2011 FELT DA

FELT bicycles

INTRODUCTION: IMPROVING ON EXCELLENCE

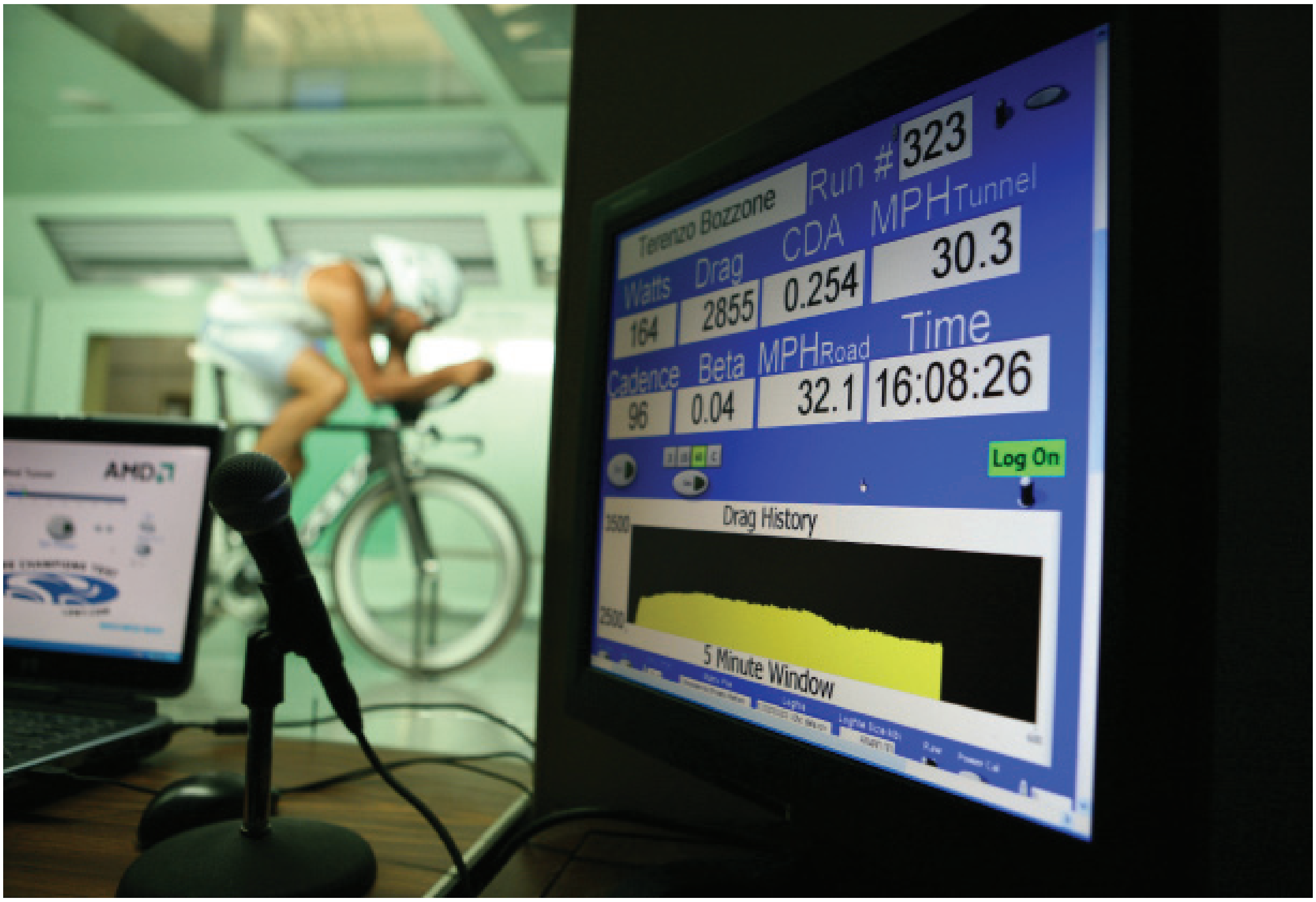
How do you improve a bike that revolutionized the concept of aerodynamic performance? That was the challenge faced by the engineers who designed the 2011 Felt DA.

When the last-generation DA was introduced four years ago, it redefined the possibilities of aerodynamic performance with unique engineering solutions that changed the way people think about TT/Triathlon bikes. The DA's Bayonet Steering System, which placed the fork steerer outside of the head tube, was a novel approach to an age-old standard. The carbon fiber frame material and shapes were the result of years of computerized and real-world analysis.

The DA wooed triathlon's greatest champions, names like Michellie Jones and Tim DeBoom, into riding Felt, and it won countless major races. Triathlons, World Time Trial Championships, major stage races. All those victories, plus the wind tunnel data and objective reviews, earned the DA its title of World's Fastest Bike.

Over the last few years, the quest to produce a bike that could match the Felt DA's performance got serious. As the triathlon/TT market grew, major brands emulated Felt's commitment to it. Recently, some of these manufacturers started launching new bikes with in-house comparison tests showing their bikes to be faster than the DA.

With these comparison tests becoming a common marketing tactic, we think it's important to state Felt's position. The first thing to point out is that no other manufacturer has tested the 2011 DA. Therefore, any result you see comparing another brand's 2011 model to a DA is analyzing old Felt technology. And as this White Paper shows, the last-generation DA, as ground breaking as it was, has been vastly improved upon in terms of aerodynamics and stiffness.



A few more points about comparison tests from bike manufacturers: Obviously, they're not objective. Every manufacturer takes a different approach, and comparing data obtained by one company's wind tunnel test to another's is apples to oranges. Even the smallest adjustments in testing standards can significantly skew results.

Felt was one of the first bicycle brands to make a practice of wind-tunnel testing. We've been doing it for nearly 20 years. But even with all the testing we've done—with Felt bikes and competitors' bikes—we've never published comparison tests. Why add to the confusion? Tailoring tests to favor a given result is not Felt's way.

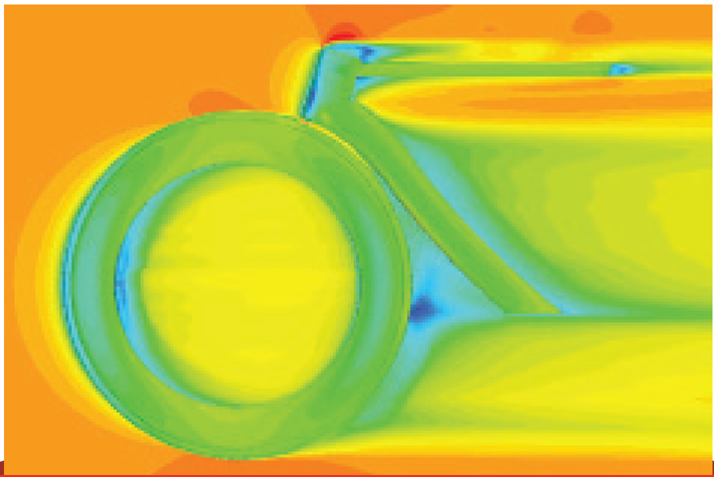
Instead, we report how our designs improve each year in terms of weight, stiffness and, in the case of the DA, aerodynamics. Yes, we pay attention to the competition. We test the competition. But as the leader in aerodynamic technology, our ultimate goal is to advance our own designs. If we do that, we win.

Which brings us back to the 2011 Felt DA. Prototype versions have already been ridden to pro victories. This is important to us. Felt athletes play a critical role in the development of new products, so no matter what the numbers say, we're not happy until our athletes are happy.

This summer Felt received an e-mail from veteran Garmin-Transitions pro David Millar. As a TT specialist who has won major races and worn yellow jerseys, David's opinion matters to us. Here's what he said about the 2011 DA:

"The TT bike is beautiful. It's noticeably stiffer, even under low power it feels stronger and more robust, especially out of the saddle. At high power, in my full TT position, it feels amazing. Every pedal stroke feels wonderfully solid. This new one is a whole different level."

It took years for Felt engineers to meet their challenge. To learn more about how they did, read on.



FIRST STEPS: COMPUTATIONAL FLUID DYNAMICS

Perhaps the most impactful element of the new DA's design was the use of a powerful technology called Computational Fluid Dynamics, or CFD. Commonly used in the design of F1 race cars and multi-million dollar yachts, CFD is a mathematical modeling process that uses computers to measure aerodynamic performance. Using CFD allows Felt engineers to accurately predict the way different frame shapes and designs will perform aerodynamically.

Long before any physical construction of the new DA occurred, Felt was refining its design ideas with CAD (Computer Aided Design) software. Incorporating CFD into this process allowed them to measure airflow over the frame's surface shapes while they were being developed in CAD. The key is high-powered mathematical calculations, which is where one of Felt's key partners, a company called CD-adapco, comes in.

CD-adapco's products allow Felt engineers to crunch massive amounts of data in as short a time as possible. This was Step 1 of the DA's development process. To understand just how big a role CFD plays, consider this statement from Felt engineer Tim Lane: "Before running the CFD models, we had no idea what the new DA was going to look like. The CFD results have determined the shape of every part of the bike."

Bill Clark, CD-adapco's Senior VP of Sales and Support, said Felt's use of this technology is a real breakthrough in cycling aerodynamics. "Just a few years ago, Felt's use of simulation would have been unthinkable because serious aerodynamic simulation was the sole preserve of the aerospace community, race car manufacturers and large automobile OEMs, each of whom employ large teams of dedicated specialists working around the clock to churn out engineering data capable of positively influencing the vehicle design," Clark said.

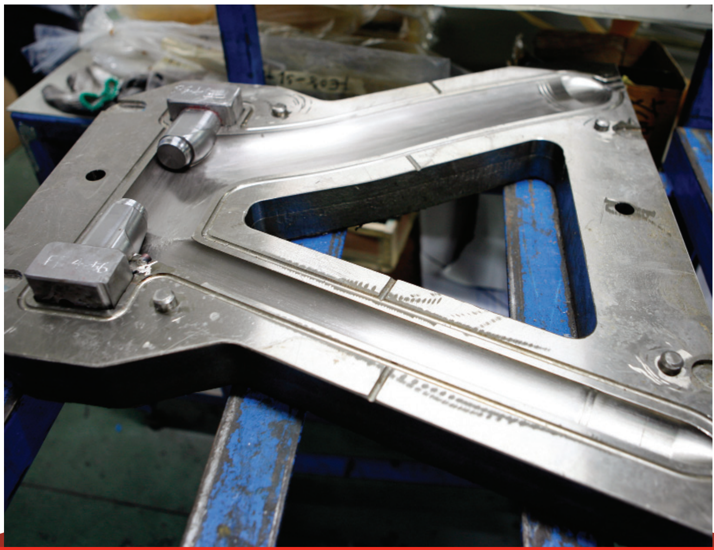
Felt relies on CD-adapco's powerful software for a variety of projects, but with all that's riding on this new DA, no expense was spared. In this case, Felt engineers used a supercomputer called BoxCluster. The BoxCluster is basically the Bugatti Veyron of computers. With 16 processors in one screaming-fast box, it's capable of working through more than 100 billion calculations per second.

"Felt used CFD to explore their designs and to reduce the amount of expensive physical testing," explained Clark.

Indeed, with the BoxCluster, Felt was able to eliminate the guesswork and speed up the development phase.

"Basically, it's like having a wind-tunnel inside a computer," Lane said. "Faster computers allow quicker CFD analysis, so we can test many variables—different aerofoil sections, alternate tube shapes, interactions between the rider, frame and wheels—and we can either isolate them or analyze combined sections of the bike."

Of course, actual wind tunnel testing—as well as rider feedback from Felt athletes and engineers—was equally important. That comes later in the development process.



MATERIALS ENGINEERING

It's no secret that carbon fiber is considered the ultimate material for high-performance bikes. High-grade carbon fiber formed the building blocks of the original DA, and does so again in the 2011 DA. Truthfully, little has changed in the raw material itself. The benefits of carbon fiber are well-documented: just as stiff and strong as aluminum, but lighter. And, equally important, carbon fiber frames can be "tuned" to yield exactly the type of high-performance ride that engineers (and riders) desire.

But the secret to achieving the desired performance in the DA—the performance that Felt's multiple Olympic champions, Ironman winners and National TT champs demand—lies in the engineering of the material. Because, contrary to popular belief, engineering and manufacturing carbon fiber frames is much more complicated than engineering steel, aluminum or titanium frames. There's much more to it than simply selecting a high-grade material, creating a mold, and cooking up framesets. Even with the best raw carbon fiber, all of the bike's performance characteristics—weight, structural integrity, stiffness, etc.—are affected by both the shape of the tubes (which, in the case of the DA, must meet strict aerodynamics goals) and the arrangement of the carbon fiber sheets, or "plies."

Constructing the DA has its own particular challenges. First, it's made with only the highest grades of carbon fiber. These have a higher tensile modulus and are therefore stiffer. This is a good thing. However, high-grade carbon fiber can also be trickier to work with because of the need to maintain a balance between stiffness, strength and durability. It's that balance that Felt always strives for. A frame that's simply lighter, or stiffer, isn't necessarily better. The goal is to consider the bike's intended purpose and balance those qualities.

The DA is also unique because of its emphasis on aerodynamics. In this case, Felt engineers were willing to add surface area, and thus weight, to improve aerodynamic performance. This differs from Felt's F Series road bikes, which favor light weight over all else. As stated earlier, the engineering goals for the DA were: 1. Aerodynamics; 2. Stiffness; 3. Weight.

But that doesn't mean weight isn't important. To keep the frameset as light as possible, the DA utilizes Felt's highest-grade carbon fiber blend called UHC (Ultra Hybrid Carbon) Ultimate+Nano. The secret to UHC Ultimate+Nano frames lies in a proprietary resin matrix. With most carbon bicycle frames, standard epoxy resin is used as a binder to hold the individual fibers together in their desired locations and orientations. But Felt's Nano Tech is anything but standard. It actually enhances the performance of the frame at the molecular level of the resin with a stronger bond between the individual fibers.

This system results in improved impact strength, and it also enhances the performance characteristics of the bike. How? By giving Felt engineers more options. With improved strength and impact resistance, they can use more of Felt's UHC Ultimate material to add stiffness without the frame becoming too fragile. The thinner walls, improved stiffness and snappy ride quality are all results of the Nano Tech resin.

Raw carbon fiber comes with different levels of modulus (60T, 40T, 30T, for example), but as the name Ultra Hybrid Modulus implies, the DA frame doesn't consist of just one type of material. It's a proprietary blend that's custom made to optimize the unique advantages of the different grades of carbon fiber. For example, stiffer fiber plies may be used in areas of peak stress such as the bottom bracket shell and down tube while higher-strength fiber plies are used in areas particularly susceptible to impact.

Once the perfect blend of materials for the DA was established through CAD modeling, prototype testing and team feedback, the final recipe was documented for production. This is referred to as the "lay-up schedule." The lay-up schedule determines the orientation and order of all the individual sections of carbon fiber plies. These plies come "pre-impregnated" with the resin, and each is meticulously cut to the shapes needed to construct the frame.

The plies are strategically laid onto specially shaped internal molds. Once the lay-up is complete, the material is placed into a symmetrically split CNC-machined mold (think waffle iron). The mold halves are then closed and locked. A precise amount of pressure and heat is applied, and the bladder pushes the carbon fiber firmly against the mold.

The above process is pretty standard with most high-performance carbon fiber bikes, but Felt takes it a few steps further with the new DA. One of the key advantages of the new frame is a proprietary "Internally Optimized" molding process called InsideOut. By placing specially designed molds inside the frames during this process, Felt is able to eliminate any excess material inside the carbon fiber tubing.

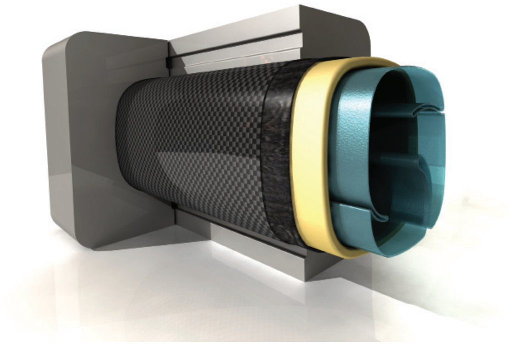
"These inserts really clean up the inside of the frames," said Felt engineer Ty Buckenberger. "The bottom bracket and other junctions are all nice and clean with no excess material inside."

When the heating process is complete, the mold is opened up and the cured frame sections are removed. The result, effectively, is a perfect frame every time—inside and out.

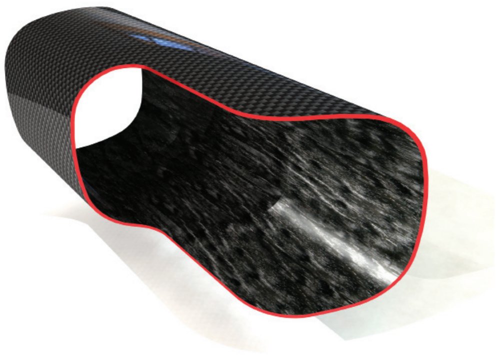
The next step of the process is called Dynamic Monocoque Construction. This is the special technique Felt uses to join the individually molded sections of the DA frame. Dynamic Monocoque Construction allows Felt engineers to optimize every section of the frame. By utilizing perfectly sized internal molds for different tubing sizes and shapes, they are able to maximize the effectiveness of the InsideOut process.

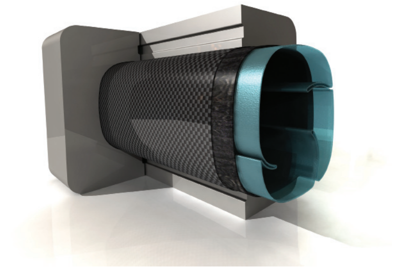
"Obviously the shapes we're working with for the front triangle are much different than those of the seatstay, for instance," said Buckenberger. "Dynamic Monocoque Construction allows us to really focus on making every single section of the frame the best it can be."

Finally, the frame sections are joined using a special co-molding technique. The individual sections are bonded together and then co-wrapped. Dynamic Monocoque Construction is considerably more complicated and expensive than other methods. But the ride quality and unparalleled strength make it worthwhile.



InsideOut technology with polyurethane inserts helps eliminate excess material build-up inside the frame and reduces overall weight.





Without *InsideOut* technology there is excess material build-up inside the frame.

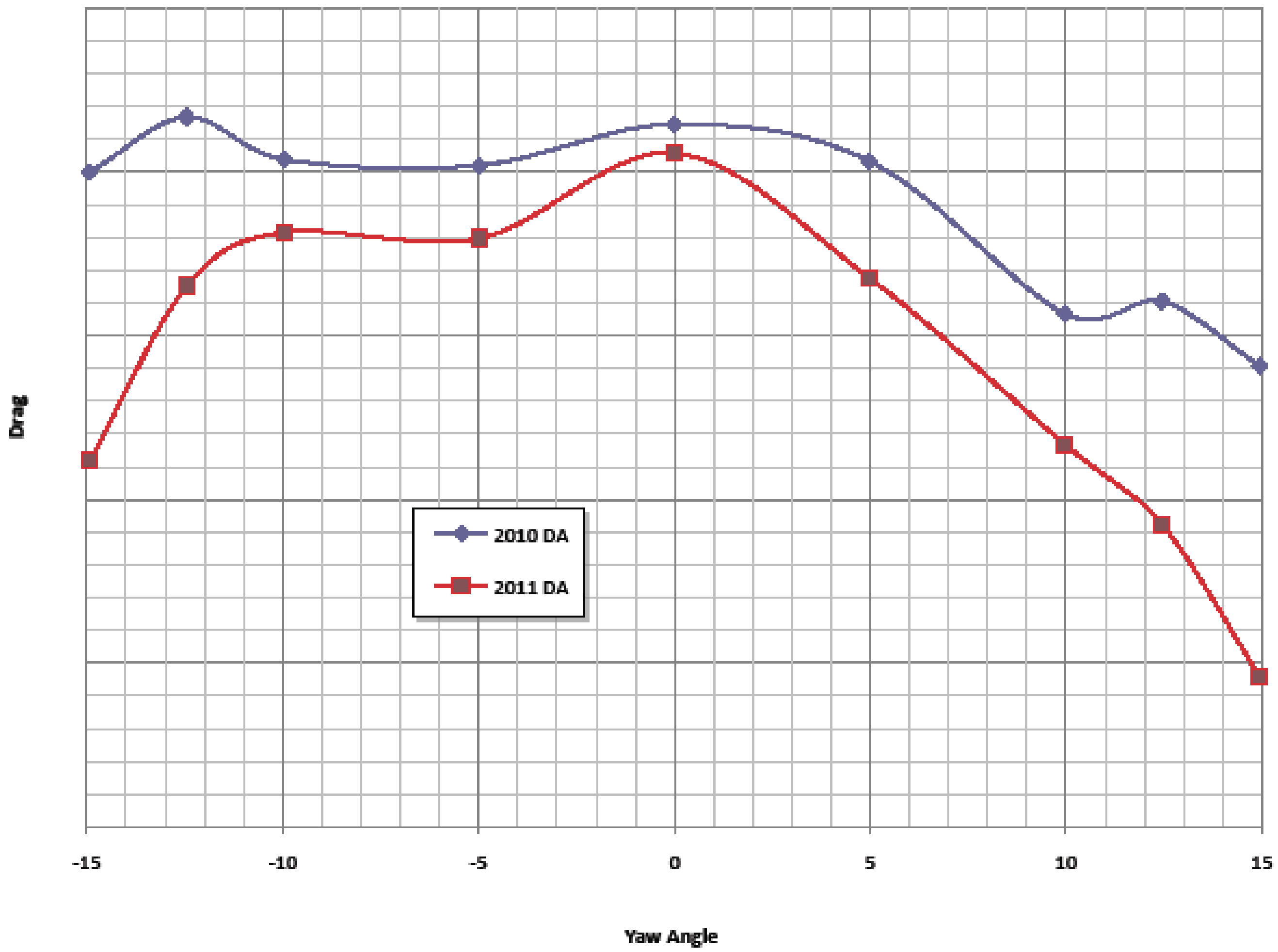
AERODYNAMICS

This is what it's all about. From the very start of this project, more than two years ago, Jim Felt (pictured above) and the team of Felt engineers faced one daunting challenge. Create a bike that's faster and more aerodynamic than the Felt DA. The current model has experienced unmatched success. Just last year it was ridden to three Elite Men's National Time Trial Championships in three different countries. It's ridden by Felt's stable of Ironman Triathlon athletes. It's the weapon of choice for four-time U.S. Time Trial Champion Dave Zabriskie.

But the new DA had to be better. And it also has to be legal in the eyes of the UCI, the world governing body of competitive cycling. Now that the objectives, the tools and the engineering process have been revealed, it's time to look at the data.

The final phase of development was wind tunnel testing and refining. In January 2009, Felt's engineering team went to the San Diego Low Speed Wind Tunnel to obtain objective third-party aerodynamic analysis on a prototype version of the new DA. Several modifications were made over the next year until the final version of the bike, the fifth in a series of prototypes, was finalized and tested. This was the bike that would be raced by Garmin-Transitions riders at the 2010 grand tours.

There are lots of different ways to gauge a bike's aerodynamic performance, but Felt focuses on real world conditions. That means considering how a bike performs with the wind hitting it at various angles. When measuring aerodynamics, the angle of the wind is referred to as "yaw angle."



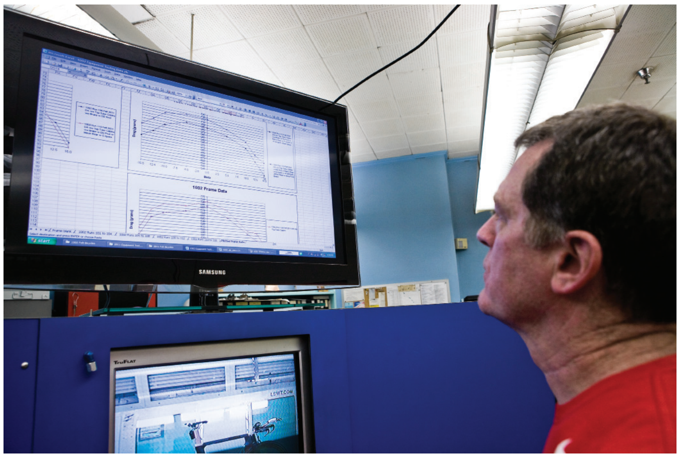
What the wind tunnel revealed was that, while some competitor bikes performed just as well as the new DA heading directly into the wind (0 degree yaw angle), the DA was untouchable with the wind hitting it at 5 to 15 degrees. Think about that. How often are you pedaling dead straight into the wind? Not too often. That's why most aerodynamics engineers focus on the numbers produced in the 10- to 15-degree range.

Not only was the 2011 DA superior to the competition at those "real world" angles, but it showed a clear improvement over the current DA. And that was the real challenge. The chart above shows the difference between the current DA and the 2011 model.

The numbers on the left side of the graph represent aerodynamic drag. The less drag, the better. The numbers across the bottom of the graph represent the angle of wind resistance hitting the bike. You'll notice there's a difference between -15 degrees and +15 degrees—that's because the bike is asymmetrical with its right-side drivetrain.

Felt engineer Ty Buckenberger sums up the results of the graph: "The 2011 DA is roughly 15 percent faster than the current DA at 10 to 15 degrees of yaw. That range, 10 to 15, is what most in the industry consider to be "real world" conditions. Over the entire range, the new bike is roughly 10 percent faster."

Those are the numbers, but what exactly is it that makes the new DA so much more slippery than the current one?



Here are five key features that contribute to the 2011 DA's improved aerodynamics:

1 **INCREASED SURFACE AREA**
CFD analysis led Felt engineers to redesign every tube shape on the DA, including the down tube, to optimize airfoil efficiencies. The new frame now has 25 percent more surface area, which in this case helped reduce drag by 14 percent.

2 **SHARPER BAYONET**
The new Bayonet 3 Steering System has similar functionality as the Bayonet 2 system on the current DA, but it was further refined for an even more aerodynamic profile. Felt created its own bearing to achieve the narrow profile—instead of a 1-inch bearing, it uses a smaller proprietary 3/4-inch bearing to reduce frontal area.

3 **SLIMMER HEAD TUBE**
Like the fork, it's narrower than that of the current DA. The width was reduced from 42 millimeters to 35, making it even more effective at slicing through the wind.

4 **SLIPPERY SEAT TUBE**
The shape of the new seat tube differs greatly. Like the down tube, it follows a true airfoil shape instead of a cutout, and also features a flare that kicks air around the rear tire.

5 **AERO BRAKES**
This was one of the biggest challenges faced by Felt engineers—not only did the new brake system have to be more aero, it had to perform better and be compatible with the wider rims being used in aero TT wheels. The solution was this innovative new V-brake system that combines unmatched aerodynamics (internal cable routing, shelter from wind drag) with improved power and modulation.

GEOMETRY

Size	51	54	56	58
HA	72.5	73	73.5	74
SA (rear position)	76	76	76	76
TT C-C	520	540	560	580
Head Tube	80	88	108	128
ST C-T	510	540	560	580
ST C-C	495	525	545	565
BB Drop	70	70	70	70
CS	395	395	395	395
Front Center	577	593	614	635
Wheelbase	962	978	999	1020
Rake	40	40	40	40
Standover	770	794	813	833
Stack	501	509	529	548
Reach	395	413	428	433

THE BOTTOM LINE

Getting back to the three main objectives of the 2011 Felt DA, here are the bottom line results.

1. Aerodynamics: The 2011 Felt DA shows a 14% improvement in aerodynamic performance over the 2010 model.

2. Stiffness: The 2011 Felt DA is 13 percent stiffer than the 2010 model.

3. Weight: Even after adding close to 25 percent more surface area to the frame to improve aerodynamics, the 2011 DA is just 2% heavier than the 2010 model.

2011 FELT DA TECHNICAL SPECS

Frame material:
UHC Ultra+Nano carbon fiber

Frame details:
Dynamic Monocoque Construction with InsideOut molding; Shimano Di2 optimized internal cable routing; BB30 bottom bracket

Fork:
Felt Bayonet 3 Steering System

Fork material:
UHC Ultimate+Nano carbon fiber

Fork details:
Dynamic Monocoque construction; carbon fiber blades, dropouts, crown and external steerer with 30mm outside diameter/19mm inside diameter Felt bearing and compression device

Sizes:
51, 54, 56, 58 cm