Avona Velum Whitepaper

A Balanced Approach to a Modern Race Bike to Achieve Robust Performance Gains

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Abstract

In the development of the Velum, we focused on combining gains in aerodynamics, rolling resistance, friction and weight to create a bike that performs in a wide range of riding situations, and to have those gains at every price point. Key facts:

- Aerodynamics on the level of the best all-round race bikes on the market
- 798 g frame weight (size 54, painted)
- Lower rolling resistance and drive train friction than your typical stock bike
- Focus on vertical compliance for increased comfort and speed

Targets

At the start of the project, we set our goal of creating a bike that addresses the needs of real riding. Optimizing a bike for a particular performance parameter or a lab test alone results in significant compromises outside of those restrictions which we wanted to avoid. Instead, our aim was to create the most balanced bike, one that performs in every riding situation. Because on most rides, you face a variety of riding situations, and you should never feel like you are riding the wrong bike. What we want to achieve is what we call robust performance gains, meaning they apply to a wide range of riding situations.

Reviewing Real World Data

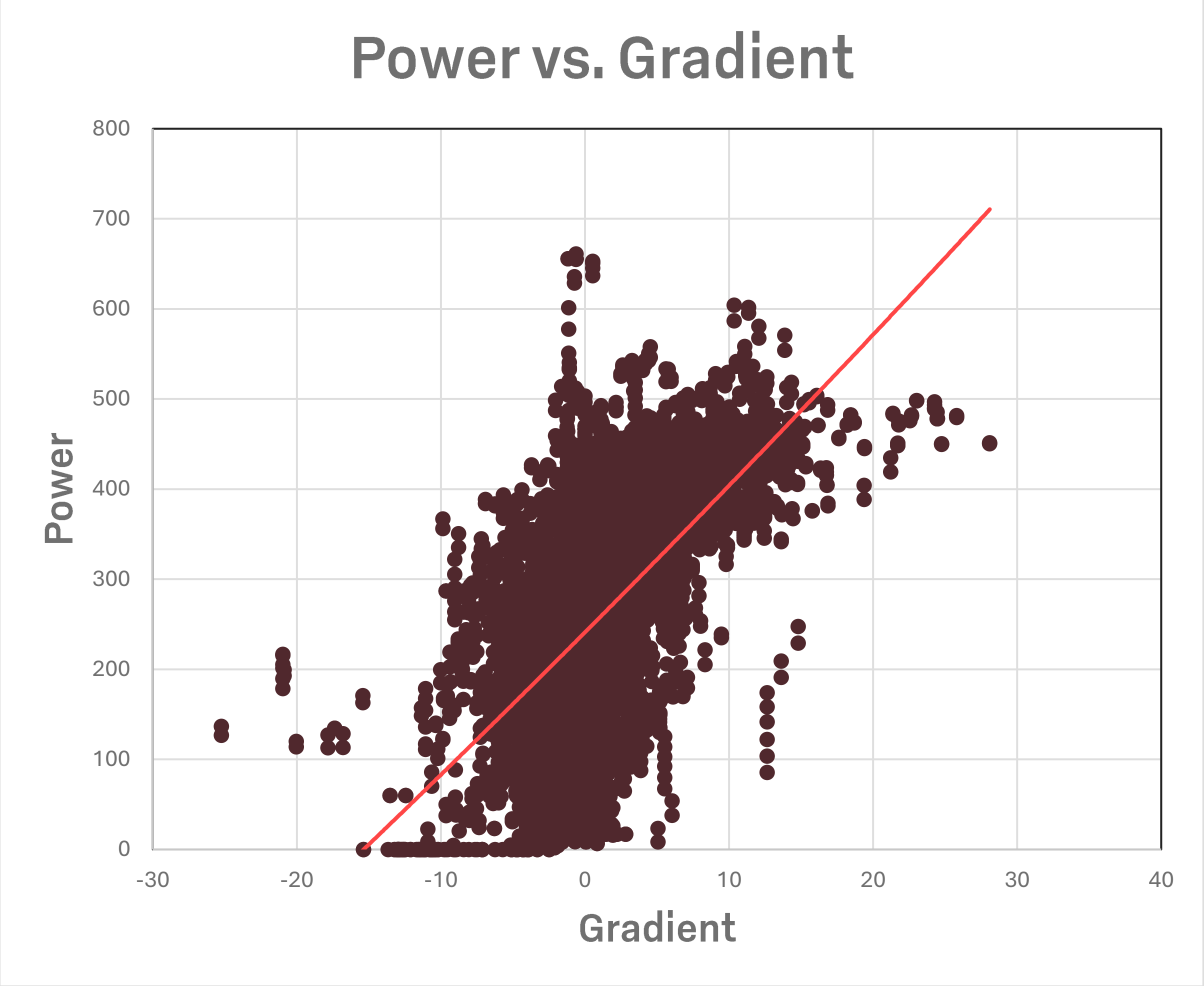
At the start of the project, we worked through hundreds of .fit files. What we looked at:

- At what riding situations do riders get to their limit?
- How much time do they spend in what riding situation?
- What type of rider benefits from what type of improvement?
- How much can we reduce normalized power by equipment optimization

Those findings allowed us to optimize performance in a way that is of the most benefit to the rider. We used them to determine which performance parameters to optimize and how to weigh them against each other.

Where Do Riders Put out the Highest Power?

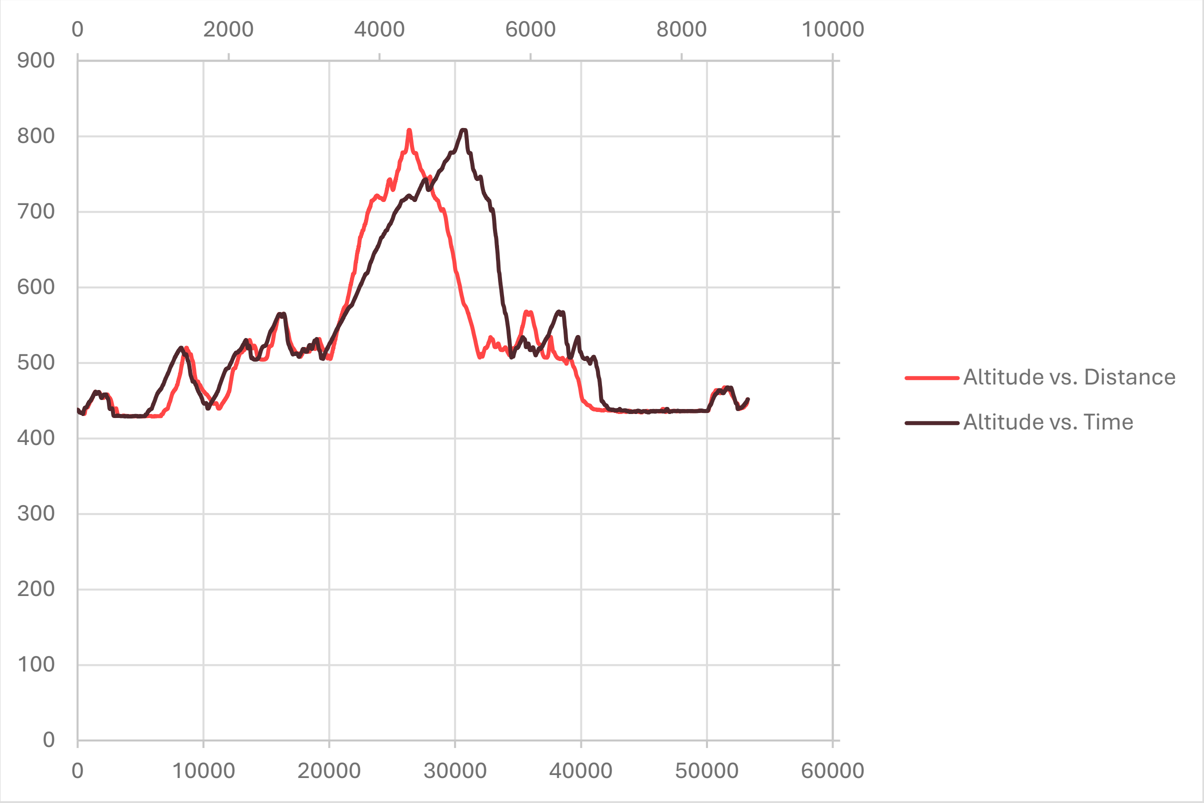
If we plot power against gradient, we get a quite clear picture:



Riders tend to put out significantly more power when climbing than in the flat. However, there are situations where a rider puts out a lot of power even in the flat, for example when closing a gap to the group in front or in a sprint. But while there is also a lot of riding at low power in the flat, that does not exist in climbing. That means climbing contributes a lot more to normalized power and therefore should be weighed higher when optimizing performance.

How Much Time in What Riding Situation?

The more time you spend in a certain riding situation, the more you benefit from the specific gains. Minutes is what matters, not kilometers. We are used to looking at graphs that plot altitude against distance, but these lead to a distorted reality: climbs look like a smaller, flat sections and descents like a bigger portion of the ride than they actually are. Plotting elevation against time gives us a more accurate picture:



Even more impressive is looking at the numbers: Even though gradients above 2% made up for only 27% of the distance, 43% of time were spent there. Again, this means we need to value improvements in climbing higher than in it might seem on first look.

What Type of Rider Benefits from What Type of Improvement?

Most of the fit files we have come from quite strong, competitive riders. But how do these simulations then apply to more recreational riders? To answer this, we created virtual riders, that did the same rides, but at lower power and/or higher weight, and did the same simulations again.

It is often stated that slow riders benefit just as much from aerodynamic benefits as faster riders, using time differences over a given distance. This calculation works out to be roughly true, but it comes with a catch: it works out so nicely because it mixes time and distance as a parameter in a flattering way. If you use the same method of asking how much faster a rider would finish a 100 km ride with equipment that is improved for rolling resistance, drive train efficiency or depending on terrain weight, you will find that a slower rider actually benefits more from those improvements than a fast rider.

Climb Comparison

Total Weight [kg]	Power [W]	CdA [m2]	Drivetrain Loss [%]	Gradient [%]	Crr [-]	Speed [km/h]	Distance [km]	Time [s]	Time Difference [s]
84	350	0.321	2	8	0.005	16.68	10	2158.27	43.1
82	350	0.321	2	8	0.005	17.02	10	2115.16	
84	250	0.321	2	8	0.005	12.25	10	2938.78	61.1
82	250	0.321	2	8	0.005	12.51	10	2877.7	
82	350	0.321	5	8	0.005	16.56	10	2173.91	58.8
82	350	0.321	2	8	0.005	17.02	10	2115.16	
82	250	0.321	5	8	0.005	12.15	10	2962.96	85.3
82	250	0.321	2	8	0.005	12.51	10	2877.7	
82	350	0.321	2	8	0.01	16.22	10	2219.48	104.3
82	350	0.321	2	8	0.005	17.02	10	2115.16	
82	250	0.321	2	8	0.01	11.87	10	3032.86	155.2
82	250	0.321	2	8	0.005	12.51	10	2877.7	
82	350	0.345	2	8	0.005	16.96	10	2122.64	7.5
82	350	0.321	2	8	0.005	17.02	10	2115.16	
82	250	0.345	2	8	0.005	12.48	10	2884.62	6.9
82	250	0.321	2	8	0.005	12.51	10	2877.7	

Flat Comparison

Total Weight [kg]	Power [W]	CdA [m2]	Drivetrain Loss [%]	Gradient [%]	Crr [-]	Speed [km/h]	Distance [km]	Time [s]	Time Difference [s]
84	350	0.321	2	0	0.005	41.25	40	3490.91	4.2
82	350	0.321	2	0	0.005	41.3	40	3486.68	
84	250	0.321	2	0	0.005	36.41	40	3954.96	5.4
82	250	0.321	2	0	0.005	36.46	40	3949.53	
82	350	0.321	5	0	0.005	40.84	40	3525.95	39.3
82	350	0.321	2	0	0.005	41.3	40	3486.68	
82	250	0.321	5	0	0.005	36.04	40	3995.56	46.0
82	250	0.321	2	0	0.005	36.46	40	3949.53	
82	350	0.321	2	0	0.01	39.28	40	3665.99	179.3
82	350	0.321	2	0	0.005	41.3	40	3486.68	
82	250	0.321	2	0	0.01	34.2	40	4210.53	261.0
82	250	0.321	2	0	0.005	36.46	40	3949.53	
82	350	0.345	2	0	0.005	40.37	40	3567.01	80.3
82	350	0.321	2	0	0.005	41.3	40	3486.68	
82	250	0.345	2	0	0.005	35.65	40	4039.27	89.7
82	250	0.321	2	0	0.005	36.46	40	3949.53	

Simulation Method

A lot of simulations show how much faster you can go at a given power. We took a different approach, taking recordings from real rides and analyzing how the power demand changes at the given speed with changes in equipment. We then calculated how that changes normalized power for the complete ride. This approach has several benefits:

- Often, speed is not determined by how fast you can ride, but by the speed of your group (be it friends or competitors) or what your gearing is.
- It reflects real riding better than assuming constant power.
- Normalized power weighs those high power efforts that really hurt (and most often are where races are decided) higher than flat power.
- It reflects a wide variety of riding situations.

As changes in equipment we used the following:

- 20 W aerodynamic drag at 45 km/h, showing the difference between a good aero bike and a modern bike without much aerodynamic considerations
- 1 kg, the difference between a lightweight bike and a bike purely focused on aerodynamics
- 9.2 W difference in rolling resistance at 29 km/h and 85 kg loading (difference for two tires between a Continental Grand Prix 5000 S TR and a Grand Prix 4000)
- A 2.4% difference in drive train efficiency

Simulation Constraints

Because of the lack of measurements (mainly of wind speed), we had to use some assumptions:

- Ambient wind and drafting were not taken into consideration
- We only looked at situations where the rider was actually pedalling

Simulation Results

We went through a lot more files, but to keep things simple, we want to focus on three races where we had files from multiple riders. They align well with what we have seen from other rides, and show three different terrains: Flat, hilly and mountainous. As you see from the normalized power, the files came from some strong riders.

		Flat	Hilly	Mountainous
	Original Normalized Power	330	319	335
Normalized Power Reduction [W]	Aero	17.7	10.1	9.48
	Rolling Resistance	24.3	16.7	14.28
	Drive Train Friction	7.94	6.84	7.58
	Weight Reduction	1	2.1	2

They show a few things:

- No matter what terrain, aerodynamics cannot be ignored
- The gains in rolling resistance were always greater than the gains in aerodynamic drag
- Drive train friction reduction results in very consistent gains

- The smallest gains come from a lower weight. Interestingly, the gains were a bit higher in the hilly race than in the mountains. This is because those punchy hills were ridden at a much higher intensity than the long mountain climbs.
- Aerodynamic gains fluctuate the most between different terrains (and if we go into detail, between riders).
- By combining all optimizations, we get much more robust gains.
- For equipment choice it does not make much of a difference whether we are in hilly, undulating terrain, or in high mountains. Only for flat terrain, the focus shifts towards aerodynamics.

Performance Parameters

At the start of the project, we had to decide how we weigh the different performance parameters. We identified six performance parameters, which we will discuss in detail here.

Aerodynamics

Aerodynamic drag is probably the most discussed performance factor of the last ten years in cycling. And there are good reasons for that, as our study shows there are significant gains to be had in lowering your aerodynamic drag, especially if you consider you can have even greater drag reductions in things like clothing, helmets or bike fit. Of all performance parameters, aerodynamic drag is the one that fluctuates the most between different riders and terrain. However, it is also the performance parameter where we can really create a difference with frame design.

Weight

Weight is the most obvious and easiest to measure performance parameter. But as our study show, it is also the one where we can make the smallest difference, and those gains only come in climbing. But we think you cannot ignore the mental side of performance, the responsive feel of a light bike gives you a boost in confidence. And undoubtedly, weight can make a difference in crucial moments of a race, which often are the steepest ramps. Up a 12% slope for only 500 m, a weight difference of 1 kg means you have a gap of 5 m at the end of the ramp, something that can make the difference.

Rolling Resistance

We are not the first to say that, but it is still not said often and loud enough: rolling resistance beats any other performance parameter. Even though rolling resistance is a comparably small percentage of our total drag, the difference between a fast and an average tire is huge. Also, rolling resistance does not fluctuate as much as aerodynamic drag, meaning you benefit from it in a wider range of riding situations. That is why at Avona, we are committed to putting the best possible tire on a bike. However, for frame design the only consideration was that often, a bigger tire is a faster tire, so we have tire clearance for tires up to 35 mm measured width.

Drive Train Friction

Similarly to rolling resistance, drive train friction is a small part of the total drag, but a gunky chain can easily triple drive train friction. And the best thing about a low drive train friction is, you benefit from it as soon as you are pedaling, no matter at what speed you are riding, making it the most robust performance gain. This is why all Avona bikes come with a waxed chain. However, this does not affect frame design.

Vertical Compliance – The Fifth Force

We did not include vertical compliance in our study, because we cannot quantify the gains to be had from it yet. We are working on that, but we are already confident to say that increased vertical compliance makes a faster bike. Not only because it keeps you more comfortable on the bike, but also because it reduces impedance. This was already documented in a study long time ago done by Bicycle Quarterly, and our own testing so far confirms this. A frame with a lot of vertical compliance also means you can optimize your tire pressure for better road surfaces, as the tires are not the only form of suspension once you get onto rougher ground. So for us it was important not to sacrifice vertical compliance for aerodynamic gains.

Torsional and Lateral Stiffness

Torsional and lateral stiffness is often touted as important for efficient power transfer, but there is no scientific proof for that. Even in the worst case scenario where all deformation energy is lost, the power losses are far below 1% at sustainable power levels. For this reason, we consider stiffness mainly a factor in handling, where a certain amount of torsional stiffness is critical.

Design Process

Having done our homework for the performance parameters, it was time to get into designing the frame.

Design Goals

Based on the previous work, we set our design goals:

- Match the torsional stiffness of our reference frame
- Match the vertical compliance of our reference frame
- Improve aerodynamics as long as we can find gains of at least 4 W drag saving per 100 g weight increase. At this level, drag reductions are beneficial up to gradients of 8%, depending on rider level.
- We did not set a specific goal for weight, it should rather be the result of above goals. But of course, we wanted to keep weight as low as possible. Therefore, keeping the design manufacturing friendly was a consideration during the whole design process.
- Tire clearance for tires labelled 32 mm on a wide rim, measuring up to 35 mm.
- Keep the design simple and customer friendly: BSA-BB, non-proprietary cockpit based on Token's spacer design, removable FD-hanger for 1x drive trains.

Our reference was a frame developed previously by bicycle.engineering, meaning we had access to 3D cad files, stiffness both in lab measurements and FEA, and aerodynamic data both from CFD and wind tunnel.

Design Iterations

We started with a base design and then made one change to it at a time to see whether it is an improvement or not. If it was an improvement, we went on to the next step. If not, we went one step back and tried a different approach. For each step, we recorded the following:

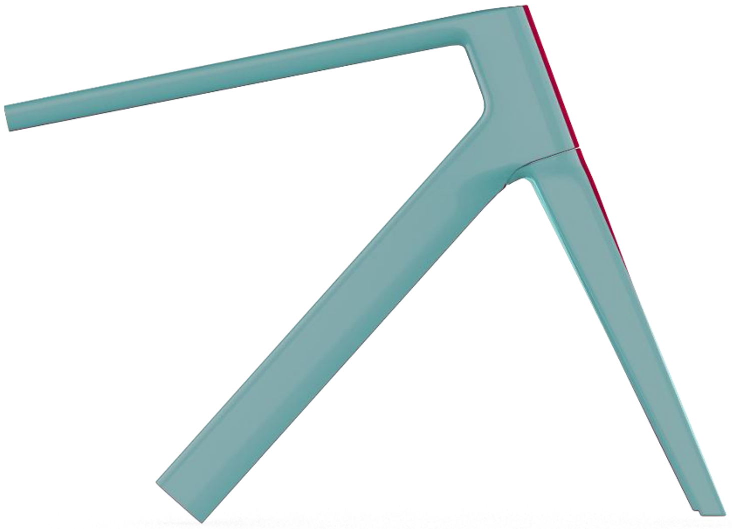
- Aerodynamic drag found in CFD
- Stiffness of a simplified model in FEA

- Surface area

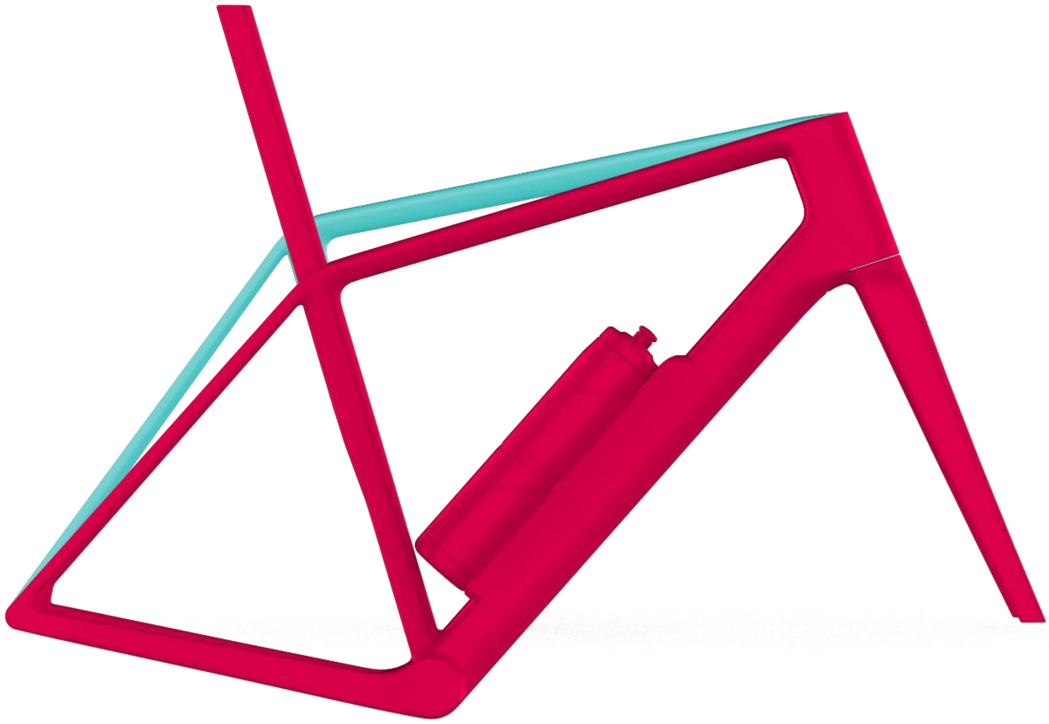
Based on surface area and stiffness we could estimate the frame weight to achieve our stiffness goals.

The most important findings in this process were:

- We can aerodynamically gain the most from extending the cross-section of the headtube towards the front, see red vs. blue below.



- A sloping top tube that meets the seatstays at the seat tube gives us the best balance of stiffness, vertical compliance and aerodynamic drag. To our surprise, a sloping top tube showed lower drag than a horizontal one. Only once the top tube gets so low that it directs air into the rear wheel, drag increases.



- A deep seat post profile absolutely ruins vertical compliance, for minimal aerodynamic gains.

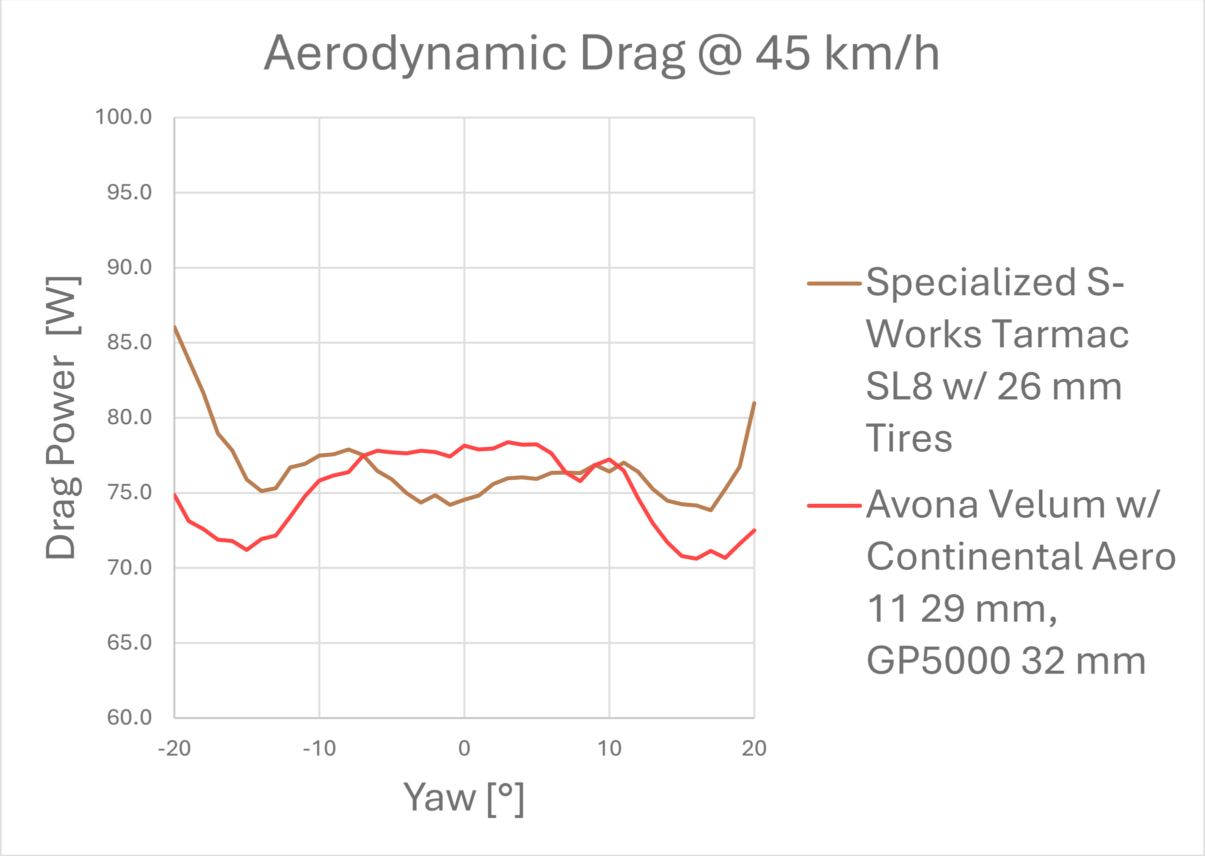
After testing more than 40 configurations, we found 15 W of drag reduction in CFD compared to our reference bike that we started with, while keeping stiffness, weight and vertical compliance on the same level.

Results

We achieved our goals for torsional stiffness and vertical compliance at a frame weight of 798 g (size M, painted, including FD hanger and seatpost clamp), with a fork weight of 380 g (cut for size M).

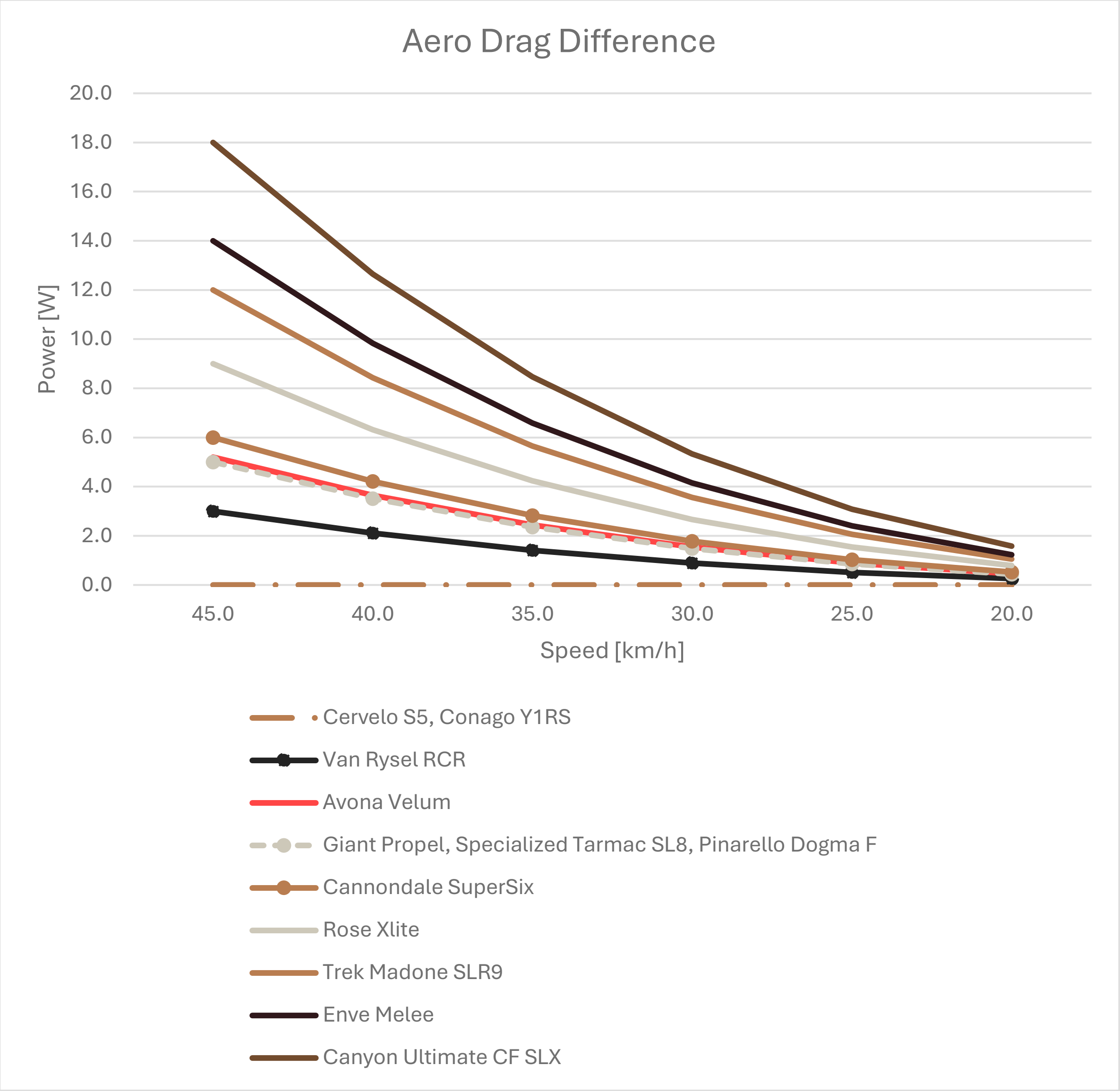
To confirm our results from CFD, we went to the GST wind tunnel in Immenstaad. We brought a Specialized S-Works Tarmac SL8 with the highest specification for reference, a bike that ranks high among the best all round race bikes in Tour magazine's aero tests.

Below you can find the comparison graph of the Velum against the Tarmac. Applying GST's weighted average, the Velum matches the Tarmac SL8 within the tolerances of the wind tunnel, 76.3 W vs. 76.1 W.



We are happy with this result given it was achieved with bigger tires, and a seatpost that gives up some aerodynamic gains for more compliance. The tires alone have a 4.5 W advantage over the tires on the Tarmac at 45 km/h, according to bicyclerollingresistance.com.

To compare, we also calculated our results against other measurements done in the same wind tunnel.



We had to plot the differences, because the absolute values are so close, you don't see anything. As the plot shows, we are in good company, and even aero specialists like the Colnago Y1RS and Cervelo S5 only have a quite small advantage.

Component Choices

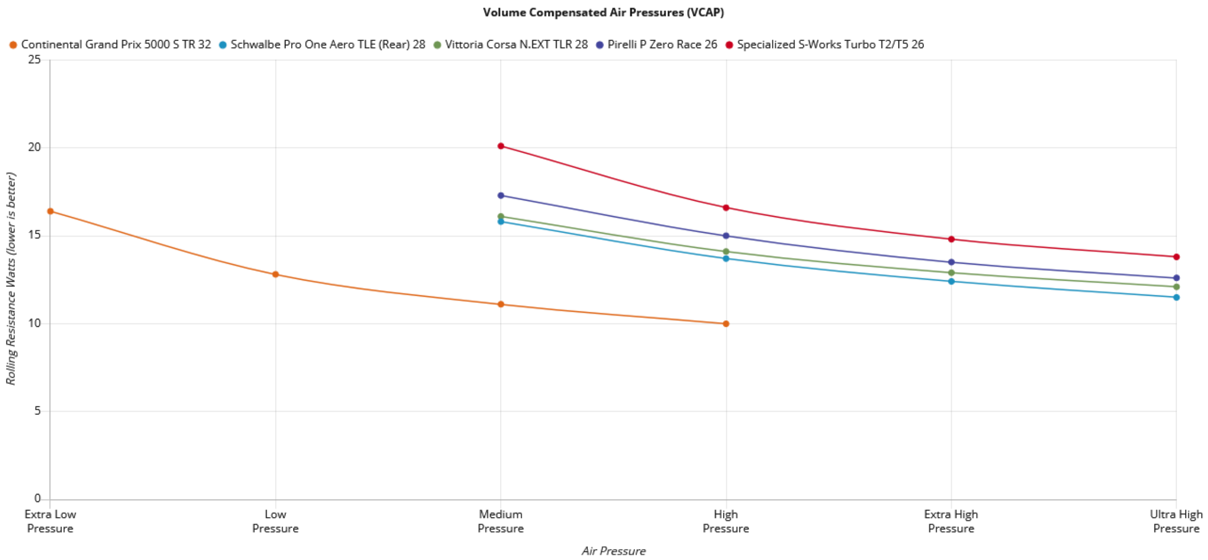
We take component selection just as serious as frame development, because it has a huge impact on the performance of the bike.

Ceramicspeed Waxed Chains

We are absolutely convinced by waxed chains. Getting a 2% boost in power no matter whether you are going fast or slow, uphill or flat is something no other equipment choice can replicate. Beyond that, maintenance is much simpler, and your drivetrain components last longer. Therefore, all our bikes come with waxed chains, an industry first.

Tires

As shown previously, tires absolutely dominate performance figures. That is why we always go with what we consider the best option for the intended use, no matter the price point. For road use, it is very difficult to look past the Continental Grand Prix 5000 TR, which is very fast, but still reasonably durable and puncture resistant. We are using a 2 mm wider rear tire because the rear tire is more important for rolling resistance, while the front tire also has significant influence on aerodynamics. Below you can find an overview (screenshot from bicyclerollingresistance.com) of the tires our competitors use on Ultegra-level bikes vs. the Continental Grand Prix 5000 TR:



That is in average a 12.4 W difference for two wheels at 29 km/h. To put that into perspective, we would have to find a massive 46 W at 45 km/h in aerodynamic drag reduction to get the same effect at 29 km/h.

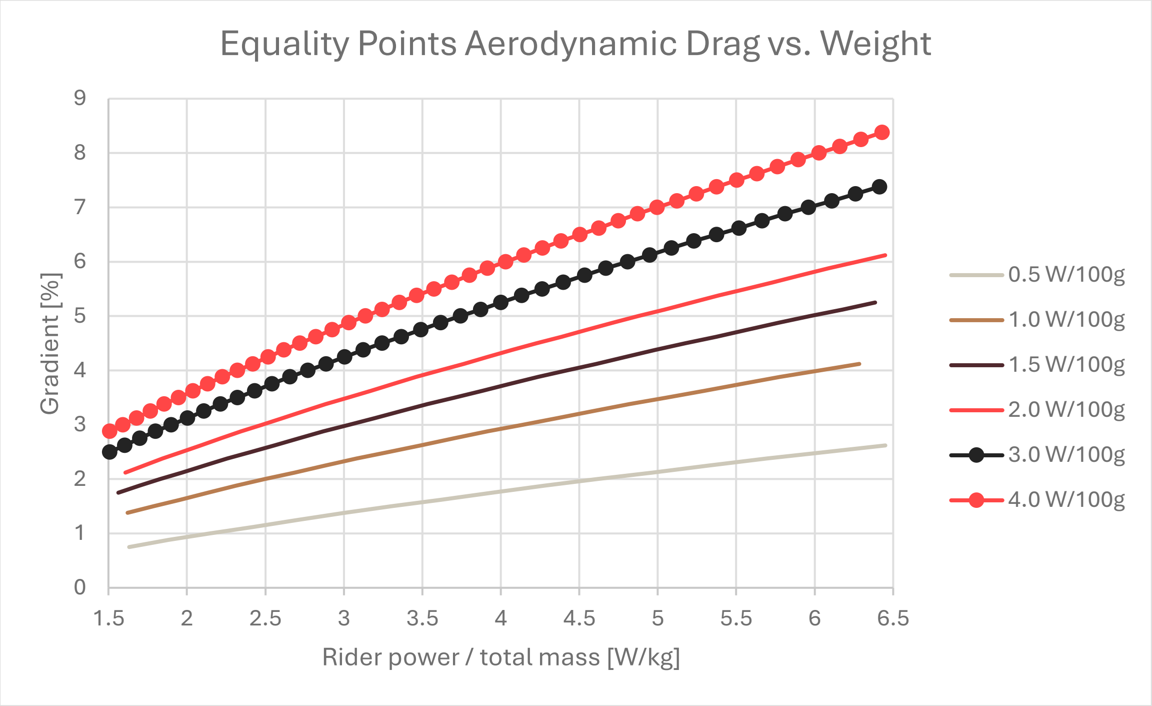
Also, our bikes come tubeless from the start, gaining an additional 3 W.

Cockpit

The cockpit is where we could find the best aerodynamic improvements, at a minimal weight penalty. The Faserwerk Luftschneider is available on all specifications Ultegra-level and higher, and as an upgrade on 105 and Rival. It saves 8.8 W of aerodynamic drag over a standard road bar and stem.

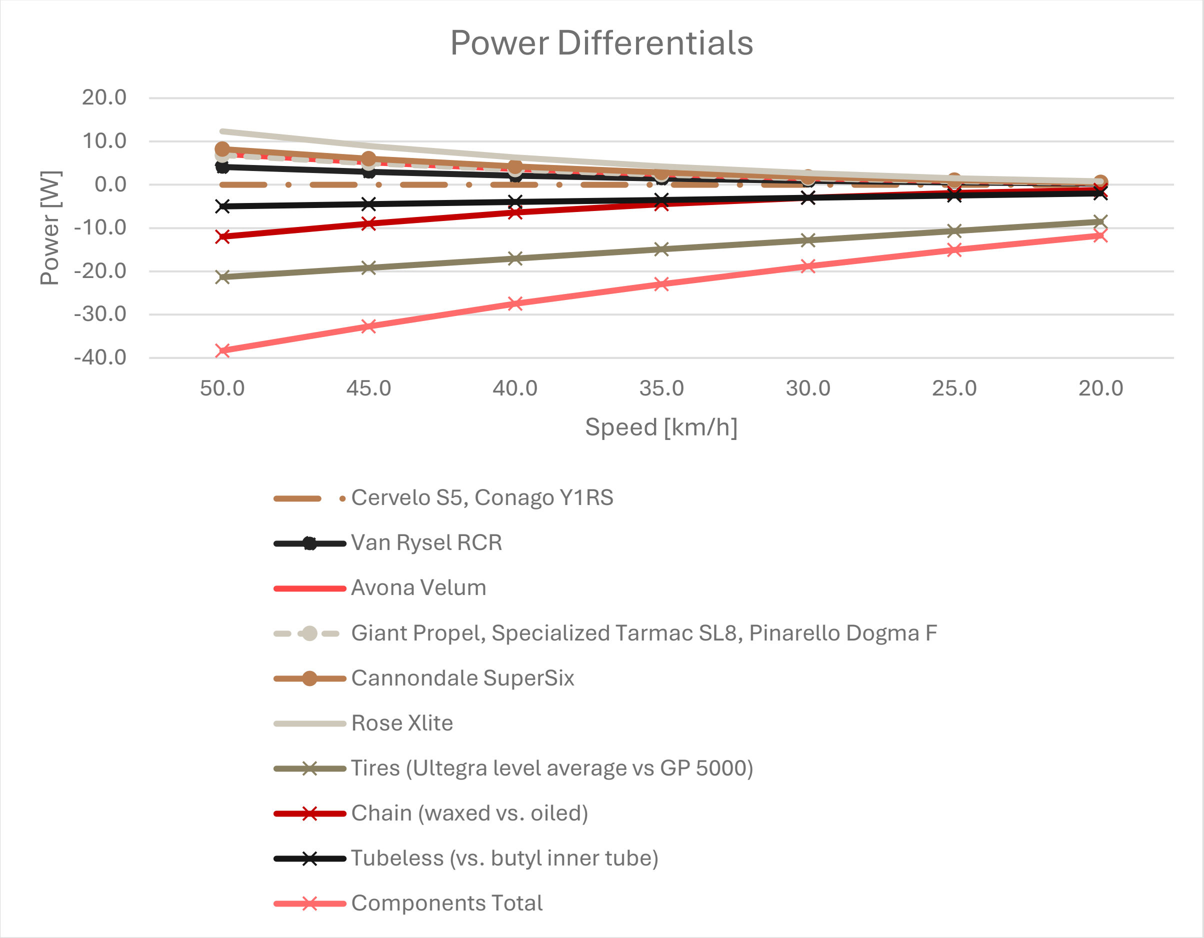
Wheels

Wheels are an excellent option to tune the performance of your bike so it matches your preferences. On most specifications, you have the choice between a Faserwerk Bergreif and a DT Swiss ARC 55 mm wheel. The Faserwerk Bergreif wheels are 280 g lighter, while DT Swiss ARC have 4.9 W less aerodynamic drag at 45 km/h. This means the DT Swiss ARC wheels save 1.75 W per 100 g added weight, you can use below graph to decide which option makes more sense to you. The stronger a rider is, the steeper the gradients to which the deeper wheel offers a benefit. For most of our customers, between 3% and 4.5% will be the tipping point.



Performance Gains

To show how massive those performance gains are, we plotted them against the drag differences between bikes we showed earlier in this paper. As you can see, they are bigger than the differences in aero drag between the best and worst bike in our comparison.



Obviously, you could do the same upgrades to any other bike, but it comes at a significant cost:

- Pair of Continental GP5000 TR 190 € RRP
- Waxed chain conversion 135 €: https://www.erfahre.com/news/werkstatt-kette-heisswachs-statt-oel
- Tubeless conversion 60€ : https://www.ihrfahrradprofi.de/products/tubelessumrustung?srsltid=AfmBOorkjW7W4xe9KKskcYqoawBbteO2Is4H5YDhdugiCTvbLfEXDGqy

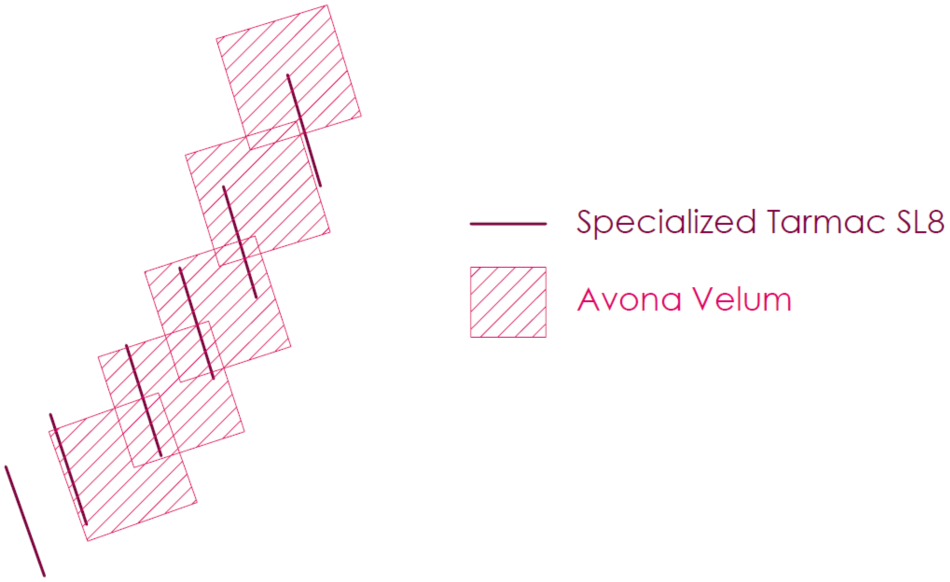
This means those upgrades we include are worth about 385 Euro.

Fit and Geometry

Having long-term experience in building bikes to customer demands has two major advantages:

- We know the fit riders want
- We can offer adjustment in three axis: amount of spacers, stem length, bar width. Unfortunately, on most bikes that come built from stock, especially with today's integrated cockpits, often changing spacers is the only option without getting into significant cost. And all too often, there is no availability for the stem length or bar width the rider wants.

Thanks to the fact that our customers can choose stem length and bar width, we can cover a large range of riders with five sizes. In the illustration below you see the comparison of stack and reach to the handlebar we can cover with our offering, compared to where you end up with a Specialized S-Works Tarmac SL8 with stock cockpit.



Our historic data also taught us two things:

- We needed to shift sizes up half a size to have a nicely centered bell curve when analyzing what sizes sell in which quantities.
- Large frames were almost exclusively ordered with a lot of spacers, so we increased stack height on the two largest sizes.

Of course, fit goes beyond stack and reach. That is why we offer further options:

- The cockpit is available in three widths for any stem length
- The seatpost is available with 0 and 15 mm offset
- Customers can choose crank length
- Customers can choose number of spacers their bike is built with

Overall, we are confident that our combination of frame sizing and component options will fit a wider range of riders than the typical stock bike.

Size	XS	S	M	L	XL
Stack	513	532	554	580	610
Reach	365	375	387	397	405
TT	512	528	546	563	580
HT	111	124	148	171	203
ST	406	436	466	496	526
SA	74	74	74	74	74
HA	70.5	72	72	73	73
Fork Offset	50	50	50	50	50
BB Drop	72	72	72	72	72
CS	408	408	408	408	408
Wheelbase	976	979	998	1006	1023
Trail	70	60	60	54	54
Standover Height	696	724	753	782	811

Pricing

Pricing for the Velum is as follows:

- Frameset with Faserwerk Luftschneider Cockpit/Faserwerk Wuthocker Aero seatpost: 3499 €
- Shimano105 Di2/DT Swiss E1800/Ceramicspeed waxed chain/Continental GP5000 TR: 4499 €
- Shimano Ultegra/Faserwerk Bergreif wheels/Faserwerk Luftschneider cockpit: 6499 €, 6.87 kg
- Sram Force PM/Faserwerk Bergreif wheels/Faserwerk Luftschneider cockpit: 6999 €
- Shimano Dura-Ace/Faserwerk Bergreif wheels/Faserwerk Luftschneider cockpit: 7999 €
- Sram Red PM/Faserwerk Bergreif wheels/Faserwerk Luftschneider cockpit: 8999 €
- Sram Red 1X with XPLR cassette & RD, powermeter, aero chainring/DT Swiss ARC1100 55 mm wheels/Faserwerk Luftschneider cockpit: 8999 €, 7.0 kg

All models are available in roségold, teal, or clearcoat over carbon paint, or as ready to paint (RTP) frame.

Additional Resources

Pictures and files can be found here: Velum Launch. Pictures are expected to be completed on September 30th.

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