POETRY IN MOTION

Simulators are playing an increasingly important role in motorsport, from the amateur club racer to Formula 1. **William Kimberley** takes a look at some of the technology on offer

IN the 10 years since it was founded by Jürgen Fett and Diego Minen, VI-grade has become a leading provider of software products and services for advanced applications in system level simulation. It boasts that it delivers innovative solutions to streamline the development process from concept to sign-off in the transportation industry, mainly automotive, aerospace, motorcycle, motorsport and railways. Its goal is to bridge the gap between virtual prototyping and testing by providing best-in-class services and products.

"We provide solutions to help companies bridge the gap between virtual prototyping and physical testing, specialising in very advanced applications and, of course, motorsport is a very good example of that with cars being highly optimised to get best lap times," says Gabriele Ferrarotti, industry manager at VI-grade. "The important thing is that what's simulated is precisely replicated on the racetrack."

Specifically for motorsport, it has developed VI-Motorsport, a software environment for vehicle modelling and dynamic analysis. It helps racecar designers and track engineers predict vehicle performance when setup parameters are modified before the car is built and also in support of race events. The program is based on a faster-than-real-time simulation solver that can predict virtual car behaviour. It helps teams reduce the time needed to find the best setup for a given car on a given circuit and to explore more design variants in less time. It has been extensively validated against test data in various racecar series.

The program can create road data – both driver line and tyre contact profiles – starting either from GPS, laser or telemetry data measurements or from a fully analytical description. Its advanced driver model allows users to drive the vehicle model around the specified track and to find the limits of the car. Applications include suspension modelling and analysis environment to derive suspension curves, a detailed description of components such as dampers, springs, bump stops, anti-roll bars, aerodynamics and tyres.

Another popular VI-grade program is VI-CarRealTime, as used by Hyundai Motorsport and many others, which provides a vehicle simulation environment where the same simplified vehicle model can be used by vehicle dynamics and control engineers to optimise vehicle and control system performance. It enables Design of Experiments (DOE) and multi-objective optimisation studies to be performed quickly and easily.

It is also the only real-time solution available in the market that can export automatically and seamlessly a real-time vehicle model directly from Adams/Car. Similarly, VI-CarRealTime enables the sharing of component property files such as tyres, springs, dampers, and bump stops with Adams/Car. It provides validated models that can be used by controls and hydraulic engineers to optimise the controller design based on accurate vehicle performance and it can also be integrated with Matlab Simulink for control systems.

VI-Sportscar is a specialised simulation environment, based on Adams/Car technology, that allows for the analysis of a number of design alternatives of a virtual racecar and its subsystems on a test rig or on a given racetrack. The vehicle is driven on a two- or three-dimensional track profile by a sophisticated driving program which pushes the car to its limits.

A specialised and extremely fast quasi-static lap time prediction program is entirely linked to the model database.

“Cars can be tested on circuits with laboratory-like consistency”

ABOVE VI-grade’s Driver-in-Motion simulator that moves on a flat surface, sliding on airpads

Validation is continuously performed in close collaboration with customers, and this helps improve the methods and the accuracy of the program prediction.

Following a partnership formed five years ago with MSC.Software, VI-grade also offers integrated multibody solutions based on MSC.Software’s Adams technology. It is the world’s most widely used multibody dynamics software, originally developed for the automotive industry but also taken up by the motorsport one as well.

Since then, the company has evolved from one providing software solutions to one that supplies hardware as well. Driving simulators have been around for years, many based on the same fundamental technology. However, VI-grade has taken a fresh approach and patented DiM – Driver in Motion – which has been designed by VI-grade and engineered and manufactured by Japanese company Saginomiya. It is a very powerful machine that uses nine electrically-driven actuators to deliver high performance and high quality motion to the driver.

The DiM tripod moves on a flat surface, sliding on airpads, which makes the simulator very reliable, silent and also extremely stiff. “It has reduced friction almost to nothing compared to the use of multiple rails, which also add cost, complexity, latency and noise while also penalising performance,” says Ferrarotti. “The hexapod is built on top of the tripod which is simulating the higher frequencies up to 50 Hz and the cockpit sits on top of that.

“Our engineers went beyond the basic six actuator design of a simple hexapod to provide a larger workspace; high stiffness has been maintained in order for the system to be more relevant for low as well as for high frequencies, which characterise automotive chassis design. It means that it’s possible to study both vehicle dynamics and ride on the same motion platform.

“It also allows the integration of all kinds of active car systems via hardware-in-the-loop and software-in-the-loop at the same time so that physical components such as control systems can talk to each other. So it’s really ▶

BELOW Citroen's WTCC simulator uses VI-grade technology. Yvan Muller and José María López both agreed that the latter's use of the simulator had played a key role in beating his more experienced colleague to the 2014 WTCC crown

BELOW Porsche's successful LMP1 prototype has been developed with the use of the Driver in Motion solution

useful for doing 'what if' studies."

The nine degrees-of-freedom DiM platform has been designed in order to take full advantage of VI-MotionCueing, an innovative motion cueing strategy developed in collaboration with the University of Padua in Italy. The technology enables the extension of the motion envelope and the separation of low and high frequency contributions, which makes this type of motion platform suitable for both vehicle dynamics and ride studies.

"Our motion cueing is also based on a completely new approach that is focused on maximising perception by utilising the full DiM motion envelope," says Ferrarotti. "By focusing on the driver, seat displacements and accelerations, a more accurate and meaningful feedback is provided. It means that cars can be tested on circuits with laboratory-like consistency with different conditions being simulated."

Porsche Motorsport has been one of the first DiM customers, using the simulator to set its LMP1 cars up before the start of the season as well as testing and optimising them as the year has unfolded. Every circuit that the cars have and will race on in the World Endurance Championship has been digitally captured so that the drivers and engineers can enjoy extensive testing sessions. The fact that it worked well was reflected in Porsche's win at Le Mans.

"Of huge importance is that the data recorded on the simulator is obtained on a realistic track so that it can be compared with telemetry data," says Ferrarotti.

"The DiM solution meets our specifications and expectations for a system that complements our existing engineering process," says Dr-Ing Malte Huneke, manager performance LMP, Porsche Motorsport. "The driving simulator is a new, innovative tool for the development of our racing cars, starting from the new LMP1 prototype, as well as in the training process of our drivers, on different tracks and in different driving conditions."

The next stage of DiM development, says Ferrarotti, is developing a more sophisticated tyre model. "The challenge is now to put a reliable and accurate tyre model in real-time, so we are talking to the main tyre manufacturers and the providers of models to implement them in such a way that they can be run in real-time."

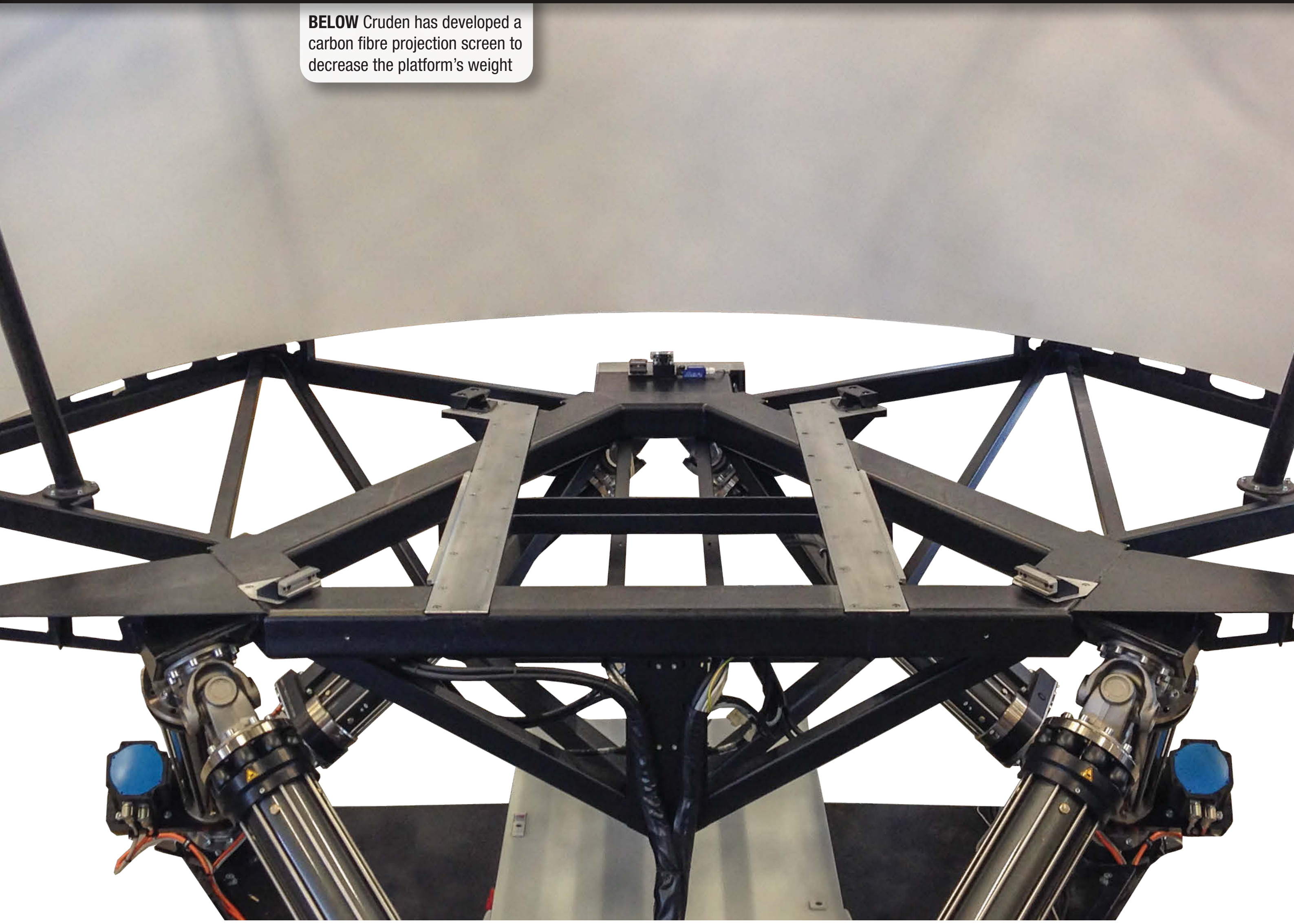
LIGHTWEIGHT REACTION

A consistent problem simulators face is reaction time. Due to their sheer weight, the pneumatics and hydraulics are not able to react in real-time, causing the reaction to be a delayed process. To overcome this, Cruden has developed a carbon fibre projection screen to decrease the platform's weight while also reducing the force and energy required to move the platform.

An additional new feature is the interchangeable driver cell which is proving to be particularly useful for those teams that run cars in different race series. The new design allows different cockpits from various racing series to be changed and fitted in around 30 minutes, without the need for specialist moving equipment. The simulator can also recognise which cockpit is in use by the joining pins as each one has its own unique arrangement.

Cruden has also addressed the issue of drivers not being able to feel all the vibrations coming through the vehicle by using actuators positioned around the driver's cell. These then produce vibrations through the chassis and adjust the height of the simulator accordingly to every detail of a track.

Late last year Cruden announced that it had developed a new approach to motion-cueing that combines vehicle side-slip angle and dynamic varying yaw pole. Following the introduction last year of enhancements to its ePhyse external physics package, which allowed new levels of motion-cueing customisation on its simulators, Cruden has recently presented its own interpretation of the interface. Adding vehicle side-slip angle and dynamic varying yaw pole to



BELOW Cruden has developed a carbon fibre projection screen to decrease the platform's weight

existing motion cues overcomes the limits of traditional acceleration cues. It is particularly useful in providing realistic feel of oversteer and understeer.

"There are limits to how well a motion-based simulator can cue acceleration on the longitudinal and lateral direction because the available space is used quickly and the feeling cannot be sustained," says Edwin de Vries, senior vehicle dynamics engineer at Cruden. "We understand that some vehicle dynamics teams, particularly in professional motorsport, need more.

"Our novel cueing method imposes the vehicle's side-slip angle – a signal that fits, unmodified, within the motion space – on the platform's yaw angle to avoid washout and high pass cueing filters, enriching the driver's handling perception.

"We can show a reduction of the latency of platform motion with respect to simulated vehicles; the yaw response is more crisp than with the traditional cueing," says de Vries.

With the new ePhyse add-on, Cruden's customers are able to bypass the standard cueing algorithms and command direct platform set points from within the Simulink environment; the motion base software continues to manage the system's inverse kinematics, workspace and safety aspects. This opens up opportunities for advanced cueing techniques like model predictive control or prepositioning.

LET'S RACE

Self-publicised as the first and most advanced Formula 1 racing simulator in the world, LetsRace, which is located in southern England close to Gatwick airport, at first sight appears to be little more than an entertainment centre for corporate events and the general public. However, look a little closer and it becomes apparent that there is far more to it.

To start with, it is the simulated motor racing arm of the Capsicum Motorsport group, the company that was set up by Grahame Chilton, father of former Formula 1 driver Max and current World Touring Car Championship driver Tom. Capsicum also owns Carlin, one of the most successful single-seater teams outside Formula 1.

It is also very well equipped with 10 full motion networked simulators. They are arranged in two rows of five, each single-seater car sitting on a modified motion bed – that has come from the medical industry – under which are three motors to drive it. There is also a ball screw and a nut and a very clever twin bearing design to allow the back to pivot independently of the front, and vice versa. The driver is confronted by three monitors that are aligned to deliver a single wraparound panoramic view.

Ensuring that everything is running smoothly for customers and teams alike is the responsibility of simulations engineer James Dover, who has a background in both motorsport and the computer games industry. He is currently upgrading the simulators to run on rFactor 2.

"Not only does rFactor 2 have upgraded graphics and a truly dynamic racing environment for the first time, it allows us to scale the motion bed control to the customer," says Dover. "So for the ▶

inexperienced person, who just wants to have fun, it might be set to low or even off; for the professional racing driver, it can be set at high."

The graphics run at around 150 frames per second (fps) and while the simulators have the capacity of running at 600 fps, Dover says that he has opted for the lower rate to avoid any possibility of motion sickness: "If a couple of frames were to be dropped and lost in translation, it's not picked up by the motion bed and it still moves. The human mind will realise that something's missing and it's that which causes the motion sickness; whereas at 150 fps, the display remains nice and smooth."

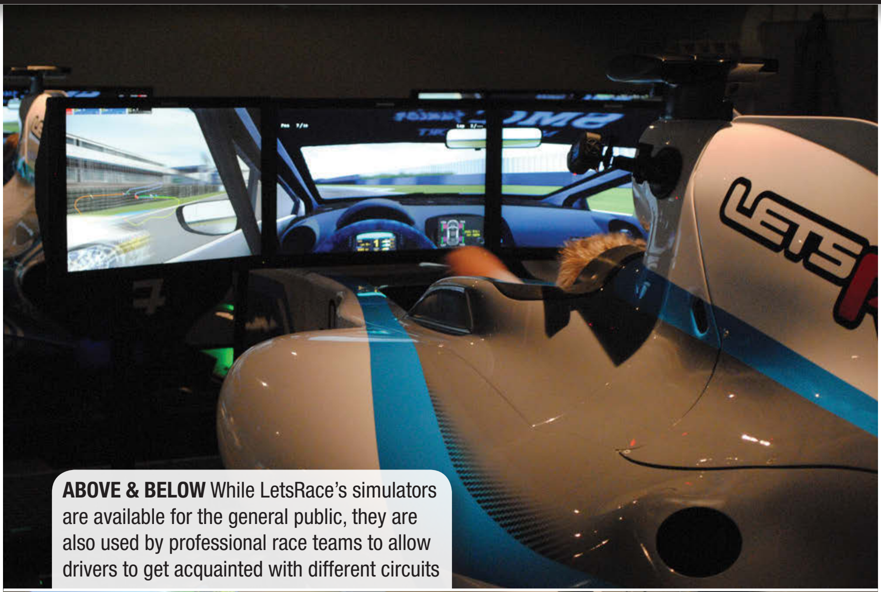
The car data is generally supplied by Image Space Inc (ISI), the Michigan-based company that has developed the rFactor racing simulation series which Dover says is pretty good straight out of the box. "We do have to change the basic setup for certain tracks," he explains. "For example, there's a very specific setup for Monaco because if you try to drive around with the setup you had at Spa, it probably wouldn't work. The steering lock's wrong, there's not enough aero, it's on the wrong tyres, the spring rates are wrong and the ride height's too low, so we have to go and change it anyway.

"Normally the only car changes we make are things like adjusting the ride height, tyre pressure and the spring damping rates. These make the car behave like we want it to, rather than trying to change the physics model itself.

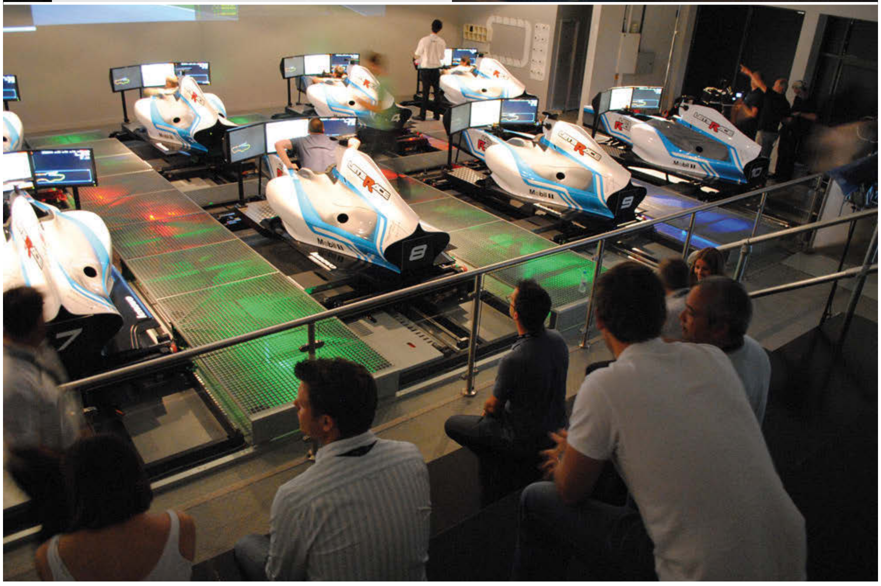
"However, if we need anything else specific for our simulators, we contact Adrian Quaife-Hobbs. He's our next door neighbour, runs Pro-Sim and has a vast data field, especially with things like GP2 and Renault 3.5 cars."

The relationship with Carlin is very close, the two companies working hand in glove with each other. "Carlin runs rFactor and has an impressive data field as well," he notes. "We sometimes collaborate with them to decide what the best thing would be. When they need help, I go there, and vice versa if I need help here."

When it comes to the professional driver, the most valuable commodity that LetsRace can offer is usually seat time. "A team can come here for a fraction of the cost of hiring a professional simulator," says Dover. "We don't have their steering wheel, pedal box or moulded seat, but for pure seat time to go and learn a circuit and get some sort of reference points, it's really good. For example, Max Chilton has been coming here to learn as many of the US circuits as he can, something he wouldn't really be getting at Carlin."



ABOVE & BELOW While LetsRace's simulators are available for the general public, they are also used by professional race teams to allow drivers to get acquainted with different circuits



Many of the circuits are released by ISI but then modified by Dover if necessary. "We can totally deconstruct the circuit and change it in the way that we want," he says. "For example, a large sausage kerb was installed on the second chicane at Melbourne that we didn't have on our model. That led to a lot of people cutting the chicane and getting faster lap times than were being achieved by the real cars, so we have remodelled it with the sausage kerb."

While the simulators are all single-seaters, LetsRace still has customers who are racing in GTs or other saloon-type cars. These include a couple of Fun Cup endurance teams that come for seat time. "They do 20 minutes in their Volkswagen Beetles and then tell us how they need to be modified to be as close as possible to the real thing," says Dover. "Sometimes it might be too much rear end grip, which then involves adjusting the ride height or taking air out of the tyres. We can also adjust the physics model, but that's only as a last resort as it gets a bit involved."

The data is robust enough to be used as a basis for setting up the real car, as Dover explains. "We can pull the data straight out of the model and give it to teams who can then take it away and do what they want with it. Nine times out of 10, especially with rFactor 1, the data pulled out about the ride height, damping rates and camber is somewhere close and a good ballpark starting place."

Conversely, teams can supply their own data which can be loaded into the simulators. "For teams that want to practice around a circuit, we do what they want to do," he notes. "So if they say, 'This is the setup we ran last year,' we can load it into the car for them and then adjust it following their driver's comments – even while he's in the car." ▶

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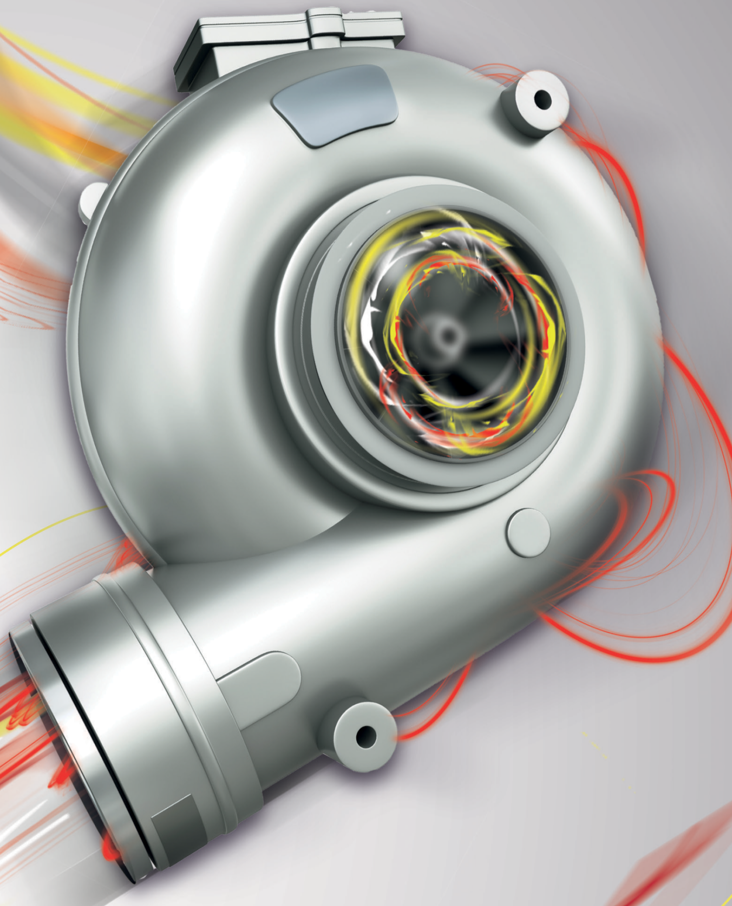

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TRACKDAY

As with the digital watch back in the day, as time moves on, so the cost of simulators comes down, *writes Scotty Whitelaw*. What was once just the domain of Formula 1 and NASCAR teams is working its way down so that they are now within the reach of pretty well every aspiring racing driver. Naturally some are better than others, and the technology involved in them is also widespread, giving the prospective customer a bit of a headache sorting out which gives the bigger bang for the buck.

Of all of the simulators I have been fortunate enough to use, a select few of them stand out from the rest and one such is The Simulator's 'TrackDay' system. One feature that is lacking in most simulators is the ability for the user to feel the precise road conditions, such as bumps and kerbs. This is one area where The TrackDay excels.

It utilises a hydraulic ram that moves the seat backwards and forwards and side to side, simulating the g forces when cornering, braking and accelerating. The driving experience is further enhanced by the use of four ButtKickers – silent speakers as seen in a surround sound cinema – located in each corner so that when the car is driven over a kerb, they create vibrations from that particular quadrant of the simulator that go through the chassis which the driver then feels. Along with these come engine tone, gearshift and other information that combined with the movement of the seat and the horizontal plane movement at the rear of the simulator all add up to give a very immersive experience.

Another area in which this simulator sets itself apart from many others is with its rear traction loss control system. Unlike others where the driver doesn't get the feeling of the back end stepping out until it becomes too late to salvage the situation, with The Simulator he does. "When a car oversteers, the front stays where it is and the back moves," says George Pilkington, managing director of The Simulator, "and that's precisely what happens in our simulator to create a perfect representation of oversteer. This is because the rear of the simulator moves in the horizontal plane and the front as in real life remains where it is on the track. Due to this motion, the driver is able to feel when the rear becomes unstable and so can react to it."

The TrackDay simulator can use both rFactor or iRacing software, says Pilkington, pointing out that every track and vehicle is laser scanned to ensure that no detail is missed. Due to this method, every change in transition or bump is accurate to within a thousandth of an inch.

While the TrackDay simulator is superb for driver development, it is also very beneficial for engineers. iRacing has allowed different track data software to be linked up with its own Atlas and MoTeC, which enables teams to train race engineers on the system without having to run actual track days, thereby saving a small fortune. RT

BELOW Heading for Eau Rouge in The Simulator's 'TrackDay' sim