MAKING THE FASTEST RACE BIKE IN THE WORLD

Tarmac SL8
White Paper

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EXECUTIVE SUMMARY

For nearly half a century, innovation has been at the core of every product we develop. The Tarmac SL8 is one of the finest examples of our team's drive to bring the next innovative bike to riders. Over the past 15 years, road racing bikes have segmented into either "aerodynamic", or an "all-around climber". As our team developed a lighter weight Venge, and a more aerodynamic Tarmac, lines between these two bike segments began to blur and the next major innovation became evident.

We took our wealth of knowledge from decades of aero development, and lightweight expertise from Tarmac SL6 to create Tarmac SL7, a bike with more World Tour race wins than any other bike in the same timeframe.

To say we're proud of the next generation Tarmac would be a massive understatement. It eclipses the 2020 Venge as the most aerodynamic road bike we've ever made, the chassis is over 200g lighter than SL7, and it improves upon the same handling characteristics from the tried-and-true Tarmac. When we say "one bike to rule them all", we mean it. Tarmac SL8 is the fastest bike in the world.

Introduction

The development for all of our bikes is tied together by one simple thread: we obsess over finding technical performance benefits for the discerning rider. For Tarmac SL8, that means helping our World Tour road athletes get to the finish line first, shaving time from local Strava segments, or winning town-line sprints on a Saturday group ride.

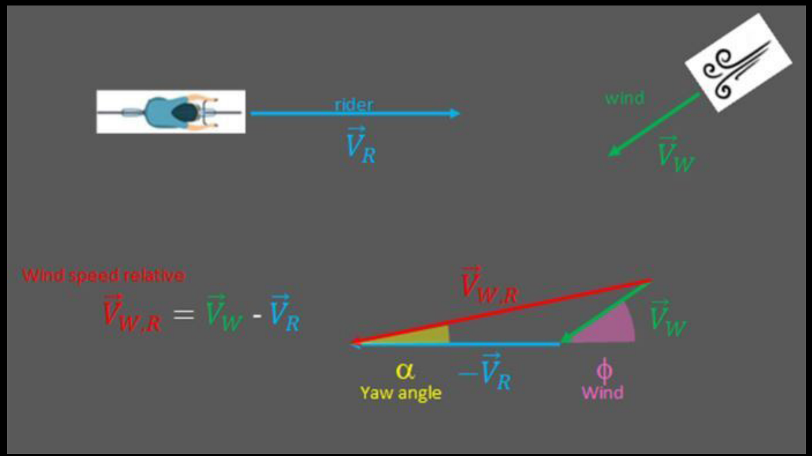
Before we began SL8's development in earnest, it was key to establish metrics to provide a consistent environment for aero prototype testing. These metrics are grounded in decades of experience working with the best road cyclists in the world, and every road rider can benefit from this improved aerodynamic performance. The wind a bike and rider experience depend on a variety of factors. Wind speed, wind direction (yaw), and rider speed all have a major impact on what wind a rider feels during a ride, and in turn how an aero bike performs to minimize drag. The yaw curve used through the entirety of SL8's development, as well as benchmarking across a variety of other road bikes, replicated rider speeds of 45kph with a variety of wind speeds coming from all angles, with the most common yaw angles from the real world weighted heaviest in our scoring. When we claim Tarmac SL8 is "16.6 seconds faster than SL7 over 40km", these are the exact ingredients.

THE ALL-NEW TARMAC SL8

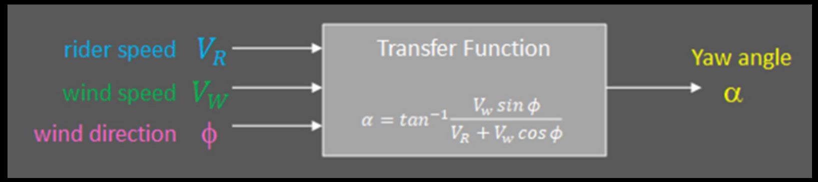
Test Conditions

Test Conditions

A rider with speed Vr experiences a relative wind speed that is a composition of their speed and wind speed. Though the wind speed has an Φ direction and an absolute magnitude Vw, the relative velocity of wind with respect to the rider Vw,r is different, depending on how fast the rider travels. The angle of wind with respect to the rider (what we refer to as "yaw angle" α) is a function of rider's speed, wind speed and wind direction:



Probability density function of yaw angles experienced by the rider under typical riding conditions



The development team treated the above equation as a "transfer function" between inputs: rider speed Vr, wind speed Vw, wind direction Φ and output (yaw angle α). This transfer function is valid during each moment of the ride, so the team applied a "population" of inputs to generate a "population" of yaw angles. These principles adhere to the Weibull density function – a well-established standard in the automotive and wind turbine industry.

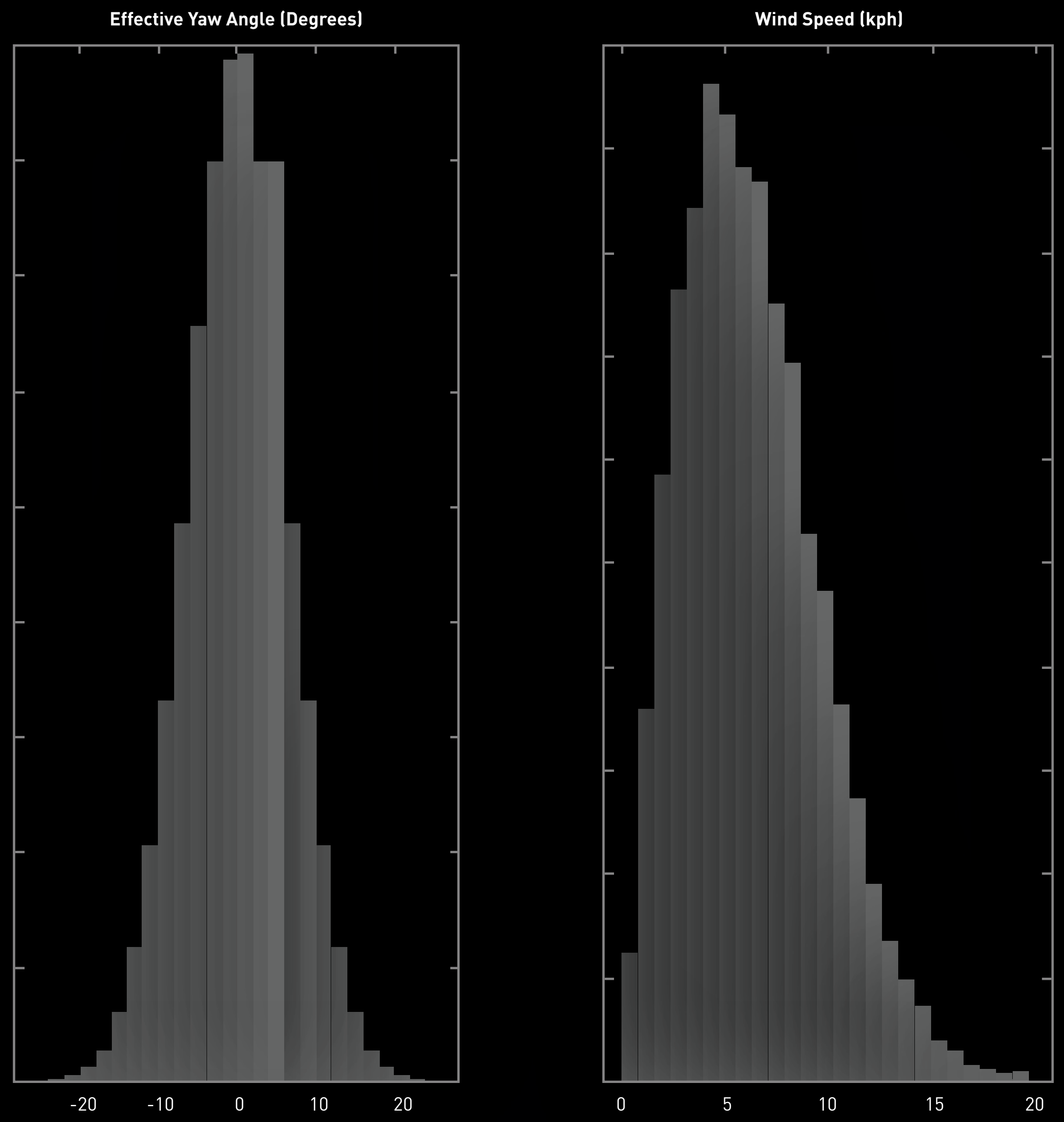
The "input" wind speed and wind direction values are all based on real-world riding conditions collected throughout decades of aero R&D, so the "output" yaw angles for which the SL8 is designed are representative of real-world yaw angles riders would experience.

These concepts were the cornerstone of SL8's development - directly informing key design decisions throughout the project. The aerodynamic tube shaping at the front of SL8, or frame tubes optimized for weight and stiffness (downtube), were outputs of the formulas listed above.

To benchmark SL8 against other bikes, we created a population of 10,000 individual rides and processed the yaw angles. These values were then used to set our wind tunnel yaw angle span and to calculate CdA values for various bike designs.

Test Conditions

Effective Yaw Angle and Wind Speed Used for Tarmac SL8 Benchmarking:



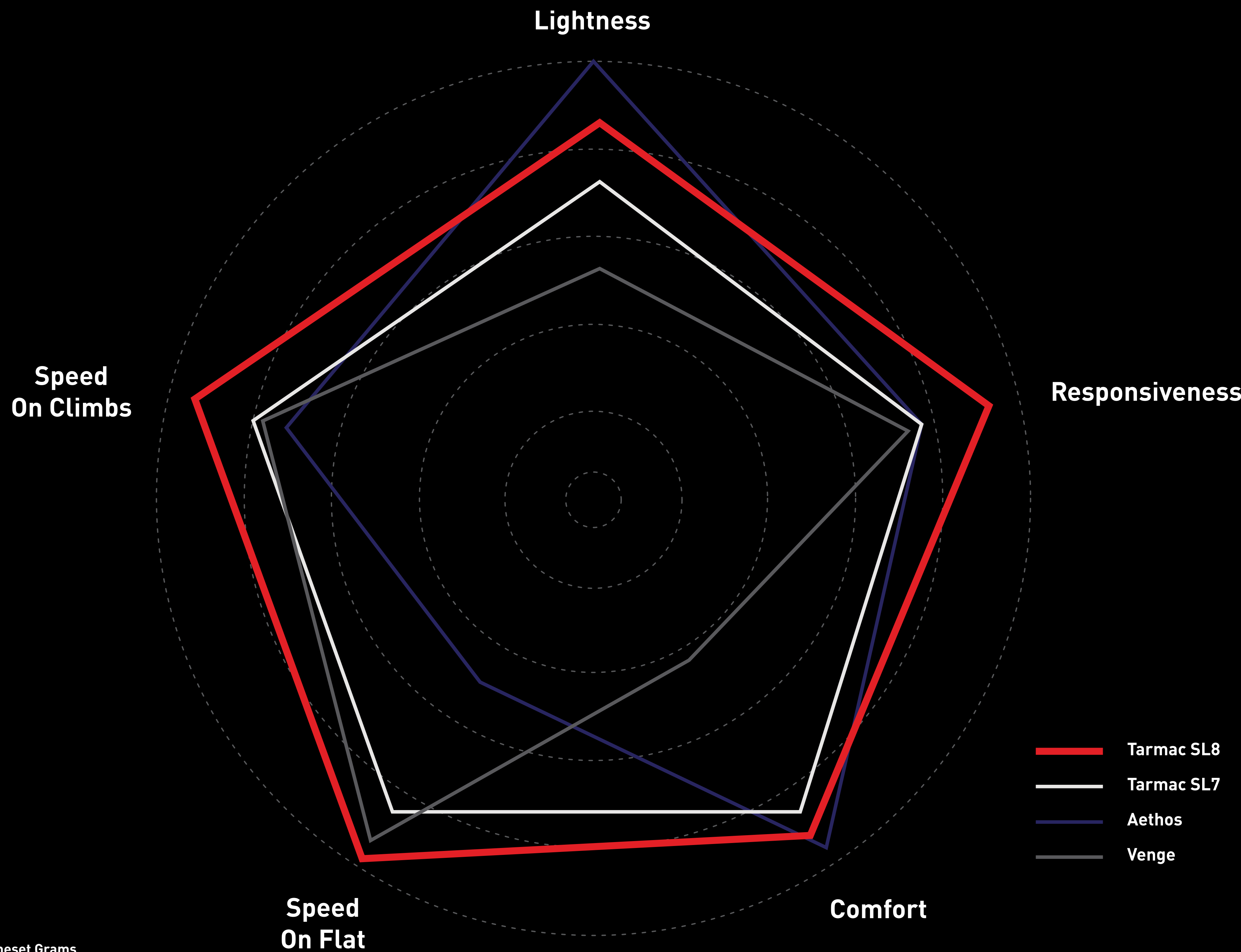
INTRODUCTION

State of Speed

Since the Tarmac SL8 is more aerodynamic than the Venge, it'd be easy to say "aero is everything" and call it a day. But we also know that weight is a crucial factor, and that there are plenty of courses with HC climbs, screaming fast descents, and flat sprint finishes. We knew Tarmac SL8 needed to be at the UCI limit (6.8kg/15lbs) ready to ride, in a full aerodynamic package. Our riders needed to be on the perfect bike in any scenario – never second guessing their choice for the day's parcours.

An aerodynamic and lightweight frame is great, but if it's flexible under high pedaling loads, or doesn't precisely respond to steering input in the final corner at 200 meters to go, it's missed the mark. Tarmac SL8 utilized our team's carbon fiber expertise guided by Rider First Engineering principles to tune stiffness per size. The result was compliance, Zedler, bottom bracket, front end, and rear end stiffness values that all surpass Tarmac SL7.

To put it simply, aero is not the only ingredient to speed. It is, of course, a key factor, but the modern state of speed requires a more complex equation. It might not take a mechanical engineering degree to know that aerodynamics, weight, and stiffness are conflicting priorities, but it takes a team of brilliant engineers to balance these attributes to bring to life the fastest road bike we've ever made.



Lightness: Frameset Grams

Speed: CdA x Weight

Mountain Stage: +/- 5000m elevation gain

Flat Stage: +/- 500m elevation gain

Comfort: Compliance at the saddle

Responsiveness: Stiffness-to-Weight

THE ALL-NEW TARMAC SL8

Development

TARMAC SL8

Development

Tarmac SL8's development was guided by our new "equation" for speed:

SL8 = [aero: equal to or surpassing Venge] x [weight: 6.8kg ready to ride] x [ride quality: stiffness >= SL7]

The team initially approached this seemingly impossible equation to balance by studying three of our most innovative road platforms: Venge, Aethos, and SL7. Could we make a lightweight Venge? Could we make an aerodynamic Aethos? Could an evolution of the SL7 platform allow us to hit our targets? The result of this initial R&D quickly became clear: with such narrow margins for success and conflicting targets, the team would need an entirely new approach with an all-new design. Taking a step back, our team looked at the bike module as a whole – a system optimization approach – to help guide next steps in development.

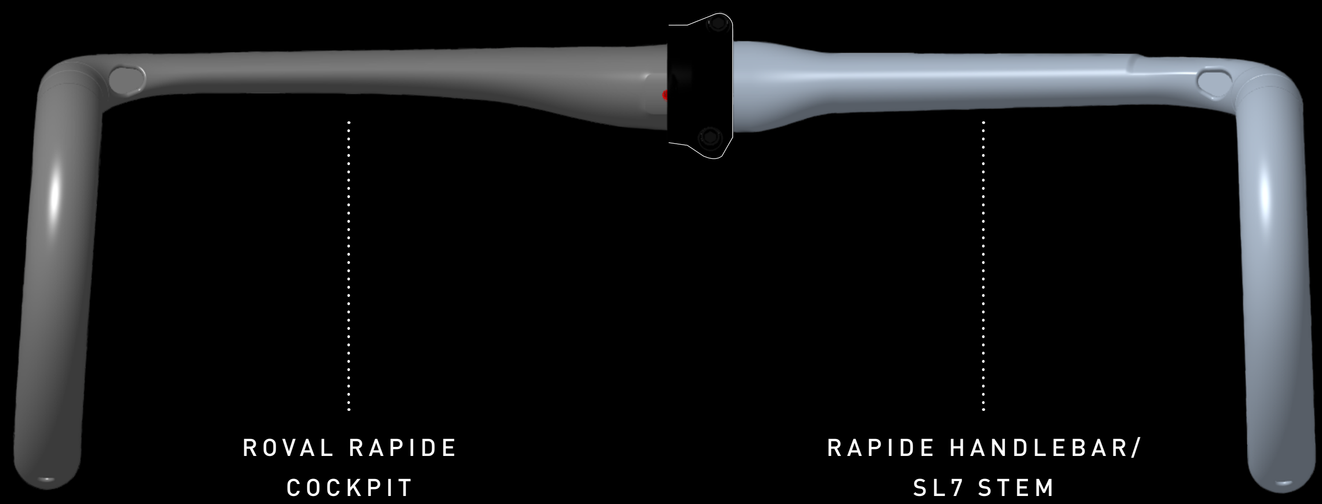
DEVELOPMENT TARGETS USING SYSTEM OPTIMIZATION APPROACH: DEFINITIONS OF INDIVIDUAL COMPONENT PERFORMANCE

Cockpit	Stiffness =	Drag ↓	Weight ↓
Frame	Stiffness ↑	Drag ↓	Weight ↓
Fork	Stiffness =	Drag ↓	Weight =
Seat Post	Stiffness =	Drag ↓	Weight ↓

Aerodynamics

The biggest learning from the first phase of system optimization R&D was that a nose cone was necessary to hit our aerodynamic targets. Through time spent in CFD and our Win Tunnel, the team determined the front of the bike, where airflow is more laminar, matters most when chasing a low CdA. Utilizing CFD and validating with 3D prints in the tunnel, we investigate six different nose cone designs and manufacturing methods. Our engineers landed on a nose cone that would add 25 grams to the headtube over SL7, but allow us to meet our aerodynamic targets. Once the headtube design was determined, the team could then begin designing the fork crown and fork blades that complemented the aerodynamics of the nose cone and headtube.

Armed with the knowledge that laminar air at the front of the bike impacts drag most, the team set out to optimize the cockpit - the other key leading edge of a frameset module. By removing the stem hardware cluster and changing to one-piece handlebar/stem, we knew we could realize substantial aerodynamic improvements. The development of the Roval Rapide Cockpit was a key ingredient to SL8's aero prowess, while also saving the team a crucial 50 grams over an SL7 stem/Rapide handlebar two-piece setup. The 15 sizes for the Rapide Cockpit were determined using our Retul Fit data base.



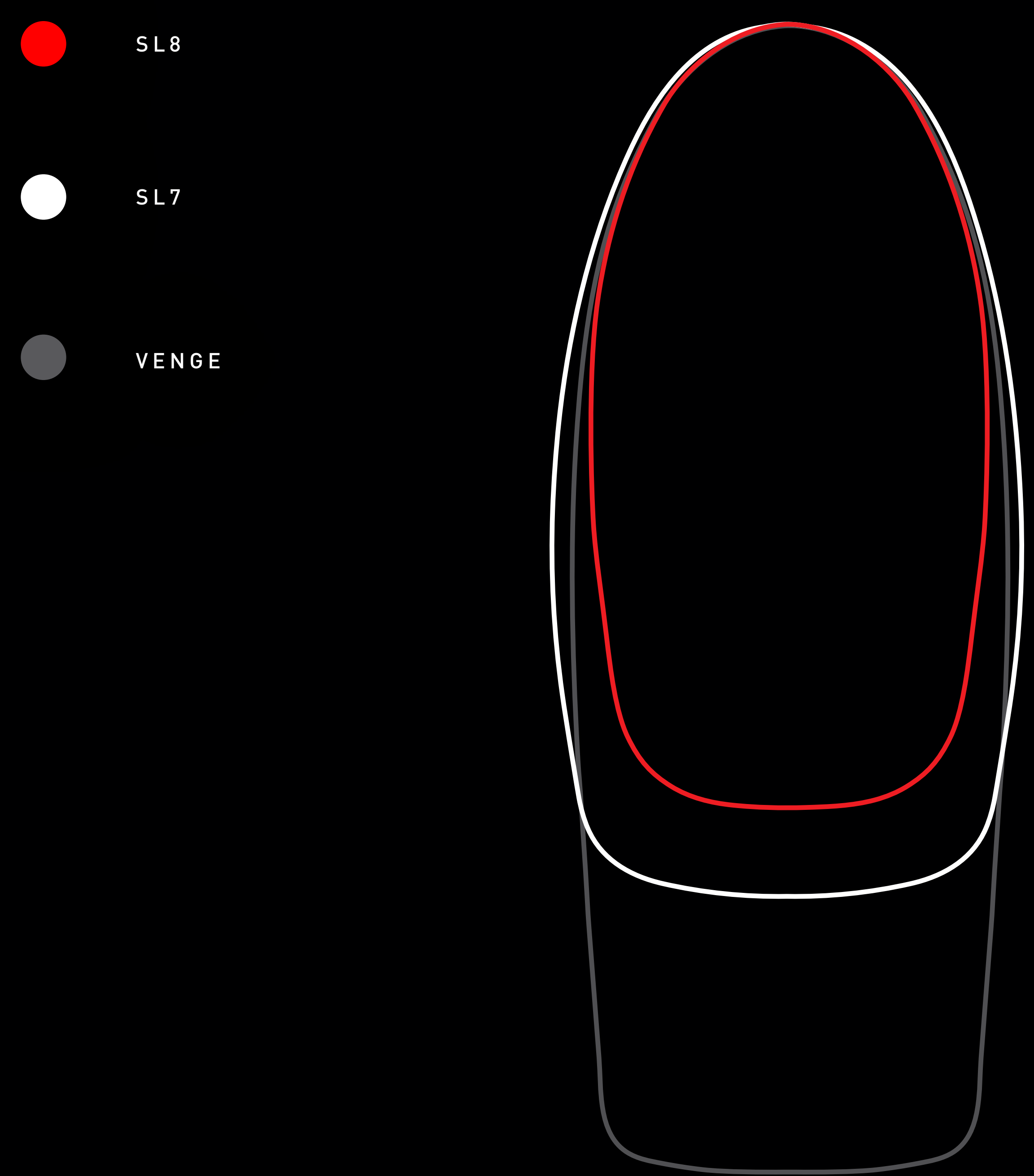
RAPIDE COCKPIT SIZES

Handlebar Width	380mm	400mm	420mm	440mm
Stem Length	75mm	90mm	90mm	110mm
	90mm	100mm	100mm	125mm
	115mm	110mm	110mm	
		120mm	120mm	
		135mm	135mm	

TARMAC SL8 DEVELOPMENT

Aerodynamics

SEATPOST CROSS SECTIONS



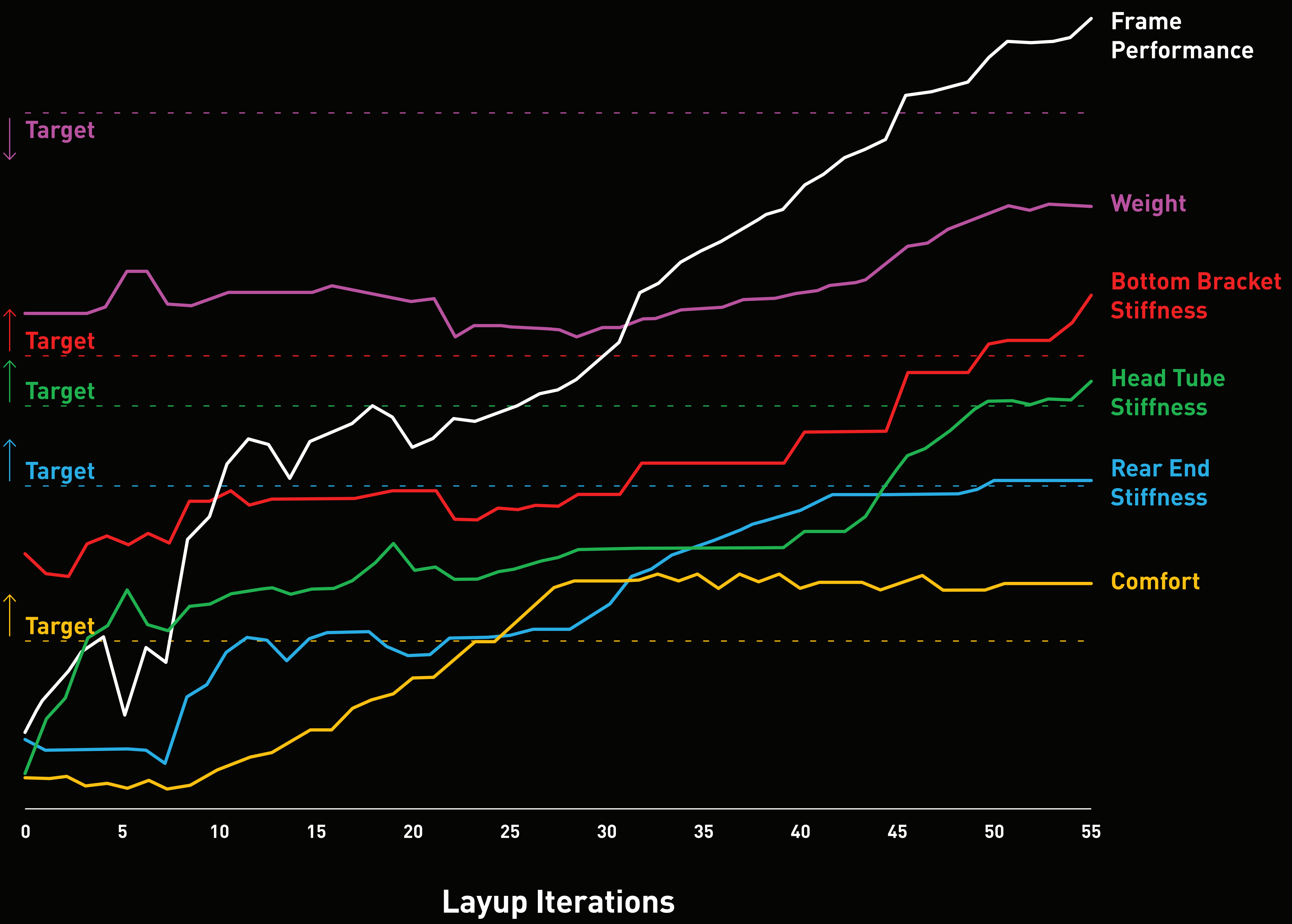
Other than the bike's leading edge, we've learned that dropped seatstays and a narrow seat post/seat tube are the other areas that move the needle in terms of aero performance. While a deep cross section for a seat post, seat tube, and seatstays may look the part in terms of aero performance, there are very little real world aerodynamic gains. Using CFD and mannequin testing to replicate real-world conditions, the team determined the air flowing around this area of the bike is much more turbulent due to leg disturbance, and the benefit of a deep section air foil at the seat post is negligible. SL8's seat tube is the same width as the 2020 Venge seat post, boosting SL8's aero performance while also shaving weight. To execute the narrower seat tube and seat post, the team came up with a novel location for Di2 battery storage – it is securely held below the seat post instead of inside the seat post as with SL6, SL7, and Venge. The seat post and seat tube design of Tarmac SL8 is a trifecta of aero, weight, and ride quality. It is 6% more complaint compared to an SL7 seat post (for/aft saddle movement) but has identical lateral stiffness.

Aerodynamic optimization for the headtube, fork, cockpit, seat tube, and seat post were not completed individually. Rather, the team utilized a parametric CFD model that accounted for the entire bike and rider as a system – not frame tubes on their own – to finalize the key aerodynamic aspects of SL8's construction.

TARMAC SL8 DEVELOPMENT

Weight

For the remainder of the bike's design, instead of a full-on aerodynamic approach, the team focused on aero where it actually matters, and opted instead to save weight where aerodynamics matters less or not at all. Using this strategy as a blueprint, the downtube, chainstays, and top tube were all optimized for the best possible frame weight and stiffness.



Weight

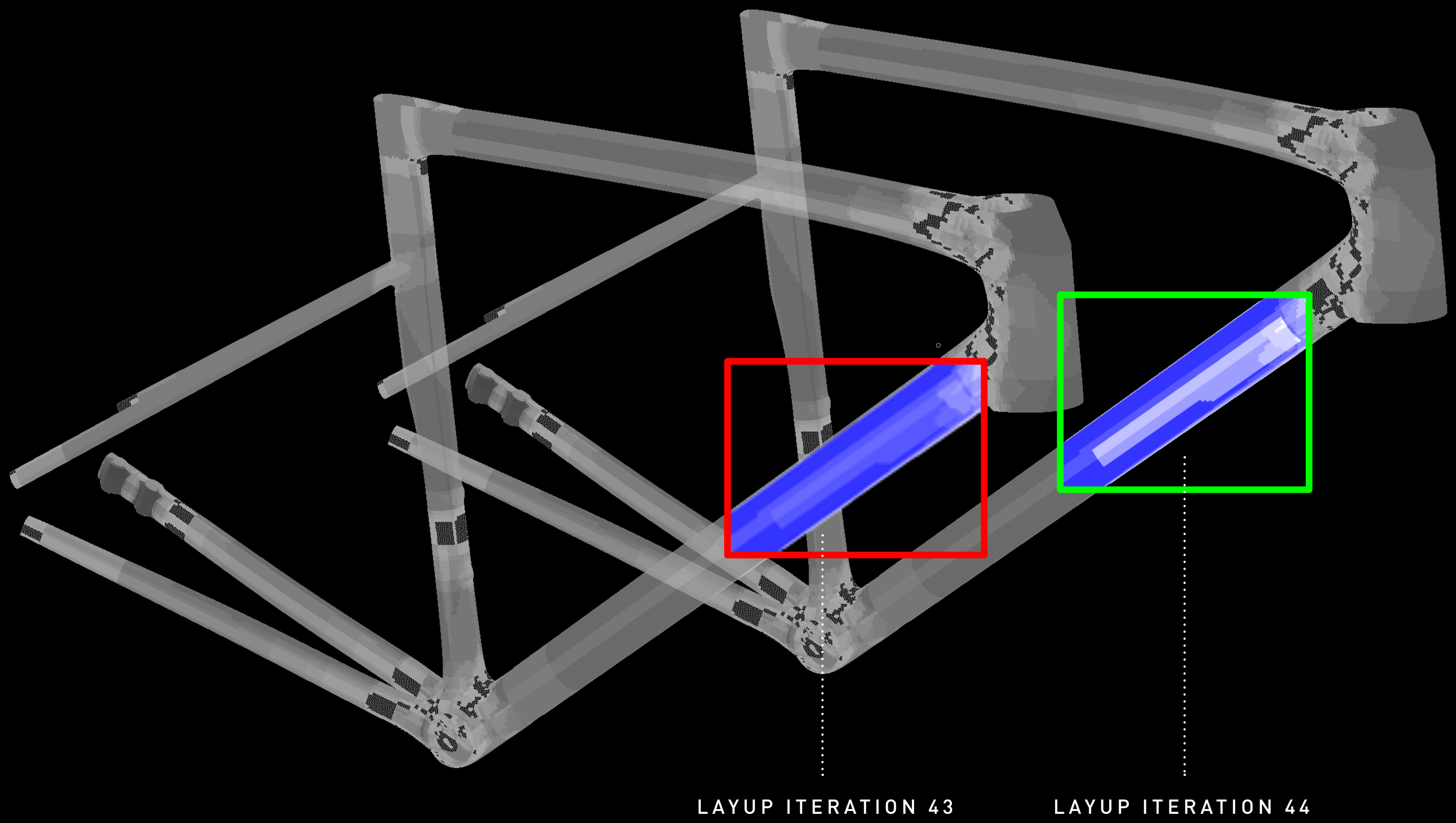
When it came to the frame's aggressive weight target, our engineering team leaned heavily into their experience developing Aethos – the lightest production road bike frame in the world. A similar FEA and ply-by-ply analysis was performed on each tube to ensure there wasn't a single gram of wasted material that wasn't contributing to the frame's stiffness, aerodynamics, and strength. While we certainly utilized learnings from Aethos to achieve the SL8's frame weight, the development process was far from cut and paste. We knew which tube cross sections and shapes would have the best structural efficiency, but with dropped seat stays and higher stiffness targets, the layup strategy from Aethos had to evolve. The front triangle went through over 53 different layup revisions before the team landed on a solution that was stiff enough to meet the rigorous targets set earlier in project – stiffness targets that were set working directly with our World Tour athletes.

In the first 34 layup iterations, weight generally held constant. For the final 20 iterations, stiffness plies were changed in key areas to meet stiffness targets. Frame performance is a weighted average of stiffness, comfort, and frame weight.

PLY-BY-PLY EXAMPLE - ITERATION 44

Weight

Similar design principles and materials were used for Aethos and SL8, but the exact layup schedule – the pattern in which carbon fiber plies are placed into each frame tube – was radically different for the SL8. This exact layup schedule is the magic behind SL8's 685g frame. The recipe is the culmination of decades of carbon fiber expertise and simulations. Every tube on the SL8 utilizes learnings from our ply-by-by analysis, and the details around this process are one of Specialized's most closely guarded secrets.



Size Comparison

SL8 WEIGHT COMPARISON BY SIZE: 12R AND 10R

Frame Size	12r Frames	10r Frames	12r Fork (240mm steerer)	10r Fork (240mm steerer)
44	640	720	358	371
49	645	740		
52	660	760		
54	670	765		
56	685	780		
58	705	825		
61	725	845		

WEIGHT COMPARISION

Venge vs. SL7 vs. SL8

Building a race-ready bike at 6.8kg was a key target to chase throughout SL8's development. The weight breakdown below shows full bike weights for Tarmac SL8, SL7, and Venge. The team obsessed over sheets like these throughout SL8's development to ensure we were staying on track and within our weight budget.

VENGE V.S SL7 V.S SL8 WEIGHT COMPARISON (GRAMS)

MODEL COMPARISON	VENGE	SL7	SL8	NOTES
Frame	**960**	**800**	**685**	**S- Works, 56 cm**
Fork	385	365	358	S-works, 44mm offset, 240mm steerer
Front Der. Hanger backing plate	-	-	4	-
Front Der. Hanger	-	9	7	-
Front Der. Hanger bolt	-	2	2	1g per bolt x2
Front Axle	30	30	23	-
Rear Axle	37	37	29	-
Rear Derailleur Hanger	13	13	9	-
Rear derailleur hanger bolt	3	3	3	-
Bottle cage bolts	5	4	5	-
Seat post wedge	35	27	23	-
Expander Plug	27	43	43	-
Headset Bearings	42	42	42	21g per bearing x2
Headset Compression ring	8	15	6	-
Headtube Transition Spacer	15	8	8	-
10mm headset spacer	7	6	6	qty 1
5mm headset spacer	3	3	3	qty 1

VENGE V.S SL7 V.S SL8 WEIGHT COMPARISON (GRAMS)

MODEL COMPARISON	VENGE	SL7	SL8	NOTES
Stem transition spacer	6	4	4	-
Headset top cap bolt	6	6	6	-
Headset top cap	4	4	5	-
Stem Cover (flush)	9	6	-	-
Seatpost w/ hardware	206	191	161	-
Stem 100mm	207	155	-	with stem bolts
Handlebar 42cm	235	225	-	-
Rapide Cockpit 100mm/420cm	-	-	323	with stem bolts
CPU mount	31	31	31	with Garmin pucks installed, bolts included
Handlebar Cable Routing Clips/bolts	6	6	-	-
Chassis with all small parts	2280	2035	1786	-

Groupset, Wheels/Tires tubeless with 30mm Sealant	2036	-	-	Rapide CLX II, Rapidair 26c, 30ml sealant each tire
Dura Ace R9200 Groupset	2473	-	-	11-30 cassette, 52/36 172.5mm crankset with 4iiii dual power meter, 140/160 rotors
S-Works Power Saddle 143mm	159	-	-	-
Bar Tape and bar end plug	68	-	-	Supacaz Sticky Kush Tape
Pedals	236	-	-	Dura Ace R9100 Pedals SPD SL
Waterbottle cages	48	-	-	S-works Carbon Rib Cage III (Qty 2)
Finishing Kit	5020	-	-	-
Full bike weight, ready to ride	7300	7055	6806	-

TARMAC SL8 DEVELOPMENT

Ride Quality & Stiffness

Receiving the first tooled and ridable prototype frames was the next major milestone in Tarmac SL8's development. The team was able to validate stiffness targets with tests in the lab, as well as ride the frames outdoors to validate ride quality and stiffness parameters. Since development was front loaded with ply-by-ply simulations, the team had a good idea for how framesets would perform riding on the road. Even still, design was tweaked and manufacturing processes were updated based on learnings from the first tooled prototypes. Stiffness was improved after receiving feedback from our World Tour athletes.

Just like every Tarmac since the SL5, the SL8 is Rider First Engineered – stiffness for every SL8 varies based on frame size to ensure riders of all sizes have the same responsive ride quality, compliance, and stiffness when applying power. As with all Specialized product, the Tarmac SL8 adheres to our Beyond Gender principles – touch points on the bike are customizable and component specifications are chosen based on our Retul fit database. We only make gender-specific product when there is data to support the difference and a true performance benefit.

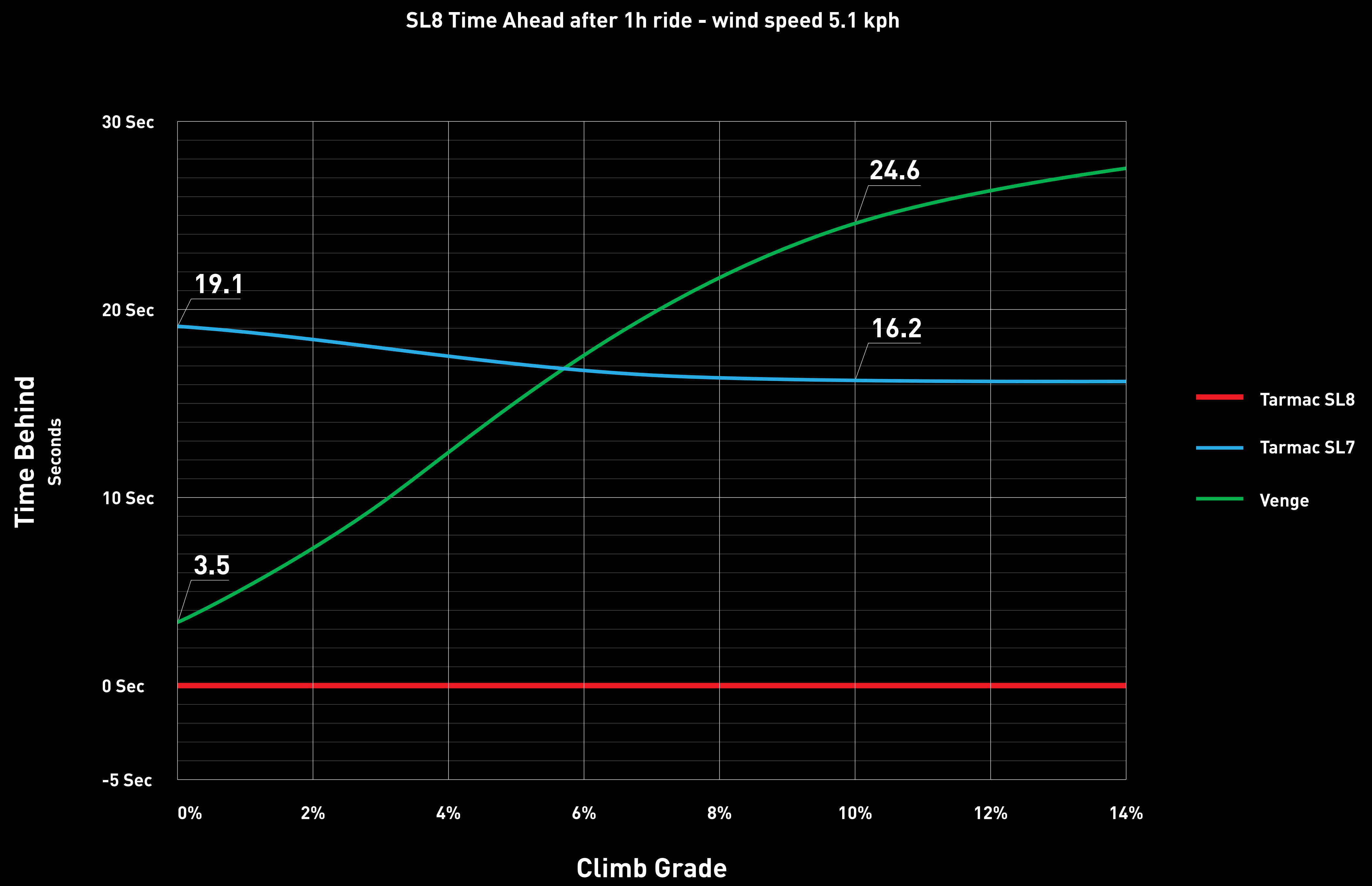
Validation

The success of Tarmac SL8's development is one of the biggest accomplishments for our bike R&D team to date. A 685g frame, aerodynamics that eclipse the Venge, and ride quality and stiffness numbers that surpass SL7 are metrics that five years ago many would have thought were impossible. Each design feature was implemented with real-world riding in mind. Every technical decision made in the development of the SL8 was informed by rigorous testing and analysis.

Using the same simulations our World Tour teams use to choose equipment on race day, we benchmarked SL8 against past Specialized road bike models. These simulations assume real-world wind directions and speeds, World Tour level power (6W/kg), Rapide CLX II wheels on all Specialized bikes to isolate the frameset module, two 22ounce water bottles mounted in the lowest position possible, 25mm tires at 90psi, and a cockpit with 42cm handlebar/100mm stem. Equal stack numbers across all bikes were utilized to obtain comparable CdA values from our Win Tunnel.

Using the same assumptions for real world conditions, our Ride Science team simulated two iconic, real-world courses: Milan San Remo and the Col du Tourmalet. Compared to SL7, SL8 is 128 seconds faster over the course of Milan San Remo, with 4 of those seconds coming in closing kilometers starting at the bottom of the Poggio. On the Col du Tourmalet – SL8 is 20 seconds faster than SL7. 16 seconds gained on the climb, and an additional 4 seconds gained on the descent.

Our simulations capture valuable data for our World Tour athletes and every road rider. As useful as these simulations can be, they don't tell the full story. Anyone who has raced in a road race, criterium, or joined a competitive group ride knows the sublime feeling of how a responsive, lightweight, and comfortable frameset performs when on the road – especially when accelerating. It can be difficult to capture this qualitative input and assign a numerical improvement. The best cyclists from around the world know this feeling is invaluable. Countless accelerations throughout a race can wear you down, and a responsive, smooth bike can make all the difference. We hope you get to experience Tarmac SL8's ride first-hand.



Appendix

CFD: Computational Fluid Analysis.

Win Tunnel: Wind tunnel onsite at Specialized HQ in Morgan Hill, CA.

CdA: Coefficient of aero-dynamic drag.

FEA: Finite Element Analysis