IS THIS A MUST-HAVE TOOL FOR AERODYNAMICISTS?

Chris Pickering investigates a real-time 3D flow visualisation technology that is already helping cut complexity, time and cost in a number of diverse sectors

THE flow of air around a car's bodywork is a mysterious thing. It can't be seen, and it can't even be felt with any meaningful degree of accuracy. And yet this intangible force plays a bigger role in the performance of a modern racing car than anything else.

Aerodynamicists have been grappling with ways to measure and visualise the flow of air for more than a century. Their solutions range from qualitative methods, such as wool tufts and smoke generators, through to 3D point scans and complex optical measurements such as particle image velocimetry (PIV).

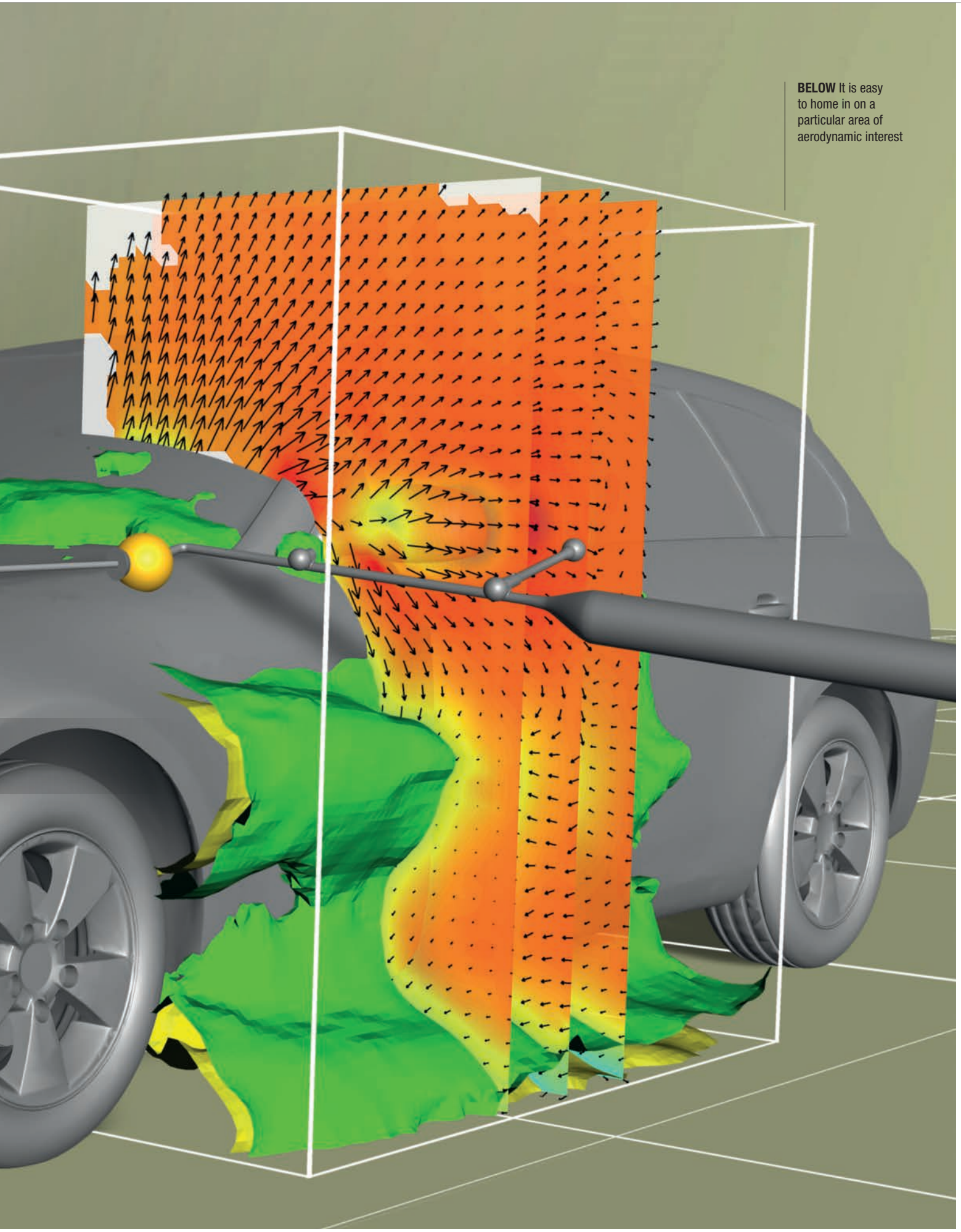
All of these techniques have their own advantages. And into this mix, Swiss company Streamwise has introduced its new Probe Capture (ProCap) technology, which is claimed to combine the simplicity of a handheld smoke probe with the detailed quantitative and qualitative data that's provided by a point scanning system. So could it prove to be a must-have tool for motorsport aerodynamicists?

The business end of the ProCap system is a 3D printed handheld probe from Vectoflow that can be equipped with a variety of interchangeable tips. These contain multi-hole sensors that are able to measure the pressure, velocity and temperature of the air.

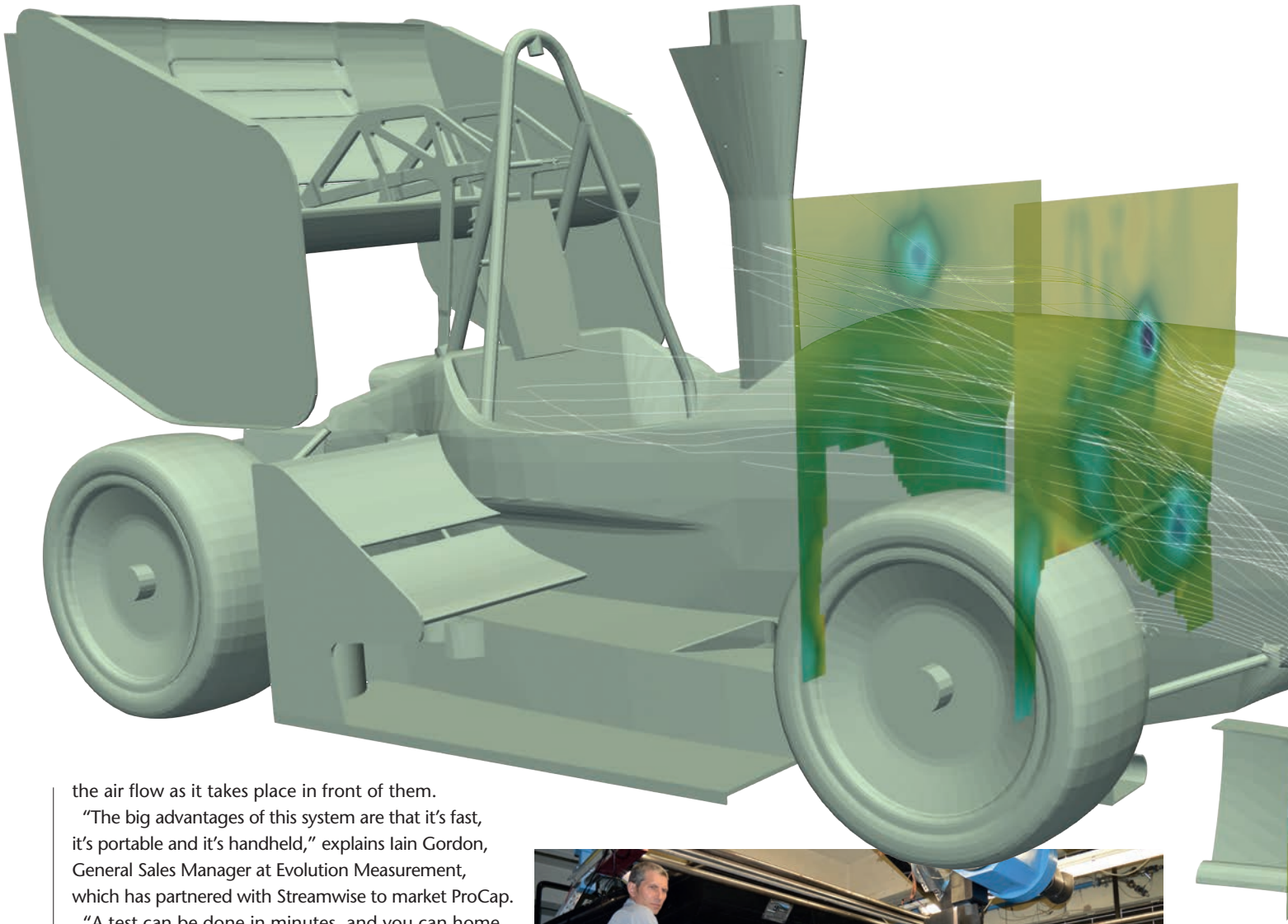
> *"The beauty of this system is that you can move around to find your point of interest"*

CFD-style visualisation

The probe can be moved anywhere around the flow field to capture the instantaneous conditions at this point. Its movement is tracked using a series of cameras that record the three-dimensional position of the probe to sub-millimetric accuracy. Streamwise's software can build up a 3D map of the results in real time, which can then be overlaid on a CAD model to give CFD-style visualisations of the real-world flow. This can be displayed on a screen or projected onto a wall, so the engineer carrying out the test can visualise ▶



BELOW It is easy to home in on a particular area of aerodynamic interest



the air flow as it takes place in front of them.

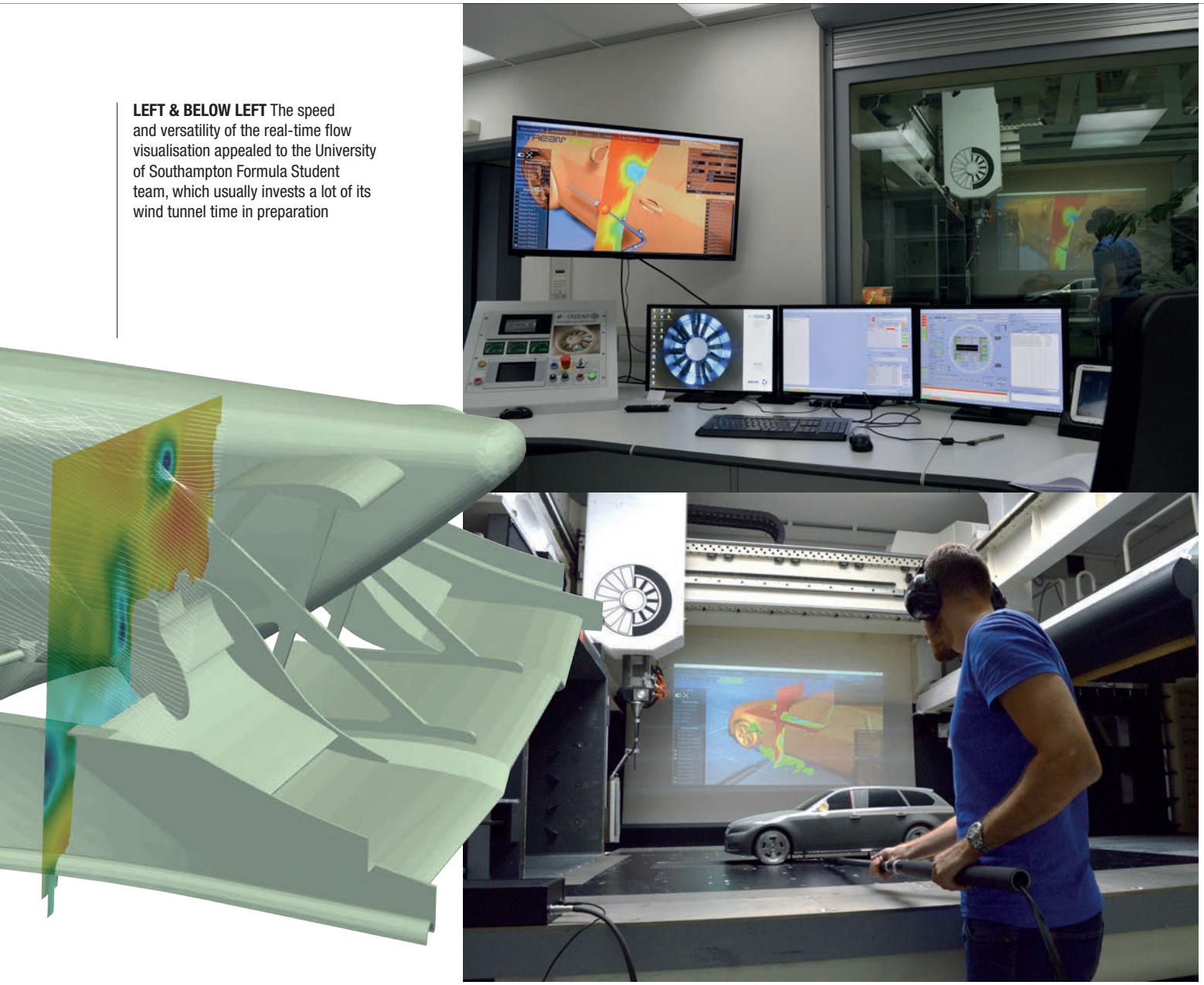
"The big advantages of this system are that it's fast, it's portable and it's handheld," explains Iain Gordon, General Sales Manager at Evolution Measurement, which has partnered with Streamwise to market ProCap.

"A test can be done in minutes, and you can home in on particular areas of interest. For instance, we did a study at the Silverstone Hub looking at the flow around a racing bicycle, and it turned out that the

> *"Painting colours in the air: you can visualise the pressures and velocities in real-time"*

area around the rider's elbow was particularly critical. We could see, in real detail, how the vortices broke away, the flow starts to detach from the surface, and you get a low-pressure area that generates drag."

ProCap is not that different in concept to the point measurement systems that robotically manoeuvre a probe around the flow field. One of the key differences, however, is the level of engineering that goes into the hardware. The traversing rigs in the point scanning systems use very expensive stepper motors to provide highly accurate motion control; they also need to be extremely stiff to hold the probe in a precise location anywhere in a wind tunnel that could cover an area of 20 square metres or more.



LEFT & BELOW LEFT The speed and versatility of the real-time flow visualisation appealed to the University of Southampton Formula Student team, which usually invests a lot of its wind tunnel time in preparation

"When you see those structures, you can really see the engineering that goes into them," comments Gordon. "Normally, they have a huge fin coming down from the roof, which is effectively a giant robotic arm. They're a seven-figure investment, and only a handful of facilities have them. In contrast, we're talking about low-to-mid five figures for the ProCap system, so it's several orders of magnitude lower cost."

Significantly quicker

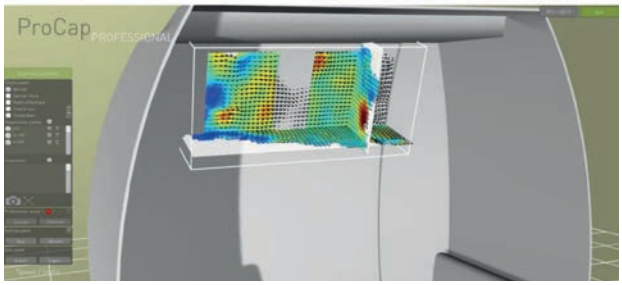
ProCap provides a comparatively affordable means of carrying out similar studies. It's also said to be significantly quicker than a traditional 3D point scan. Not only does it avoid the lengthy programming process required to set up a traverser, but the real-time results mean that the engineers can identify and analyse the crucial areas of the flow field as they go along, skipping areas that a traverser would continue to sample on its pre-programmed route.

However, ProCap still has its limitations. For instance, placing an engineer inside the tunnel with a handheld probe limits the wind speeds that can safely be achieved. And although it's possible to extend the speed range with some sort of rig, it becomes uncomfortable at some point. On the other hand, you can go much closer to a surface and even into cavities with the hand-held approach. As Gordon points out, the two technologies complement each other, rather than competing against one another.

"We've taken ProCap to a number of high-performance road car manufacturers that have traversers, but they also see value in having a handheld device that can operate very quickly," he comments. "You can gather a lot of interesting data at low air speeds, which shows you the areas to focus on. We talk about it painting colours in the air, as you can visualise the pressures and velocities in real-time as you build up a picture with the probe."

According to Gordon, ProCap can be used to measure just about any off-surface pressure. The probe's compact dimensions and its handheld configuration mean that it can be used for detailed ▶

ABOVE With the probe able to measure the pressure, velocity and temperature of the air, applications already include automotive scale and full-scale testing



LEFT One of its early jobs, in the wake of COVID, was to analyse ventilation in a ski gondola

BELOW A study at the Silverstone Hub analysed the flow of air around a racing bicycle. It revealed that the area around the rider's elbow was crucial when it came to drag reduction

work around small vents and other areas that might be hard to reach with traditional methods.

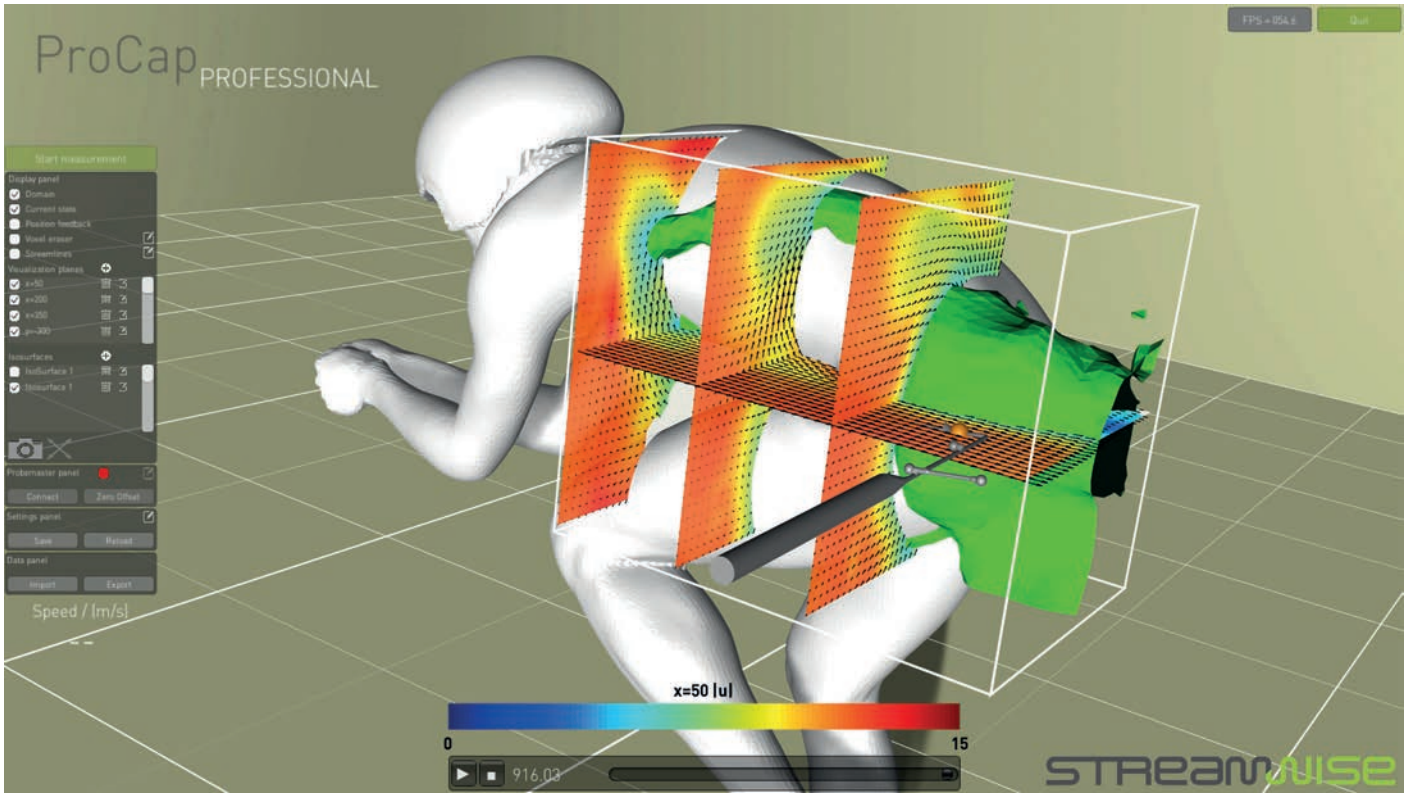
It's this flexibility that's key to the appeal of ProCap. Aerodynamicists generally have a pretty good idea of where the critical areas are likely to be on the car, thanks to CFD work, previous investigations and intuitive engineering judgement. But surprises are not uncommon, and a few minutes with a handheld probe could help to prevent costly blind alleys.

"If you drill a lot of holes in your car to measure the surface pressure, you'd have to have a pretty good idea of where you wanted to do your measurement, otherwise you risk doing that and finding that nothing interesting is happening and you need to move them somewhere else," comments Gordon.

"A lot of this complexity comes from the interaction of different features on the car. For instance, designing a rear wing it would be relatively straightforward if the air flow meeting it was completely clean. In reality, it's going to be turbulent and some of it may even be heading in the wrong direction. And those issues could be created by the changes that someone else has made to the front wing or the mirrors."

Flexibility

This is where the flexibility of ProCap comes into its own, he says: "The beauty of this system is that you can move around to find your point of interest. And while the photos and renderings that you see often show the



> *"Combines the simplicity of a handheld smoke probe with the detailed quantitative and qualitative data that's provided by a point scanning system"*

whole car, the reality is that the aerodynamicists are generally more interested in specific details like the flow separation off the door mirrors or something like that. Wind tunnels sometimes need to be booked three or four months in advance and it can be many thousands of pounds a day to hire one, so you don't want to finish the session and realise that you should have captured detail in a particular area."

There's also a significant time saving if some or all of the investigation can be carried out using off-surface readings from a device like ProCap, he points out: "We work with the University of Southampton, which has its own wind tunnel. The team there said that they allocate two or three days to put their Formula Student car in the wind tunnel and gather the data, but a lot of that time is getting the model prepared, and getting all the pressure tappings into place and things like that. They said that this could really change how you do that kind of measurement, because you can get the car in there, secure it, get the wind flowing and then start gathering data immediately."

Live data from the system can also be fed into CFD simulations. For instance, the turbulent air flow over the centre section of the car could be captured by ProCap and used as the input condition for a model of a new rear wing design. In fact, it is ideal for that as it provides both velocity and pressure field. Similarly, if a particular area of the flow is hard to capture experimentally, the input and output conditions from the wind tunnel testing could help to refine the CFD model of the air flow in between.

"CFD and wind tunnel testing should be two complementary techniques – they don't have to be kept separate," comments Gordon. "Sometimes, you've got reliable real-world data in some areas, but there are others where you just can't get that data or where you don't have the physical parts to test. ProCap effectively digitises the real-world results, so it's ideal for those sorts of scenarios."

ProCap is a relatively new innovation. So far, its applications have ranged from wind turbine development to investigating the ventilation of cable car cabins used by skiers in the wake of the COVID pandemic. But with its minimal setup requirements, accurate data and fast results, it could prove a useful addition to the motorsport aerodynamicist's tool kit. RT

ABOVE Test results can be viewed in real time