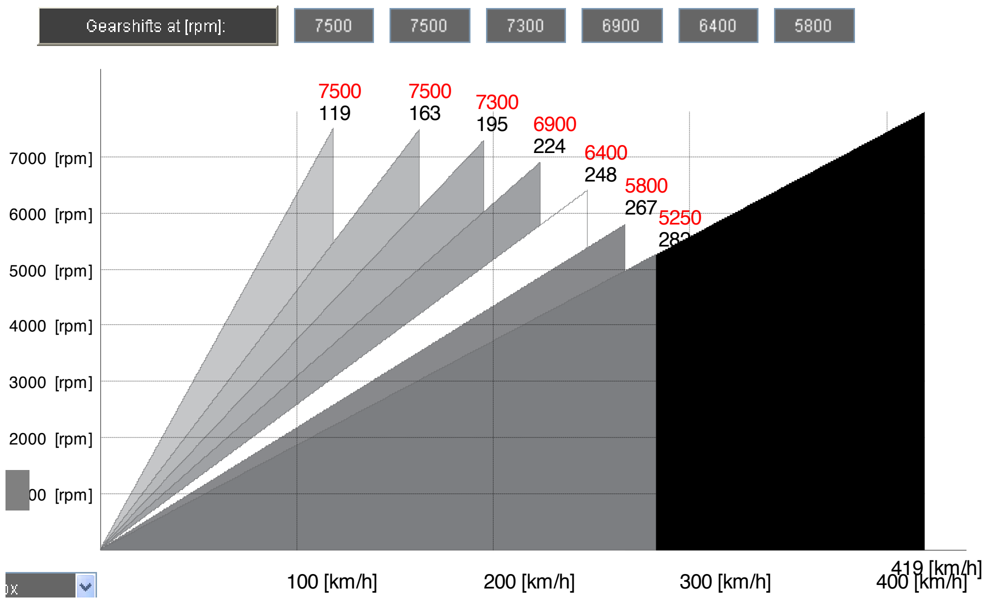

Figure 7: gearbox graph for a 4-litre with a 34ml/sec flow limit

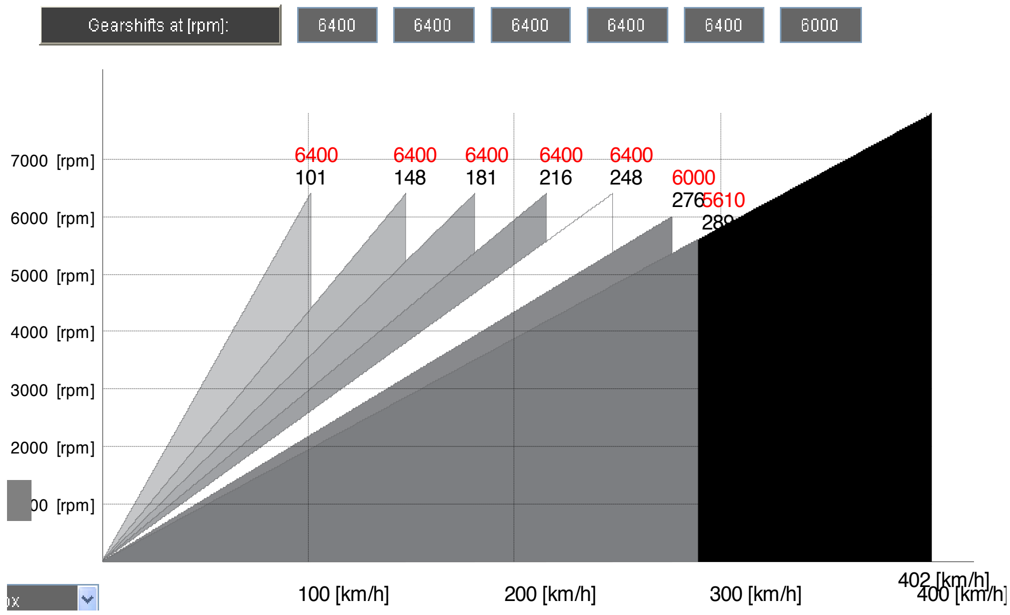

Figure 8: gearbox graph for a 4-litre with a 30ml/sec fuel limit

shown in **Figure 7**. All the gears are short shifted in order to keep the engine in its most efficient range. This combination of engine, gearbox and shift points results in a lap time of 3:39.88 and a fuel consumption of 4.95-litres over a lap. Top speed is also 277km/h.

Comparing the graphs of the fuel consumption explains the reason for this much faster lap time, with equal fuel consumption.

In the top graph of **Figure 6**, it can be seen that in the lower gears, the extra power is used to accelerate faster out of the corners, which helps a lot for the lap time. At this moment the stronger engine uses more fuel compared to the less powerful engine. However, as both setups shift to the higher gears, the bigger engine is more and more short shifted, reducing the engine rpm and subsequently the fuel consumption. Next to this advantage, in the third graph it can be seen that the more powerful engine is constantly run in a more effective rpm range. Its theoretical efficiency is close to 35 per cent whereas the smaller engine runs 32-33 per cent.

FUEL FLOW LIMIT

In the draft regulations of August 2012, the ACO stated a maximum fuel flow of 34.4ml/sec. The V8 engine detailed on the previous page does not even reach that limit. So one could go even a small step further, increasing the engine a bit more to accelerate fast out of the corners and perhaps run subsequently part throttle in highest gear, or even let the car roll from a point onwards.

As a comparison, a fuel flow of 30ml/sec would cause the bigger engine to short shift also in the lower gears, in order to remain below the 30ml/sec limit. If there would be a fuel flow limit of 30ml/sec, the gear ratios and shift points need to be altered as in **Figure 8**.

Running the model on the Le Mans track leads to a lap time of 3:40,72 with again a fuel consumption of 4.95-litres. With this setup, the model reaches a top speed of 284km/h.

In **Figure 9**, the simulation results shows that due to this shift strategy, the model loses in the initial acceleration, but wins by the end of the straight, resulting in a higher top speed. The white line represents the 30ml limit configuration, while the black lines show the results when setup for the 34.4ml/sec limit. The 30ml/sec limit will cause the car/driver to drive a normal "full power" strategy. With the higher limit, there will be an active fuel save strategy on the straights, leading to possible strange and potentially dangerous racing behaviour of the drivers.

In the example above, the model is roughly 174 seconds on full throttle, and 10 seconds on part throttle. To simplify things, lets assume that in the part throttle period, the engine consumes on average half of the full throttle amount. This would mean that the 4.95-litre needs to be consumed in 174 + 0.5 x 10 = 179 seconds. So the average fuel flow would be 27.65ml/sec.

If the lap time is reduced by 10 seconds to 3:30, for simplicity reasons one could assume that the 179 seconds will be reduced to 169 seconds, which would mean an average full flow of 29.29ml/sec. In order to see the drivers really having a race, and not backing off on the straights, it seems beneficial to reduce the maximum fuel flow limits compared to the values proposed.

AERODYNAMIC EFFECTS

How do the aerodynamics of the vehicle influence the result? Will there be a tendency to go to an absolute low drag, no wing chassis?

In the example, the chassis has a frontal area of 1.9 [m²]. The drag coefficient is 0.38 and the total downforce 1.66 (0.67+0.99). So the aerodynamic efficiency (downforce/drag) is 4.37. Comparing the figure to the CW value of street cars, it seems already quite a low drag variant, considering the amount of downforce that is generated.

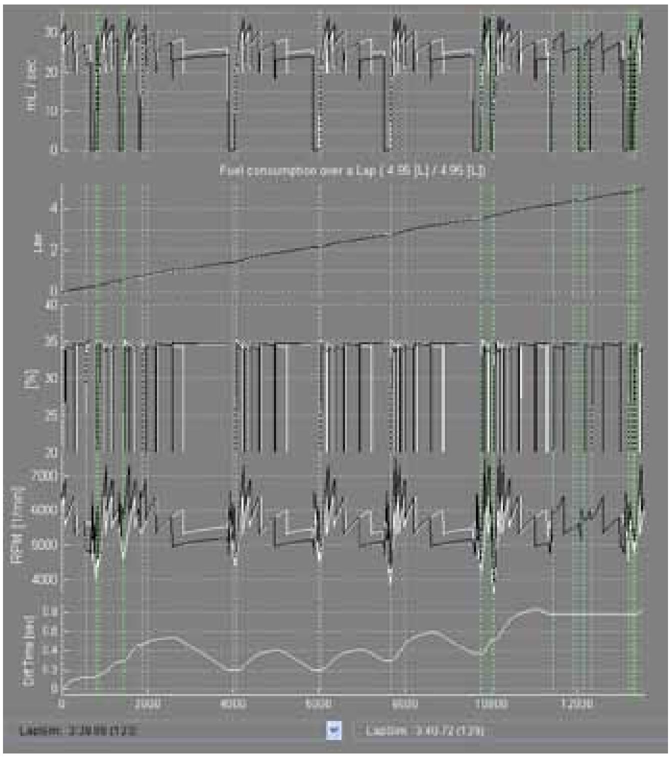

Figure 9: comparison simulation results 4-litre with a 30ml/sec (white) or with 34ml/sec (black) fuel low limit

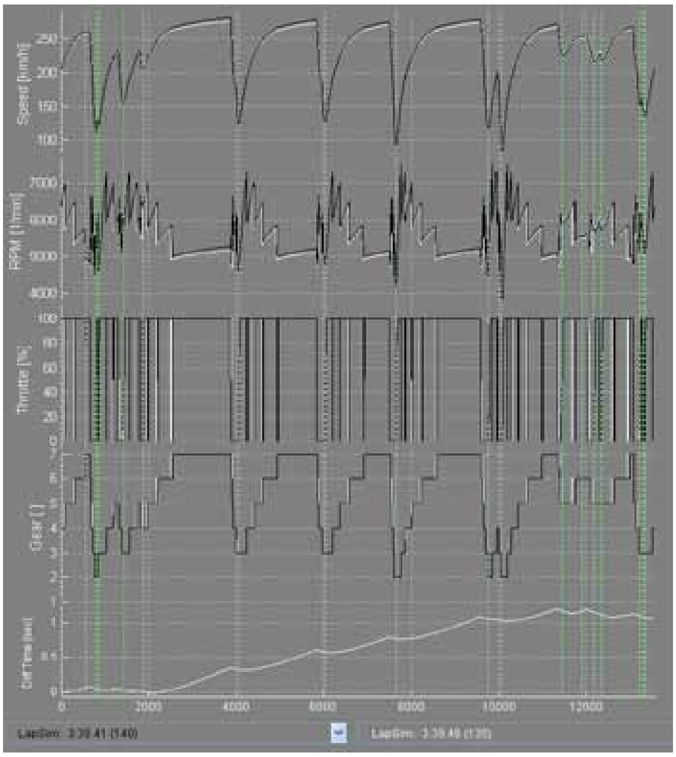

Figure 10: illustrating a direct comparison between +5 per cent downforce and -5 per cent drag

As an alternative, a variant 5 per cent more downforce is calculated. Drag coefficient remains the same at 0.38, and downforce coefficient is increased to 1.75 (0.71+1.04). The shift points need to be slightly reduced in order to reach the fuel limit. With 4.95-litres consumed the lap time is 3:39.46, an improvement of 0.42 secs.

Going in the opposite direction, reducing the drag by 5 per cent to 0.362 leads to a lap time of 3:38.41 with 4.95-litre fuel used. This would mean an improvement in lap time of 1.45 secs.

As a comparison, a sensitivity analysis is made for the engine efficiency. What would be the effect of a five per cent more efficient engine? To get a first impression and to keep things simple, a pretty quick and dirty solution can be found simply by increasing engine power with the same engine efficiency. In order to simulate the increased engine efficiency, both the fuel limit as well as the maximum fuel flow is increased by 5 per cent, meaning 5.20-litres per lap and a maximum 36.1ml/sec. As a reference, the standard aero variant is chosen, so drag is 0.38 and aerodynamic efficiency 4.37.

With optimised gear ratios and shift points, the lap time is reduced to 3:36.47, with a top speed of 282km/h and the desired fuel consumption of 5.20-litres. This leads to a lap time improvement of 3.41 seconds.

SHIFTING DEVELOPMENT

Announcing the regulations, FIA Endurance Commission president Lindsay Owen-Jones said: 'Thanks to in-depth work and excellent collaboration, the ACO and the FIA have announced a unique set of extremely innovative technical regulations for 2014 that are in phase with the times we live in. It should encourage the development of powerful and spectacular cars, and also the development of technologies that have real meaning for the everyday motorist.'

There will be a increase in lap time, but the cars will still be fast and be driven flat-out. Instead of developing engines which run in a maximum power state, which is unrealistic for every day driving, they will be run in a state which has much more relevance for our daily driving. Reducing drag will still be important for race victory, but maximum downforce, for the first time in decades, significantly loses its relevance. An increase of 5 per cent engine efficiency will lead to a reduction in lap time of more than 3 seconds, whereas an increase in downforce of 5 per cent brings only 0.42 seconds. There will be a huge shift to the development of engine efficiency and drag reduction, two areas where the public can profit from the factory's racing efforts. Congratulations to those involved for making such a simple, but very effective regulation.

OVERVIEW

	Mass	Drag	Downforce	Fuel	Fuel Flow	Lap Time
LMP 2012	1000 [kg]	0.38	1.66	6.18	No Limit	3:32,81
2014 364 HP 2.8 6 Cyl	930 [kg]	0.38	1.66	4.95	34.4 [mL]	3:45,46
496 HP 4.0 V8	930 [kg]	0.38	1.66	4.95	34.4 [mL]	3:39,88
max 30 [mL/sec]	930 [kg]	0.38	1.66	4.95	30 [mL]	3:40,72
+5% Downforce	930 [kg]	0.38	1.75	4.95	34.4 [mL]	3:39,46
- 5% Drag	930 [kg]	0.362	1.66	4.95	34.4 [mL]	3:38,41
+5% Engine Efficiency	930 [kg]	0.38	1.66	5.20	36.1 [mL]	3:36,47

Chris van Rutten graduated from Delft University, under Prof Hans Pacejka, in 1995.

He began development of LapSim software in 1997 – the first release was in 2000. In 2005 the development of an engine simulation started. This had the same goal as the chassis simulation: easy to use, accurate and fast, supplying answers.

Over the years, LapSim has been used to develop sophisticated traction control algorithms, both for petrol as diesel engines. Cars running these traction control systems have won Le Mans, both in GT, LMP2 and LMP1 class.