

# RaceTech

The science that drives the sport



## Aero wheel development

# Lust & Enve

For over a year, *ProCycling* has exclusively followed the development of the new Enve wheels from start to finish

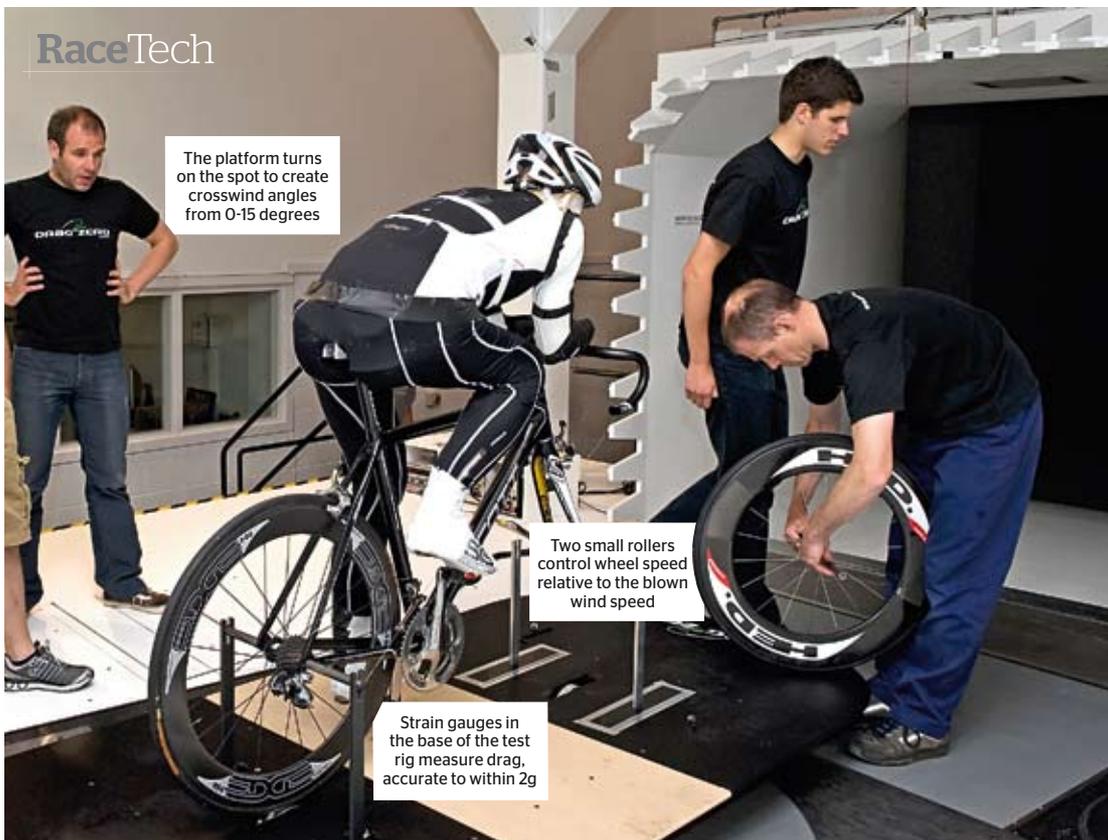
WRITER: Jamie Wilkins || PHOTOGRAPHY: Rob Monk; Will Ireland

Speed lives here. The windowless grey buildings suggest top secret work takes place behind their walls, the ambience somewhere between that of a military installation and a science laboratory. Smart Aero Technology is based inside the Mercedes F1 team's huge complex in Brackley, the heart of Britain's world-renowned motorsport valley. One look around tells you that this is a place where fast things are born.

Recent successes from within these gates include Jenson Button's 2009 world championship winning Brawn F1 car and, shaped in the same wind tunnel by one man in an office at the far end of the facility, Scott's new Foil aero road bike and Plasma3 TT sled, and the Giant Trinity Advanced TT bike before that – prolific winners all. Since Mercedes bought the Brawn F1 team at the end of 2009, the bikes developed by ex-F1 aerodynamicist Simon Smart have been doing a disproportionate amount of the winning. All of it, in fact.

The aerodynamics expertise found in Northamptonshire, England, is mirrored by the hotbed of carbon composites knowledge in and around the headquarters of Enve Composites in Utah, USA. It's a young, ◀

◀ The Mercedes GP wind tunnel shaped Jenson Button's F1 title winning car and now Enve's new wheels



The platform turns on the spot to create crosswind angles from 0-15 degrees

Two small rollers control wheel speed relative to the blown wind speed

Strain gauges in the base of the test rig measure drag, accurate to within 2g

vibrant and ambitious company that has experienced huge growth in a short time as word of their range of ultra-light carbon fibre wheels, forks and components has spread since launching in 2007. Already their wheels have been ridden by several top teams. Enve Composites – formerly Edge until global expansion brought up trademark clashes – then started to consider the aero market.

Beverly Lucas, Enve's vice president of global sales and marketing, remembers the pivotal moment. "We'd been to the San Diego wind tunnel with our stuff in **November 2008** and it tested well but not as good as any of us really wanted it to. We wanted to go really big but knew we had to make a bigger investment in order to make it happen."

The aero wheel market is packed and fiercely contested between several well established brands with many years of development behind them – you don't simply walk in. Lucas says the solution arrived by chance: "I'd come to the UK on business in **March 2009** and I was watching the Australian Formula One GP in the hotel. Back then we were sponsoring Fly V which also had Virgin branding. Then on the television I saw the Brawn GP car wheeled out and it had a Virgin sticker on the nose. I made some calls and got a

▲ Early development work was carried out using the still secret and patent pending testing rig



■ The rapid prototyping system devised for the project increases the efficiency and fidelity of the testing process



■ In partnership with Enve, aerodynamicist Simon Smart has created a whole new generation of wheels

contact at Brawn GP and requested a meeting with them. They put me on to Simon Smart who had a contract to use their wind tunnel. From the first time we met I knew he was the guy we needed."

As well as ten years of experience in F1 and two of the fastest and most successful TT bikes on his CV, Smart is a keen and rapid time triallist himself. But most crucially, he was already thinking along the same lines as Enve. The development of the Giant and Scott TT bikes had involved a lot of wheel testing and he'd soon started having ideas on how to make faster wheels than were currently offered. He just needed a manufacturing partner...

It was a perfect fit. If Enve had any doubts, it was that they might bite off more than they could chew. "I can't tell you how much thought went into this project before we committed," says Lucas. "We had to be sure we could actually make what Simon came up with."

It was decided that the new range should consist of three wheelsets shaped to fit particular scenarios: a climbing and multi-purpose set, a mid-depth road race and TT pair, and a flat-out TT set. Smart first set about conceiving a new R&D method. With an agreed target of nothing less than 'making the most aerodynamic wheel range in the world', and a number of ideas stored up from his work in frame design, Smart knew that faster wheels had to start from better testing protocols.

He was also convinced that there was plenty of room above the best existing wheels: "There are some good products out there but none tick all the boxes.

Enve has a massive opportunity," he told *ProCycling* in **May 2010**.

### Method

It was clear from the start that wheel testing had to be done in a bike. "It doesn't take Einstein to work out that when you put a wheel in the bike the flow it's seeing is being interfered with," said Smart. The current leaders in the aero wheel industry agree – Zipp and Hed developed their latest generations with Cervélo and Trek respectively. However, Smart wanted to extend the testing method further and give buyers a range of wheels that would work in a broader spectrum of bikes.

"The development of one wheel in one bike is limited because of the huge choice of designs out there. For example, you could [run your own test] with a Cervélo P3 and you'd choose a Zipp 808. You do the same test on another bike like the Trek or Giant and you'd choose a Hed S9. The consumers are completely baffled by all this information so really the strategy is to try to develop a range of wheels that work in many different bikes. We are investing a huge amount of money in doing all this development for the wheels and we can hand that knowledge on to the consumer to make sure they are actually buying a wheelset that goes fast when they put it in their bike. It's an exciting challenge to make wheels that work in multiple bikes."

Smart's process therefore requires wheel concepts to prove themselves in two very different TT bikes, the Cervélo P3 and Trek Speed Concept, and two road bikes, the Cannondale SuperSix and Specialized Tarmac. On top of this, the Scott Addict-based development rig built by Smart exclusively for Enve can include a dummy rider and ensures a high degree of accuracy for repeatable measurement of marginal improvements. Other metrics are recorded, too, but they're kept secret.

In terms of ride quality, the new aspect that Smart and Enve wanted to pursue was stability in crosswinds. Many wheels are sold on their aero performance at a particular crosswind yaw angle, "so you've got this sweet spot but can you ride it?" says Smart. "Many wheels are too unstable at their most effective angle. The big compromise is rim depth versus stability. So in the wind tunnel we're doing some really unique stuff. We're going to be the first to test stability in a wind tunnel. We've got a stiffness target, a weight target, a stability target and a drag target and we're going to put all those in the

## FROM HIS WORK IN FRAME DESIGN, SMART KNEW THAT FASTER WHEELS HAD TO START FROM BETTER TESTING PROTOCOLS



pot and test all these variations of rim width and depth.”

The pressure of producing and testing that many variations led to another innovation – a proprietary rapid prototyping system. “It allows us to test many more rim shapes in a smaller timeframe and with a greater degree of fidelity,” says Simon. Enve place such a high value on this innovation that the exact details of it are kept secret, but we can disclose that it allows the bike to stay on the rig while prototype versions are swapped. This means it avoids the risk of introducing any error and saves time.

**First test**

The first wind tunnel test is in **May 2010**. The aims are to confirm the computer modelling and create a shortlist of rim cross-sections. There are at least 19 profiles to be tested – five overall shapes are narrowed down to two, then seven micro-variations of each – and all at a full range of yaw angles and in at least two of the four bikes Smart has picked out. A measurable change in aerodynamic behaviour and crosswind stability can be seen from a change to the rim width as

small as 0.2mm. “Half a millimetre can generate a difference of five or six watts,” says Simon. After 50km that could yield as much as 18 seconds – enough to win a grand tour, let alone a club time trial.

There’s a huge amount of work to get through but behind the focus is nervous excitement. Even if they won’t quite say as much, it’s a very big day in Enve’s ambitious future. In attendance are: Brett Satterthwaite, Enve co-founder, fluid dynamicist and civil engineer; Kevin Nelson, design engineer; marketing VP Lucas, who also has a construction engineering degree; and mechanical engineer and ex-F1 aerodynamicist Smart. In this company, *Pro Cycling* feels extremely unintelligent and concentrates hard on not asking stupid questions.

Sound engineering, state-of-the-art technology and a team of brains like a multi-core supercomputer mean that there are no significant surprises or disappointments through the initial phase of testing. The shapes that looked the best in the tunnel. “This first test gave us results that we’d have been happy with as a final outcome,” Nelson comments later. One indicator of this early success is that the first patent is filed immediately after the test. With that result in the bag, there’s a new confidence and eagerness to see what more can be achieved.

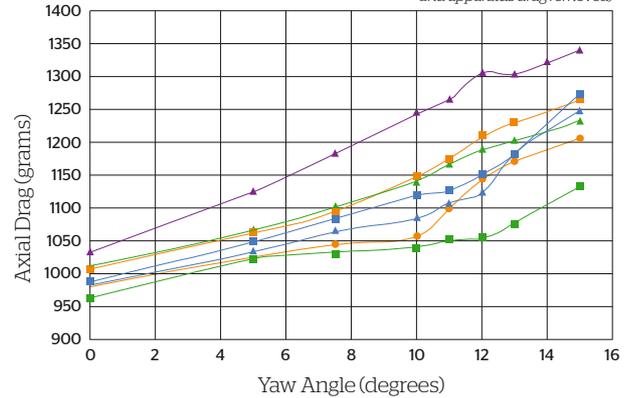
With so many performance targets, aesthetics couldn’t be a factor even if Enve – never knowingly overstated – wanted it to be. “We’re straight down the line form-follows-function. If the fastest shape

**BEHIND THE FOCUS IS NERVOUS EXCITEMENT. EVEN IF THEY WON’T SAY AS MUCH, IT’S A BIG DAY IN ENVE’S AMBITIOUS FUTURE**

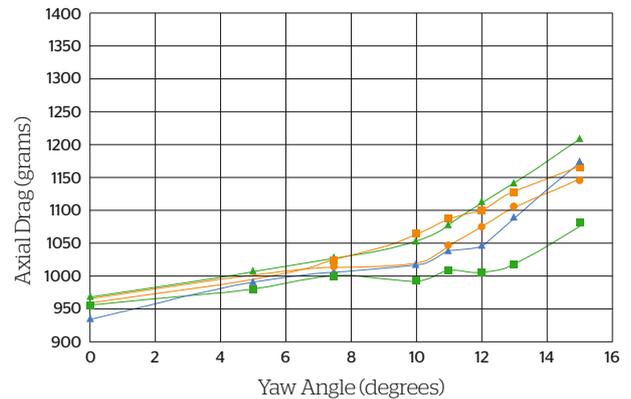
**Wind tunnel testing against other top brands**  
New Enve wheels and rivals in road and TT bikes

**Cannondale SuperSix Hi-Mod**

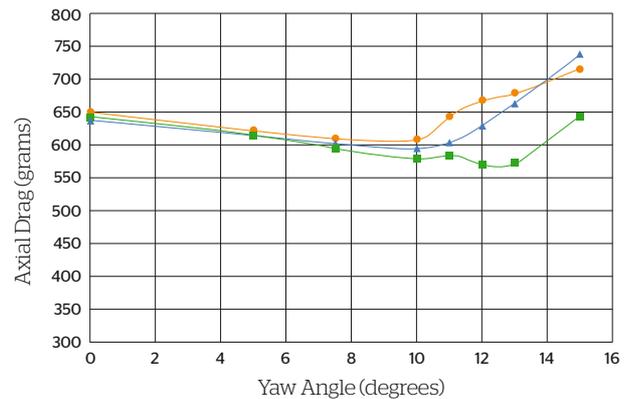
*All wheelset comparisons  
50kph, no rider (Normalised  
and apparatus drag removed)*



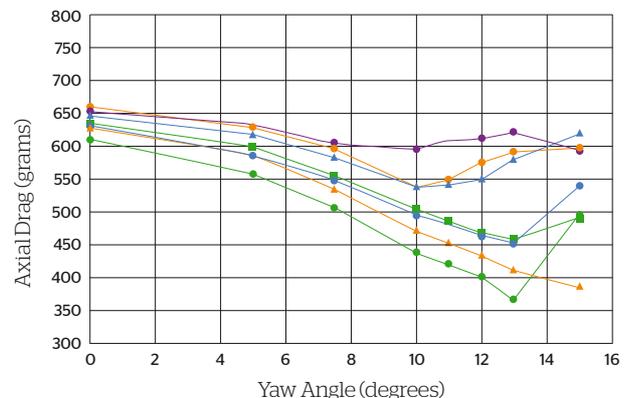
**Specialized Tarmac**



**Cervélo P3**



**Trek Speed Concept 9.8**



**Key:**

- ▲ ENVE 3.4      ■ Zipp 303      ■ HED S4      ● Bontrager Aeolus 5.0
- ENVE 6.7      ▲ Zipp 404 Firecrest      ▲ HED S6      ▲ Baseline carbon 40mm wheelset
- ENVE 8.9      ▲ Zipp 808 Firecrest      ● HED S9

looks like a cow then the new wheel will look like a cow,” says Lucas. While it’s already near certain that the new wheels will actually be black and round, they will differ significantly from anything else on the market, as Smart explains:

“The rim cross-sections will definitely be different front to rear because of the interaction with the bike and the flow past the rider’s legs. No one else does that but we know it’s the way to go. The front and rear wheels have unique jobs to do because they see totally different air flow.”

**Road testing**

Using the shapes established in the first wind tunnel test, Nelson immediately sets to work back in Utah designing the rim structures and carbon lay-ups, then making the first prototypes in carbon fibre so that they can be ridden and strength tested. By the end of **June 2010**, various Enve staff, select racers and Smart are piling on the test mileage.

The rapid progress is possible because of the relatively small number of people involved and Enve’s in-house design and manufacturing. It’s also boosted by how Nelson and Smart are so tuned in to each other, as Lucas has noticed: “It’s a joy to watch them together. They’re completely on the same wavelength. They really spark off each other. There’s always the challenge of 7,000 miles between them but it’s a great relationship.”

In **July 2010** a second wind tunnel test rules out one whole concept for being too heavy and complicated to manufacture, though they’re keeping the details quiet as it may yet be useful in the future. At the same time, a ‘top pro team’ tries out prototype wheels in secret, with very favourable results.



▲ The 85mm front rim from the 8.9 wheelset surprised all the test riders with its stability

**Key:**

- ▲ ENVE 3.4
- ENVE 6.7
- ENVE 8.9
- Zipp 303
- Zipp 404 Firecrest
- Baseline alloy 24mm wheelset
- ▲ Baseline carbon 40mm wheelset

It raises the question of whether Enve will look to sponsor a top flight team to showcase the wheels. “ProTour is the ultimate test,” says Lucas. “They know what they want and won’t settle for less. It’s the level of racing, the distances, the high expectations...”

“I’ve had calls from a couple of ProTour teams in 2010 and I said to them, ‘Okay, what do you need?’, and it’s always a monetary figure first rather than the product. Then you look at other managers who say, ‘I won’t take anything less than the best stuff and my guys get to choose what they like.’ We’re looking at teams like that, who won’t compromise.”

By **November 2010** the rim profiles have all been finalised and a second patent application is submitted. Significantly, this one is for the ground-breaking and now proven R&D process as well as for the new shapes and the 10mm difference in depth between the specific fronts and rears in each pair.

**Gearing up**

Going into **spring 2011** the workload shifts back to Enve in Utah. “We had to live up to Simon’s expertise,” says Nelson. “The sensitivity of the shape meant it

**First test ride**

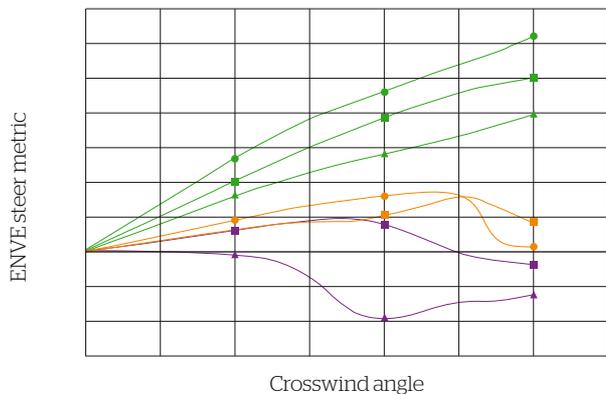
Riding the new Smart Enve System 6.7 wheels



ProCycling had an exclusive early test of the 6.7 wheelset in March. That easy aero feeling was there as we rolled along on the flat, still chatting casually at 32kph, and during harder efforts we found that speed clings to them like pollen to a honey bee. Stability in crosswinds is hard to judge without a windsock every 200m to show you what you’re dealing with. However, when the roadside flora and fauna is blowing around but your bike isn’t, it’s clear how the Smart Enve System improves stability.

**Stability graph**

**ENVE front wheel benchmark test at 50kph**  
Steering torque vs crosswind angle  
Apparatus drag removed, data normalised  
Front wheels only



couldn't be compromised to meet the structure. It was a case of refining what we had already been doing by tightening up the tooling tolerances. We also wanted to improve the braking further but we had to use a new method because the new brake track is part of the shape. That was the hardest thing to overcome."

Enve co-founder Jason Schiers explains why such an ambitious undertaking appeared to run so smoothly: "Our culture is about constantly challenging ourselves to innovate. In a different company with a more structured environment this project could have caused a lot of headaches."

The focus in early 2011 is on establishing production processes that maintain the fidelity of the design. Every time the Enve engineers adjust a piece of tooling or the carbon lay-up, another prototype is sent to Smart to ensure there's no loss of performance, however small.

The final comprehensive wind tunnel test takes place in **March 2011** to test all the wheels in all four frames against their rivals, producing the data represented in the graphs on these pages. The first full production spec wheels will also be tested in early May to validate the manufacturing fidelity against the concepts.

## Stability

It's one thing for a wheel to be aerodynamically effective in a varying crosswind but it's quite another for it to be rideable. Ease of handling and confidence stem from predictable behaviour which in turn owes everything to a linear response from the wheel as the crosswind changes. As is so often the case in any interaction between man and machine, from the brakes in your car to your PC's mouse, linearity allows the user to calibrate their actions and working in harmony with the machine – in this case, their bike.

Smart's wind tunnel rig allowed him to measure the steering torque applied to the front wheel by a crosswind. Baseline tests with existing wheels that were known to be tricky to ride in gusty conditions showed a non-linear response to crosswinds. That is, as the wind angle increases you might have to steer into it



▲ Now ProContinental, the UnitedHealthcare team provide Enve with quality feedback from top level race situations



■ Enve's Kevin Nelson formed an excellent partnership with Smart, ensuring the carbon fibre lived up to the aero

more but then if it increases again past a certain point then you would need to steer against it a lot less.

By designing this in from an early point, Enve and Smart were able to achieve a near-perfect ratio of steering input to angle. That means that you can run your deeper, faster wheels when everyone else is reaching for their skinny back-ups.

## Ready to launch

The Smart Enve System goes on sale in **June 2011**, led out by the 6.7. There's no doubt that it has the performance to shake up the market but, even so, for a relative newcomer to challenge the hegemony of Zipp and Hed will be seen as brave. The point certainly isn't lost on Enve co-founder Jason Schiers: "We know that what we're doing is like picking a fight with an 800lb gorilla. There are some good products out there but after more than 1,000 individual tests and hundreds of hours in the Mercedes GP wind tunnel we know that we'll have the lightest, strongest and fastest wheels.

"What we're launching now is just the tip of the iceberg. We know we can keep this momentum going and we've no intention of letting off the gas." ▶

## Smart Enve System

These wheels will either be under you or beating you



**3.4** - 35mm front, 45mm rear, 1,250g per pair. A climbing wheel with aero properties that can do anything from mountain stages to sportives. Excellent stability makes it ideal for time trials or triathlons on windy days.

**6.7** - 60mm front, 70mm rear, 1,415g per pair. The fastest mid-depth wheelset available with a stability index suitable for experienced riders in all conditions and novice riders on calmer days. Best weight and stiffness in its depth category.

**8.9** - Specification and weight to be announced. Proven in testing as the outright fastest wheelset when in a TT bike, with class leading weight, stiffness and stability. Usable by experienced riders in all but the windiest conditions.

(Weights are for wheels built with 20/24 Sapim CX Ray spokes and DT Swiss DT240s hubs)

**STABILITY MEANS THAT YOU CAN RUN YOUR DEEPER, FASTER WHEELS WHEN EVERYONE ELSE IS REACHING FOR THEIR SKINNY BACK-UPS**