2014 Speed Concept

White paper for the all-new Trek Speed Concept bicycle

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Contents

1 Executive summary

Trek has taken the fastest production bicycle in the world and made it faster. For several years, we've been quietly studying and measuring real-world bicycle aerodynamics using advanced sensors and data collection on actual Ironman courses. We've used this real-world aerodynamic data to refine our already industry-leading techniques in CFD, race simulation, and airfoil design to address the true aerodynamic conditions that triathletes face. We've leveraged these tools with years of aerodynamic research, airfoil development, and wind tunnel testing to create a new Speed Concept that's not only faster than our previous Speed Concept, it's faster with all the available integrated storage solutions on board.

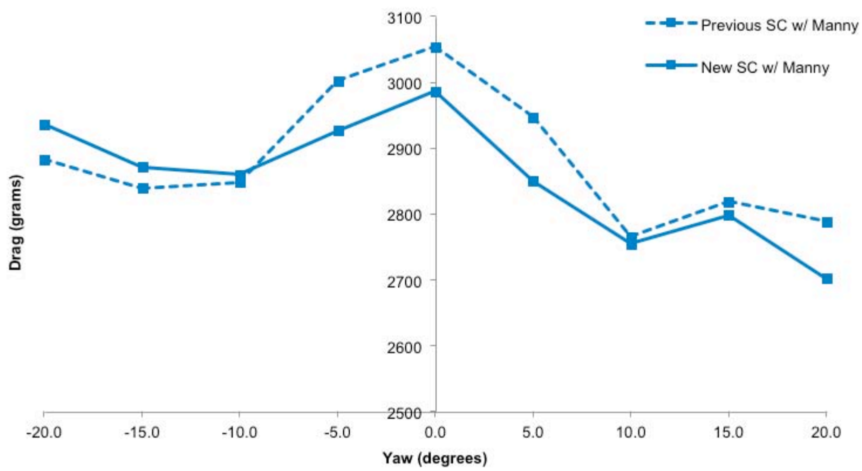

Figure 1: Previous Speed Concept compared to the New Speed Concept. San Diego Low Speed Wind Tunnel, November 2012. With mannequin. Tares removed.

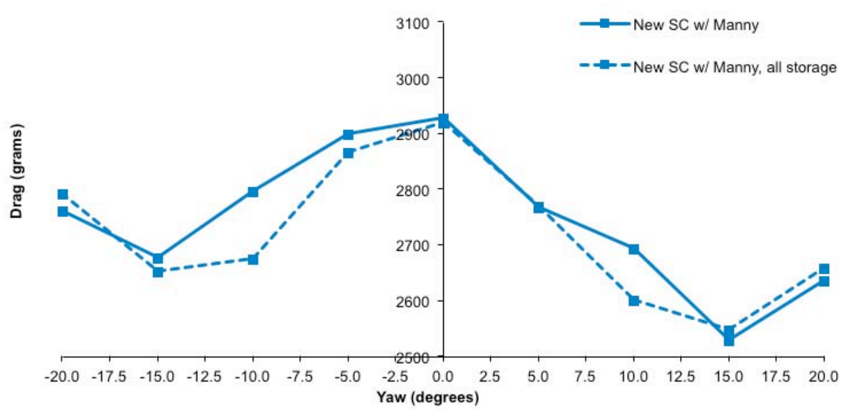

Figure 2: New Speed Concept with all storage compared to the new Speed Concept with no storage. San Diego Low Speed Wind Tunnel, April 2013. With mannequin. Tares removed.

2 Introduction

Trek is dedicated to continually improving our products to make you faster and to make your cycling experience more enjoyable. We have taken the original Speed Concept and made it faster, lighter, and easier to fit and assemble. The previous Speed Concept used our groundbreaking airfoil design, the Kammtail Virtual Foil (KVF), and added elegant integrated storage solutions. The new Speed Concept combines an updated KVF design with real-world yaw testing. The new Speed Concept also features a new aerobar system and improved storage solutions to make an even faster bicycle.

Not only is the new Speed Concept faster than the original, but its design is greatly simplified. It uses fewer parts, resulting in nearly half the typical build time, easier adjustments, and nearly a pound in weight savings, all while maintaining Speed Concept's industry-leading fit range and bike feel (if your position is constrained by lack of fit, your power output and bike splits will suffer, no matter how fast your bike).

The original Speed Concept white paper went into detail describing KVF principals, bicycle aerodynamics, and an in-depth discussion of our development process.[i] This new white paper will focus on Trek's real-world aerodynamic testing and on the improvements made to the Speed Concept. Trek engineers were able to make substantial drag savings over the previous Speed Concept while still working within the bounds of UCI rules and within our stringent stiffness and weight targets. Such a significant reduction in drag within the same design constraints will most likely take years, if ever, to repeat.

3 Designing for real-world aerodynamics

Wind tunnel tests are conducted at a range of yaw angles, typically up to about 20°. But what yaw angles do cyclists actually encounter in the real world? This has been a fundamental question for Trek engineers, because the answer would allow us to tailor the bicycle's aerodynamics for maximum efficiency at the yaw angles that matter most to our customers. Many have tried to calculate real-world yaw angles using mathematical models—but all such models require the user to define the ambient wind speed and direction, and determining the ambient wind along a bicycle race course is much more difficult than one might expect.

3.1 The complexity of real-world wind

First, wind is highly variable through time, fluctuating moment to moment and following consistent daily and yearly cycles, as shown in the following figure showing weather station data on daily wind cycles near the Ironman Hawaii course and yearly wind cycles near the Ironman Arizona course.

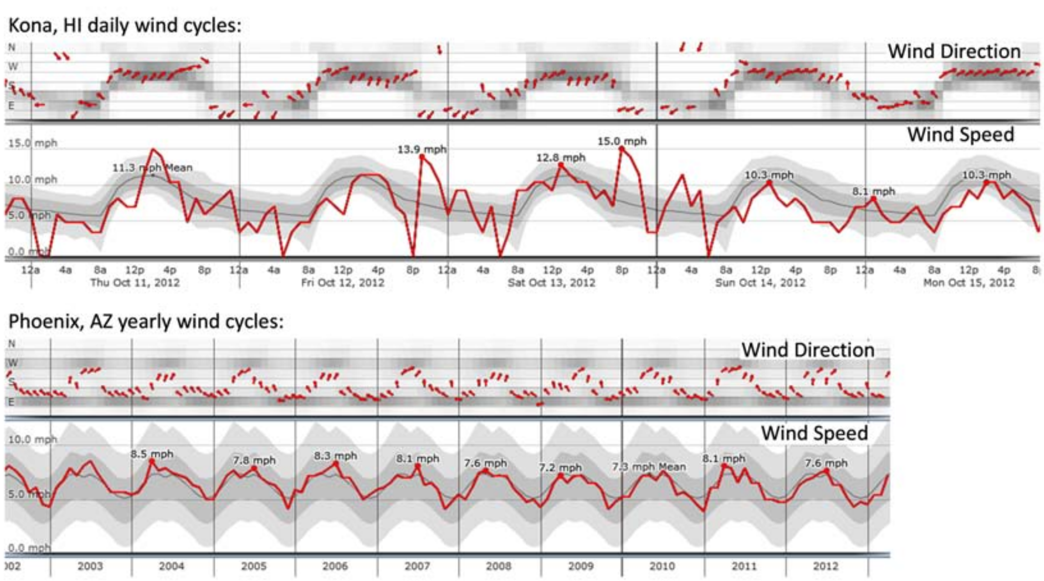

Figure 3: Daily wind cycles in Kona, HI during the 2012 Ironman Hawaii, and yearly wind cycles in Phoenix, AZ. Actual data in red, average historical data in grey.[ii]

Second, the wind varies greatly depending on a cyclist's location along a course. Anyone who has ridden the Ironman Hawaii course knows that the wind in Kona is vastly different from the wind near the turnaround in Hawi. Topography and roadside features like hills, trees, and buildings all block and redirect the wind, resulting in further variation of already fluctuating wind conditions. The case of the Hawaii course is particularly dramatic due to the coastline and mountains. In Figure 4, we see a typical scenario where the notoriously strong NE wind near Hawi curls around the island to create the W wind near Kona that appeared in Figure 3. *Note that it is conventional to state wind directions as the direction from which the wind is blowing.*

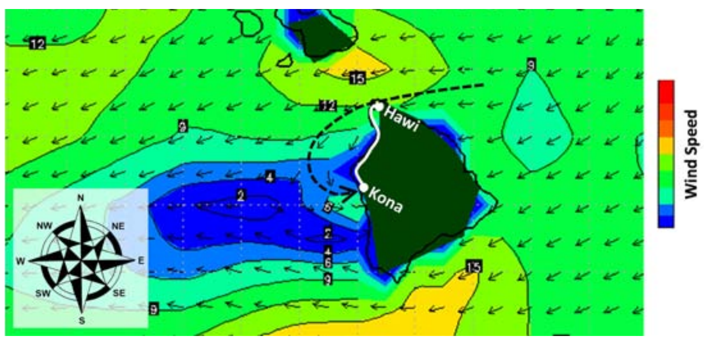

Figure 4: Example of the varying wind conditions along the Ironman Hawaii Course.[iii]

Third, weather station data can be misleading. Wind measurement sensors are typically located on the top of buildings and/or in open areas like airports. Obviously, the wind high off the ground in a flat open field is quite different from the wind at ground level near trees, hills, or buildings. In addition, weather stations often disagree with each other, as we see in the following figure showing data from several weather stations within a couple miles of the Ironman Wisconsin course during the same time period. This disagreement further illustrates the significant variation in wind across even a small area.

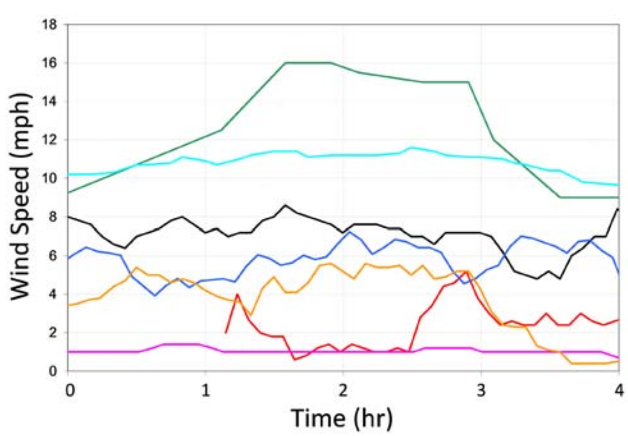

Figure 5: Simultaneous wind speed data from multiple weather stations, all within a few miles of the Ironman Wisconsin course.

3.2 Measuring aerodynamics in the real-world

Clearly, the real-world wind conditions at ground level along a race course can be extremely complicated and hard to determine. But without this knowledge, even the fanciest algorithms cannot accurately calculate the true yaw angles a cyclist encounters in a race. So in early 2009, Trek engineers designed and built a mobile sensor system to directly measure yaw angle and airspeed, along with GPS speed, location, heading, and altitude. The yaw and airspeed sensor is made from 3 tubes arranged on a pole that extends in front of the bike. The pressure at each tube is measured at 10,000 Hz and averaged down to 100 Hz for extremely high fidelity and response. The system uses the most sensitive pressure sensors on the market, ensuring accurate measurement of the exceedingly low air pressures experienced in low-speed and tailwind scenarios.

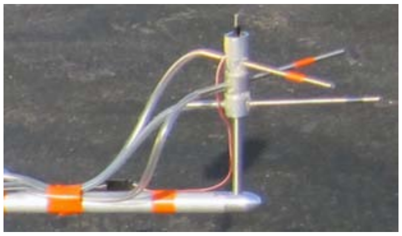

Figure 6: The head of the yaw/airspeed sensor.

In June, 2009, we calibrated our yaw and airspeed sensor at the San Diego Low Speed Wind Tunnel. Using a telescoping pole, we tested a full range of lengths to ensure that the sensor was located in a region where the effect of bike + rider on the flow was minimal and consistent. We ran the sensor through large sweeps of yaw and airspeed, and we used this data to create a calibration algorithm that converts raw pressure signals into airspeed and yaw. Developing this algorithm was the most challenging aspect of this sensing method, since it is very difficult to ensure that any given combination of pressure values describes the one correct combination of airspeed and yaw.

Figure 7: Sensor calibration in the San Diego Low Speed Wind Tunnel.

After calibration, we ran initial tests in a wide range of wind conditions near Trek Headquarters in Waterloo, WI. We also created a digital wind vane to verify the yaw calibration in some simpler conditions that the wind vane could handle without the limitations of flutter or response time.

Figure 8: Initial validation tests with the calibrated sensor system.

One drawback of our test method as originally designed was that the data acquisition system, while the smallest available back in 2009, had to be carried in a backpack. This backpack added both weight and aerodynamic drag, thus changing the cyclist's speed. To ensure that test method did not artificially affect the cyclist's natural speed variations across varying elevations and wind conditions, we decided to take the system off the rider and put it on a scooter instead. This scooter would then use the cyclist for pacing throughout a ride, following at a distance at which yaw would not be influenced by the leading cyclist. With this improvement in test philosophy, we were ready to test some real race courses.

Figure 9: Setting up the scooter in the hotel room before a test.

For the bulk of our real-world testing, we focused on triathlon, where aerodynamics is king. In November 2011 at the Ironman Arizona course, we tested seven laps over two days, using two riders who averaged 25 and 22 mph. In August 2010 at the Ironman Wisconsin course, we tested a complete loop using a rider who averaged 22mph. In September 2011 at the Ironman Hawaii course, we tested three laps over three days, using three riders who averaged 23, 20, and 18 mph. These courses cover the wide range of wind conditions a triathlete might face: Arizona is an out-and-back with typically light wind; Wisconsin is a nearly circular loop with typically moderate wind; and Hawaii is an out-and back with typically strong wind. Note that we tested each course at the same approximate time of year and time of day as each respective Ironman race.

Figure 10: Testing at (A) Arizona Ironman course, (B) Hawaii Ironman course, and (C) Wisconsin Ironman course. (D) Downloading data after a lap in Arizona. (E) Roadside anemometer measurement of a gust in Hawaii.

To gain a strong intuitive sense of how yaw and airspeed vary throughout real-world races, we visualized the data as an animated dashboard of data and graphs which plays through the course at accelerated speed. In the following example, we see an instant in time on the Hawaii course during the notoriously difficult section before the turnaround. Notice that at this moment, the rider is facing a side-headwind from the NE and an uphill grade, resulting in a bike speed that is much lower than the apparent wind speed, as shown in the lower right graph. The segments of calm, tailwind, and headwind on this graph agree very well with both the conditions measured with an anemometer every three miles along the course and the feedback from Trek pro triathletes about the typical wind conditions on the course.

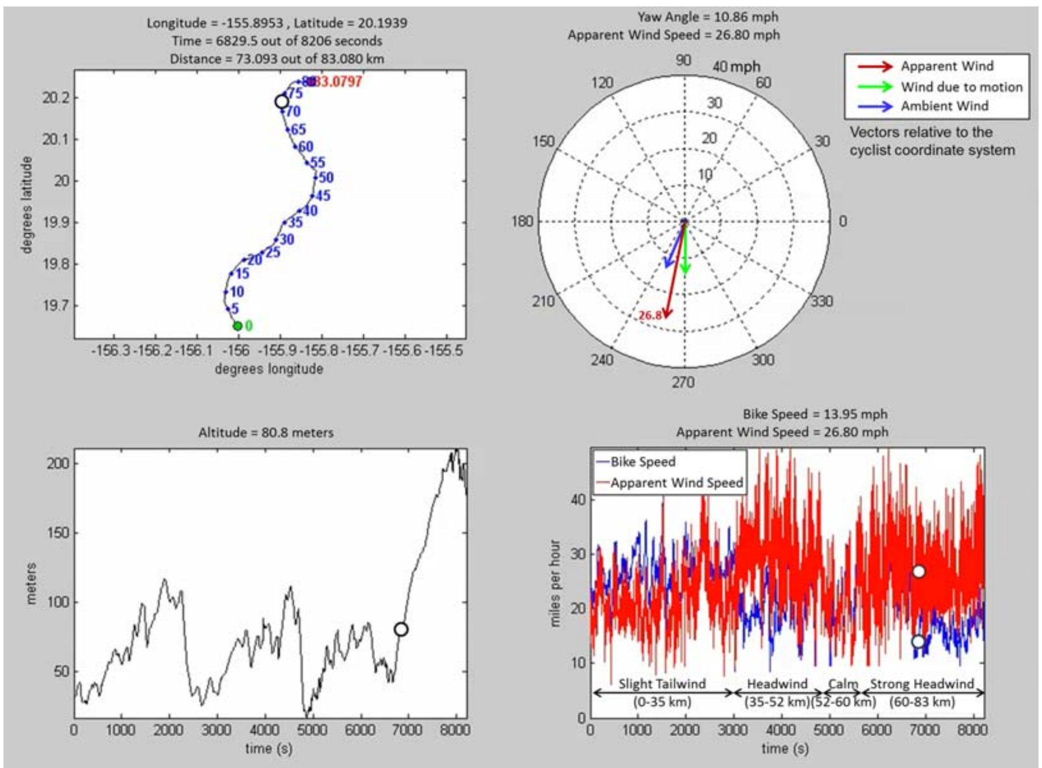

Figure 11: One frame from a graphical animation of the first half of the Hawaii course. The upper right graph shows the vectors of air motion relative to the cyclist's local (moving) coordinate system. First 7km of course omitted.

We also ran a full statistical analysis of each test, finding average yaw angles and, more importantly, yaw angle distributions—that is, the percentage of time spent at each yaw angle, as shown in Figure 12. For Arizona, we see that most of the time is spent at low yaw, and the distribution tapers off evenly at high yaw. In this trial, the average yaw was only 3.6°, which was on the low end of the 3–5° average yaw range in the Arizona trials. For Hawaii, we see that the distribution is much more spread out and has a distinct bulge at higher yaw due to the distinctly windy section near the course turnaround. We see that while there are certainly periods of very high yaw angles, much of the time is spent at low to moderate yaw angles, resulting in an average yaw angle of 10.6°. This particular trial was also on the low end of the Hawaii trials which ranged up to a 13° average yaw. The Wisconsin course fell between these extremes, averaging 6° yaw in our trial.

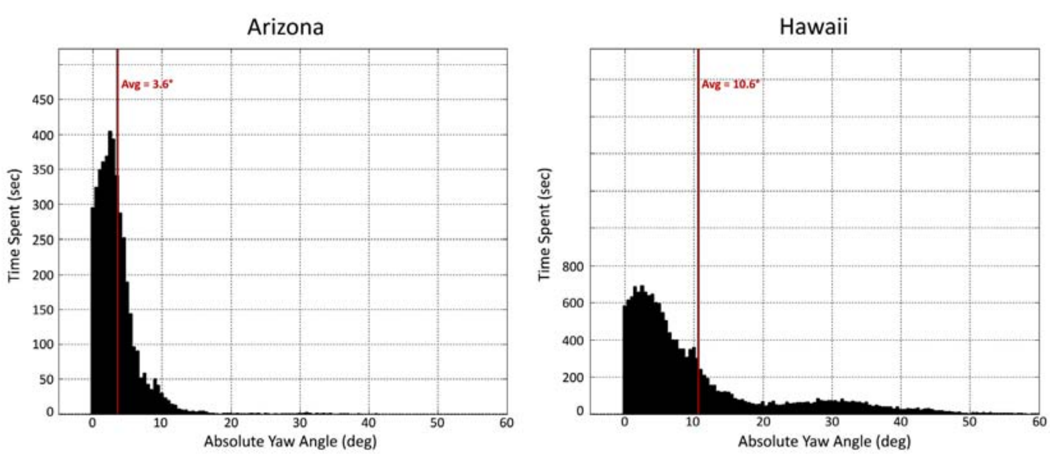

Figure 12: Example absolute yaw angle distributions measured on the Arizona and Hawaii courses.

3.3 Real-world data used in “what if” simulations

While this research has shed new light on real-world aerodynamics, the question remains: How should we design the next bicycle to save the customer the most time and energy in real-world races? To answer this question, we go back to the topic of mathematically simulating a bicycle race. Over the past five years, Trek engineers have developed and fine-tuned proprietary race simulation software. This 3,000-line code captures all the subtle physics involved in cycling, including the complex circular relationship between speed, yaw, and aerodynamic drag.

But even the best race simulation algorithms are only as good as the assumed ambient wind along the course. Interestingly, we can obtain the real-world ambient wind speed and direction by subtracting the rider’s GPS-measured bicycle speed and heading from our aero sensor-measured apparent airspeed and yaw. The next figure shows the ambient winds measured along the Hawaii course. This case is interesting because it not only depicts the variability due to gusting and roadside landscape, but also depicts the two distinct wind conditions that were previously discussed – light SW wind over much of the course, and strong NE winds at the north end of the course.

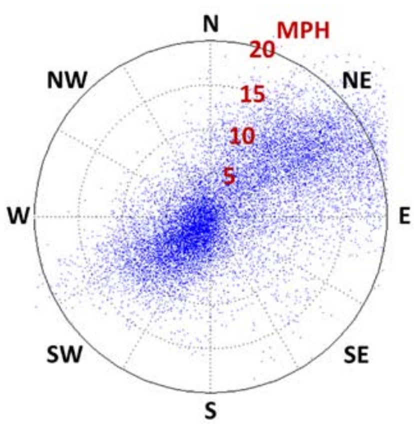

Figure 13: Ambient winds measured along the Hawaii course. Note that we follow the convention that the wind angle is the direction from which the wind is blowing; i.e. a point in the lower left quadrant represent a wind blowing from the SW towards the NE.

With the measured ambient wind data, bicycle speed data, and GPS data for each course, we used our race simulation software to virtually race a variety of theoretical bikes against each other. These simulated races revealed the design changes for the new Speed Concept that would be of most benefit to real-world triathletes. The figure below shows the energy difference (negative means energy savings) for five theoretical bike designs compared to a previous Speed Concept, across a set of trials that represents the widest possible range of yaw conditions. Simplified thumbnails of the drag vs. yaw curve are shown in red for the theoretical bikes and in black for the baseline. As shown by the red stars, theoretical bike 1 was most energy efficient in all but the most extreme wind conditions. Since bike 1 focused on pre-stall (0–12.5° yaw) drag savings, this became the design direction for the new Speed Concept.

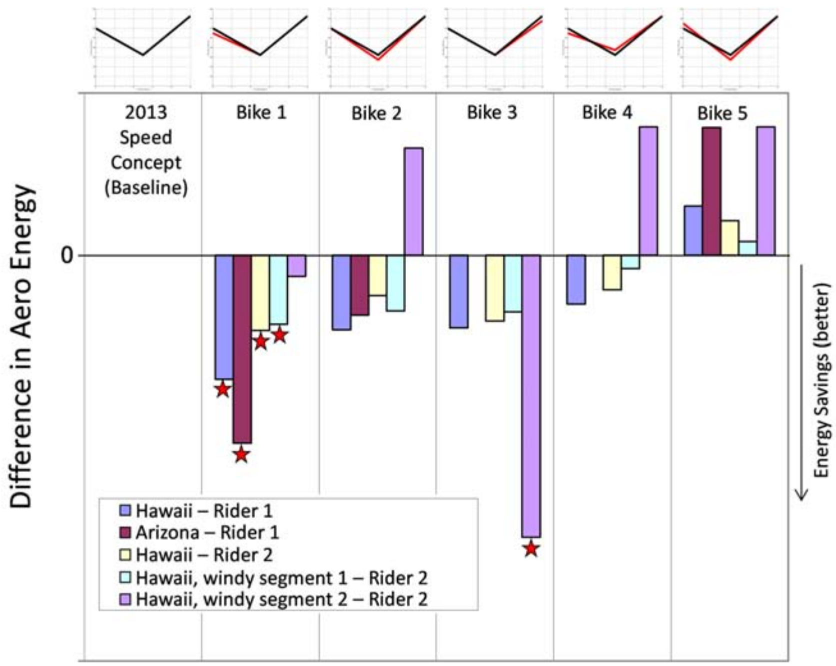

Figure 14: Race simulation results, showing the difference in aero energy for five theoretical bikes compared to the previous Speed Concept.

Note that these simulations take into account the key subtlety that not all time at a given yaw angle is the same. For example, a 5° yaw angle can occur in a wide range of conditions — headwinds, tailwinds, fast descents, slow climbs, etc. So, it is important to also consider the apparent airspeed and bike speed for each time segment at a given yaw angle. This allows us to more appropriately analyze the bike's true aero energy consumption and time savings at all moments during the ride.

For the same reason, it is technically more appropriate to plot yaw as a distribution of energy consumption instead of time consumption. Most notably, the Hawaii yaw distribution gets skewed a few degrees to the right (higher yaw) when considering energy consumption. This occurs because in Hawaii the time periods of high yaw angle typically occur during periods of high apparent airspeed and therefore, high aero energy consumption.

3.4 Real-world validation of the final design

Just as we used real-world data to inform the design of the new Speed Concept, we used real-world-data-based race simulations to validate our final design's tunnel performance. Focusing on both the highest and lowest drag courses, we found that a racer who averages 20 mph on the previous Speed Concept will save 99 seconds in Ironman Hawaii and 148 seconds in Ironman Arizona after upgrading to the new Speed Concept.

In addition, we took the new Speed Concept to the Valencia Velodrome for real-world aero testing with Fabian Cancellara. In repeated trials using Trek's state-of-the-art Alphamantis Aero System[v], the new Speed Concept saved Fabian the drag equivalent of 30-40 seconds in a one-hour time trial. These real-world findings agree well with the wind tunnel results at 0° yaw.

Figure 15: (Left) Fabian Cancellara testing the new Speed Concept on the track. Note that he is riding with a new real-world aero sensor. (Right) On-track aerodynamics testing system.

3.5 Ongoing real-world aerodynamics research

Real-world aerodynamics continues to be an active area of R&D at Trek. In Spring 2012, Trek became the first bicycle company to adopt the Alphamantis Aerostick sensor.[v] This sensor gives us the same functionality as Trek's original hand-built yaw and airspeed sensor, but in a much smaller package that can go on a bike without significant weight or aero effects. This specific sensor was built to custom Trek specifications and remains the most advanced yaw sensor in the world. In addition, we used our wind tunnel mannequin to create a proprietary set of calibration functions which accounts for the influence of bike + rider on the airflow. This Trek calibration has proven critical for extreme accuracy. Ongoing research includes the study of an even wider variety of riding scenarios, including the effects of roadside topography and drafting.

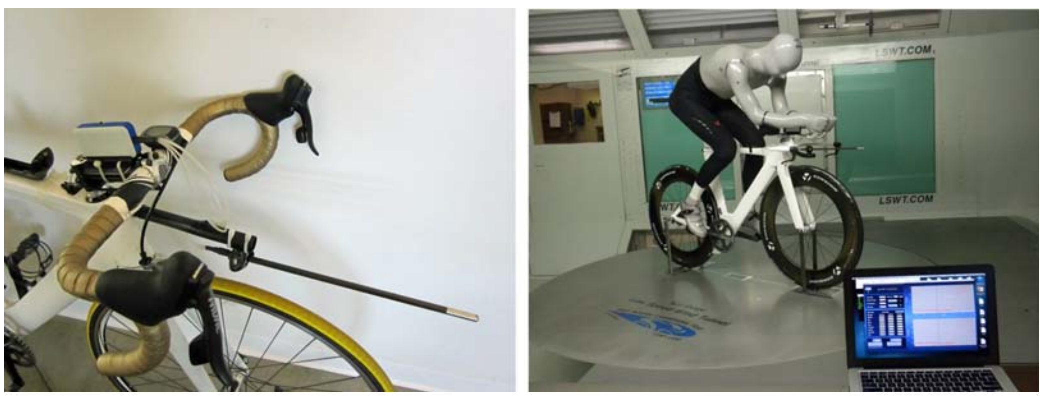

Figure 16: Trek's early production Aerostick sensor (Left) on a Madone and (Right) on a Speed Concept with mannequin during calibration at the San Diego Low Speed Wind Tunnel.

4 Aero performance

Designing a bike simply by following the rule that "narrow is aero" would create a very aerodynamic bicycle, but at the expense of low stiffness, or excess weight, as is common on many triathlon bikes. The new Speed Concept frame is lighter and more aerodynamic than its predecessor but without any compromise in stiffness or ride quality. Finite element analysis (FEA) played a major role in optimizing the performance of the frame.

Using FEA simulations, Trek engineers were able to identify the areas of the Speed Concept frame that contribute most to frame stiffness, and other areas where the tube's cross section could be driven completely by aerodynamics. Our engineers then used computational fluid dynamics (CFD) analysis to design tube shapes with the desired cross sections for the lowest possible drag. We then validated the design using prototype and low speed wind tunnel testing.

Through selective shaping, we reduced the frontal area of the seat tube and down tube by 13% compared to the current Speed Concept, while maintaining high torsional and bending stiffness in critical areas. We increased the lateral width of the head tube and fork leading edge by up to 60%. CFD analysis showed drag reductions from increased width in a high-aspect-ratio airfoil shape, as used in the head tube region. This increased width also improved full-frame torsional stiffness, which has a large effect on the handling of the bike.

Another notable addition to the new Speed Concept frame: the large fillets between the main frame tubes. The high-aspect-ratio airfoils designed for these sections of the frame increase side surface area and reduce drag at higher yaw angles. (Side surface area on a bicycle frame can generate increased wind-axis lift, i.e. the "sail effect," which decreases bike-axis drag.) These fillets also stiffen the frame by reducing effective tube length. In simple terms, one can think of the tubes that make up the front triangle of a bicycle frame as three cantilevered beams. The addition of fillets between the tubes reduces their cantilevered length and thus their deflection under load.

4.1 Low speed wind tunnel testing

Trek's wind tunnel testing protocol is the foundation for our bicycle airfoil development and validation. Trek adheres to strict standards developed over 13 years of low speed wind tunnel testing.[i] Trek engineers use low speed wind tunnel testing to validate CFD results, test different airfoil shapes, test interactions with rider on and rider off, and compare our bike to the best competition in both normalized and fastest configurations. A normalized configuration consists of setting up all bikes being tested to the lowest common position that they all can meet. All aspects of the bike adjustment will be set as close to identical as possible: equal pad width, pad stack, pad reach, extension length; and saddle height, angle, and setback. All other aspects of the bikes are kept the same, such as drivetrain parts, tires, wheels, brake levers, etc. For example, when Trek engineers were comparing the P5-6 to the new Speed Concept, we had to use thicker arm pads on the Speed Concept to put our bike in the same pad stack position as the P5. The thicker pads slowed our bike down but it was the right thing to do to compare normalized setups. When bikes are being compared in their fastest setup, they will be configured with all spec proprietary components and set to their lowest pad stack position.

We discussed the use of our mannequin, "Manny," in our previous Speed Concept white paper.[i] The beauty of Manny is that he provides repeatable results (+/- 8 grams of average uncertainty between duplicated tests). Manny doesn't get tired after days of work at the wind tunnel, and his articulated legs allow us look at true interactions between the bike and a rider actually pedaling.

Figure 17: Manny on the new Speed Concept in the San Diego Low Speed Wind Tunnel.

4.2 New Speed Concept development

To quickly analyze and validate CFD analyses, we made the analyzed airfoil shapes into skins and tested them in the wind tunnel on the Speed Concept frame skeleton (we discussed our frame skeleton and the creation of prototype test skins in the previous Speed Concept white paper).[i] Testing began by running a baseline bicycle that would also be tested at the end of the day to check repeatability. Then the frame skeleton, with skins attached, was placed on the balance and the setup methodically checked. The setup was held constant throughout testing, and only the skins were changed from test to test. We swapped skins in different locations depending on what we were testing, changing only one variable at a time. Once we found airfoil shapes that performed the way we wanted, we began looking at interactions by changing different sets of skins, multiple variables at a time. If we were testing components or storage, such as a seat post shape or handlebar shape, we changed only that component. We included Manny in these tests where appropriate.

Figure 18: A2 Wind Tunnel, frame skeleton with skins.

The next step was to take the insights gleaned from wind tunnel testing and modify the airfoil design shapes. We then ran analysis, made new skins, and retested in the wind tunnel. The result: a bicycle that is faster and lighter than the previous Speed Concept, and still retains the desired ride feel.

4.2.1 Frame and fork development

The KVF technology developed for the original Speed Concept was a huge leap forward in bicycle airfoil design. We knew that developing a Speed Concept that improved significantly on that original design would require testing of many new airfoil frame skins. We analyzed and tested many different shapes and sizes of fillets, tubes, and covers in the wind tunnel. Figure 19 shows just a few of the wind tunnel test results using these different airfoil shapes. The dark blue line is the previous Speed Concept. The graph shows how difficult making large steps in drag reduction can be when you already have class-leading airfoils.

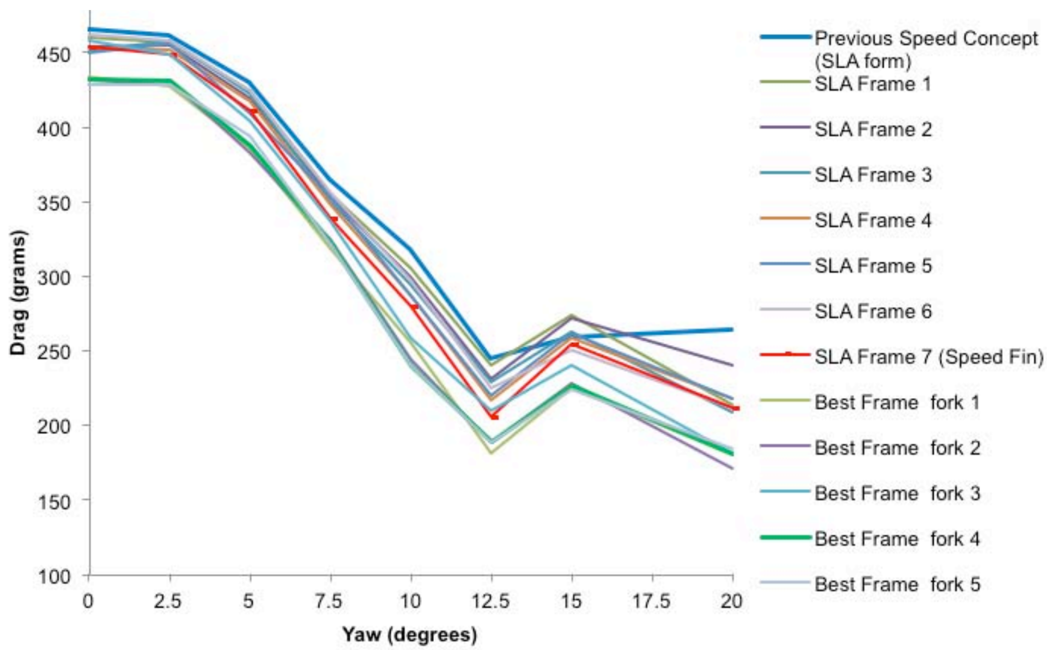

Figure 19: Speed Concept frame skeleton with various airfoil skins. A2 Wind Tunnel, March 2012. Bike only.

Trek engineers tested six prototype fork designs in the wind tunnel before generating the final design. The winning design has a UCI-illegal, high-aspect-ratio (6:1) airfoil cross section. The first question that comes to mind for the new fork shape: why a traditional airfoil rather than KVF? As discussed in the previous Speed Concept white paper, KVF is the best alternative to a full airfoil shape when weight and stiffness are key parameters.[i] A large tube, such as a down tube, will benefit from a KVF shape, since it offers better aerodynamics with less weight than a traditional airfoil shape at the same stiffness. However, a fork leg has a lot less surface area than the down tube. Therefore, using a traditional airfoil induces a only small weight penalty compared to KVF and creates a faster airfoil.

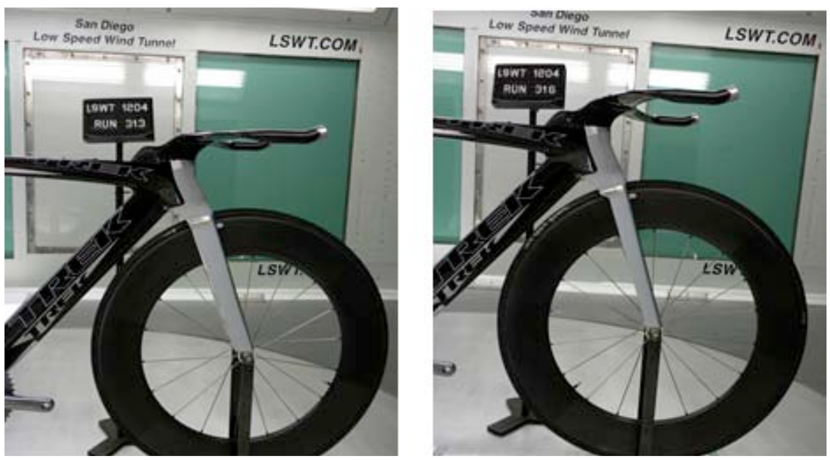

Figure 20: San Diego Low Speed Wind Tunnel triathlon and UCI fork photos.

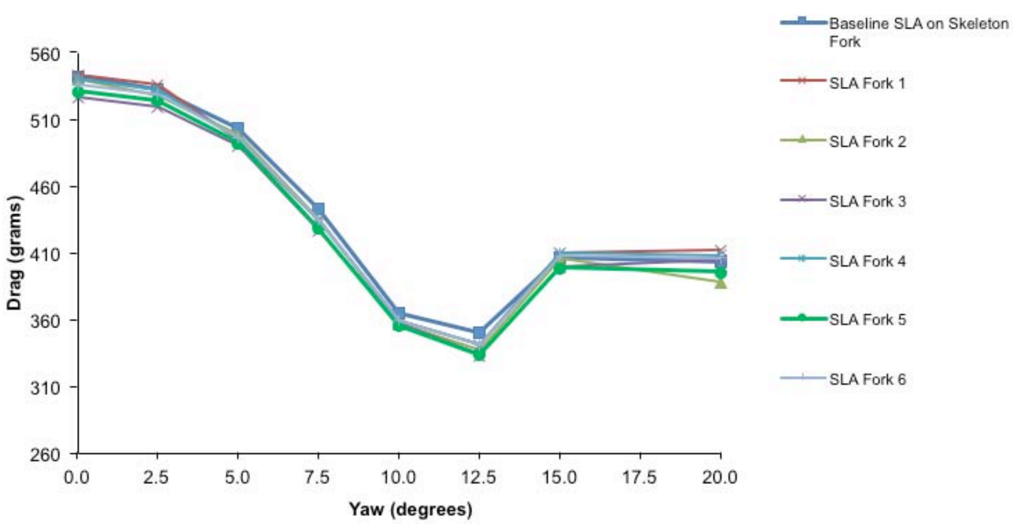

Figure 21: Previous Speed Concept with various fork airfoil concepts. San Diego Low Speed Wind Tunnel, January 2012. Forks tested with the frame, bike only, no rider.

The final bike turned out faster than the original. Figure 22 compares wind tunnel data for the new and previous Speed Concept frames taken at the San Diego Low Speed Wind Tunnel in November 2012. The new Speed Concept with rider on saves an average of 43 grams over the critical yaw range of -12.5 to +12.5 degrees compared to the previous Speed Concept. If all the available integrated storage is put on the new Speed Concept (Torpedo Bottle, Draft Box, Speed Box, and 2-Pack), the average drag savings compared to no storage over the same yaw range is 36 grams.

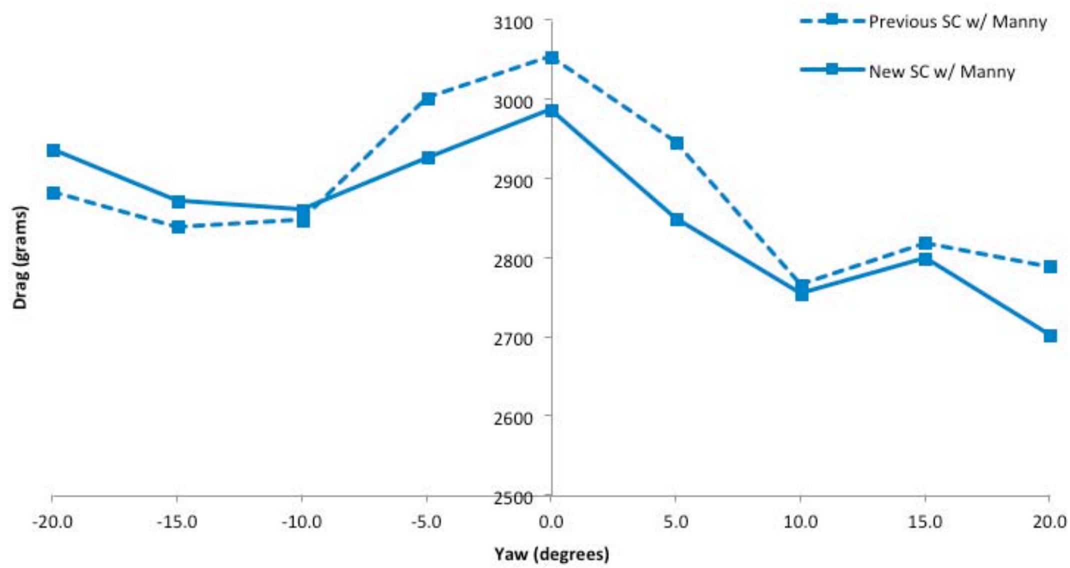

Figure 22: Previous Speed Concept compared to new Speed Concept. San Diego Low Speed Wind Tunnel, November 2012. Rider on. Data pulled from a head-to-head test day which included the Shiv Tri; bike setup normalized to the Shiv Tri lowest position, resulting in higher pad stack than would normally be run.

4.2.2 Drag savings, in practical terms

Comparing the new Speed Concept to the previous Speed Concept in our race simulation program, we calculated a time savings for the Hawaii and Arizona Ironman courses. As previously stated above, a rider who typically averages about 20mph will save 99 seconds in the Hawaii Ironman or 148 seconds in the Arizona Ironman by doing nothing other than upgrading from the previous Speed Concept to the new Speed Concept.

If that same rider, in the same conditions, uses all our storage solutions on the new Speed Concept, the average time savings compared to riding the previous Speed Concept for the Hawaii and Arizona courses would be 151 and 200 seconds respectively. If that same rider uses only the 2-Pack storage solution on the new Speed Concept, their time savings compared to riding the previous Speed Concept would be 187 and 253 seconds for the Hawaii and Arizona Ironman courses respectively (as we see, the primary drag savings comes from the 2-pack).

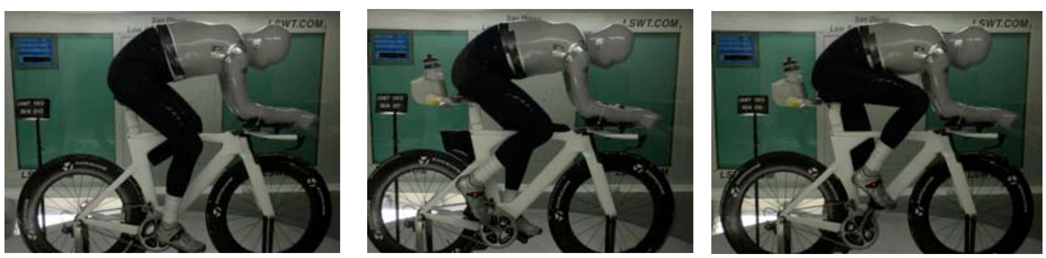

Figure 23: Various storage testing at the San Diego Low Speed Wind Tunnel. (A) New Speed Concept with Manny. (B) New Speed Concept with Manny, Draft Box, Speed Box, and 2-Pack. (C) New Speed Concept with Manny and 2-Pack.

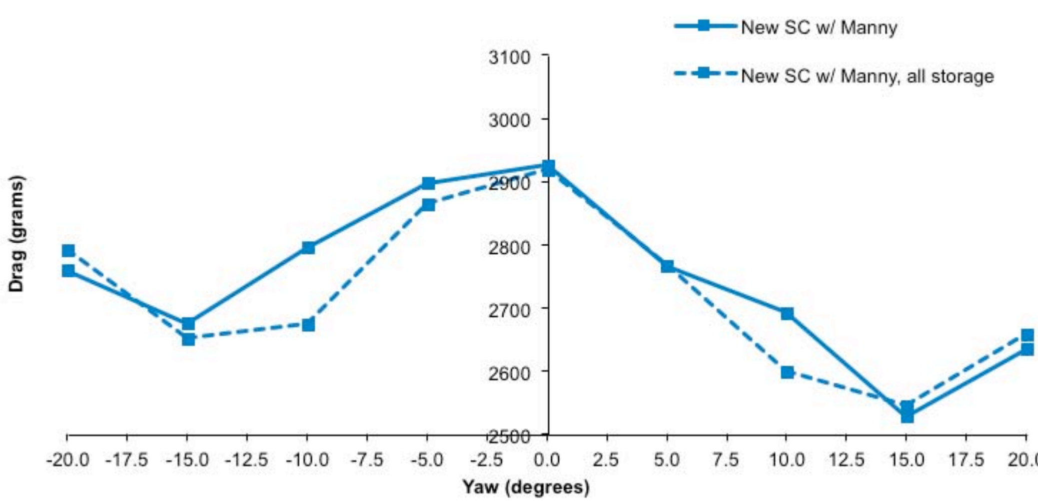

Figure 24: New Speed Concept compared to New Speed Concept with all storage. San Diego Low Speed Wind Tunnel, April 2013. Rider on. Data pulled from a head-to-head test day which included the PS-6; bike setup was normalized to the PS-6 lowest position, resulting in a lower pad stack position than was run when the Shiv Tri was included.

4.2.3 Components

Trek Engineers made the front of the bike lighter and faster, changing the extensions from a traditional extension-plus-spacer design to a mono extension design that uses a single spacer. Wind tunnel testing showed a 20-gram average drag savings from 0 to 12.5 degrees yaw when comparing the previous Speed Concept setup to the mono extension setup.

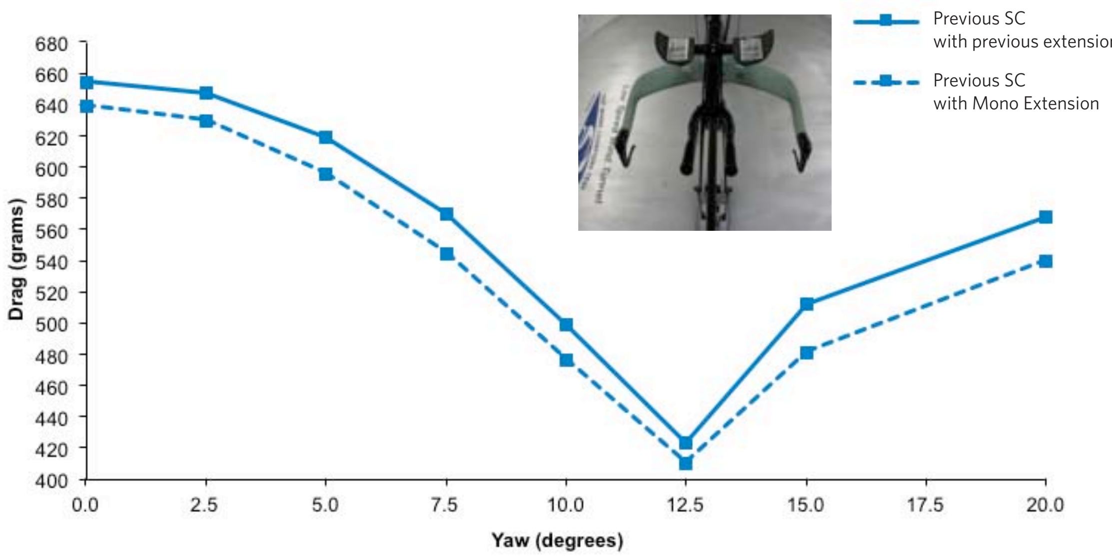

Figure 25: Previous Speed Concept setup compared to previous Speed Concept with mono extension. San Diego Low Speed Wind Tunnel, January 2012. Bike only. Bikes were tested in equal setups.

4.2.4 Brake covers, triathlon and UCI compliant

Trek engineers look at every detail of the bike to make you faster. Our brake design includes a cover with an integrated bridge, which serves not only to stiffen the brake, but to keep dirt and debris out of the system. There are two Speed Concept brake cover designs. The triathlon brake cover, called the Speed Fin, features a tail for improved aerodynamics. The Speed Fin saves an average of 10 grams of drag between 0 and 12.5 degrees of yaw. The UCI compliant version has the tail removed, and features an integrated battery mount.

Figure 26: New Speed Fin triathlon brake cover

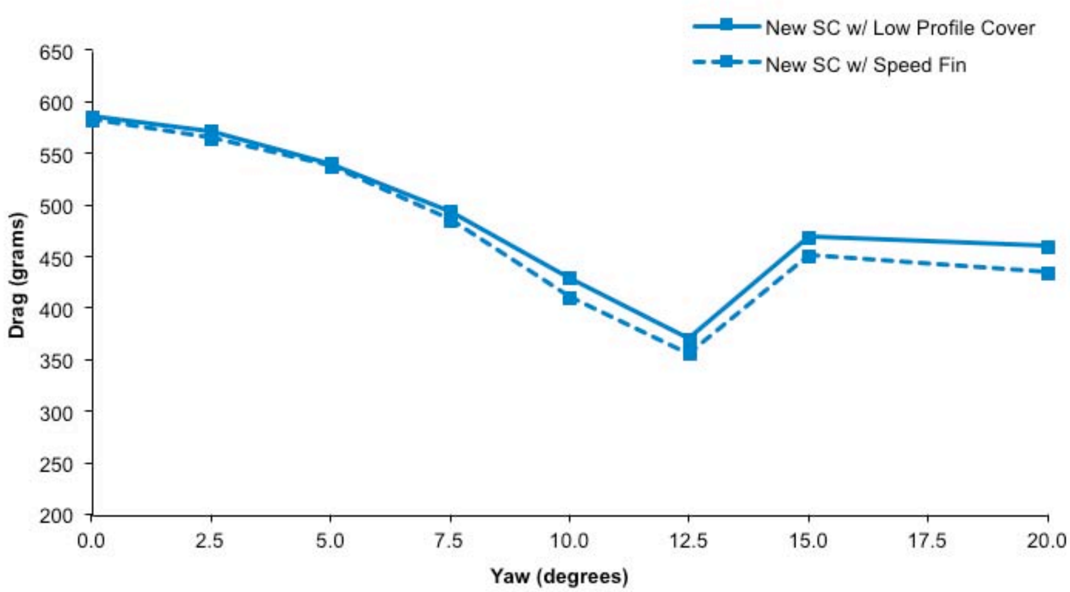

Figure27: New Speed Concept rear brake cover tests. San Diego Low Speed Wind Tunnel, January 2012.

5 Speed Storage

The Trek engineers working on Speed Concept are triathletes ourselves, so we know how important storage is—and we love our integrated storage solutions. Over the past year and a half we have made four trips to the wind tunnel specifically to test storage ideas. Testing included a new Draft Box 2-Pack Aero, Speed Box, torpedo bottle cage with integrated computer mount, and behind-the-saddle storage.

Figure 28: New Speed Concept with Draft Box, 2-Pack, and Speed Box storage.

5.1 Draft Box

Our goals for improving the Draft Box were to 1) increase the storage volume so a tubular tire would fit, 2) make installation and removal easier, and 3) design a shape that would be drag neutral—or, ideally, would make you faster.

In January of 2012, Trek engineers took the current Draft Box and three new Draft Box concepts to the San Diego Low Speed Wind Tunnel to be tested with Manny on the Speed Concept. We tested the current Draft Box, then tested with taller, longer, and wider versions, all of which used a new attachment method.

Figure 29: Wider Draft Box. San Diego Low Speed Wind Tunnel, January 2012.

The data in Figure 30 shows the results from the initial Draft Box study. The data shows a trend of being drag neutral, with the wide version possibly being the better choice for future study.

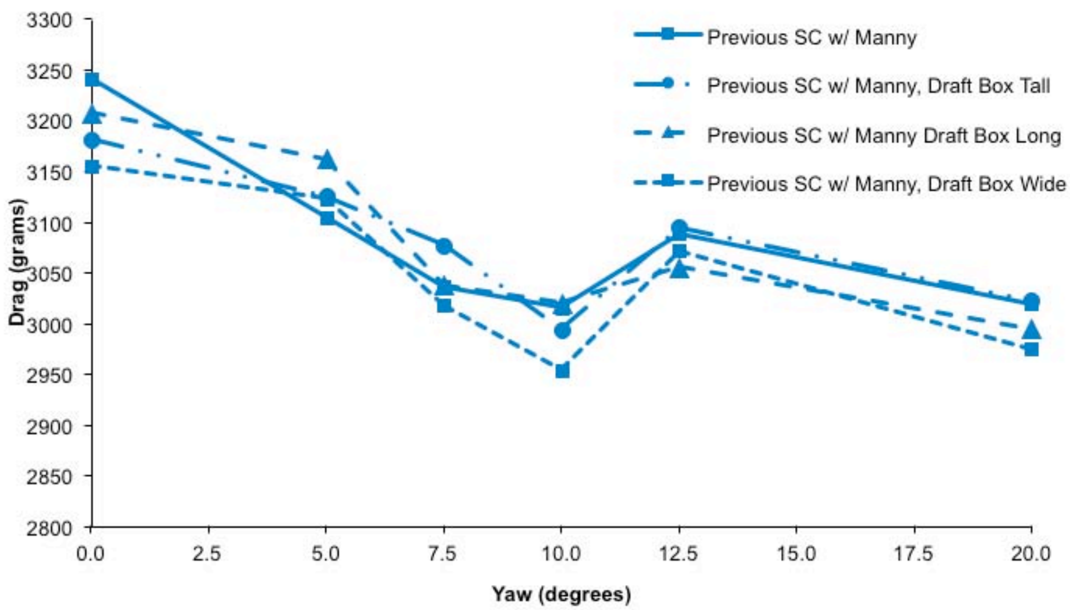

Figure 30: Initial Draft Box study. San Diego Low Speed Wind Tunnel, January 2012. Rider on.

We tested a final version of the Draft Box, based on the wider version from the January 2012 San Diego test, in the A2 Wind Tunnel in December 2012 and again in the San Diego Low Speed Wind Tunnel in April 2013. The data from the April 2013 San Diego test is shown in Figure 31. The data supports the results from the December 2012 A2 trip (not shown) and shows that the Draft Box is drag neutral. In practical terms, this means that you can carry your spare tube, tire levers, and CO_2 without incurring a drag penalty.

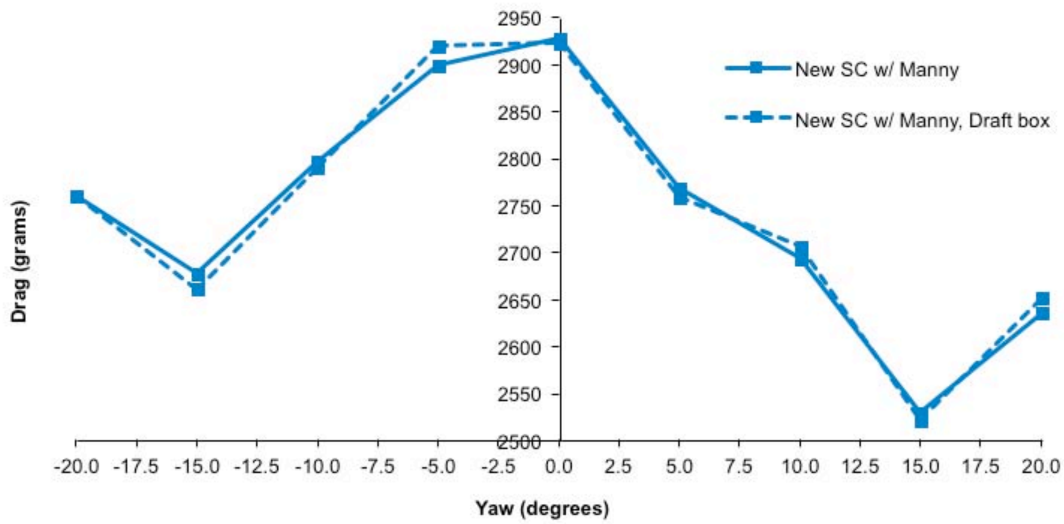

Figure 31: New Speed Concept final Draft Box concept test, rider on, normalized with the PS-6 lowest position. San Diego Low Speed Wind Tunnel, April 2013.

5.2 2-Pack behind-the-saddle storage

Trek engineers understand the problems of behind-the-saddle storage. Our design goals were to make a storage solution that would not only hold onto your bottles securely without launching them into space, but would also make you faster and give you extra storage space.

We began with CFD investigation of storage shapes of what we called a "draft pack." There were two major takeaways from the CFD analysis: 1) in the velocity contour the draft pack behind the rider elongated the wake structure and gave a bit more structure to the flow, and 2) the draft pack encouraged fluid reattachment. What did this mean? It meant that the use of the draft pack should lower your drag compared to not using a draft pack.

We made a trip to the San Diego Low Speed Wind Tunnel in January 2012 to test different bottle locations and storage shapes. Figure 32 shows data for an initial idea along with a baseline. The results were encouraging.

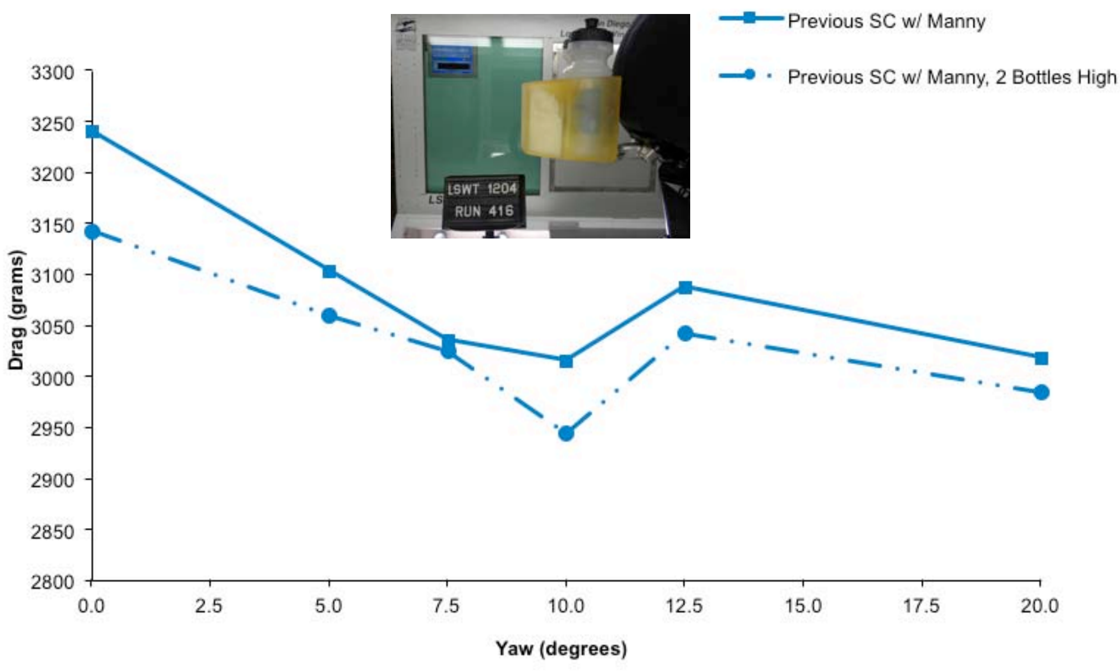

Figure 32: Initial behind-the-saddle storage test on previous Speed Concept, rider on. San Diego Low Speed Wind Tunnel, January 2012.

Trek engineers went back to the A2 Wind Tunnel in March 2012 with this storage concept, now named 2-Pack, and looked at three different positions: 120mm higher than neutral, 92mm lower than neutral, and neutral (typical location for behind-the-saddle storage). Wind tunnel results showed that the neutral position and lower test positions decreased overall drag compared to the baseline setup. The higher position had more drag between 0 and 5 degrees yaw, then became drag neutral.

Conclusion: the 2-Pack can make you faster.

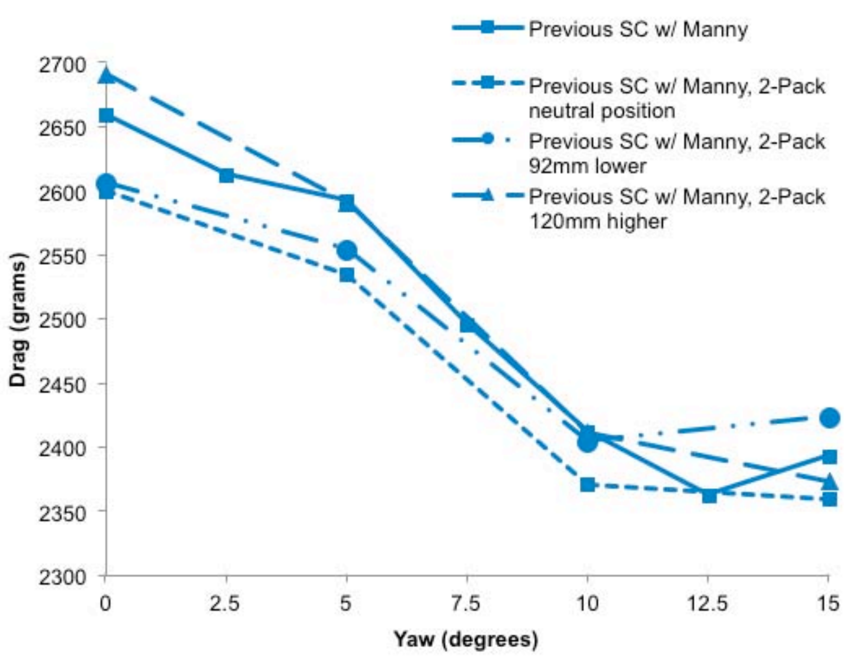

Figure 33: Behind-the-saddle storage test on previous Speed Concept, rider on. A2 Wind Tunnel, March 2012.

Trek engineers went to the wind tunnel two more times to look at the 2-Pack final design. Figure 34 shows data from our December 2012 A2 Wind Tunnel test trip. Data from the April 2013 San Diego Low Speed Wind Tunnel test trip supports this data but is not shown.

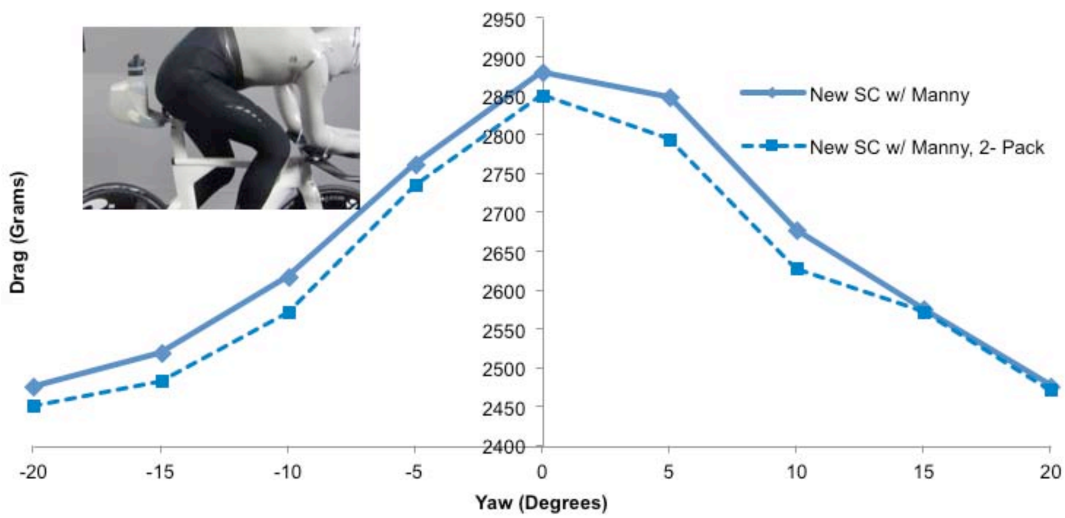

Figure 34: New Speed Concept with and without final design of behind-the-saddle storage, rider on, normalized to the lowest PS-6 position. A2 Wind Tunnel, December 2012.

5.3 Speed Box top tube storage

Trek engineers also improved the Speed Box, redesigning it to allow triathletes to hold two gel flasks or seven gel packs. We tested various Speed Box designs in the wind tunnel along with the other storage solutions. The Speed Box, like the Draft Box, was designed to be drag neutral.

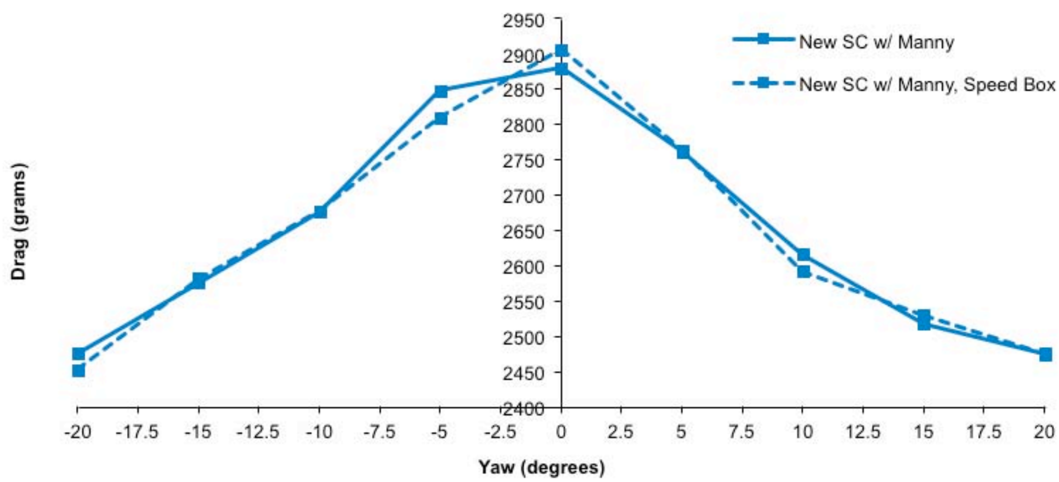

Figure 35: New Speed Concept with and without Speed Box, rider on, normalized to the lowest P5-6 position. A2 Wind Tunnel, December 2012.

5.4 Torpedo bottle cage with integrated computer mount

The final storage solution we studied was a torpedo water bottle cage with an integrated computer mount. We added mounting holes to the mono extension for a clean, simple attachment method. Our design goal was to create a system that was drag neutral. We confirmed that result in an April 2013 test at the San Diego Low Speed Wind Tunnel.

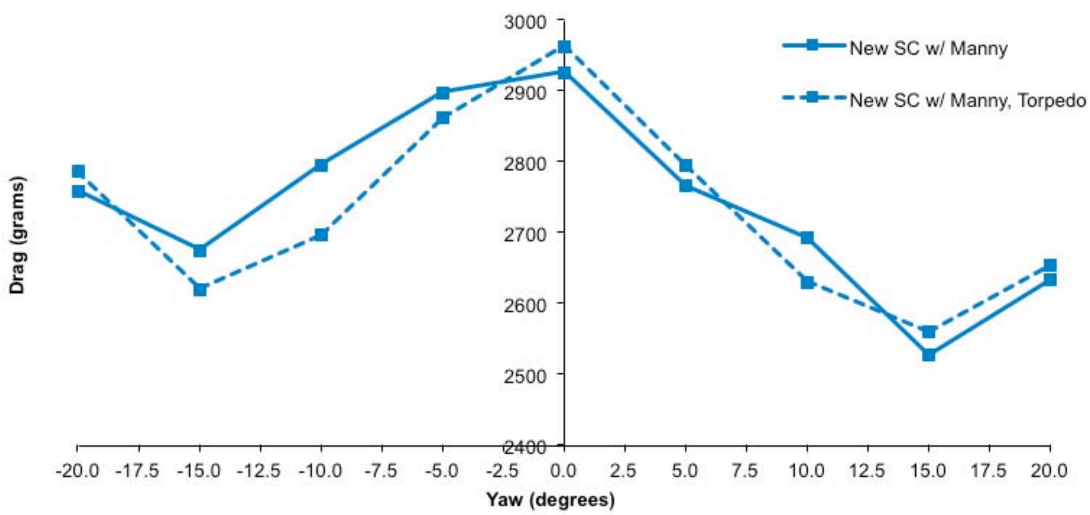

Figure 36: New Speed Concept with and without Torpedo bottle cage with bottle, rider on, normalized to the lowest PS-6 position. San Diego Low Speed Wind Tunnel, April 2013. Note: Hard stall point seen at the San Diego Low Speed Wind Tunnel is typical; we don't see that at the A2 Wind Tunnel.

Below is a nice picture of Manny with the Torpedo Bottle cage with bottle in the A2 Wind Tunnel.

Figure 37: A2 Wind Tunnel, December 2012.

6 Fit

The new Speed Concept keeps the same frame stack and reach as the current Speed Concept, but has expanded on its best-in-class pad fit range. We made adjustments based on customer feedback, so you can now get lower and further forward than on the current Speed Concept.

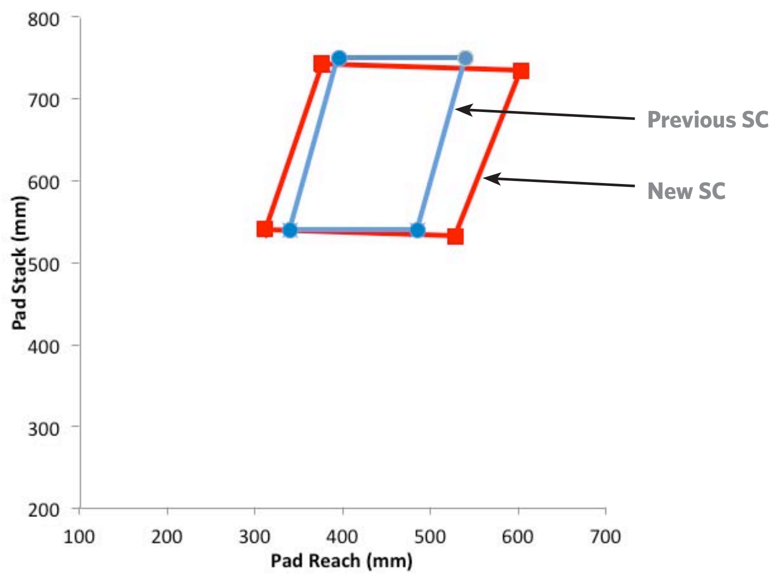

Figure 38: Previous Speed Concept compared to new Speed Concept pad fit range.

We now capture 98% of the fit data on the Slowtwitch User Group.[vi] As you can see in the graphic below, our fit range is by far the largest compared to three other major brands.

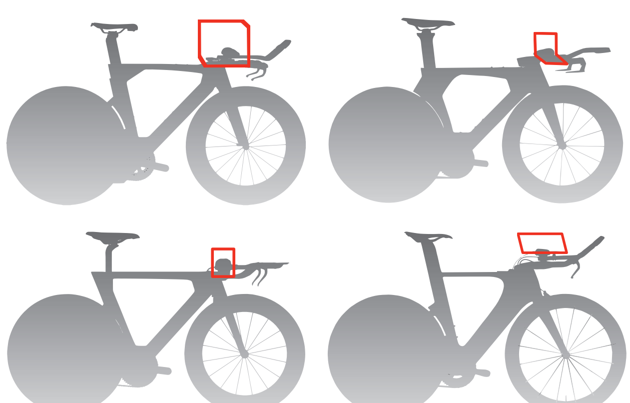

Figure 39: New Speed Concept pad fit range compared to the competition.

6.1 Stem

Pad stack and reach positions are made by first selecting a stem to put you in an approximate proximity to your desired fit. We made the low far stem stack 7.5mm lower than the low near stem. The previous Speed Concept low far stem and low near stem had equal stack. The new Speed Concept stem stack then adjusts in 35mm increments. The mono spacers come in 10mm increments. There are no longer 5 and 10mm individual spacers to stack and clamp together along with different bolt lengths to keep track of.

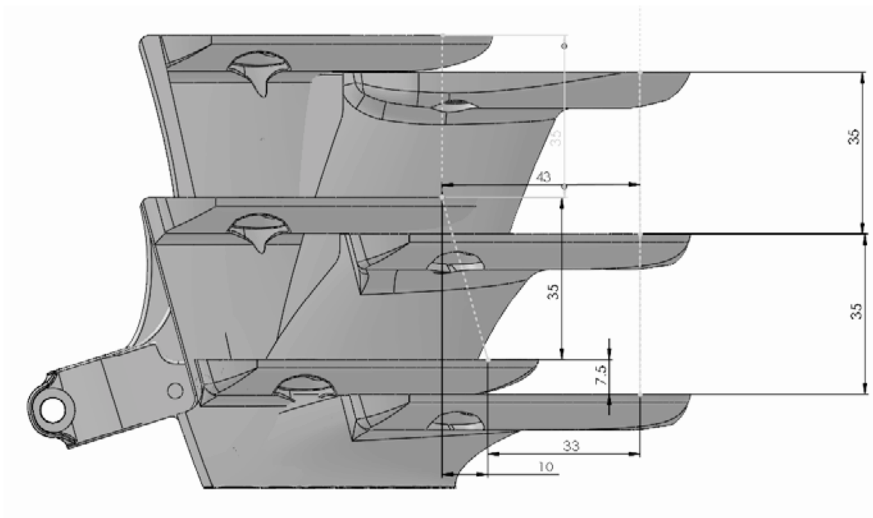

Figure 40: New Speed Concept stems.

Reach has more micro adjustment than stack. Macro reach adjustment is made by selecting your frame and stem size. Micro reach adjustment can be made by adjusting the pad wing position, arm pad position, and extensions that infinitely adjust both fore/aft, including tilt.

6.2 Base bar

We have moved the base bar forward 4mm and added 10mm of fore/aft adjustment, resulting in 4-14mm more knee clearance compared to the previous Speed Concept. We moved the brake levers back 30mm toward the rider for more comfort while climbing. We redesigned the arm pad rests for comfort, and reduced the stiffness of the arm pad system to match that of typical road bars. We also increased maximum pad width by 30mm compared to the current Speed Concept.

6.3 Extensions

Trek engineers have also improved the Speed Concept bar extensions. There are four versions: S-bend, straight, ergo, and short ergo. You can shorten any of them by cutting (the current SC extensions could not be cut due to the bend radius—doing so would reduce the straight section needed to fit the bar end shifters). You can adjust the extensions by loosening two bolts and sliding the bars to your ideal position, for 40mm of infinite adjustment. As added improvements, you no longer have to adjust each extension independently, and we've significantly reduced the number of bolts needed to adjust the extension tilt and reach.

The most aerodynamic position for the base bar and extension is parallel to the ground. (The previous Speed Concept White Paper discussed misaligned airfoils.i) However, not all our customers want to ride in that position. We've added a tilt adjustment to the new Speed Concept so you can adjust the extension angle for your most comfortable position.

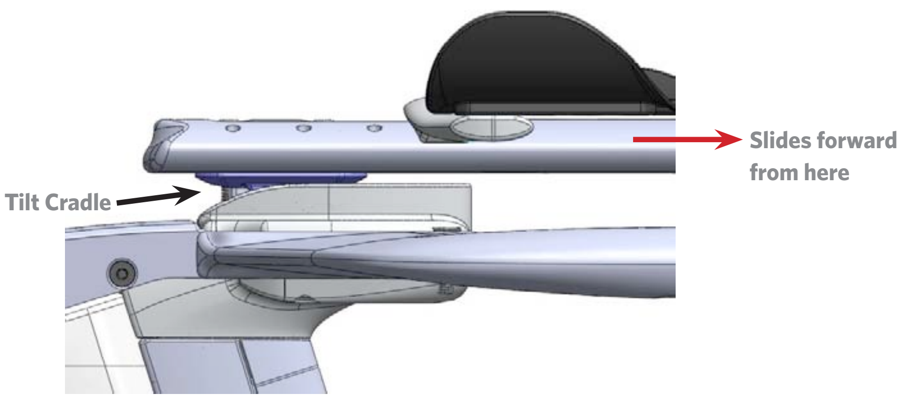

Figure 41: New Speed Concept front end. Pads are at their most fore position.

7 Simplification

One of the main design goals of the new Speed Concept was to reduce the number of fastener operations, the number of unique tools, and the amount of time required to assemble the bike and perform a position change.

The new stem, for example, takes 3 fasteners compared to 4 on the old Speed Concept stem. The new Speed Concept requires 2 fasteners in total to attach the pad holders to the extension, compared to 2 per side on the current bike.

The seat post has also been simplified. It now uses a 2-bolt clamping method, which includes a thumb wheel for saddle angle adjustment and an integrated spring that keeps the top and bottom plates from coming apart during saddle installation. The fore/aft setback can changed by flipping the seat post, instead of having to reorient or change the head as required on the previous Speed Concept seat post.

You will find the reduction in the number of parts and fasteners speeds up the build process significantly (an average of 1.5 hours for the new Speed Concept, compared to 2.5 hours for the current model) and allows for quicker stem changes and bike packaging for shipping. We've also simplified fit adjustment, making a bike that is easy to live with.

8 Appendix

8.1 November 2012 head-to-head wind tunnel test

Trek engineers took the current Speed Concept, the new Speed Concept, the Shiv Tri, and the P5 to the San Diego Low Speed Wind Tunnel in November 2012 and to the A2 Wind Tunnel in December 2012. All setups were normalized to the lowest possible pad stack and reach that all the bikes could hit. For this trip, the Shiv Tri was the limiter because its integrated aerobar system could not match the lower positions of the P5 or Speed Concept. Therefore, the reader is cautioned not to compare data from this test to tests where the lowest common position would be lower.

Typical data for head-to-head comparisons of the Speed Concept, P5, and Shiv are shown below.

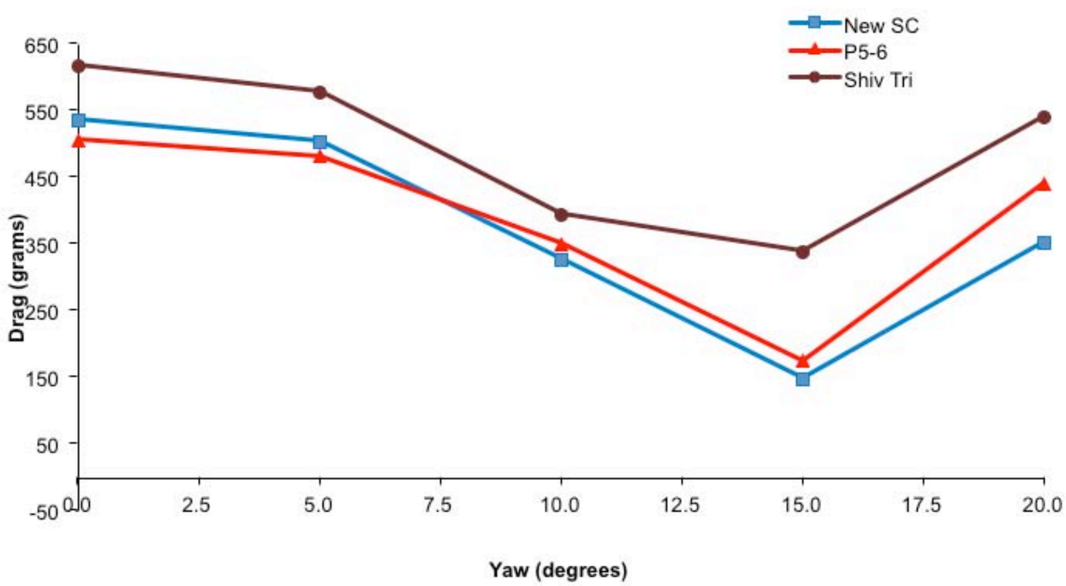

Figure 42: New Speed Concept, P5-6, and Shiv Tri. San Diego Low Speed Wind Tunnel, November 2012. Bike only. All bikes were normalized to the lowest Shiv Tri pad stack position.

Although the data from other head-to-head tests are not shown, they follow the same trend as Figure 42. The data also supports the results presented by Inside Triathlon's head-to-head shootout at *Faster* wind tunnel in Scottsdale, AZ.[vii]

8.2 April 2013 head-to-head wind tunnel test

We brought the same bikes and components to the April 2013 head-to-head tests at the San Diego Low Speed Wind Tunnel, except that the Shiv Tri was replaced with the Cannondale Slice. We tested the bikes in normalized configurations at lower pad stack positions than were tested when the Shiv Tri was included. This time the P5 was the limiter. The same front and rear derailleur, cranks, saddle, wheels, and tires were used on all bikes. The tip of the saddle is always set in line with the center of the bottom bracket.

Table 1: Bike setup (in mm). San Diego Low Speed Wind Tunnel, April 2013.

Model	Size	Stack	Reach	Pad Width (mm)
New Speed Concept	M	585	490	210
Cervèlo P5-6	54	586	490	205
Cannondale Slice	54	587	490	215

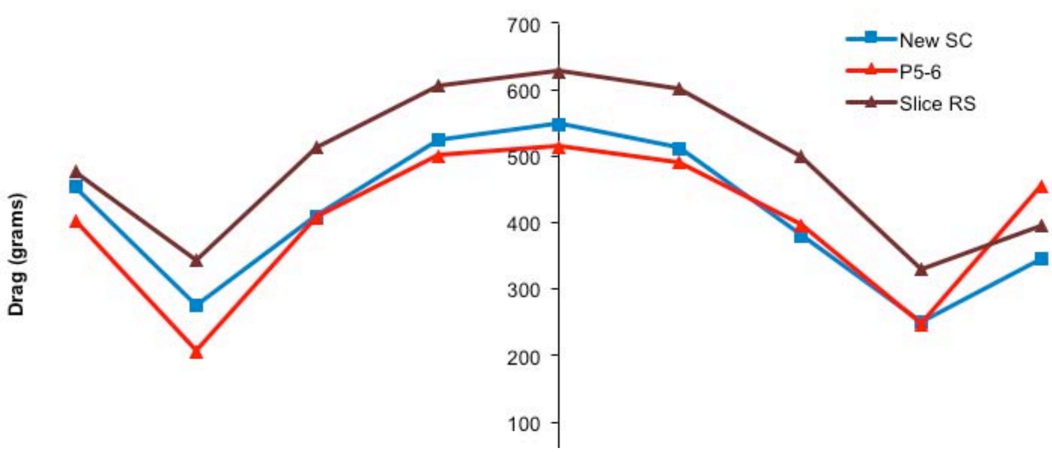

Figure 43: New Speed Concept, P5-6, and Cannondale Slice. San Diego Low Speed Wind Tunnel, April 2013. Bike only. All bikes were normalized to the lowest P5-6 pad stack position.

References

[i]Paul Harder et al. TREK BICYCLE SPEED CONCEPT WHITE PAPER. (2010) http://www.slowtwitch.com/Downloads/TK10_SC_white_paper_lores.pdf

[ii]WeatherSpark, http://www.weatherspark.com

[iii]Surfline, http://www.surfline.com

[iv]Weather Underground, http://www.wunderground.com

[v]Alphamantis Technologies, http://alphamantis.com/

[vi]Trek Bicycle proprietary data

[vii]Aaron Hersh, Race Rockets, Inside Triathlon, March/April 2013, pp. 34-40