PINARELLO DOGMA F10 WHITE PAPER 1.0

PINARELLO DOGMA F10

CONTENTS

1. INTRODUCTION

a. Pinarello

Cicli Pinarello SpA is one of the most famous and winning bike manufacturer in the world. Founded in Treviso (Italy) in 1952 by Giovanni (Nani) Pinarello, it produces high end racing bikes. This name, Pinarello, recalls legendary victories of the greatest cyclists of all times: since 1975, the first victory in *Giro d'Italia* with *Fausto Bertoglio*, Pinarello has won all the most important races in the world, including *Olympics*, *World Championships* and *Tour de France*.

Just in the recent past, we celebrated for:
Elia Viviani - gold medal in Omnium, Rio 2016 Olympics
Chris Froome - winner of Tour de France 2013·2015·2016
Wout Poels - winner of Liege-Bastogne-Liege 2016
Vasil Kiryienka - Time Trial World Champion in Richmond 2015
Sir Bradley Wiggins - Hour Record holder in London 2015 and
Time Trial World Champion in Ponferrada 2014


Sir Bradley Wiggins


Wout Poels


Vasil Kiryienka


Chris Froom


Elia Viviani

1. INTRODUCTION

b. Team Sky

Pinarello has supported Team Sky since its foundation in 2009, providing the team with the best bikes in the business. This collaboration allowed us to test our bikes in the most important races across the world and to gather precious feedbacks to further improve them.

During these years, we developed 8 road bikes and 3 time trial bikes, which have been successfully used by the team to win its races.

Our collaboration is now extended, at least, up to 2020, and we are already working on new amazing projects.

1. INTRODUCTION

c. Dogma F8

Dogma F8, presented in May 2014, is one of the most famous and winning bike in the world. It is also the best-selling frame in the Pinarello history, and the most imitated frame on the web, an unquestionable symptom of how it is the absolute benchmark in the cycling world.

On-board Dogma F8, riders of Team Sky have won more than 90 races in the last 3 years. These races include sprint finish, uphill finish and breakaway finish: this highlights the “all-round” character of this fantastic bike.

Dogma F8 has won innumerable awards, among which Best Road Bike of the World – Bicycling Editors’ Choice 2015 and 2016 and London Design Award 2014.

1. INTRODUCTION

d. Bolide TT

Bolide TT debut in 9th stage of Giro d'Italia 2016, helping Mikel Landa to ride an excellent TT stage. Few weeks later, during Tour de France and Vuelta a Espana, it allowed Chris Froome and Team Sky to gain 3 victories and a second place on 4 races… amazing!

The development of Bolide TT used Bolide and Bolide HR as starting point, adding some innovative technologies and cutting-edge features, such as the concave down tube.

These ideas and technologies were later adjusted to a road bike to develop the new Dogma F10.

2. PRELIMINARY DESIGN

a. Purposes

At the beginning of the project, we established the required design changes, to follow them along the development and, at the end, to verify that the new bike complies with them.

The main aim of the new bike was to maintain the “all-around” characteristics, which means a stiff and light bike, with excellent aerodynamic balance. At the same time, we had to maintain the unique “Pinarello feeling”, synonymous of agility and precision in every corner.

Considering the entire purposes, main targets were:

- **Maintain same handling**, to guarantee the unique Pinarello feeling to every rider and cyclist. We maintained same the geometries of Dogma F8 (13 sizes in total, to allow every rider to find the frame which best accommodates his/her body), and same tapered headset (top bearing 1” 1/8, bottom bearing 1” 1/2);
- **Increase stiffness**, to avoid any waste of energy and to have a more balanced behaviour of the bike. A further development of asymmetry concept allowed us to reach this, in combination with the carbon fibre choice;
- **Reduce air drag**, to reduce any waste of energy due to air resistance. We added new innovative features, derived from the development of Bolide HR and from an in-depth CFD (aerodynamics) analysis, which optimizes the airflow along the bike;
- **Reduce the weight**, to reduce the energy needed in a hilly route or climbs and to allow quicker accelerations and brakings. The choice of the carbon fibre, in combination with the optimization of the tubing sections and the further development of the asymmetry concept helped us to reach this purpose.

b. Aesthetics

Pinarello bikes are unique because mix performances with aesthetics. All the bikes that we develop and produce are not just winning bikes… they are also beautiful. Therefore, during development, we took care to combine the features derived by CFD and FEA (for the structural performance) with the aesthetics… what results is simply a work of art!

You can see here below few sketches used during the development. These sketches, even if preliminary, already have some important features which had been later developed, such as the elongated fork dropouts or the enlarged transition between top tube and seat tube or concave down tube.

Aesthetics was then finalized "by hand". Using 3D printed samples, we could see and touch the shape of tubes and transitions; using sand paper and apposite tools we smoothed and improved the surfaces. These modifications were then applied to the 3D drawing, in order to obtain the final design and proceed with production.

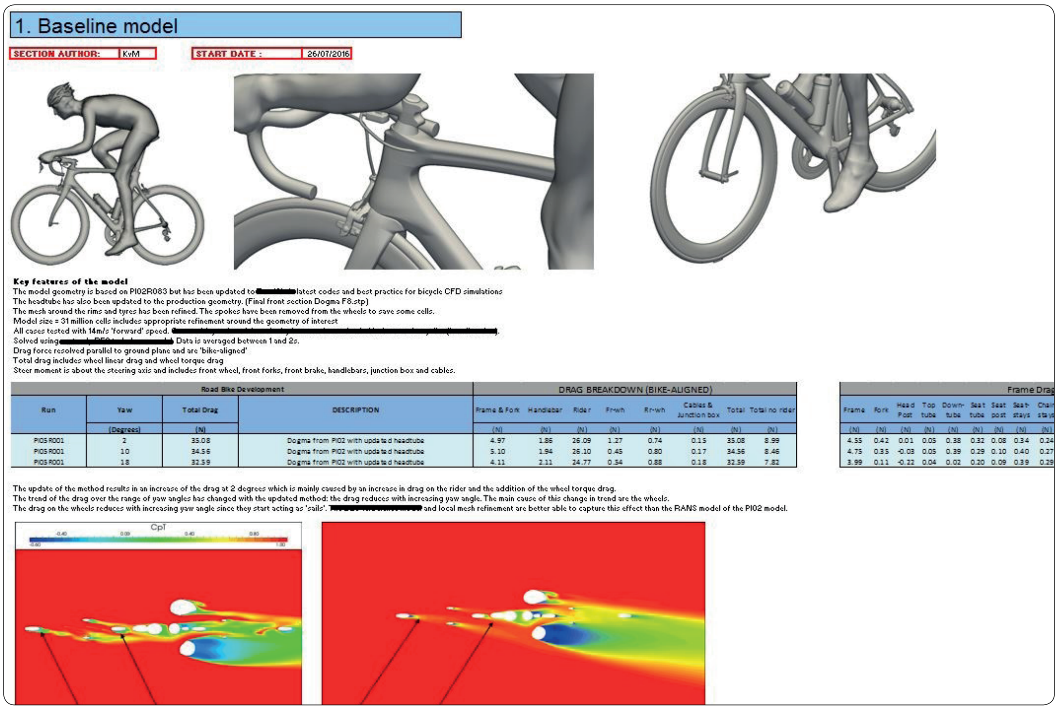
2. PRELIMINARY DESIGN

3. AERODYNAMIC DESIGN

The in-depth aerodynamic analysis and the huge amount of data derived by the development of Bolide HR and Bolide TT was used to improve aero performances of Dogma F10.

Analysis and improvements were focused to reduce the overall drag of the entire system “bike + rider”. Aerodynamics, indeed, is a complex area to study because of the interaction between the airflow and all the components, not just the frame or the fork. The optimization of the parts/components one by one could cause a worsening of overall performance, exactly because does not consider the interaction between the parts. On the contrary, a modification of one part that cause a little increase of the aero drag of the single part, could lead the overall drag to decrease.

3. AERODYNAMIC DESIGN



1. Baseline model

SECTION AUTHOR: KvM

START DATE : 26/07/2016

Key features of the model

The model geometry is based on PI02R083 but has been updated to [redacted] latest codes and best practice for bicycle CFD simulations
The headtube has also been updated to the production geometry. (Final front section Dogma F8.stp)
The mesh around the rims and tyres has been refined. The spokes have been removed from the wheels to save some cells.
Model size = 31 million cells includes appropriate refinement around the geometry of interest
All cases tested with 14m/s 'forward' speed. [redacted].
Solved using [redacted] Data is averaged between 1 and 2s.
Drag force resolved parallel to ground plane and are 'bike-aligned'
Total drag includes wheel linear drag and wheel torque drag
Steer moment is about the steering axis and includes front wheel, front forks, front brake, handlebars, junction box and cables.

Road Bike Development				DRAG BREAKDOWN (BIKE-ALIGNED)							
Run	Yaw	Total Drag	DESCRIPTION	Frame & Fork	Handlebar	Rider	Fr-wh	Rr-wh	Cables & Junction box	Total	Total no rider
	(Degrees)	(N)		(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)
PI05 R001	2	35.08	Dogma from PI02 with updated headtube	4.97	1.86	26.09	1.27	0.74	0.15	35.08	8.99
PI05 R001	10	34.56	Dogma from PI02 with updated headtube	5.10	1.94	26.10	0.45	0.80	0.17	34.56	8.46
PI05 R001	18	32.59	Dogma from PI02 with updated headtube	4.11	2.11	24.77	0.54	0.88	0.18	32.59	7.82

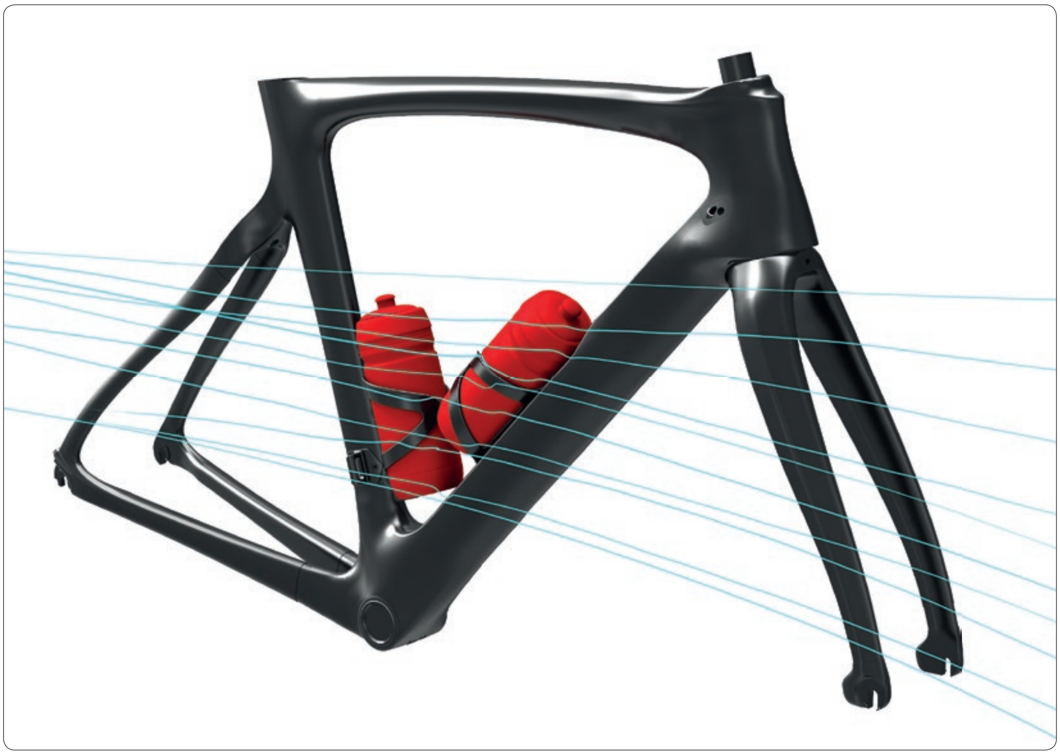
Frame Drag								
Frame	Fork	Head Post	Top tube	Down-tube	Seat tube	Seat post	Seat-stays	Chain stays
(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)
4.55	0.42	0.01	0.05	0.38	0.32	0.08	0.34	0.24
4.75	0.35	-0.03	0.05	0.39	0.29	0.10	0.40	0.27
3.99	0.11	-0.22	0.04	0.02	0.20	0.09	0.39	0.29

The update of the method results in an increase of the drag at 2 degrees which is mainly caused by an increase in drag on the rider and the addition of the wheel torque drag.
The trend of the drag over the range of yaw angles has changed with the updated method: the drag reduces with increasing yaw angle. The main cause of this change in trend are the wheels.
The drag on the wheels reduces with increasing yaw angle since they start acting as 'sails'. [redacted] and local mesh refinement are better able to capture this effect than the RANS model of the PI02 model.

CpT

a. Concave Downtube

The down tube is one of the parts of the frame which has a significant influence on the aero performances. Because of its position, just behind the front wheel, and its dimensions (the more massive tube of the frame), it generates more that 15% of the overall drag of the frame. Therefore, intuitively, the reduction of its drag would improve also the overall drag. But the aerodynamics is quite complicated in that area with a lot of interactions so it deserves more attention.



3. AERODYNAMIC DESIGN

The down tube is placed in front of the bottles and the seat tube and, in a certain way, protects them from the airflow. A certain modification of the shape of the down tube, apparently, could lead to an increase of its drag but, at the same time, a more drastic reduction of the drag generated by the bottles and seat tube. As a result of this modification, therefore it generates more advantages than disadvantages, but only if it is done correctly.

We developed several possible cross sections for the down tube, in order to find the one that optimize the interaction between all these components. CFD analysis allowed us to analyse and compare many different options.

The chart here below is an extract of the results comparing Dogma F8 and Dogma F10.

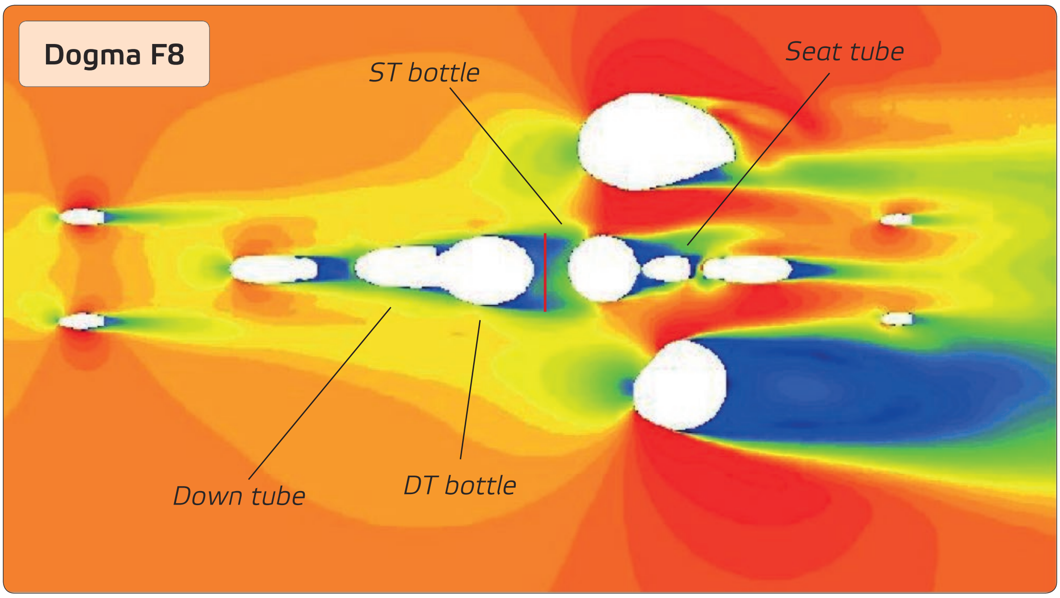
Drag (N)	DT	DT bottle	ST bottle	ST	Local difference* %
Dogma F8	0.31	0.17	0.67	1.15	-12.6%
Dogma F10	0.19	0.13	0.68	1.01	

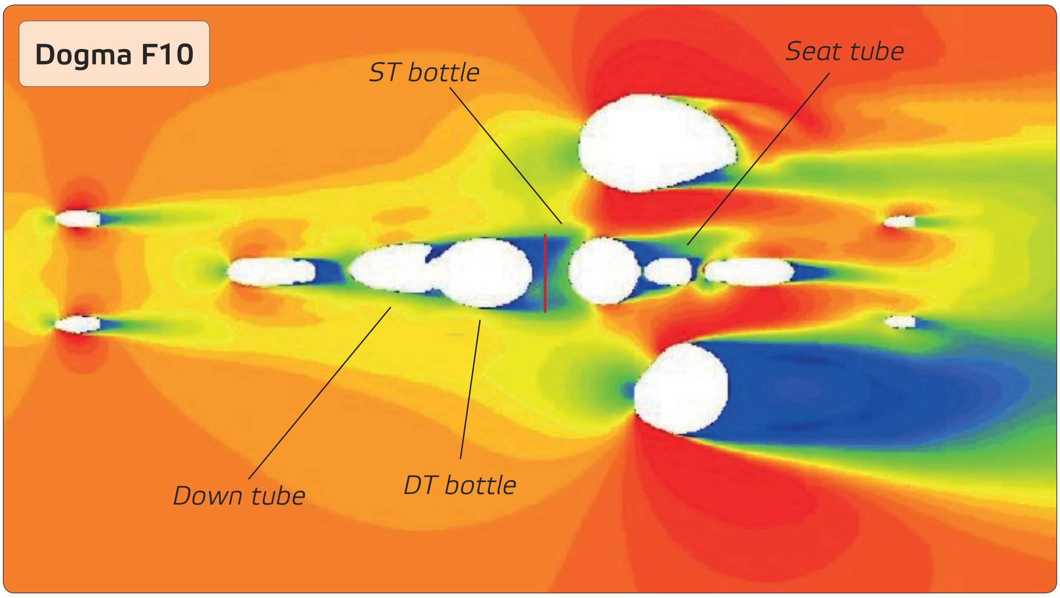
* Local difference is the percent variation of drag generated by the down tube and bottles combination

The final design of the down tube leads to extraordinary results: the drag of the tube itself was reduced and, and the same time, the bottles' drag decreases. The local variation of the drag, in the area between down tube, seat tube and bottles was reduced of 12.6%.

3. AERODYNAMIC DESIGN

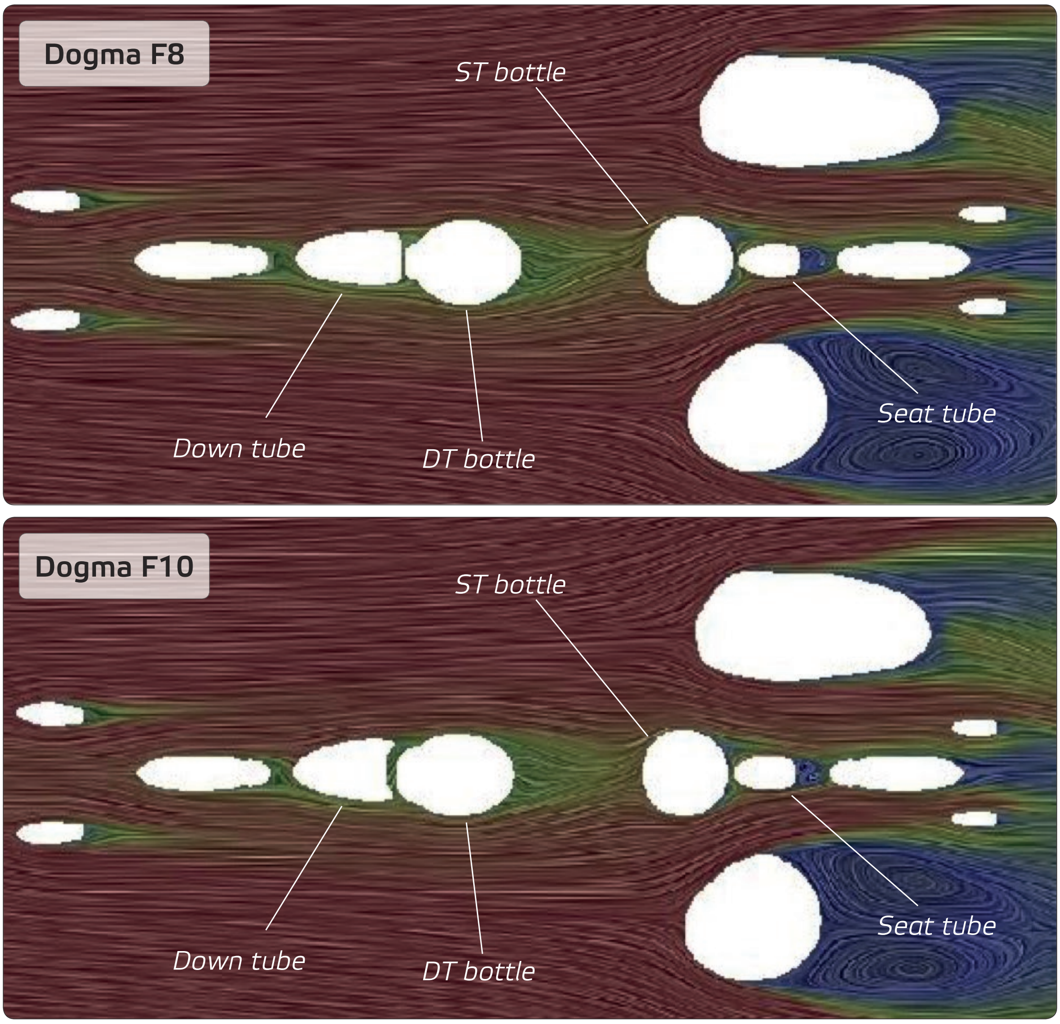
Images below compare the airflow between Dogma F8 and Dogma F10. In particular, colours distribution shows how it varies along the bike. Blue colour indicates low-pressure areas, which is where most the drag is generated, and red colour indicates high-pressure areas. A red bar with equal length is visible on both, to ease the comparison. It can be seen that in the case of Dogma F10, there is a small but measurable reduction on the size of low pressure area (blue). This effect, multiplied by the length of the area is what is giving us the improvement.





3. AERODYNAMIC DESIGN

Images below visualize how the air flows along the bike. The transition of the airflow between down tube and DT bottle is smoother on Dogma F10, because of the shape of the down tube which partially "shields" the bottle.

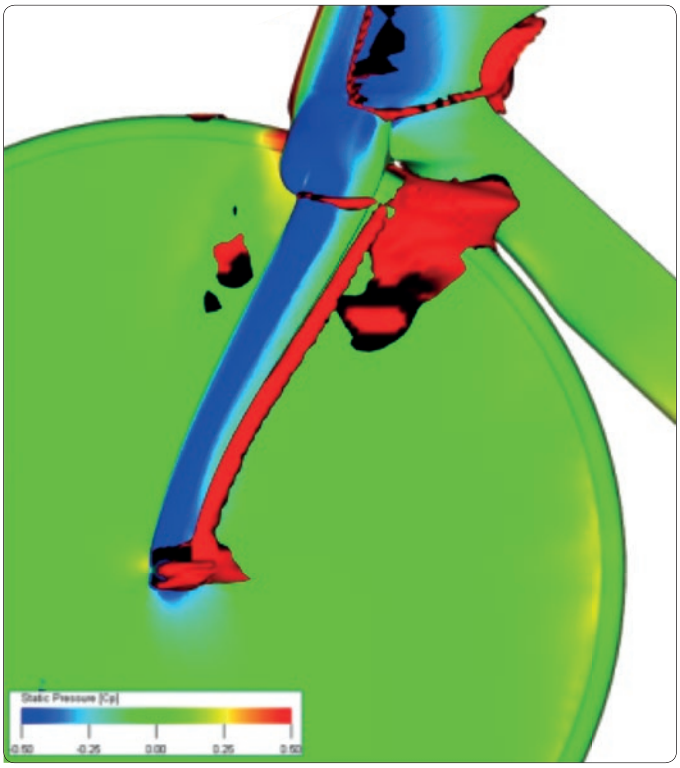


b. “Fork Flap”

The front of the bike is the most important in terms of aerodynamics, because it is the first part which runs into the airflow and influences everything behind. Therefore, even a little improvement of this area could be crucial.

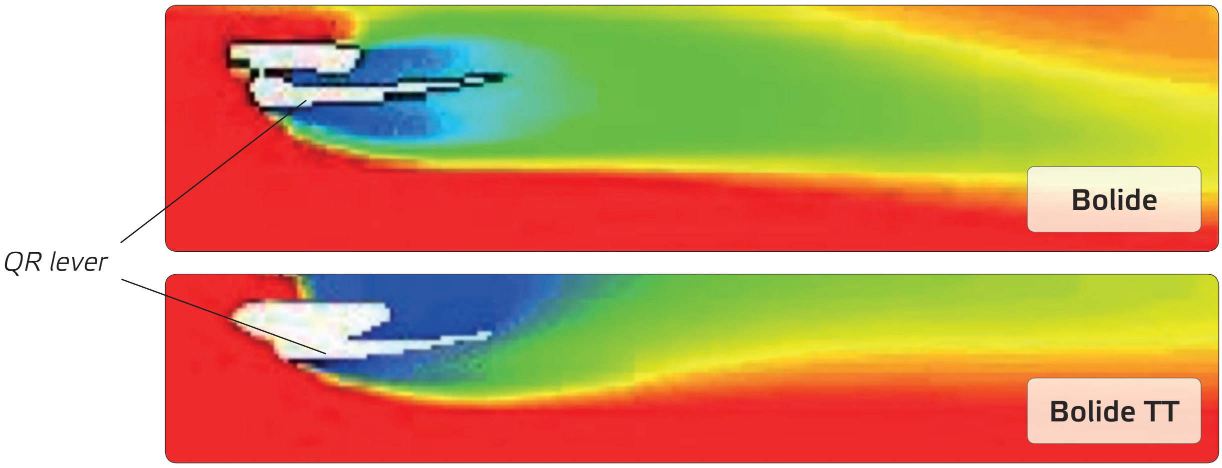
On the road bikes, the wheels are fixed using quick release skewers. The quick release consists of a rod threaded on one end with a lever operated cam assembly on the other end. This mechanism allows the possibility to quickly change the wheel but, in term of aerodynamics, is not the optimal choice. The nut and, especially, the lever are quite bulky components and compromise the aerodynamics of the front dropouts.

A in-depth analysis of this topic was performed during the development of the Bolide HR. CFD image below shows the drag generating area behind the fork of Bolide (the time trial bike used to develop the Hour Record bike). Please note that this is actually a very small area indeed.



3. AERODYNAMIC DESIGN

The presence of the QR lever generates a big slipstream behind the dropout, with the consequence of increasing the drag. Modifying the shape of the dropout's area, adding material where the slipstream is high, we were able to reduce it, decreasing the overall drag. Even if a small modification, this leads to a drag reduction of the fork up to 10%, because of its importance (data derived by the analysis of Bolide TT fork).



Images above show the comparison between slipstream generated by the left dropout and QR lever on Bolide and Bolide TT. What appears is that on Bolide TT, because of the design of the dropout which "encloses" part of the QR lever, the slipstream is narrower and, especially, tends to move towards the frame. On the contrary, on the Bolide, the slipstream moves away from the frame. So, even if locally the blue area is larger on Bolide TT, the gait of the slipstream lead to a lower final drag.

3. AERODYNAMIC DESIGN

On Bolide HR, finally, we could further reduce the drag integrating the screws which fix the wheel (common fixing on a track bikes). We later used this technology while developing Bolide TT: in this case, the wheels are fixed with standard quick release so the dropouts were designed in order to fit the commercial QRs. On Dogma F10 we used same concept of Bolide TT, taking in account also the fork's weight: the final design is the compromise between the optimal aero and the lowest weight. Pictures below shows, from left to right, the fork dropouts of Dogma F10, Bolide TT and Bolide HR.

4. STRUCTURAL DESIGN

a. Tubing Design

Cross sections and shape of tubes, as much as the material's choice, are very important to ensure stiffness and lightness. At the same time, as discussed above, it has a deep influence on the aerodynamics. Therefore, the final design of tubes is the optimal compromise between an aero shape and a stiff shape.

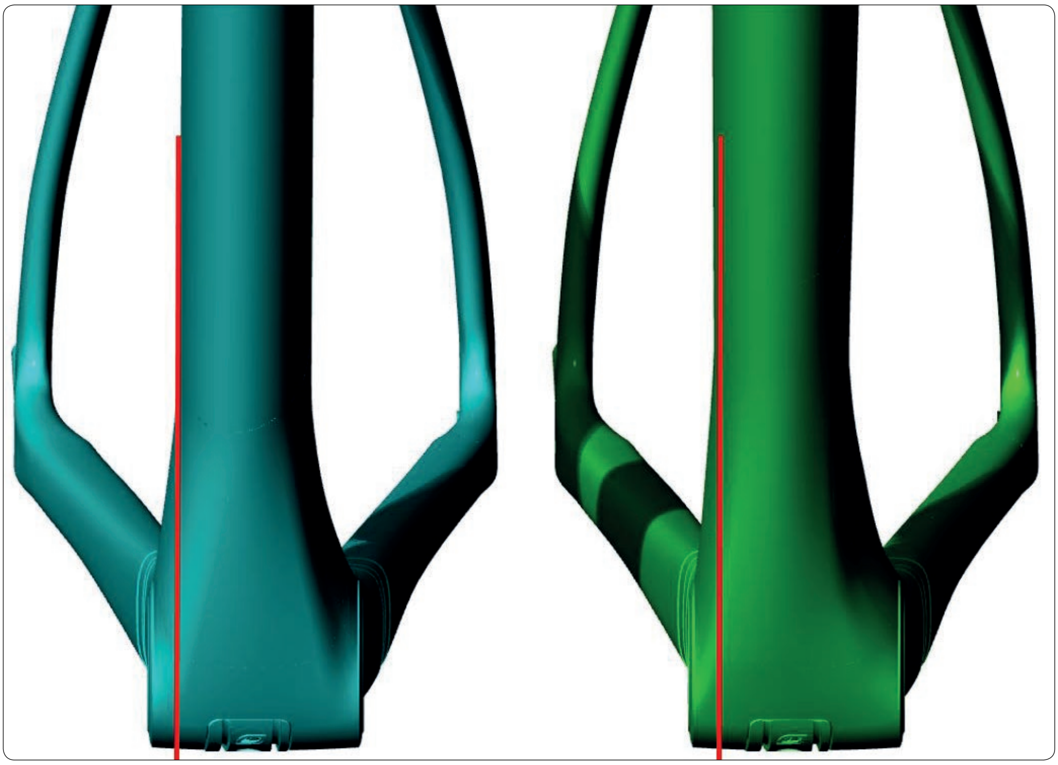
Pinarello, since 2009, has studied and developed the asymmetry concept. At first, it might sound a bit strange, but let us explain the logic behind it. A "normal" frame is symmetric, i.e. the left side will be a mirror image of the right side. Although, at first glance, this may sound correct, in fact it completely ignores a crucial fact. The transmission (chainset, chain and gears) are on the right side only. So, when the rider is pushing the pedals, the majority of the forces from the tension of the chain are acting on the right side of the bike only. Therefore, a correct design should take this into account and make the frame asymmetric because the forces acting on it are asymmetric. A symmetric frame will cause a reduction of the frame's stiffness and, above all, an unpleasant feeling of the bike, especially if highly stressed (sprint, climb out of saddle, etc.). The asymmetric design of Pinarello frames (the right side of frame and fork tubes is larger than the left side) optimally counteracts the asymmetric forces and provides a stiffer and more balanced bike.

In 2013, while developing Dogma F8, supported by FEM, we revolutionized this concept. Tubes were not only enlarged, but also "moved" to the right side of the frame. Results were amazing, with 12% increase of the stiffness and 16% increase of balance of the frame.

Now, developing Dogma F10, we further developed this asymmetry of the frame, moving tubes even more on the right side. This new design further improved the overall performances of the bike, especially in terms stiffness.

4. STRUCTURAL DESIGN

Below you can see the comparison between down tube of Dogma F8 (left) and Dogma F10 (right) near the BB. Red line, positioned at the same distance from the centre of the bike, highlights that the down tube of Dogma F10 is further moved towards the right side of the bike. This difference, even if small, further improves the performaces of the frame.



b. Material's Choice

The proper choice of material deeply influences the performance of the frame. Carbon Fibre Reinforced Polymer (CFRP), in particular, could be optimized for every single area of the frame, to achieve the best stiffness and lightweight, based on the local stresses.

Carbon fibre indeed, which the proper name is "composite material", is a mixture of carbon fibre/fabrics and resin, and all its properties deeply depend on fibre properties, resin properties, lay-up and production method: if just one of these characteristics change, the behaviour of the material will be definitely different.

Traditional metals, such as steel or aluminium or titanium, are isotropic materials, which means that their properties are uniform in all directions. This entails good average properties, but does not allow to distribute the material following the stresses' trends. On the contrary, composite materials are usually orthotropic materials, which means they have properties that differ along three mutually orthogonal twofold axes of rotational symmetry. In simple terms, the material's properties change with the direction so the material can be optimized following the local stresses.

We describe here a quick example to explain the concepts above. The down tube of the frame is primerely subjected to torsion and lateral flection. The effect of these stresses is very burdensome for the down tube, which should be reinforced to resist properly. In the past, the down tube of the bikes was a circular tube made in steel, a very stiff material which adequately counteracts the stresses. Then, moving to aluminium, which ensures lighter frames but less stiff, the shape of the down tube became elliptical, with longer dimension transversal to the frame; this modification increased the inertia moment of the tube, recovering that lost by the material. Nowadays, CFRP can be draped in the optimal direction to counteract the stresses; this allow the possibility to have very aero cross-section without any loss of stiffness.

4. STRUCTURAL DESIGN

A second advantage of composite materials is the possibility to use different material (type/grade of carbon fibre and/or resin) based on the local stresses. So, in areas where the stiffness must be favourite, a high modulus fibre (HM) could be used, while where the strength is primary, a high strength fibre (HT) should be preferred. This variation of material could be done locally, into the same frame, while a metallic material would entail constant properties in the entire frame.

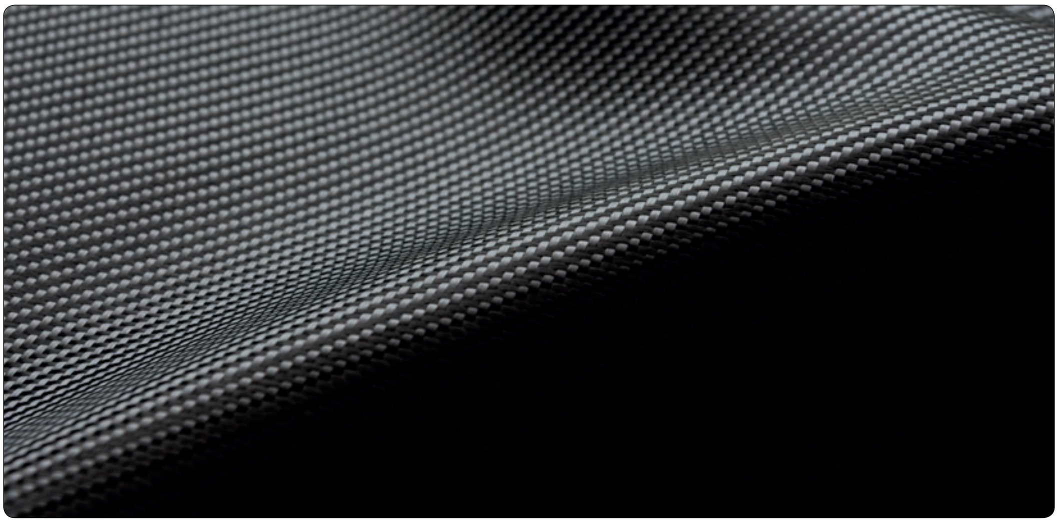
On Dogma F10, the main material used is Torayca T1100 1K, which ensures the highest tensile strength in the world. This choice contributes to increase the impact strength, to prevent breakages.

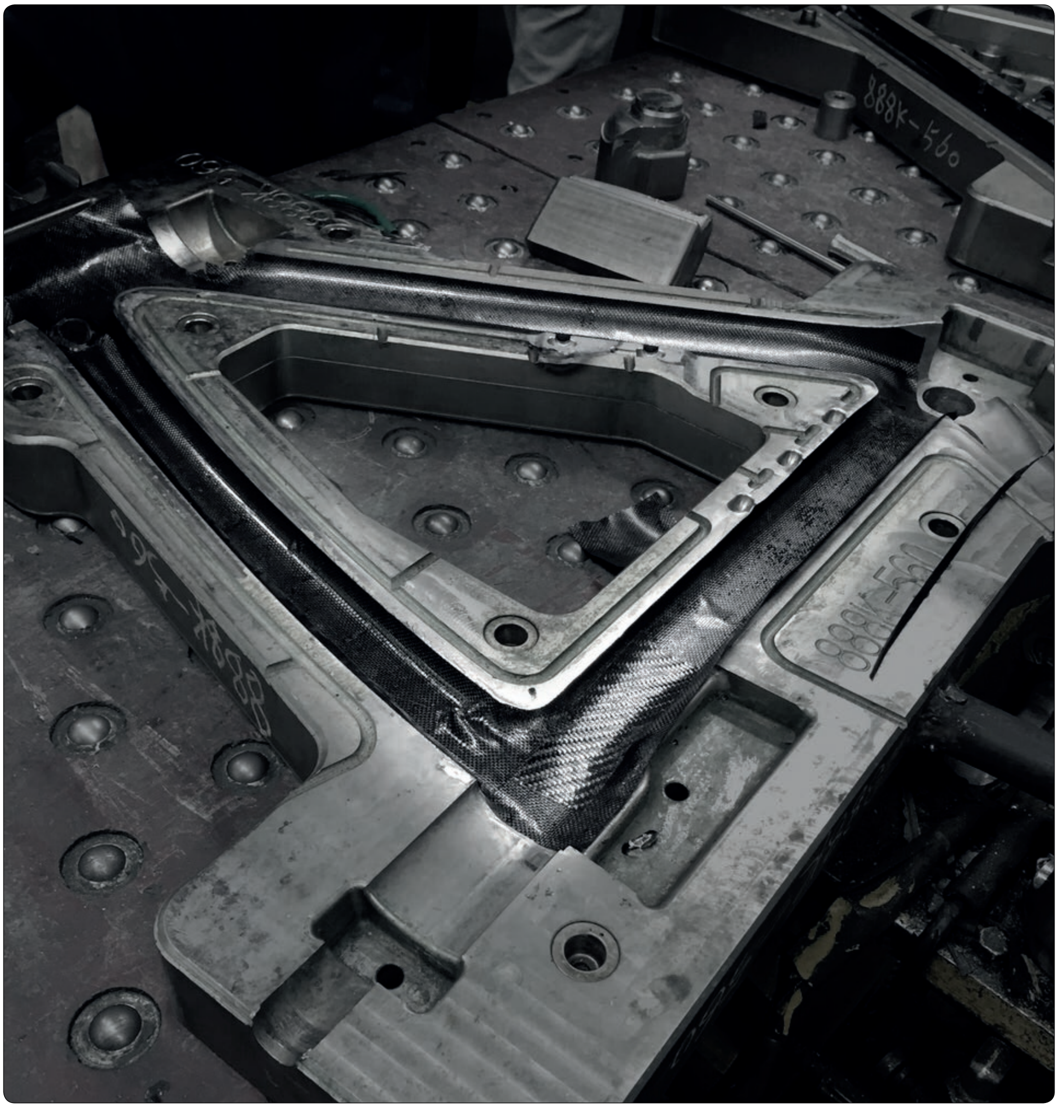
The improvement of asymmetry, with down tube further moved to the right, allowed us to increase the stiffness due to the shape, recovering that stiffness lost with the usage of less material.

Thanks to the highest grade of carbon fiber used (especially higher strength) we were able to get a lighter frame maintaining its strength unchanged. T1100 fibers have been used in the higher stressed areas, in order to take advantage of its incomparable strength.

For better explanation about CFRP, please refer to Pinarello Dogma F8 White Paper 1.0.

4. STRUCTURAL DESIGN

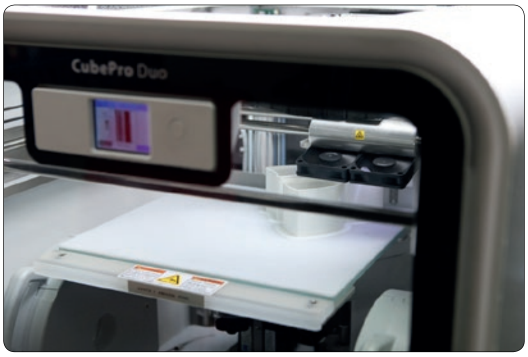




5. PRODUCTION

a. RP Samples

During the development of the bike we largely used 3D printing technology, to have a continue control of real samples. In particular, using an in-house machine, we realized many samples of part of the frame to verify aesthetics and matching with other components. For example, several shapes of the down tube were "printed" to check the matching with bottles and final aesthetics.



We also realized RP samples of the entire frame, to finalize the aesthetics and for final controls, before proceeding with mold openings and pre-production.

5. PRODUCTION

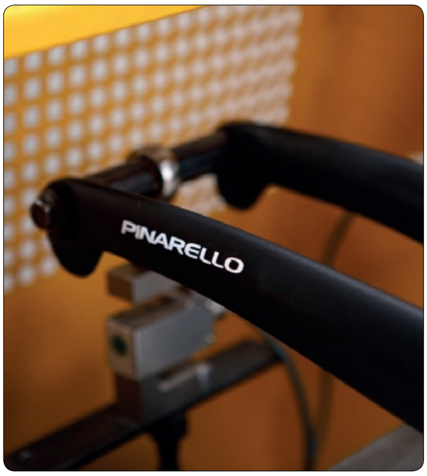
b. Carbon Samples

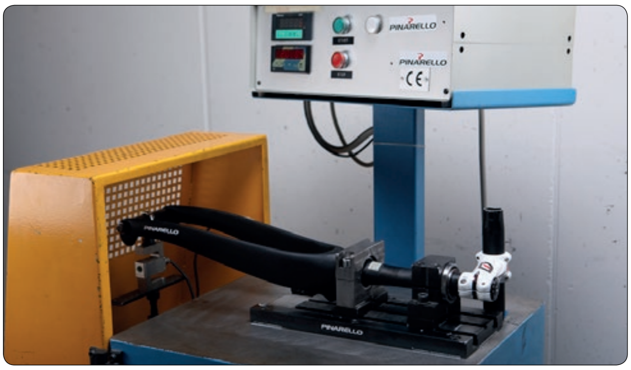
Once finished the main development phase, we proceeded with production of initial samples. These samples were used, first, to verify complete assembly and performances. In particular, with static and fatigue test, we were able to measure the stiffness of the bike, to compare it with initial targets, and to verify the proper strength of the frame.

6. TEST

a. Lab Test







6. TEST

b. Road Test

We also performed several road tests, to verify the real behavior of the bike. These tests also offered useful feedbacks from the riders, to further improve and finalize the project. Chris Froome was the first rider to test the new Dogma F10. His first words were: “great work guys!”, a very good feedback from one of the best pro riders.

7. RESULT

a. Structural performances

Once the designing phase was finished, we produced samples to test performances of the frame and to compare with the initial purposes.

We tested several frames on fatigue test and crash test to verify strength and safety. We also measured the mechanical performances (stiffness and weight), and compared the results with Dogma F8. Below the comparison of size 530.

	AVG weight (g)	Specific Stiffness		
		HT (Nm/ºg)	BB (N/mm g)	Double CS (N/mm g)
Dogma F8	875	0.1454	0.2079	0.0564
Dogma F10	820	0.1526	0.2196	0.0608
% increase	-6.29%	4.93%	5.63%	7.78%

What is clearly evident, first of all, is **6.3% reduction** of the frame weight. **Dogma F10 frame weights just 820 g (size 530, raw frame).**

Secondarily, all the values of specific stiffness we usually measure and compare are higher than the values of Dogma F8. Comparing two different frames without considering the effect of the weight could provide wrong results; the weight, indeed, has a deep influence on the stiffness (more material used, stiffer will be the frame…but also heavier). Therefore, we used the specific stiffness, which is the value of the stiffness divided by the weight; it allows to compare two frames without the influence of the weight. In short, **the specific stiffness of Dogma F10 is 7% higher than Dogma F8.**

In brief, Dogma F10 frame is 6.3% lighter and 7% stiffer than Dogma F8…great result!

b. Riding performances

Numbers above are extraordinary, especially considering that the comparison is made on the Dogma F8, the best bike produced by Pinarello so far. But, at the same time, they are quite technical and it is not easy to understand the direct relation with real riding feeling. What a rider commonly perceives is the reactivity and the handling of the bike; frame, fork and wheels are the main players to gain this.

Reactivity, defined as the frame's quickness in transforming cyclist actions into bicycle acceleration, resulted to be one of the main performance requirements perceived by the cyclists. This characteristic depends especially on 2 factors: weight and stiffness. The lower weight of Dogma F10 frame and fork ensures quicker accelerations and decelerations, very important while climbing or sprinting. The higher stiffness, especially of down tube, bottom bracket area and chain stays leads to a better power transfer, without useless deformation of the frame and consequent power losses. All the power generated by the rider goes directly to rear wheel and the road.

Handling, defined as the capability to change direction quickly and to corner precisely, mainly depends on the geometry (head tube angle, fork's rake, wheelbase, etc.) and the stiffness of frontal part of the frame (head tube and fork).

Geometry has been maintained same as Dogma F8, which was judged by rider as very precise and responsive; even stiffness of head tube and fork was increased.

These important characteristics, theoretically described by the numbers above, have been also confirmed during the road tests performed by the riders. Now it's your time to test and enjoy it!

c. Integration

Integration of all the parts is an important factor that ensure the good performances of the bike. In particular:

E-Link: the junction of new Shimano DuraAce Di2 (EW-RS910) will be integrated into the down tube, and easily accessible for adjustment and recharge;

Internal cable routing: housings and electronical cables pass internally the frame, for a better aerodynamics and aesthetics;

Think2 technology: the frame is compatible both for mechanical or electronical group-sets;

Internal battery: the battery is fixed inside the frame, for a better aerodynamics and aesthetics;

Integrated seatclamp: the Twin Force seatclamp, integrated into the frame, ensures low aero drag and a strong clamping of the seatpost.

7. RESULT

d. Main Features

The incomparable performances of Dogma F10 heavily depends on the innovative features applied. The most important of these are the following:

FORK FLAP

E-LINK

CONCAVE DOWN TUBE

8. TECHNICAL SPECIFICATIONS

a. Specifications

Dogma F10 continues the evolution of Pinarello bikes, with exceptional characteristics.

E-Link
Fork Flap
Concave down tube
Carbon Torayca T1100 1K
Asymmetric Frame
Italian thread BB
Tapered headset 1˝ 1/8 (upper) – 1˝ 1/2 (lower)
Think2 technology
Internal Cable Routing
Battery inside
Twin Force Closure
3 x Air
Flat Back Profile
25 mm tires fitting
820 g for raw frame, size 530

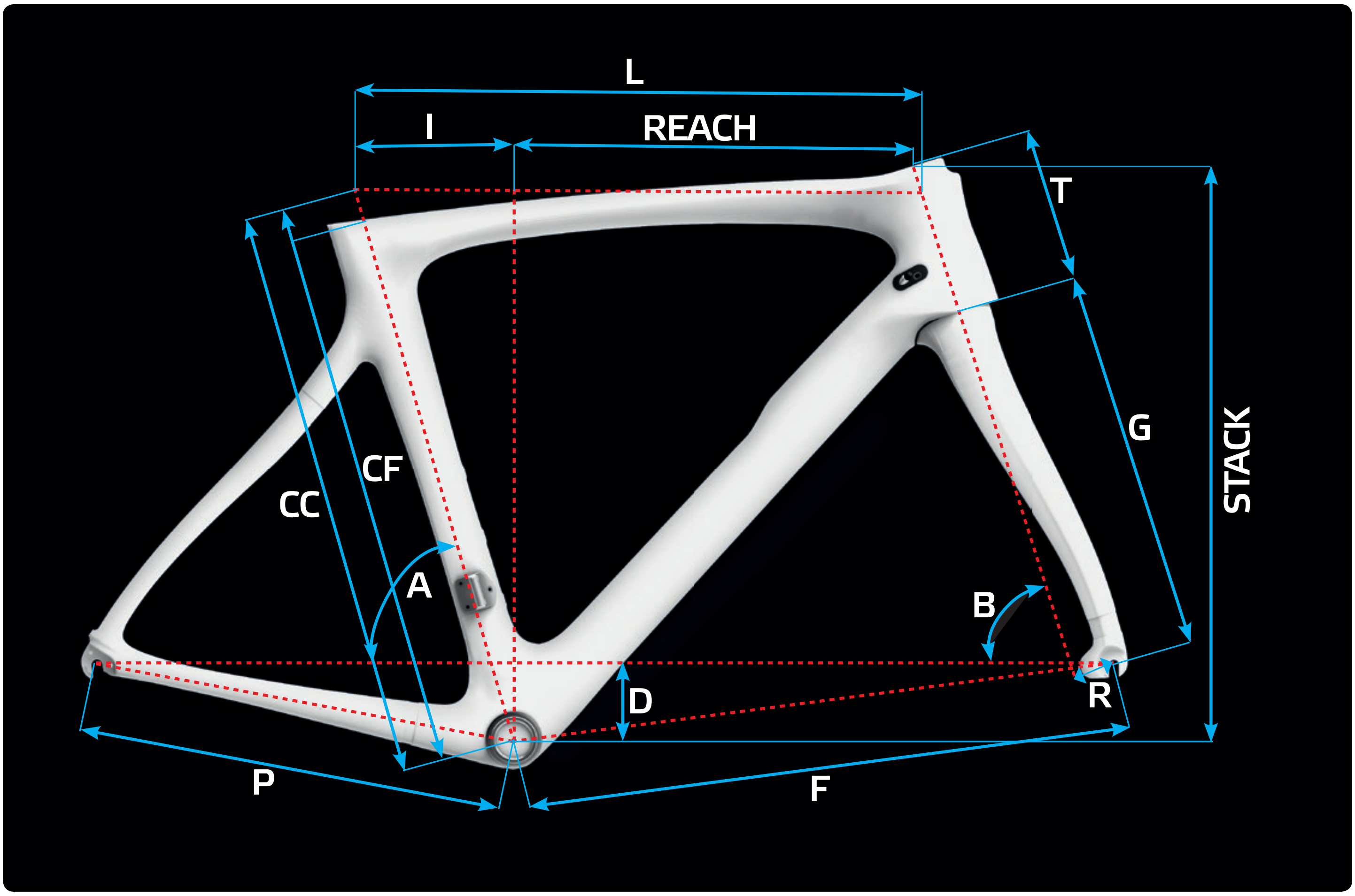
8. TECHNICAL SPECIFICATIONS

b. Geometries

Pinarello is used to offer every single rider the best bike. We developed 13 sizes to allow every rider to find the one that best fits his body. Everyone of these sizes are designed and produced individually: the bigger sizes are reinforced and shaped in order to bear higher stresses; the smaller sizes can be made using less material, saving weight.

CF	*CC*	L	I	A [º]	B [º]	F	P	T	D	R	G	REACH	STACK
415	***420***	498	113	74.40	69.15	564	406	105	67	43	367	351	493
435	***440***	503	118	74.40	70.00	564	406	110	67	43	367	357	501
455	***465***	515	125	74.40	70.50	573	406	115	72	43	367	367	512
455	***470***	525	128	74.00	71.40	575	406	125	72	43	367	373	525
480	***500***	525	138	74.00	71.40	575	406	120	72	43	367	374	520
495	***515***	535	145	73.70	72.00	577	406	125	72	43	367	380	527
510	***530***	545	149	73.70	72.50	583	406	139	72	43	367	386	542
520	***540***	550	154	73.40	72.80	583	406	147	72	43	367	386	550
530	***550***	557	157	73.40	72.80	590	408	158	72	43	367	389	561
540	***560***	565	164	73.00	73.20	591	408	165	72	43	367	391	569
555	***575***	575	168	73.00	73.70	596	408	179	72	43	367	397	584
575	***595***	587	180	72.40	73.40	605	408	215	67	43	367	394	612
615	***620***	620	192	72.00	73.40	633	411	255	67	43	367	410	651

8. TECHNICAL SPECIFICATIONS



9. RACING

a. UCI Approved

Dogma F10 is UCI approved, so it can be used in all international competitions.

9. RACING

b. Debut

Dogma F10 will debut in January 2017, ensuring a new extraordinary season for Team Sky, in the pursuit of new victories.

Cicli Pinarello SpA
Viale della Repubblica 12
31020 Villorba (TV) Italy
tel. +39 0422 420877 fax +39 0422 421816
infobike@pinarello.com
www.pinarello.com