Cervélo RCA White Paper

By

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1. Background

The story of the new Cervélo RCA starts with its predecessor, the R5ca. The R5ca was Ryder Hesjedal's weapon of choice in his victorious battle in the last Giro d'Italia.

1.1 R5ca, Giro d'Italia winner

Figure 1. Ryder Hesjedal, 2012 Giro d'Italia winner, rides his Cervélo R5ca in stage 8.

The Cervélo R5ca is strong, smooth and comfortable enough to carry Ryder Hesjedal to victory in the last Giro d'Italia.

1.2 R5ca, winner on the scale

Until the RCA, the R5ca was the lightest frameset in the world.

MARKE MODELL	RAHMEN-SET										
	Frameset weight Gewicht Rahmen-Set, Gramm	Fahrstabilitat, N/mm	Seitensteifigkeit Gabel, N/mm	BB stiffness Kraftubertragung, N/mm	Komfort Rahmen, N/mm	Komfort Gabel, N/mm	Lack	Finish	Bedienungsanleitung	Garantie	Note Rahmen-Set
Prozentantell an der Gesamtnote	25	15	15	10	10	10	5	5	2.5	2.5	100
CANNONDALE Super Six Evo Ultimate	1188	107	47	53	26	77					
	1.3	1.0	2.0	2.3	1.7	3.0	1.0	1.0	1.0	1.0	1.6
CERVELO R5ca	1084	101	57	70	91	99					
	1.0	1.0	1.0	1.0	1.3	5.0	1.0	1.0	1.0	2.0	1.5

Figure 2. TOUR Magazin comparison. Weights include hardware and are mathematically scaled to a theoretical 57cm frame size.

According to TOUR Magazin’s independent testing, the Cervélo R5ca is 104 grams lighter and 32% stiffer than the second lightest frameset tested. The Cervélo R5ca’s high and balanced stiffness earns TOUR’s best score, a perfect 1.0 for torsional stiffness (“Fahrstabilitat”)and a perfect 1.0 for bottom bracket stiffness (“Kraftubertragung”).

1.3 R5ca, wind tunnel winner

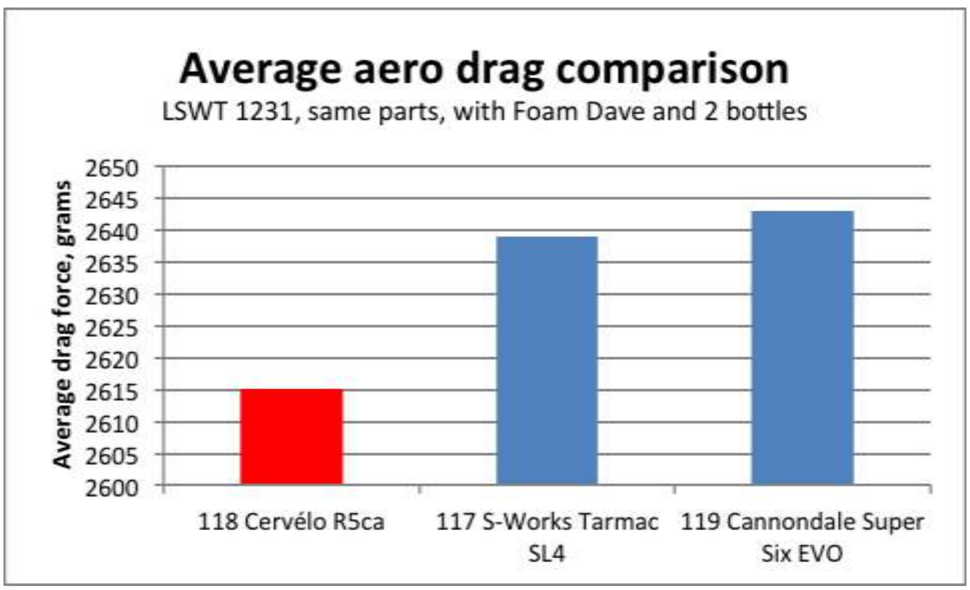


Figure 3. Bar chart comparing the average drag of various road bikes. The Squoval™-shaped Cervélo R5ca has the lowest drag of this test group.

Squoval™ and Second Generation Squoval™ R-series Cervélo bikes were engineered solely for light weight and high stiffness, without regard to any aerodynamic qualities. But when we finally included an R-series in a routine wind tunnel test along with several other road bikes, we were surprised to find it had the lowest drag among non-aero road bikes, with only the dedicated pure-aero road bikes, like the Cervélo S-series, having less drag. By accident, the structurally optimized shape of Squoval™ (convex sides, precise radius corners) wasn't bad aerodynamically. In fact, it was better than traditional round tube bikes. Naturally, we saw this as a chance to add a little aero engineering to Squoval™ shapes, maybe even without disturbing their already class-leading stiffness and light weight qualities.

2. From R5ca to RCA

Figure 4. Cervélo R5ca (left) and the new Cervélo RCA (right).

This new model will simply be the top of the R-series line. Reflecting its *hors catégorie* status, outside normal series production, it's simply the RCA – we've dropped the "5" from the name.

The RCA Mission

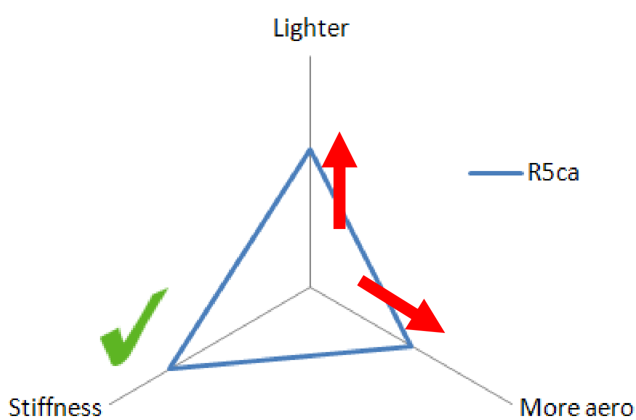


Figure 5. Spider chart illustrating the desired increase in performance of the RCA over the R5ca

With such technical and sporting success with the R5ca, the mission for the new RCA was clear: Improve on it. First of all, make it even lighter. Second, keep the optimum stiffness. And third, add as much aero as possible. Long known as the team focused on driving technical advances aimed at making riders faster, Team Garmin-Sharp riders requested a light, stiff bike that was also aero. Their request and our mission matched perfectly: (1) Make it lighter. (2) Keep the stiffness. (3) Add aero. To successfully meet these requirements called for all our engineering capabilities.

3. Engineering capabilities

With more engineers than bike models, Cervélo has always used the most advanced engineering tools, in some cases going as far as programming our own software when what we need is not commercially available.[1] Four of our key engineering capabilities are highlighted here.

3.1 Project California

Figure 6. An RCA main triangle mould in our Project California lab

Having our own advanced composite R&D lab in the heart of the U.S. military-industrial-aerospace region makes engineering the lightest and stiffest bikes easier for us. Project California functionally allows us to have full control: Our aerospace engineers, our composite analysis tools, our CNC cutting table, our tool design and mould fabrication, our moulds, our test lab, all under one roof. The fact that every RCA will be completely cut, kitted, laid up, machined and bonded by hand, in this same lab, makes it possible for our engineers to push the performance limits farther than ever before. Project California has already excelled in raising the light weight and stiff bar in the R5ca, and this same technology has already trickled down into every R-series Cervélo made today. As the designated sole manufacturing site of the new RCA, Project California is a foundational component in the creation of the new RCA.

[1] E.g. CETOP, custom pre-processing software written by Cervélo engineers to speed up the FEA analyses during initial development of Squoval tube shapes in 2005.

3.2 Laminate Tools

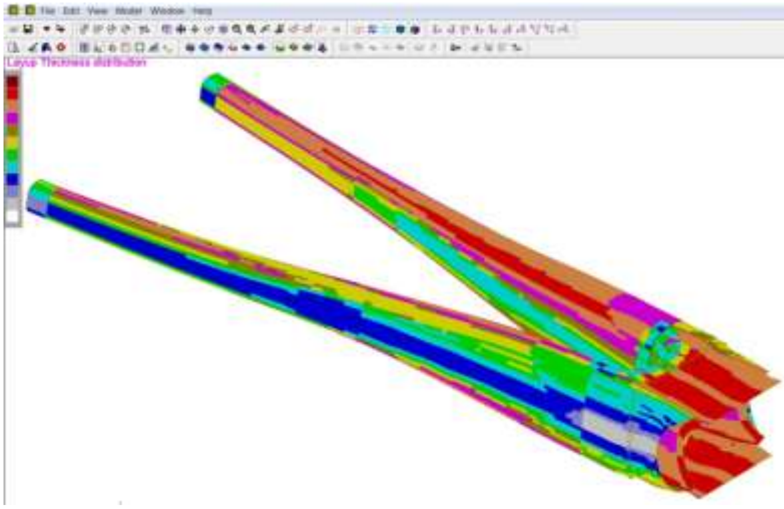


Figure 7. Layup Thickness distribution prepares CAD models for FEA and displays the complexity of optimizing ply shapes & drop-offs for best frame performance

More than just FEA, Laminate Tools lets our engineers predict structural properties & behavior of complex anisotropic materials. This stress-based analytical layup development process results in the right carbon, in the right spot, giving optimal performance with no excess weight.

One key to quickly optimizing the lay up is software that can accurately predict direction and magnitude of stresses and strains throughout a complex multi-layer, multi-geometry composite structure. Simple FEA isn't enough: we've added Laminate Tools to our engineering capabilities to enable ply-by-ply analysis, modeling each of over 400 pieces of carbon fibre individually, including their individual dimensions, location, orientation and varying material properties. As you reduce weight by taking out carbon, you have to be sure the carbon left behind to do the work is in the right place, in the right orientation, in the right amount and of the right type to withstand the demands of the job. Other bike companies might farm out this analysis step to outside consultants for their most expensive model only, or use the "make it and break it" technique of physically testing moulded prototypes, but neither of those techniques provides the engineering precision or insight of being able to see analytical results directly, nor the in-depth technical insights necessary to successfully trickle to successfully integrate the increased performance throughout our model line.

3.3 Validated CFD

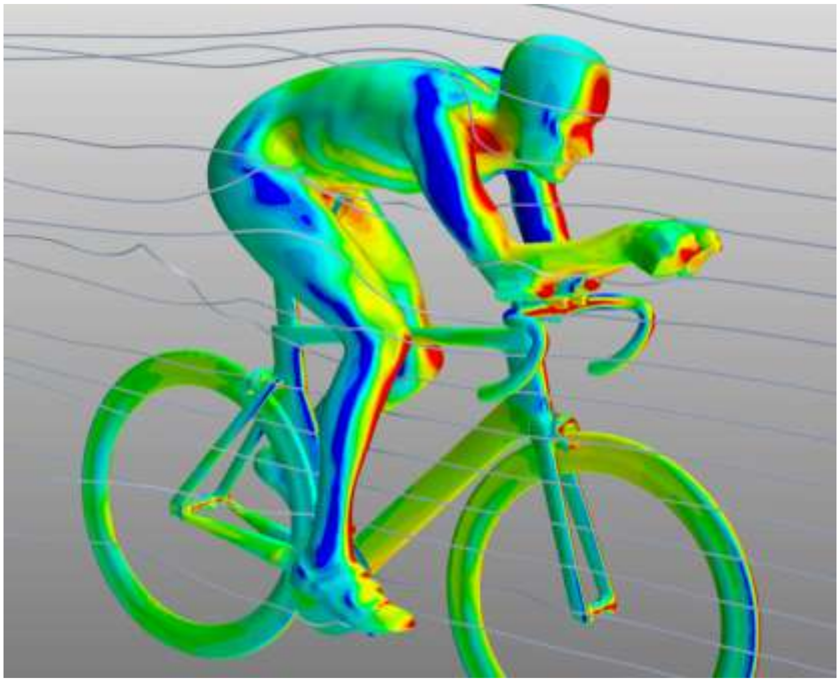


Figure 8. Validated CFD showing pressure distribution on and streamlines around a rider on a Cervélo S5

Just as our Project California capabilities makes engineering the lightest bikes easier, having our own advanced F1-level CFD simulation and analysis capabilities in our Toronto headquarters makes engineering the most aero bikes easier. Our software, our aerodynamicists, our CAD models, our visualization tools, all painstakingly validated and calibrated to our wind tunnel test results, make it possible for our engineers to push the aero performance limits farther than ever before. Our validated CFD process has already proven itself in designing the most aero road and triathlon bikes in the world—the Cervélo S-series and P-series— and is another of the engineering capabilities we've put to full use in engineering the new RCA.

3.4 Precision wind tunnel & test protocol

Figure 9. Cervélo engineers working with Foam Dave in the San Diego Aerospace Technology Centre's Low Speed Wind Tunnel.

Another necessary element to engineering the new RCA is our industry-leading wind tunnel test protocol. We use only the best wind tunnels, fully qualified and aerospace-certified to provide minimal blockage, minimal boundary layer thickness, uniform velocity and flow conditions throughout the test section, and a long expansion section behind, to let the wake form naturally without affecting upstream flow or pressure forces that can create unrealistic flow conditions, which can corrupt the drag measurements. Combine our long history of repeatability analysis, the daily use of a symmetrical bike (to check flow symmetry) and twice-daily use of a known standard reference bike (to check drag accuracy) together with our realistic "Foam Dave" mannequin & precision positioning and you have a accurate, repeatable tool to measure drag forces that directly relate to real world performance.

3.5 What these engineering capabilities have gotten us so far

Project California and Laminate Tools are advanced structural engineering tools; validated CFD and a precision wind tunnel & test protocol are advanced aero engineering tools.

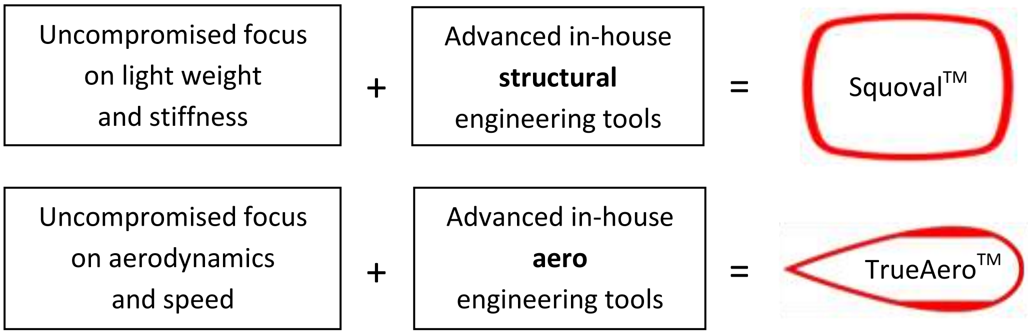


Figure 10. Schematic showing first, Squoval™ as the outcome of (1) an uncompromised focus on light weight and stiffness, plus (2) application of advanced *structural* engineering tools, and second, TrueAero™ as the outcome of (1) an uncompromised focus on aerodynamics and speed, plus (2) application of advanced *aero* engineering tools.

The Cervélo engineering capabilities listed above have been proven in developing the R-series, the lightest road bikes in the world, and the S-series, the most aero road bikes in the world.

4. Engineering the RCA: CASE

The engineering mission in designing the RCA was to combine these engineering capabilities in a Concurrent Aero & Structural Engineering (CASE) process to produce (1) an even lighter road bike with (2) as much aerodynamics as we could apply, (3) without losing any stiffness. We did that in two phases: First, Parametric Analysis, and second, Iterative Design.

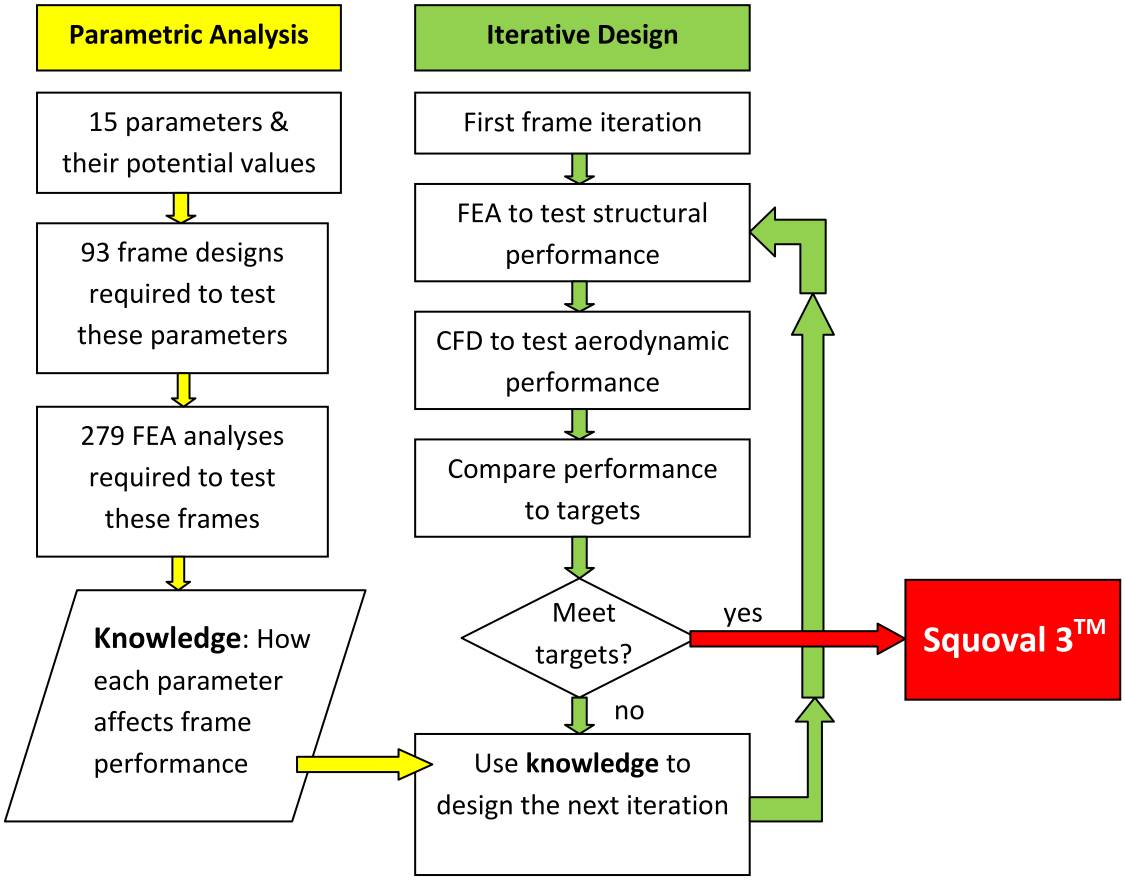


Figure 11. Flowchart illustrating the Parametric Analysis stages as preparation for the Iterative Design stages.

First we'll describe the Parametric Analysis phase, then the Iterative Design phase, then the outcome of the overall CASE process.

4.1 Parametric analysis

Before developing the RCA, we designed 93 new frames.

In order to begin engineering the RCA, we systematically quantified the performance effects of every parameter of the frame. Knowing how each parameter affects the weight, stiffness, comfort, and aerodynamics of the bike gives us the control needed to tune the various parameters to achieve an optimum blend of all the performance attributes. This parametric analysis is the engineering preparation necessary before beginning design of the next Cervélo. It's doing our homework.

Of course, the effects of many frame parameters are already well known, such as oversized frame tube dimensions increasing stiffness. Basic tube cross section dimensions strongly affect frame performance (weight, stiffness, comfort, aero). That's why existing Cervélos have Squoval™ or TrueAero™ tube shapes; relentless engineering towards either light weight or aerodynamics naturally results in those distinctive families of cross sections.

But other frame dimensional parameters, such as depth of the chainstay crotch or lateral spacing of the seat stays, also have an effect. What happens to frame performance if you choose a larger radius between the seat tube and down tube? Smaller? If you choose a longer down tube chord, or shorter? What happens to overall frame stiffness if you take material from the chainstays and put it in the seat stays? In order to maximize performance and minimize weight, we quantified the effects of those parameters and more.

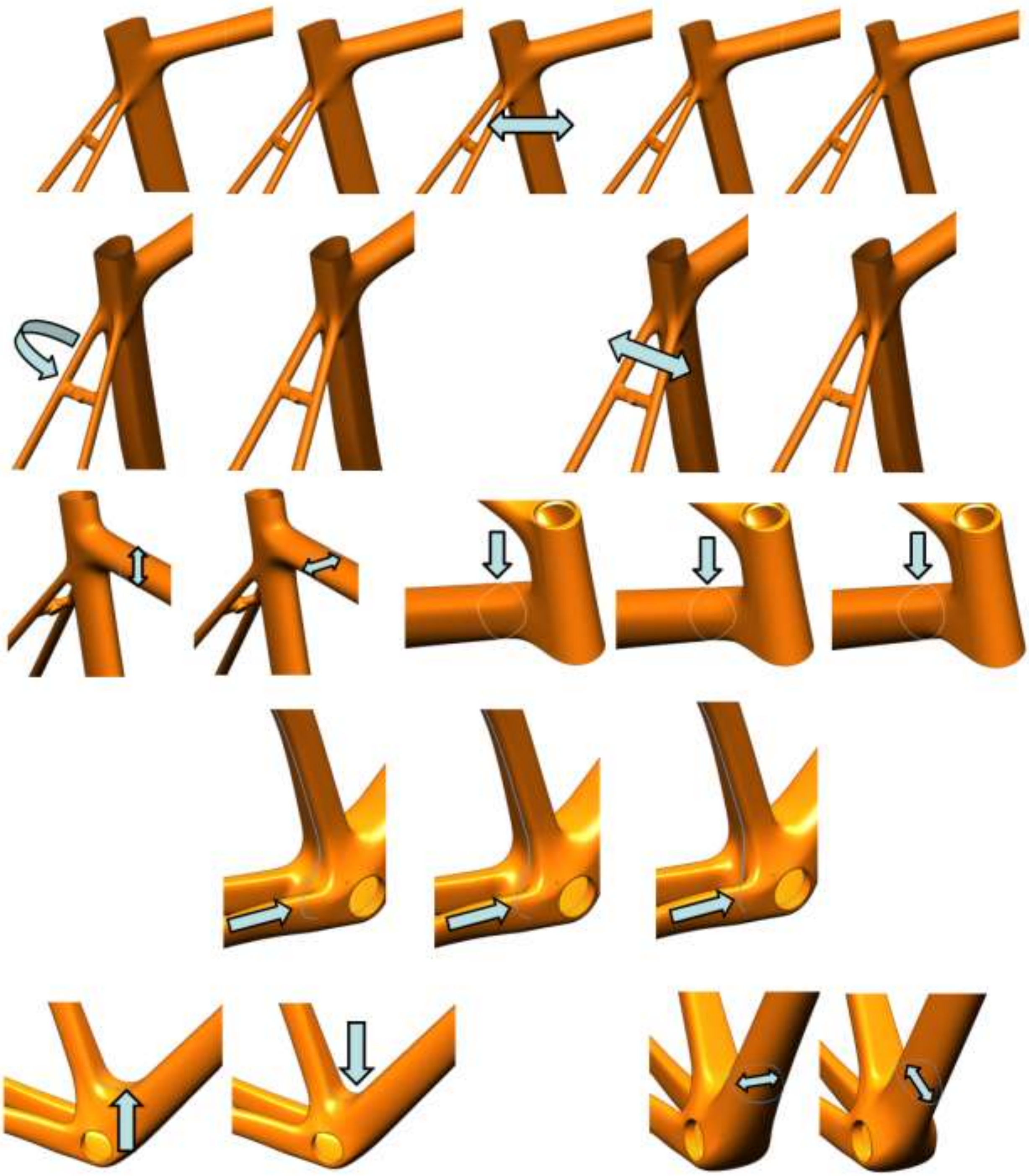


Figure 12. Some frame dimensional parameters optimized for the RCA

- 15 parameters, and multiple values of each
- 93 different frame shapes
- 279 FEA analyses

We systematically examined multiple values of 15 specific design parameters. The resulting 93 individual frame designs were virtually tested and evaluated for stiffness, weight and comfort using 279 FEA analyses. Result: in addition to basic tube cross section shapes, we now know what other parameters of the frame to change, by how much, to tune the performance of the frame. With this knowledge, and with optimum weight, stiffness, comfort and aero goals firmly in our sights, we were ready to begin designing the RCA.

4.2 Iterative design

Figure 13. Some of the iterations of the RCA's CAD models used in virtual testing to evaluate the effect of various combinations of design parameters on weight, stiffness, comfort and aerodynamics.

With exhaustive knowledge of the effect of every parameter as a means to control changes in the frame's performance, we were ready to design the first iteration of the RCA's frame shape.

The first concept of the RCA was designed and its performance was virtually tested: Structurally, using FEA, and aerodynamically, using CFD. Then we used the knowledge gained from the parametric analysis phase to further tune the design, resulting in the second iteration. This design process is a cycle: design, virtually test, redesign, test again. It is a non-linear process, since changing one area of the frame affects all areas of the frame. For example, if you make the seat stays stiffer, the stress in the chain stays changes. And most – but not all – shape changes affect aerodynamics. Knowing the effect of each parameter, we were able to choose precisely the right changes to improve the next iteration. With each iteration, the new design came closer and closer to perfection, step by step.

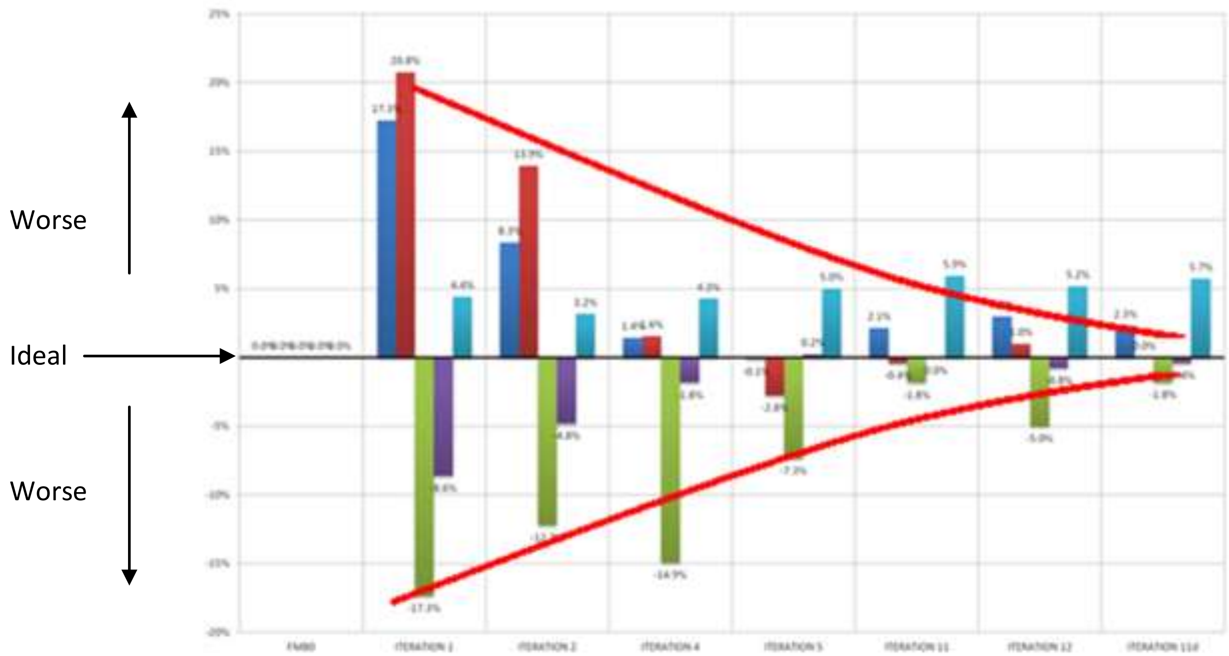


Figure 14. Improvements come step by step. Frame design iterations plotted along the horizontal axis. Percent deviation from the ideal performance (weight, stiffness, comfort, aero) plotted on the vertical axis. Red curves show the trend toward the ideal.

By comparing the predicted weight, stiffness, comfort and aerodynamics of each frame iteration to the ideal targets, we can see progress being made with each iteration. Knowing how each frame parameter affects performance (a result of the previous parametric analysis) has given us the tools needed to tune overall frame performance.

Simultaneously evaluating the aerodynamic and structural properties of each frame iteration is the key to the RCA's excellent performance. That's the value of Concurrent Aero & Structural Engineering (CASE).

4.3 Outcome: Squoval 3™ family of shapes

Stiff, light and now aero too.

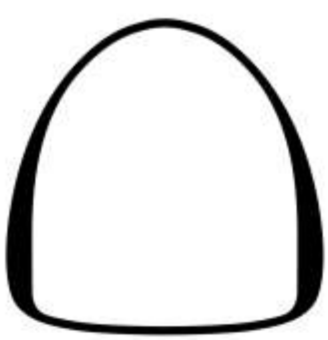


Figure 15. Squoval 3™ is a family of tube cross sections (one example, left) used in various frame tubes (seat tube shown at right).

Squoval™ family tree

The Squoval 3™ family of tube shapes is a direct descendant of first- and second-generation Squoval™. The first generation of Squoval™ tube shapes were engineered in 2005 purely for high strength, stiffness and low weight. In 2009, second generation Squoval™ used new engineering technology gained in Project California to further lighten, strengthen and stiffen Squoval™ Cervélo models. Only afterwards, when tested in a wind tunnel, did we find Squoval™ frames had better aerodynamics than traditional round tube frames. By lucky accident, Squoval's structurally engineered convex sides and corner radii were pretty good in the wind, much better than the simple square examples in fluids textbooks.

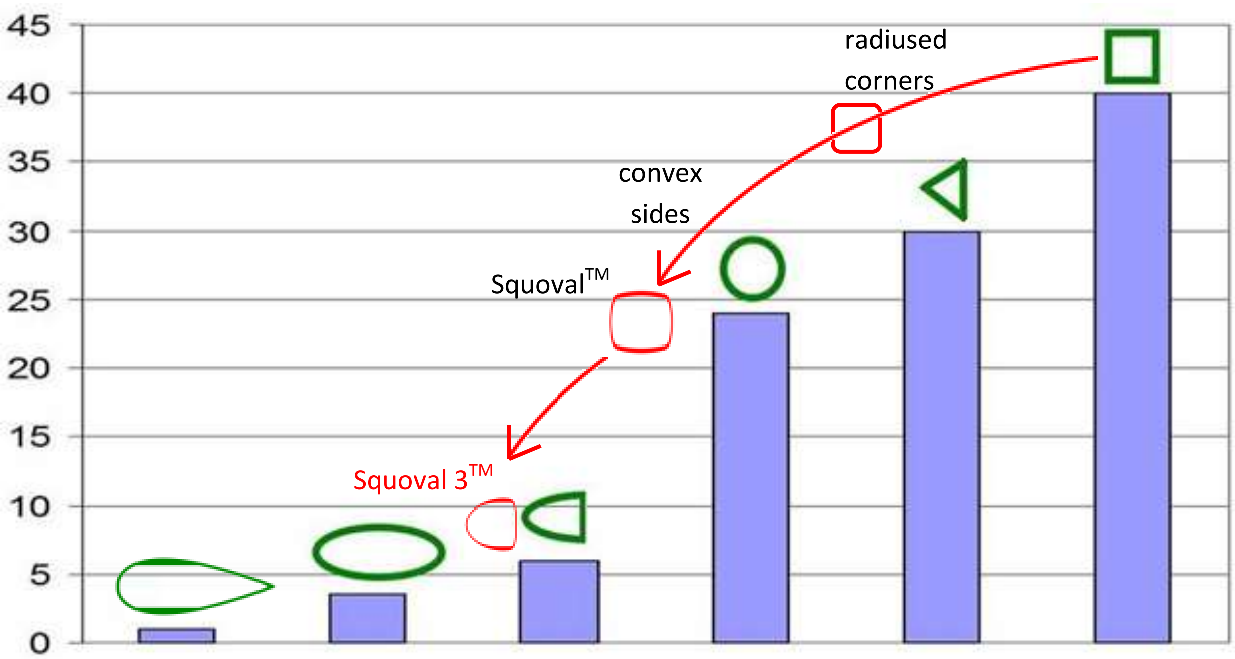


Figure 16. Relative aerodynamic drag. Aerodynamic drag is on the vertical axis, in multiples of a true aero shape. Each shape has the same frontal area, so the chart compares the drag due to shape only.

For many years now, we've used the above chart with the green shapes as a reference. Now in red, we've added a path showing an evolution from square, to radiused, to convex sides leading to the surprisingly low drag of Squoval™.

The descendant

Could we improve Squoval™? Yes! Using the Concurrent Aero & Structural Engineering process described above, we:

- Sculpted the leading edges (down, head and seat tubes),
- Turned two ellipses by 90 degrees (lower seat stays) and
- Tweaked the corner radii (trailing edges).

Of these changes, sculpting the leading edge has the largest aerodynamic effect, and this change in shape reduces drag via two primary mechanisms:

1. First, the when the leading edge is curved, more like a true airfoil, pressure on the leading edge is reduced: air flows more freely around an airfoil's nose. This is evident in CFD analysis results as a reduced size of the red or orange coloured high pressure zones on the surfaces.
2. In addition, the pressure on the surface is by definition normal to that surface – and Squoval 3's curved leading edge means the pressure vectors do not point aft, as they do on a flatter, blunter leading edge, but at an angle from the bike's direction. This is important because this angled pressure vector can be split into two component vectors, side force and drag, both of which represent less force than the normal pressure from which they are derived.

Thus, in addition to the first effect above (less pressure), the smaller drag component of the normal vector also reduces drag on the bike.

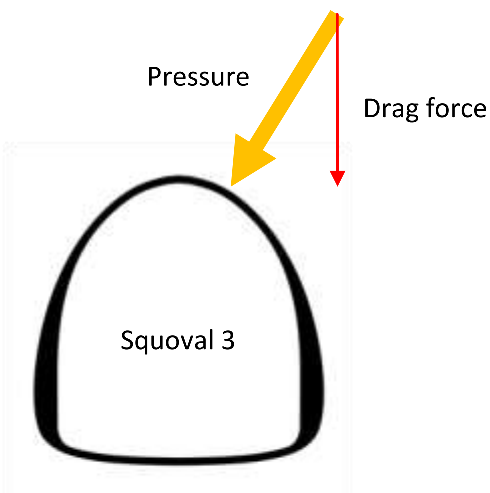


Figure 17. Most of Squoval 3's airfoil leading edge is not perpendicular to the bike's direction, so drag force is reduced: it's a smaller component of the normal pressure vector.

AeroZone™ included

Included in the Aero component of the CASE process is the AeroZone™ concept developed as part of the Cervélo P5 project, which simply states that parts upstream affect flow downstream, and that drag can be further reduced if skin surfaces are locally shaped to optimize them for flow conditions.

The Squoval 3™ down tube is a good example of the application of the AeroZone™ concept. Near the top of the down tube, close behind the front wheel, the cross section is roughly four-sided, very similar to Squoval 1 or 2, while near the bottom of the down tube, farther away from the front wheel, the section is roughly three-sided, with a leading edge more like a TrueAero™ airfoil. This change in down tube shape matches the change in local flow conditions: the top part of the down tube is drafting in the wake of the front wheel, so aero shapes are less important and structural considerations can drive the shape.

One of the AeroZone™-driven changes in Squoval 3's shapes can be seen on the right in the image below. Compare the roughly four-sided section at the top of the down tube to the roughly three-sided section at the bottom.

Figure 18. Left: Cervélo R5ca. Right: Cervélo RCA. Red & orange colours represent higher pressures; blue and green, lower. The red area, highest pressure, is approximately the same on both bikes, but the orange area, second highest pressure, is much smaller on the RCA (right).

Only top tube and chain stays have no aero influence in their design, as our analyses revealed they have virtually no effect on aerodynamics. As a result their cross sections are chosen to maximize structural performance (stiffness, light weight and comfort), with no consideration for aerodynamics.

Squoval 3™ benefit

As will be detailed elsewhere in this report, the Squoval 3™ frame shape reduces aero drag by a whopping 74 grams (equivalent to 7.4 Watts) compared to second generation Squoval™ frames, without giving up any stiffness or gaining any weight. Now you can have your cake and eat it, too.

5. CASE: the results

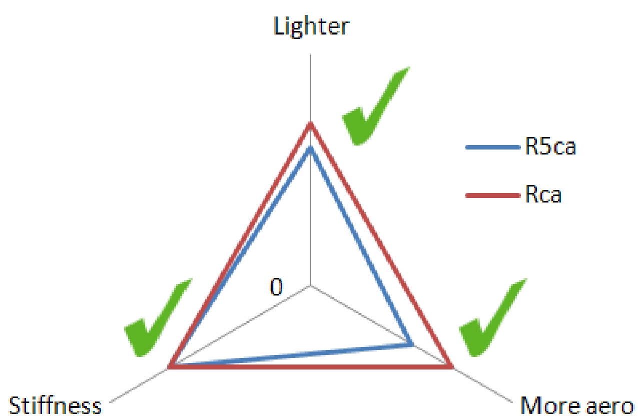


Figure 19. Illustration of the performance improvements of the RCA over the benchmark R5ca.

Let's look in detail at each of the above areas of frame performance: weight, stiffness and aerodynamics.

The results of combining Cervélo's unique in-house engineering capabilities (Project California, FEA Laminate Tools, validated CFD and precision wind tunnel & test protocol) in a Concurrent Aero & Structural Engineering (CASE) process are as follows.

5.1 Weight

Figure 20. This size 54cm RCA weighs 667 grams with paint& hardware. Electronic hardware (shown in the photo but not on the scale) weighs three grams less than the mechanical hardware it replaces.

The Cervélo RCA is a weight weenie bike: we took the lightest frameset in the world and made it lighter. Average weight of the Rca is **667 grams** +/-20g, size[2] 54cm with paint & parts. Production is closely monitored in our Project California facility to minimize variation – no weight gain over time in production here. Your RCA will be light.

Size	48			51			54			56			58			61		
	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
Weight (w/ FDM, WB bolts), sanded/prep	563	583	603	570	590	610	574	594	614	583	603	623	638	658	678	693	713	733
paint finish	27	27	27	28	28	28	30	30	30	30	30	30	34	34	34	36	36	36
Finished weight	590	610	630	598	618	638	604	624	644	613	633	653	672	692	712	729	749	769
Hardware	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Total weight	**633**	**653**	**673**	**641**	**661**	**681**	**647**	**667**	**687**	**656**	**676**	**696**	**715**	**735**	**755**	**772**	**792**	**812**

[2] Size 54 is the average frame size for Team Garmin-Sharp pros.

Table 1. Cervélo RCA weights. Statistics calculated based on first production period.

We show this production data to also point out that we could have claimed an unpainted frame weight in the 500s of grams.

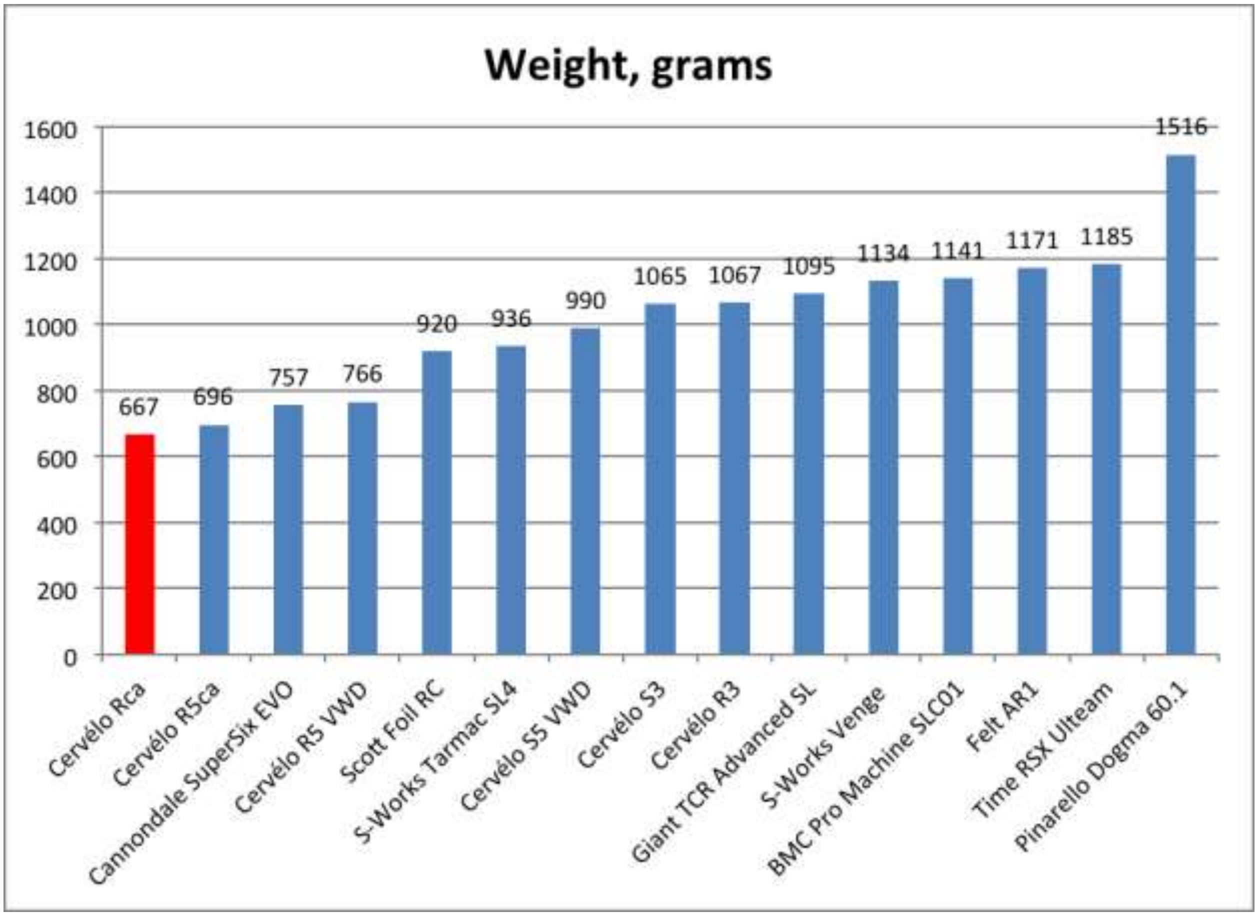


Figure 21. Frames are listed from left to right in order of increasing weight. Source: Frames purchased through the normal distribution channels and weighed at Cervélo Cycles, Inc.

Light weight is important when climbing and accelerating. In these often critical race situations, all else equal, a lighter bike is a faster bike.

5.2 Stiffness

With a three percent increase in torsional stiffness and three percent decrease in bottom bracket stiffness, the RCA has maintained essentially the same stiffness as its top-scoring predecessor, the R5ca.

5.3 Aerodynamics

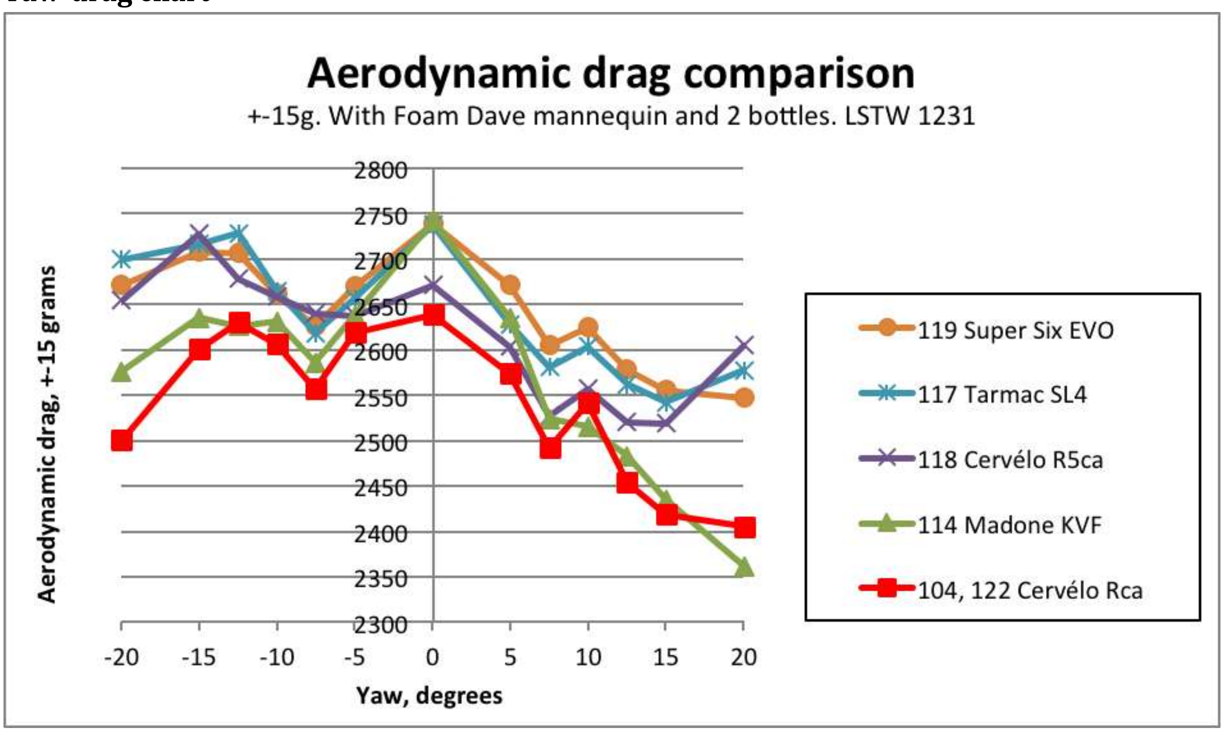
Wind tunnel data

We compared the aerodynamic performance of the RCA to other road bikes in the San Diego Aerospace Technology Center's Low Speed Wind Tunnel (LSWT.com).

Figure 22. Cervélo RCA in the wind tunnel

All bikes used the same athlete (Foam Dave), the same riding position and the same component parts, following our standard wind tunnel protocol.[3]

Yaw-drag chart



[3] http://www.slowtwitch.com/Tech/A_Day_in_the_Life_of_a_Wind_Tunnel_2198.html

Figure 23. Drag-yaw chart. Aerodynamic drag force is on the vertical axis (lower drag is better). Yaw (apparent crosswind angle) is on the horizontal axis, representing crosswinds from the left and right sides of the rider.

In the figure above, the RCA is shown in red squares with a thick red line. This chart shows that at nearly every yaw point, the Cervélo RCA has the lowest aerodynamic drag in this test group.

Sometimes comparing a typical drag-yaw chart such as the one above can be overwhelming with too much information. Since at any single yaw point a different bike may have higher or lower drag, it's not always easy to see the overall difference. One way to provide a clearer view of the overall aero performance of the different bikes is to average the yaw data. While it loses some granularity, averaging all yaw points into a single number for each bike can simplify the comparison.

Average drag chart

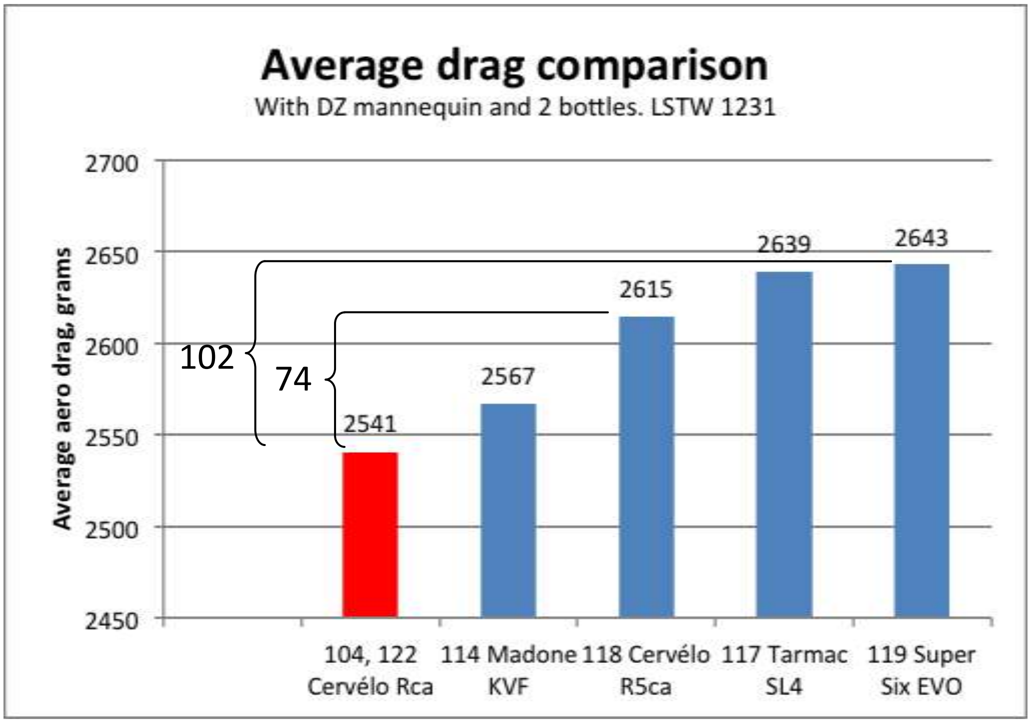


Figure 24. Average drag of the same bikes in the drag-yaw chart above. Lower drag is better. Compared to the Cervélo RCA, other (slower) bikes have up to 100 grams higher drag.

The figure above compares the average aero drag of the RCA against other high-end road bikes. The chart shows that the RCA has the lowest average drag of the bikes in this test group. This reduction in aero drag means the other road bikes require more power for the same speed. Compared to the benchmark R5ca, the new RCA saves 74 grams of drag, equivalent to 7.4 Watts at 40 km/h (25 mph). Over a 5-hour stage, this adds up to more than 100 kiloJoules of energy saved.

How much power[4] can the RCA save?

Bike	drag (grams)	RCA saves (Watts)

[4] Based on average drag and using Dr. Andrew Coggan's rule of thumb that 100 grams is equivalent to 10 Watts.

Cervélo RCA	**2541**	**0 (baseline)**
Madone 7.9	2567	2.6
Cervélo R5ca	2615	7.4
Tarmac SL4	2639	9.8
Super 6 EVO	2643	10.2

Table 2. Additional power required to maintain 40 km/h (25 mph) on a road bike other than the Cervélo RCA.

6. RCA Benefits

We've looked at Cervélo's in-house engineering capabilities and CASE design process that led to the RCA's performance, but what does it mean to the rider?

It's tempting to look at special features and insider technical stories themselves as making a bike good, and such insights into technology and design are indeed interesting. But if they don't make the bike faster, they're of no performance benefit to the rider. Frame performance comes down to weight, stiffness, comfort and aero. Everything else is either a means to these ends or doesn't affect performance. With the RCA, every special feature and technical story exists as a result of our focus on improving the rider's performance.

Weight: The RCA is the lightest frame in the world. Light weight helps on every acceleration and climb.

Stiffness: The RCA keeps the same test-winning stiffness of its predecessor, the R5ca. The right amount of stiffness helps the rider in accelerating, climbing and sprinting, as well as handling: enough torsional stiffness is needed for precise turn in and tight cornering.

Comfort: Together with ComfortPly™ technology, the RCA's thin walls, small diameter seat stays and optimized tapered steerer tube provide the perfect feedback from the road to the rider: in touch with the road, but not rough riding.

Aerodynamics: The RCA is 7.4 Watts[5] faster than the R5ca and up to 10.2 Watts faster than typical road bikes.

These real performance benefits help the RCA athlete in all riding situations.

7. Innovations

In engineering the RCA, we developed several material and design innovations. These innovations each play a small role in making the RCA the lightest bike in the world, with all the test-winning stiffness of the R5ca and better aerodynamics than other road bikes.

[5] Riding alone at 40 km/h

7.1 New materials

Integran/PowerMetal Nanovate™

We take fork steerer tube safety seriously.

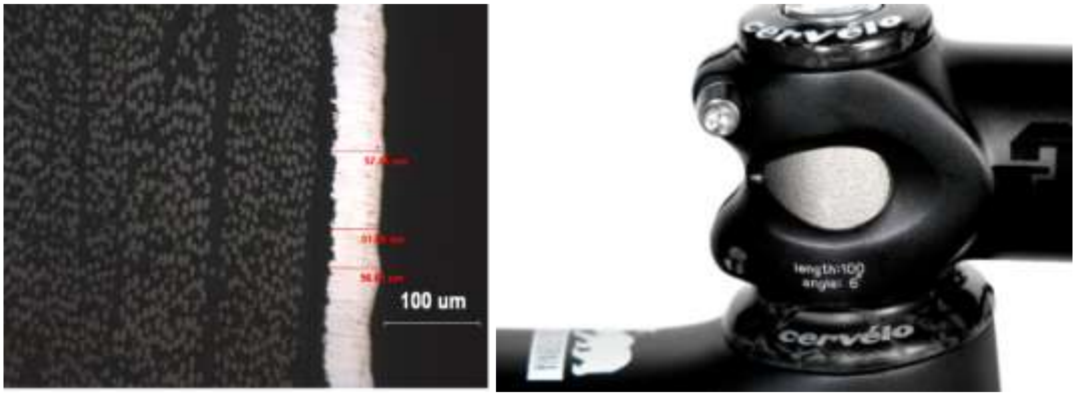


Figure 25. Left: Magnified image of a cross section showing the composite steerer tube (left) and the Nanovate™ nano nickel coating (silver colour). Right: You can see the textured, silver-coloured nickel on the outside of the fork steerer tube.

Why add nickel to carbon fibre? Metals have toughness composites don't. PowerMetal Nanovate™ adds a strong, light coating on the fork steerer. Decreasing metallic grain size increases the yield strength by the well-known Hall-Petch mechanism. The grains in PowerMetal Nanovate™ nickel are 1000 times smaller, increasing yield strength by 7 times over conventional nickel. Unlike typical nano materials, PowerMetal Nanovate™ is formed in-situ in a proprietary process that creates zero porosities, resulting in higher ductility as well. Strength plus ductility is toughness, which is how we've been able to engineer a tougher fork without adding weight.

3M™ Powerlux™ resin system

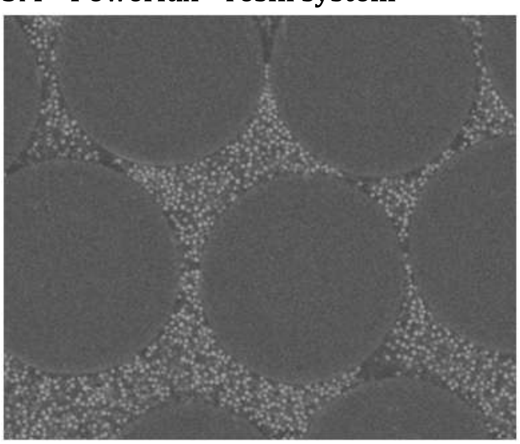


Figure 26. Micrograph showing ideal and even dispersal of nano-silica reinforcement (grey dots) within the resin in between each carbon fibre (black circles)

3M's nano-silica filled, 3M™ Powerlux™ resin system improves interlaminar shear & compression strength, the first nano-resin to demonstrate real structural improvements in rigorous carbon fibre coupon testing. We were able to reduce frame weight for the same strength. Compared to more common nano-rubber filled epoxy resins (“toughened” resin systems), which increase toughness at the expense of interlaminar shear strength and compression strength, 3M’s new resin system improves all three properties – but as a premium material, it’s used in the RCA in a few critical areas only.

7.2 Design features

Hollow carbon fibre dropouts

A smart reversal of internal and external coupling.

Figure 27. Left: Male stays are bonded into female dropouts. Polymer cable housing stop is also shown, partially installed. Right: Looking through the hollow dropout along the straight-shot cable route.

Stays are bonded into dropouts instead of the reverse. By bonding two precision moulded surfaces together, we eliminated the sacrificial plies in the stays, saving 5 grams per frame. These sacrificial plies were necessary when we used to machine the inside of the stays to bond them the opposite way (dropout into the stays). The hollow right dropout also gives the internal rear derailleur cable a straight shot through the chain stay and dropout, eliminating another bend and another source of cable friction.

Future-proof internal cable stops

Sleek, smooth and mechanic-friendly

Figure 28. Down tube mechanical cables (left) and electronic cables (right) are easily interchanged on the same frame. Click-in guides are also available for hydraulic lines.

Cables easily run inside the down tube, bottom bracket and chain stay, whether mechanical, electronic or hydraulic. Putting cables inside reduces aero drag and cleans up the exterior of the bike. Interchangeable ICS (internal cable stops) are light weight, and click into the frame to fit mechanical, electronic or hydraulic lines.

Integrated Power Meter Magnet

Figure 29. Close up photo of the right side of the RCA down tube. Decal near the crank indicates magnet location.

A strong neodymium magnet is laid in between the carbon fibre plies of the frame's down tube near the bottom bracket, positioned at the perfect radius from the crank axis to be sensed by popular crank-based power meters.

8. Specifications

Geometry

The RCA has the same geometry as current Cervélo R-series models.

Size	**48**	**51**	**54**	**56**	**58**	**61**
Head Tube Angle, degrees	70.5	72.2	73.1	73.5	73.5	73.5
BB Drop, mm	68	68	68	68	68	68
Head Tube Length, mm	108	128	148	173	199	225
Front Centre	575	577	575	587	604	620
Rear Centre	405	405	405	405	405	405
Stand Over Height	693	723	753	784	815	846
Stack	505	530	555	580	605	630
Reach	360	369	378	387	396	405

Fork Offset	53	53	43	43	43	43
Top Tube	516	531	548	564	581	597

All sizes have 700c wheels and 73.0 degree seat tube angle.

Table 3. Cervélo RCA sizes and geometry

Frame features

Bulkheads

Adding the right structural elements reduces weight and increases stiffness.

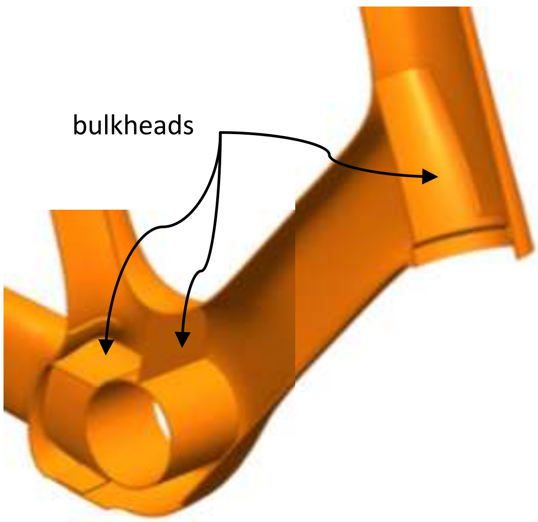


Figure 30. Internal bulkheads at the chain stays and bottom bracket (left) and head tube / down tube area (right)

On very light frames only, unsupported thin frame walls can buckle slightly under high loads, reducing strength and stiffness. Light weight carbon fibre bulkheads at strategic locations (down tube at head tube, seat tube at top tube, above the bottom bracket shell) brace the walls, boosting stiffness while adding less weight than would be needed to thicken the walls. Net result: 2.2 grams lighter and 6% stiffer, as seen in the RCA. Frames with sufficiently thick walls wouldn't benefit from adding bulkheads, so bulkheads are currently found in the R5ca, RCA and S5VWD only.

ComfortPly™ technology

Built-in comfort

Figure 31. ComfortPly technology adds only the plies needed for performance, none of the plies that can lead to a harsh ride.

ComfortPly™ technology uses the same composite analysis software tools not only to optimize strength, stiffness and weight, but also to fine-tune frame properties in two ways: First, we know where to put the stiff fibres and where to put the strong fibers. Second, during layup development, once strength and stiffness targets are achieved, ComfortPly™ technology actually removes unneeded fibres to reduce weight and vibration and improve ride quality.

BBright™

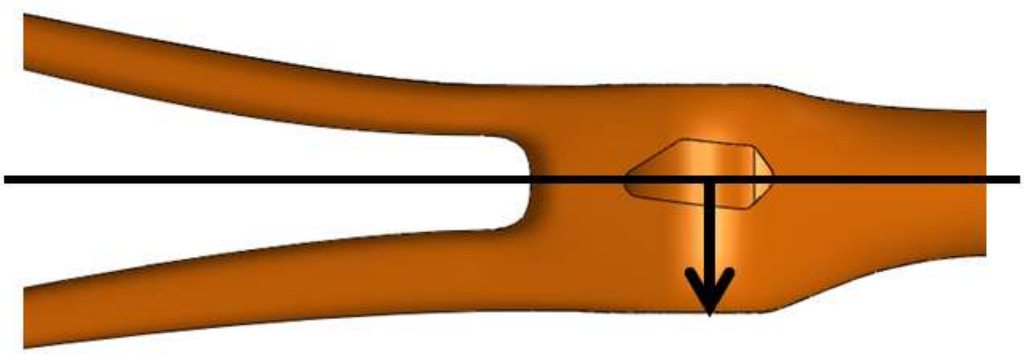


Figure 32. BBright extends the left side 11 millimeters to increase stiffness while saving weight.

Asymmetric, stiffer, lighter: BBright is the only Bottom Bracket standard that uses an oversize 30mm axle and allows for oversized frame tubes (up to 16% wider than standard bottom brackets). It offers the optimal combination of stiffness and weight for the overall system. The RCA follows the BBright PressFit bottom bracket standard. See http://bbright.net/ for more information.

SmartWall™

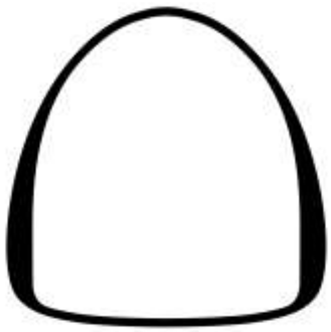


Figure 33. Squoval 3™ showing SmartWall™: thicker walls on the sides.

SmartWall™ intelligently redistributes material around the tube cross section to increase lateral and torsional stiffness while adding the least weight.

Most unwanted frame flex is out of plane, putting one side in compression and the other side in tension. Thus, material farthest from the center plane has the greatest effect on improving stiffness. SmartWall™ adds material only at the outside walls, farthest from the center plane, to maximize lateral stiffness and minimize weight.

Ultra thin seat stays

Figure 34. Ultra thin seat stays on the Cervélo RCA

Long proven in the existing R-series Cervélo models, the RCA also uses our trademark Ultra Thin seat stays. Now, as part of the Squoval 3™ family of tube shapes, the bottoms of the stays have been rotated 90 degrees. The major axis of the cross section is now oriented parallel to the air flow, to reduce aero drag.

Single-bend cable routing
Shift perfectly.

Smooth shifting that is easy to set up is no accident, when small details have a huge impact.

Each individual cable gets its own individual curve. One curve, in one plane, with the perfect radius and perfect direction. The cable bends once, only around the bottom bracket, not side to side. By removing twists and bends from the cable path, friction is removed ensuring crisp, effortless shifting in all conditions.

The RCA uses an internal version of Cervélo's single-bend BB cable guide. Even though it's inside the frame, we've opened up the edge of the hole just enough to allow a mechanic to install either cable without having to remove anything else: not the other cable, not the crank or bottom bracket, not a single bolt.

A small detail, but very effective.

END