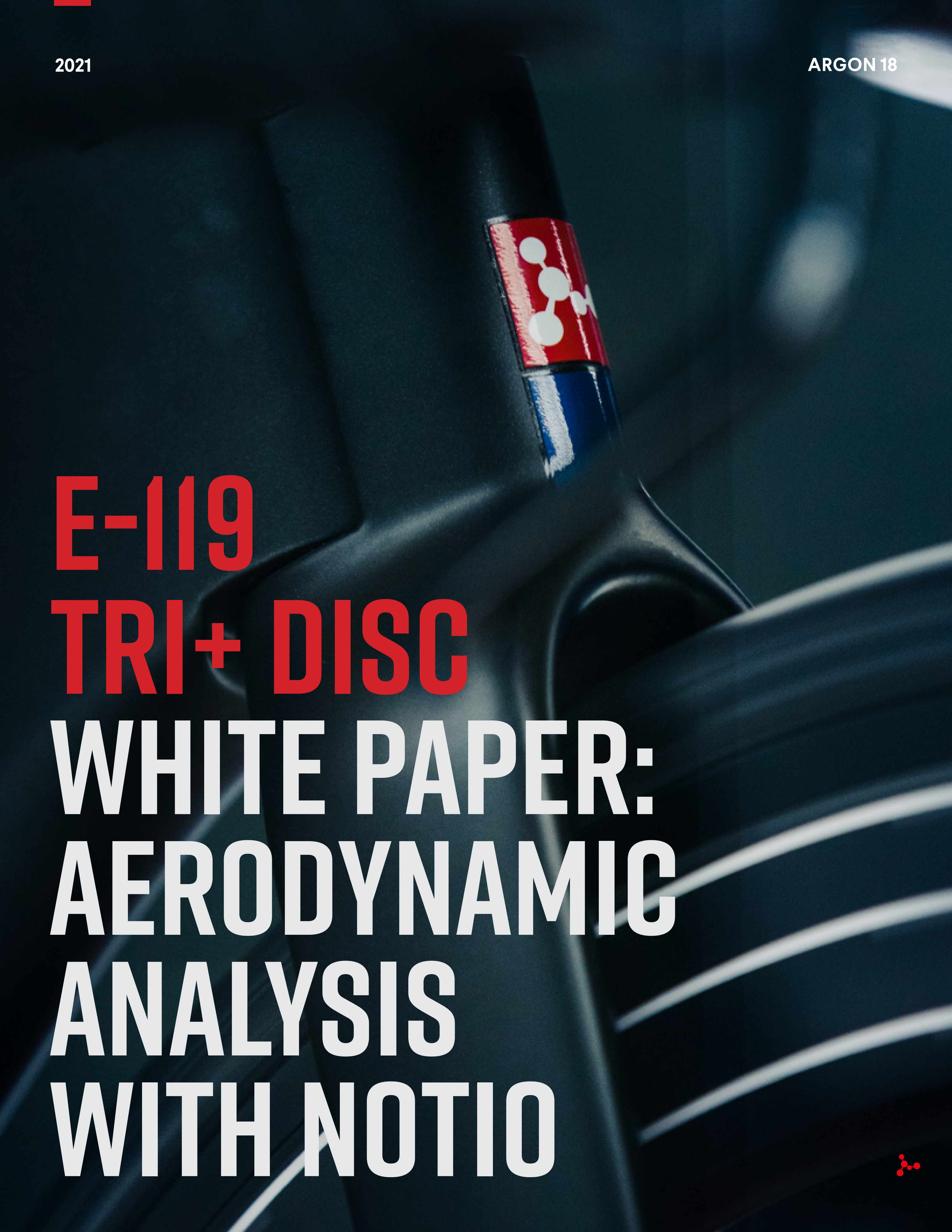

E-119 TRI+ DISC

WHITE PAPER: AERODYNAMIC ANALYSIS WITH NOTIO

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1.0 INTRODUCTION

Project Summary

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Argon 18's E-119 Tri+, launched in 2016, was our most integrated, rider-oriented and aerodynamically advanced triathlon bike, and the one that our elite triathletes trusted for their biggest races. Therefore, when we were ready to add discs to the **E-119**, we wanted to ensure we would achieve the same level of innovation, and provide our athletes with an all-new category-leading racing machine. We went back to the drawing board to develop the **E-119 Tri+ Disc** to address all performance benchmarks of the frame, beyond those simply needed to address the requirements of disc brakes. That meant optimizing our tube shapes, increasing useability, and of course, maximising aero performance.

Overall, the new **E-119 Tri+ Disc** offers up to a **10W** advantage over the previous-generation **E-119**, considering frame optimization, system integration, and compatibility with advanced aero components, such as wheelsets. When optimal rider position is factored in, using our new fit range capabilities, it can add an additional advantage. Taken together, the new **E-119 Tri+ Disc** can offer a total of up to **17W** aero advantage when considering the full bike and rider system.

1.0 INTRODUCTION

Our Design Approach · From Concept to Production

–

Argon 18's unique bikes are developed through our unique approach to the design and production process. Design, simulation, prototyping, testing and manufacturing all work as a cycle to continually deliver the best possible performance for our riders. In the development process of a new bike, such as the **E-119 Tri+ Disc**, we work through rigorous modelling, prototyping and testing phases to ensure our design delivers on our performance benchmarks and most importantly, delivers results to our athletes.

Evaluating the aerodynamic performance of our bikes is essential to our development process, as it is for all major bicycle manufacturers. However, **Argon 18** has a unique partner in **NOTIO**, which allows us to undertake real-world testing using the **CdA** calculations provided by the **NOTIO** device. This informs our development process as well as provides data to validate our products once the design is completed.

While the development of the **E-119 Tri+ Disc** included both **CFD** and prototype testing in the wind tunnel to evaluate aero performance, the majority of the tests outlined in this paper were undertaken with **NOTIO**.

1.0 INTRODUCTION

E-119 Tri Disc Performance benchmarks:

Within the scope of the **E-119** project the key areas of focus were:

1 · Integration: integrated brake calipers and hydraulic lines, integrated toolkit and bento box designed for full IM-distance requirements, integrated hydraulic reservoir in the brake levers;

2 · Aero performance: optimised tube shapes within the constraints of rider-oriented adaptations, such as the widened BB area to allow for the toolkit;

3 · Fit and Ergonomy: a fully redesigned cockpit in collaboration with 51 Speedshop to optimise rider position.

We should note that we address aero performance of the complete bike (and rider) in the following sections, rather than measure the results of individual design decisions on select segments of the frame, such as the fork or cockpit. However, the effect of integration of individual elements, such as brake calipers, hydraulic reservoir and cables, has been evaluated through **CFD** and should be considered as crucial to the overall aero performance of the bike. Our focus on fit and adjustability was also factored into our tests, as detailed in section 4.3.

2.0 NOTIO AND TRACK TESTING

2.0 NOTIO AND TRACK TESTING

The aerodynamic performance of the **E-119 Tri+ Disc** frame was evaluated using the **NOTIO** device at the Mattamy National Cycling Centre in Milton Ontario, in July, 2020. In the following sections we discuss the basic equations used in the calculation of **CdA** and how this data is captured by the **NOTIO**.

2.1 Power equations

Equation 1 › Aerodynamic power equation

$$\eta . P_{Athlete} = P_{Aero} + P_{RR} + P_{WB} + P_{AG} + P_{KE}$$

Figure 1 › Resistance experienced by a cyclist

Air resistance + *Acceleration resistance* + *Altitude gain resistance* + *Rolling, mechanical and bearing resistance*

2.0 NOTIO AND TRACK TESTING

The aerodynamic performance calculation provided by the **NOTIO** device is based on the cycling power equation in detailed in Reference 1. This equation describes how the power supplied by the rider pedalling is dissipated in different components:

$P_{Athlete}$	is the athlete pedalling power, recorded by the powermeter;
η	is the drivetrain efficiency. A percentage of the athlete power is dissipated by the friction between chain and chainring and sprockets;
$P_{RR} + P_{WB}$	are the powers dissipated in rolling resistance (friction of tires on the road) and wheel bearing resistance;
P_{AG}	is the power required to gain altitude (when climbing) or given to the rider (when descending);
P_{KE}	is the kinetic energy power; it is positive if the rider is accelerating and negative if slowing down;
P_{Aero}	is the power dissipated by air resistance (or aerodynamic drag).

It should be noted that this equation does not account for braking power, so it is only valid if the rider is not braking.

Aerodynamic resistance can be detailed as follows:

Equation 2 › Formula of aerodynamic resistance

$$P_{Aero} = \frac{1}{2} \rho \cdot v^2_{AirFlow} \cdot v_{Rider} \cdot C_dA$$

This is where the well-known **CdA** comes into play. ρ is the air density, v_{Rider} is the rider speed and $v_{AirFlow}$ is the air speed that the rider experiences (equal to rider velocity if there is no wind).

2.0 NOTIO AND TRACK TESTING

2.2 Notio CdA measurement

NOTIO is an on-bike aerometer that determines **CdA** while riding. The apparatus, attached to the front of the bike and linked to a system of sensors, measures various criteria that influence the rider's aerodynamics. This data is transmitted to the **NOTIO** application which analyses the data to provide the rider's **CdA** (see Reference 6).

NOTIO gathers most of the data required to calculate **CdA** from the measures detailed in the power equation. The rider speed, measured by speed sensor, is used within P_{Aero}, P_{RR}, P_{WB} and P_{KE}, $v_{AirFlow}$ is measured with the pitot stick (the visible tube on the front of the **NOTIO**), $P_{Athlete}$ comes directly from the powermeter, and the altitude gain used in P_{AG} is measured primarily with the barometer.

Some more data are required in the equation: the total weight of the rider and bike which come into play in P_{RR}, P_{KE}, P_{AG} and the coefficient of rolling resistance and drivetrain efficiency. These two last parameters are difficult to measure without laboratory equipment, but accurate values can be found in the literature (References 2 and 3).

NOTIO requires calibration of the pitot tube to get accurate data. As explained before, we need to measure $v_{Airflow}$, the real airflow speed, not perturbed by the rider, which is not possible unless we are able to position the **NOTIO** few meters ahead or on the side of the rider (see Figure 2). The strategy is to use a coefficient of calibration which is determined on the road by doing an out and back and assuming that the wind velocity remains the same during both legs of the ride, and on the track, by assuming that the rider velocity is equal to the air velocity.

With this data **NOTIO** is able to calculate **CdA** as soon as the rider begins moving, but due to the variable accuracy of all sensors used, there can be variability in this real-time value. A minimum distance is required to get reliable and relatively precise data: (3km) on the road and 8 laps (2km) on the track.

Figure 2 > Air disruption in front of a moving cyclist

2.3 About CdA

As seen before, **CdA** comes into play in the equation shown in Equation 3. This is the measure of the aerodynamic performance of a body – in our case of a rider on his bike. The lower the **CdA**, the better the aerodynamic performance. If we come back to a simplified version of the equation above (no altitude gain, constant speed, no wind, no drivetrain, bearing or rolling losses):

Equation 3 › **Simplified formula of aerodynamic resistance**

$$P_{Athlete} = \frac{1}{2} \rho \cdot v^3_{Rider} \cdot C_d A$$

In the case of constant rider power, if **CdA** goes down, to keep the equation valid, the rider's speed must have gone up.

	Rider Power	Rider CdA	Environment	Air density	Coefficient of rolling resistance	Drivetrain efficiency	Rider velocity	Time difference with reference over 10km	Comments
	$P_{Athlete}$			ρ	μ	η	v_{Rider}		
	W	m²	-	kg/m³	-	-	km/h	-	
Reference condition	300	0.300	25°C sea level	1.184	0.002	0.96	**41.30**	**0s**	
Rider in drops instead of TT position	300	0.375	25°C sea level	1.184	0.002	0.96	**38.35**	**+67s**	Gain of riding in TT position vs. Road position
Cold weather	300	0.300	5°C sea level	1.269	0.002	0.96	**40.36**	**+20s**	In winter a significant part of velocity is lost because of temperature only
Ride at high altitude	300	0.300	25°C 2000m	0.941	0.002	0.96	**44.59**	**-64s**	Illustrates why hour record riders like doing attemps in altitude
Lower drivetrain efficiency	300	0.300	25°C sea level	1.184	0.002	0.94	**41.00**	**+6s**	
Tires with higher rolling resistance	300	0.300	25°C sea level	1.184	0.004	0.96	**40.40**	**+19s**	
Lower rider power	250	0.300	25°C sea level	1.184	0.002	0.96	**38.71**	**+58s**	

Table 1 › **Example of effects of different parameters on CdA**

The great advantage of talking about **CdA**, rather than drag force or drag power, is that within a certain range of conditions it remains "constant" and only depends on rider position, equipment, and bike shape. It allows a very simple comparison of aerodynamic performance between bikes or rider position.

While we say "constant", it is, to be more exact, the value which changes the least, because it does change with airflow speed and yaw (airflow direction in regard to rider). Rider **CdA** variation is illustrated in figures 3 and 4, below.

2.0 NOTIO AND TRACK TESTING

Figure 3 > illustration of effect of yaw

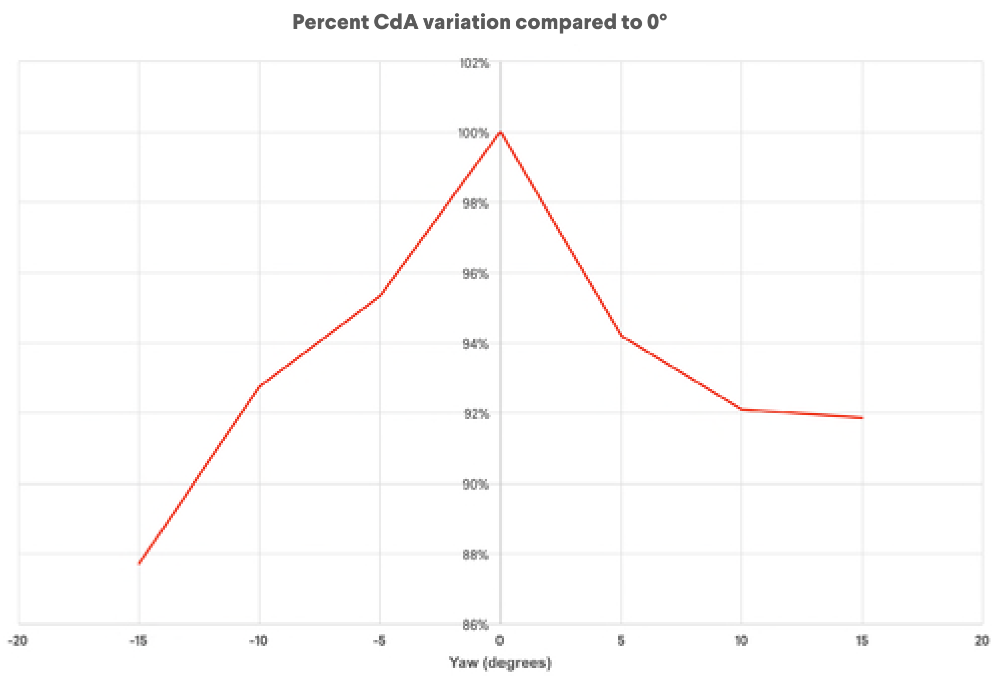
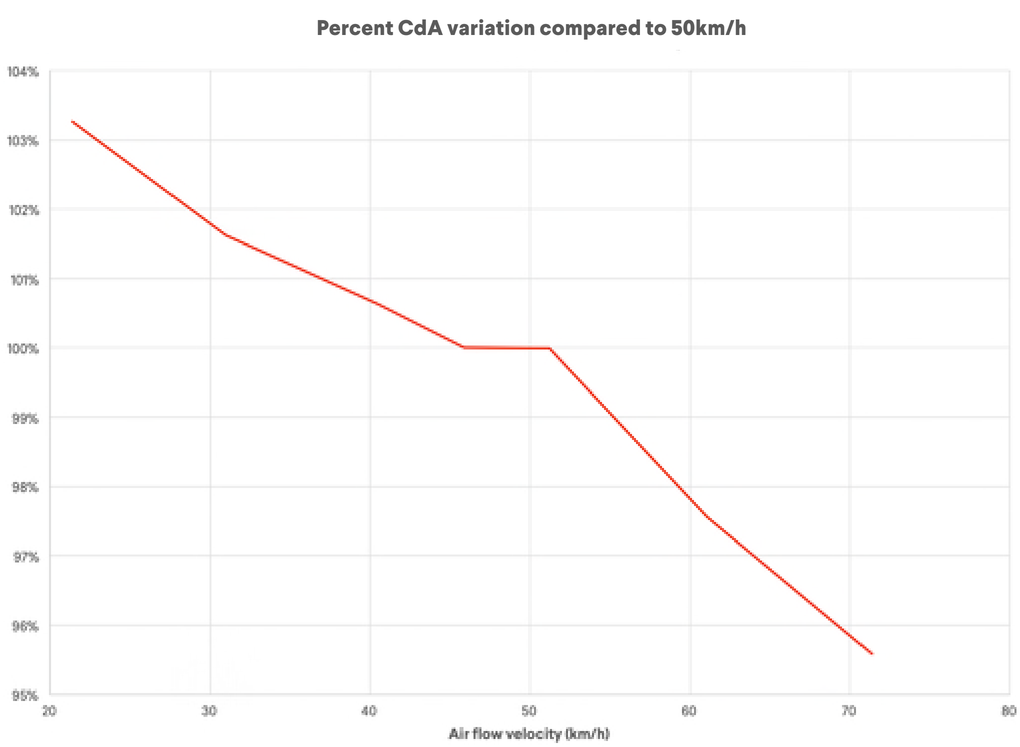


Figure 4 > Effect of air flow velocity



2.4 Different CdA measurement methods

There are different ways to measure or estimate **CdA**.

2.4.1 CFD

CFD stands for computational fluid dynamics. **CFD** uses numerical models which simulate the air flow behavior around the rider and allows for the calculation of several metrics, including **CdA**. It is not a measurement of **CdA**, but a method to predict it. The advantage of **CFD** is that it can be used at an early design stage to evaluate several design solutions without requiring manufacturing and testing of expensive prototypes. The capability to visualize the flow or to separate the drag for certain sections of the bike helps in understanding the aerodynamics around the bike and informs design decisions. However, the models used are a simplification of real air conditions and rider behavior. Even if **CFD** provides a strong indication of what to do at the design stage, it needs to be validated afterwards.

2.4.2 Wind tunnel

In wind tunnel tests, a controlled air flow is applied to the rider and bike and force sensors are used to measure drag. The rider (or mannequin) and bike are often maintained in position on a structure which allows the rider to pedal and which can rotate to allow for the measurement of yaw angles.

The wind tunnel allows us to capture very small differences between setups, up to 0.2% of the rider **CdA**. It also allows measurement of **CdA** with yaw, which other real-world methods cannot do. By using plastic prototypes, it allows for testing of different configurations without the need to manufacture an expensive mold to have a rideable bike. Such prototype tests have been done by **Argon 18** for the **E-119 Tri+ Disc** development, and also for the **Electron Pro TKO**.

However, as accurate as it can be, wind tunnel testing is not representative of real riding conditions. Even if a rider is used in the tunnel, or a mannequin is pedalling, the force on the pedals is not what it would be in reality, so the position for a short test duration may be different than what it would be on the road.

2.4.3 Notio on the road

The limitations of the **NOTIO** device on the road come from the fact that the environment is not controlled: side winds, wind gusts, road cracks, and temperature changes all affect the precision of measurement. Tests performed with the **NOTIO** team show that measurements are within 1.5-2% of the rider's **CdA**. But this method is still the best to represent real riding conditions since... these are real riding conditions. Tests performed showed that, with a good testing protocol, this method is very efficient to measure rider fit differences or equipment differences when the difference is higher than 1% of rider **CdA**.

2.4.4 Notio on the track

Track testing with **NOTIO** stands between wind tunnel testing and using **NOTIO** on the road: the rider is really riding the bike and the environment is controlled, there is no wind, the track has a uniform surface, there is no denivelation. The number of variables that can affect the test result is highly reduced, and a precision of less than 1% of rider **CdA** can be reached with this testing method. The main limitation in our case is that no yaw angles can be introduced (please see section 5.2 for further discussion on yaw).

For the **E-119 Tri+ Disc** we decided to primarily use this testing environment – **NOTIO** on the track - because we wanted to be as close as possible to the real riding conditions. We also know that after years of aero bike development, the differences between our models are very small, so it requires great precision to catch differences between our framesets. As for the limitations coming from yaw measurement, it was decided to rely on additional analysis of wind tunnel and **CFD** results.

3.0 TEST SETUP

3.0 TEST SETUP

To get reliable and accurate results it is necessary to control the test setup and parameters, to avoid any variation in the results which could come from factors that we do not want to evaluate. For example, a variation in tire pressure would have an effect on rolling resistance. Since we work with a fixed rolling resistance value, this variable would therefore have an effect on the calculated **CdA**, which is why we control the tire pressure before each set of tests.

Bike Models Tested: (all size medium)

- Argon 18 E-119 Tri+ Disc
- Argon 18 E-118 Tri+
- Argon 18 E-119 Tri+ (rim)
- Argon 18 E-117 Tri Disc

3.0 TEST SETUP

3.1 Bike setup

The same fit was used for all bikes, and the same tires to avoid any variability which could come from different rolling resistance. A dual side powermeter was used, as required for accurate **CdA** results, and it was the same for all tests. (Single-side powermeters assume that rider power is twice the power measured on one side, which is unprecise, since not all riders exert the same power with both legs.) The same chain and cassette were used for all tests, and lubrication of the chain was checked regularly during all the tests. The thru-axle handles were removed during tests. The same wheelset was used for all disc brake bikes, and for the **E-119 rim brake** model, the wheel had the same rim but a different hub. 140mm diameter rotors were used.

- Tires: Vittoria Corsa G+ 700x25
- Wheels: HED Jet Plus Black 6&9
- Powermeter: 4iiii dual-side precision 170mm Ultegra R8000 (52/36)
- Chain: Shimano HG701-11
- Cassette: Shimano Ultegra R8000 12/25
- Rotors: Shimano RT-800 140mm (FR&RR)

3.2 Rider

The same rider was used for all tests. Joffrey Renaud is Argon 18's Composites Specialist as well as a long-distance triathlete, so he is able to maintain his position on the bike over the duration of the tests. This is essential since **CdA** variation due to changes in rider position may be higher than the difference we want to measure between bikes. The same kit and helmet were used during all tests. Rider fit was checked carefully for all bikes tested before going on the track, so that the rider had precisely the same position on all four bikes.

3.3 Test parameters

Since gearing influences drivetrain efficiency, the same gearing was used for all tests. We chose a riding power that our rider was able to maintain throughout all tests. The same speed and **NOTIO** sensors were used, a careful adjustment of the Notio sensor position and angle was made before each set of tests. A precise measurement of wheel circumference, and bike and rider weight were made prior to tests. The powermeter was calibrated after each installation according to 4iiii procedure.

Each data point is composed of three rides. Each ride was 12 laps, and the first two laps and last two laps were not used in the calculation of **CdA**, because the rider was either accelerating or decelerating, which has an effect on **CdA** calculation.

- Tire pressure: 90psi
- Rider power: target between 260W and 270W (approx. 41km/h speed)
- Rider gearing: front: 52, rear: 17
- Speed sensor: Garmin speed sensor 1
- Wheel circumference: 2105mm
- Computer: Garmin Edge 130

3.4 Hypotheses

To calculate **CdA**, Notio uses drivetrain efficiency and tire rolling resistance. These two parameters cannot be measured easily, so they must be assumed. Drivetrain efficiency is the percentage of rider power that is transmitted from the rider's legs to the rear wheel. A couple of percentage points of this power is lost due to chain friction. Rolling resistance characterizes the amount of power lost in the contact between the tires and road. The exact value of these parameters is not very important for the tests we undertook, as long as the value does not change between tests (because of chain wear or tire pressure variation during the tests, for example), since we want to measure **CdA** variation between tests and not the absolute **CdA** value. In other words, if we use a drivetrain efficiency of 96% and we measure a 2% **CdA** variation between two setups, we will still measure a 2% variation with the hypothesis of 98% drivetrain efficiency. It is the consistency of the drivetrain efficiency figure that is important.

It was also assumed that the velocity of the rider's center of gravity is equal to wheel velocity, but this is not true in this case due to the banking on the track. The rider is leaning and turning, which makes the rider center of gravity slower than the wheels, and this has an effect in the calculations. However, upon deeper analysis of the results we determined that this assumption had very limited effect on the differences in measurement between setups.

The **NOTIO** requires the calibration of the aero sensor. This calibration is performed on the road by doing out-and-backs, and it is used to determine the factor of correction between far field air velocity and air velocity measured by the **NOTIO**. On the track, we use the assumption that the air velocity is equal to the rider velocity measured by the speed sensor, because there is no wind. A factor of calibration is calculated for each setup over the three rides of each test. This assumption is true at the speed we were maintaining (around 40km/h) but at higher speeds (around 60km/h for pursuit riders, for example) it can be noticed that wind is created on the track by the rider, and this has an effect on the results.

- Drivetrain efficiency (from Ref 2): 0.96
- Coefficient of rolling resistance (from Ref 3): 0.002

3.5 Tests performed

Our primary focus for this testing session was comparing our lineup, but we also wanted to use the time we had on the track to document procedures regarding the use of **NOTIO** and what we are able to measure in the track environment.

3.5.1 Spheres

The first test performed is a test we do nearly each time we measure **CdA** variations with the **NOTIO**: we install spheres of different diameters to the front axle of the bike. The spheres have a known **CdA**, therefore if we ride with and without the spheres, and if we can measure the expected **CdA** differences, it means that the test is relevant to measure such differences. The sphere's **CdA** had been determined by manual calculation and checked during wind tunnel test sessions. In this case we tested with two spheres, a 73mm diameter sphere with a 0.004m^2 **CdA** and a 113mm sphere with a 0.007m^2 **CdA**. The spheres were attached with a stick 300mm from the fork. It was determined with **CFD** that at this location the influence of the rider on the airflow is highly reduced.

3.5.2 Frameset comparison

First the three current triathlon framesets, **E-119 Tri+ (rim)**, **E-118 Tri+** and **E-117 Tri Disc**, were tested and compared to the new **E-119 Tri+ Disc**. These tests were performed with the bike "naked": no bottle, no bags, etc. We then performed a comparison of the new **E-119 Tri+ Disc** and the **E-119 Tri+** rim with the full Ironman setup: food, water and toolkit. This aimed at measuring the influence of the integration of the bento box and toolkit within the frame.

3.5.3 Fit modification effect

The **E-119 Tri+ Disc** cockpit, developed with **51 Speedshop**, differs from the **E-119 Tri+ rim** cockpit by its ease of adjustability. A test was performed to see if we could improve rider aero performance with a quick fit modification. Our mechanics and experienced fitter, who accompanied us on the track, did a quick modification of the angle of the extensions (higher angle) and elbow pad position to move the rider's hands higher a modification which took less than five minutes to execute. This is the position where more riders currently tend to be, since it is considered to be more aero.

3.5.4 Equipment comparison

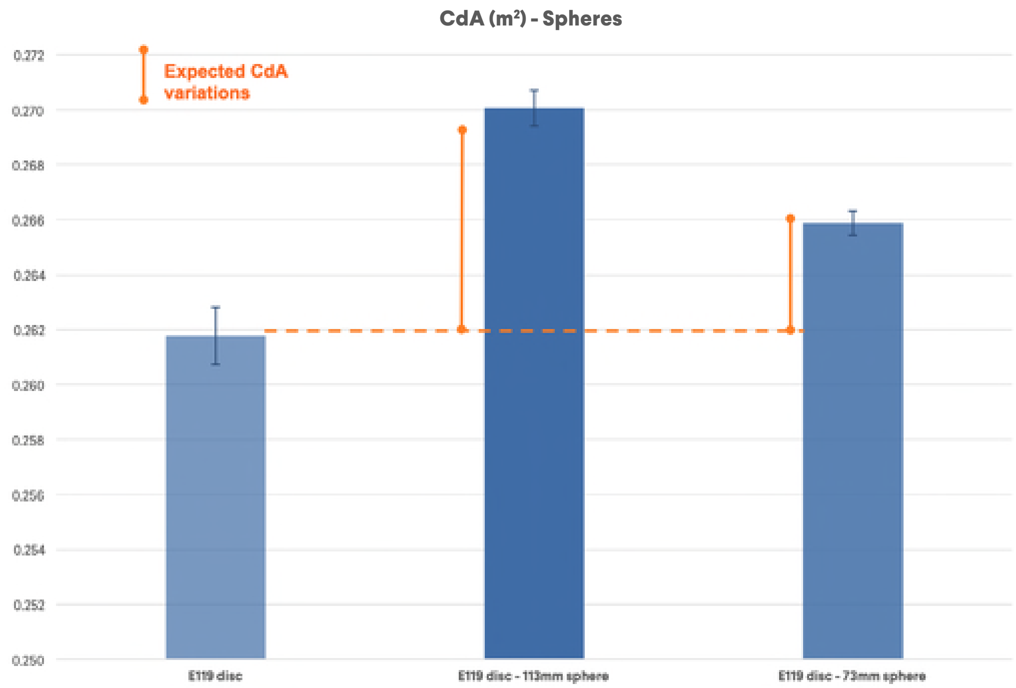
The last tests were performed to evaluate the ability to measure the aero performance of equipment with **NOTIO**. The rider made all the previous tests with an aero helmet (**Smith Podium TT**). A test was then performed with a road helmet (**POC Ventral Air Spin**) to evaluate the effect of changing helmets. The same procedure was performed with two different wheelsets: **HED Jet 6&9** was our reference for all tests. It is a midrange wheelset, with flat surfaces on the rim for rim brakes (even for the disc brake version) and it was compared to another wheelset (which we will call B) which is disc brake only, so has a wider and more profiled rim, which could be expected to be more aero. All of these equipment tests were performed on the same frame, the **E-119 Tri+ Disc**.

4.0 RESULTS

4.0 RESULTS

4.1 Spheres

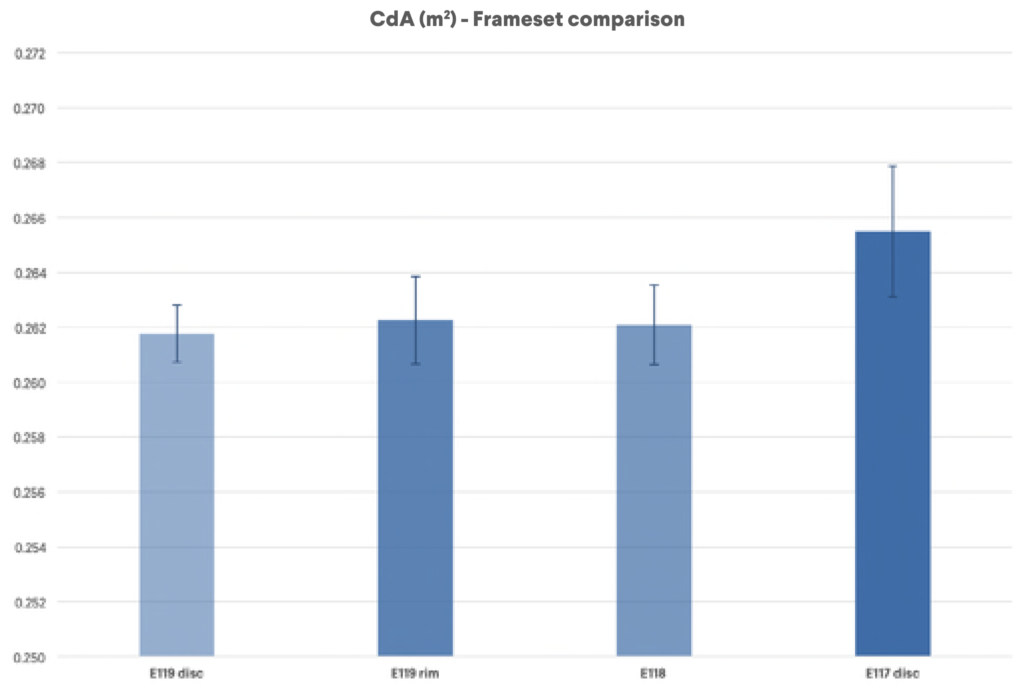
Figure 5 > **Results of tests using spheres**



The tests performed with the two spheres show that with the test protocol we are using, we are able to measure the expected variations within 0.001m^2 of **CdA**. We can note that the amount of variation between each repeat (standard deviation) is also in the order of 0.001m^2.

4.2 Frameseset comparison

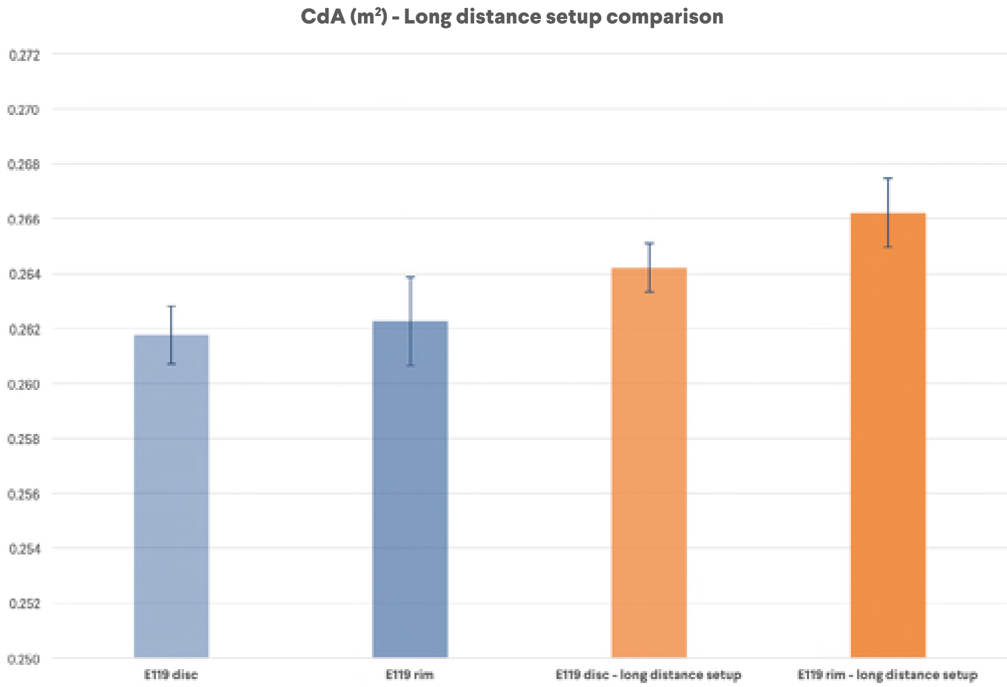
Figure 6 > Results of frameset comparison



The **CdA** results of the rider on the bike for the four different framesets tested show no statistically relevant difference for the three main aero bikes (**E-119 Tri+ Disc**, **E-119 Tri+ rim** and **E-118**). It does not mean that there is no difference whatsoever, but the variability between the runs of each test is higher than the difference between the three framesets (lower than 0.001m^2, about 1W) so the test method used is not able to measure the difference. For the **E-117 Disc**, an entry-level bike with no cockpit integration, a clear difference can be noticed from the three other bikes (between 0.003 and 0.004m^2).

4.0 RESULTS

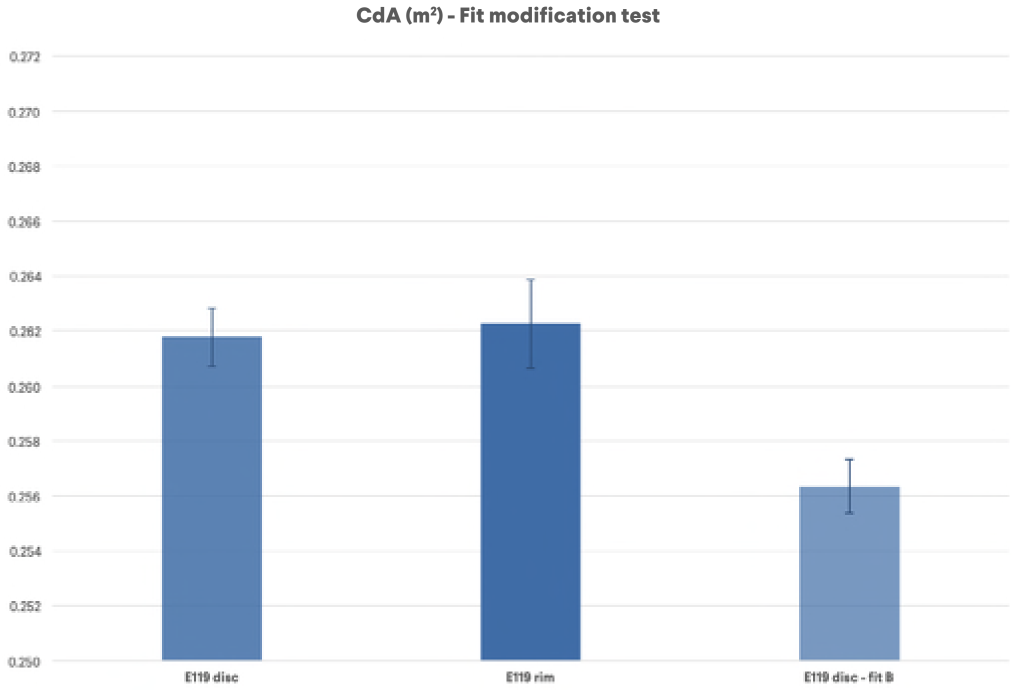
Figure 7 > Results of long-distance setup test



The results of the long-distance setup (tools + food + water) reveal a real advantage for the **E-119 Tri+ Disc** integration, in the order of 0.002m^2. Note that even though no test was performed with the **E-118**, we can reasonably assume that the **E-118** with the long distance setup would perform similarly to the **E-119** rim because the level of integration is similar for the two bikes.

4.3 Fit modification effect

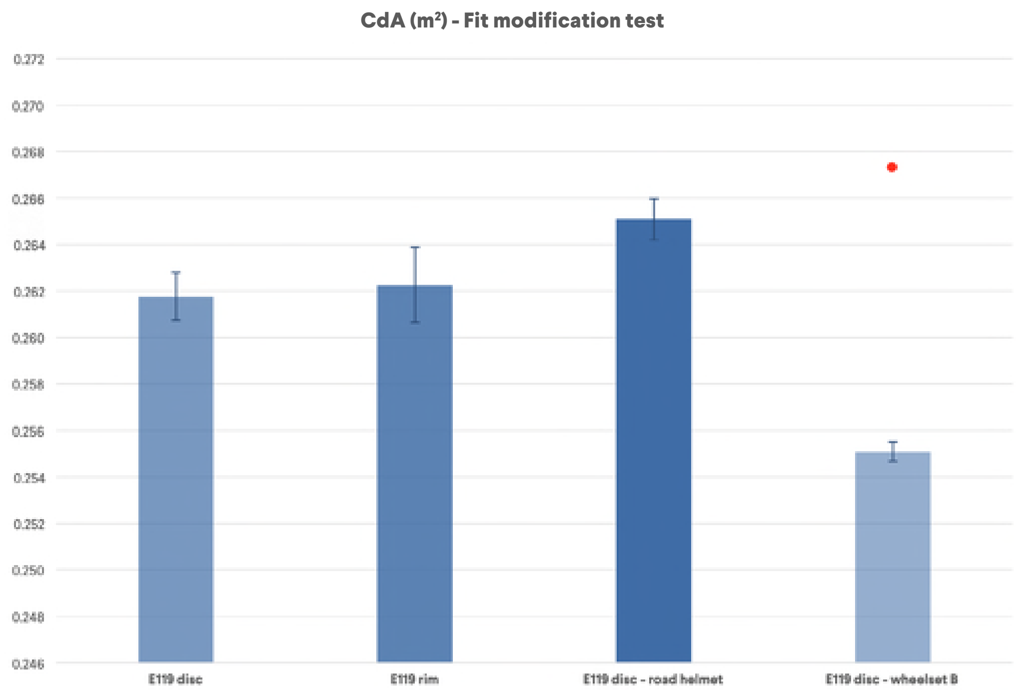
Figure 8 > Results of fit modification test

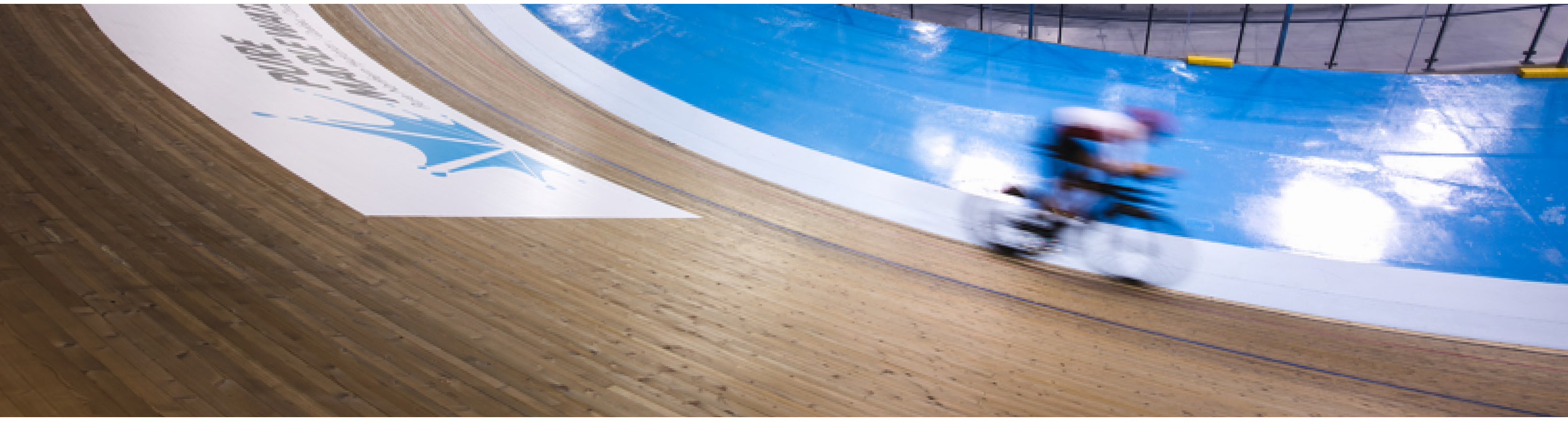


The rider's body has the highest contribution to aerodynamic drag force, that is why it is necessary to work on rider position to improve performance. For this test, our mechanics and fitter chose to change to a more aero rider position. The result is interesting since, by using the new cockpit design, a quick modification helped our rider improve **CdA** by more than 2%. This example shows how the combination of **NOTIO** sensor and an easy-to-use cockpit helps improve the rider's performance in a very short time.

4.4 Equipment comparison

Figure 9 > Results of equipment comparison test

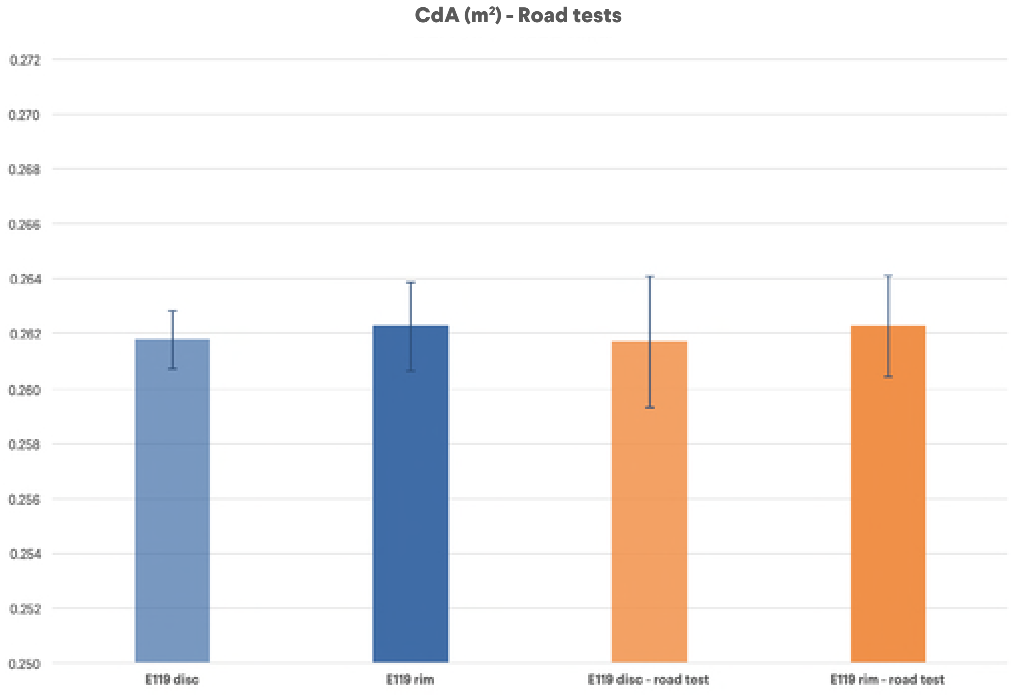




The results of the wheelset and helmet testing are as expected: a road helmet is slower, and the newer-generation, higher-end wheelset is faster. The difference found in the wheelset B test is particularly striking since the rider and bike **CdA** is reduced by more than 2%. With bike **CdA** at around 20% of total **CdA**, this means that wheelset B improves the aero performance of the bike by more than 10%. This illustrates the gains that can be obtained with a new-generation rim designed to improve the airflow around rim and tire. For this last test, a data point was removed because the value obtained was very far from the others (red point on the graph). We cannot be absolutely sure of the reason why this data point is so far from the others; it may have been caused by the rider moving from his reference position for this test.

4.5 Comparison to road test

Figure 10 > Results of comparison with road tests



Our track tests were compared with road tests which had been performed a few days before going to the track. The tests on the road were a little bit different: different tires and powermeter were used than the ones we had on the track. On the road, three out-and-back runs were performed for each configuration on a 3km segment. Interestingly, the results obtained on the road are very close to the results we had on the track, with a slightly higher standard deviation. These results show how efficient Notio can be even in a less-controlled environment.

4.6 Summary of Aero Improvements

Each of the tests detailed in this section corelate with one of the areas of focus for the new **E-119 Tri+ Disc**: the overall frame improvements, system integration, and compatibility with advanced aero components. This includes our test with disc-compatible aero wheelsets, as thanks to the wider tire/rim clearance available on the new **E-119 Tri+ Disc**, more aero wheelsets can be used. When we combine these advances, we see a **10W** advantage over the previous-generation **E-119**.

If our test results on optimal rider position are also factored in, based on the new fit range offered by the **E-119 Tri+ Disc** cockpit, we see this advantage increase again. Taken together, the new **E-119 Tri+ Disc** can offer a total of up to **17W** aero advantage when considering the full bike and rider system. These gains can also be expressed as time or distance advantage, as shown in Table 2.

Table 2 > Summary of Aero Improvements

		CdA Bike + rider IM configuration	Power required to keep equivalent velocity	Velocity @300W flat	Time over 90 km
		m²	w	km/h	-
Reference bike	E119 (rim) et E118	0.266	300	44.12	2h2min22s
New generation gains E119 Tri+ Disc	E119 Tri+ Disc	-0.002	-2	+0.11	-18s
	New generation disc brake wheels	-0.007	-8	+0.39	-64s
	Improved rider position	-0.006	-7	+0.34	-56s
	Potential total gain	-0.015	-17	+0.86	-2min20s

Rider power = 300w **Distance** = 90km

5.0 DISCUSSION

5.0 DISCUSSION

5.1 E119 Tri+ Disc project achievements

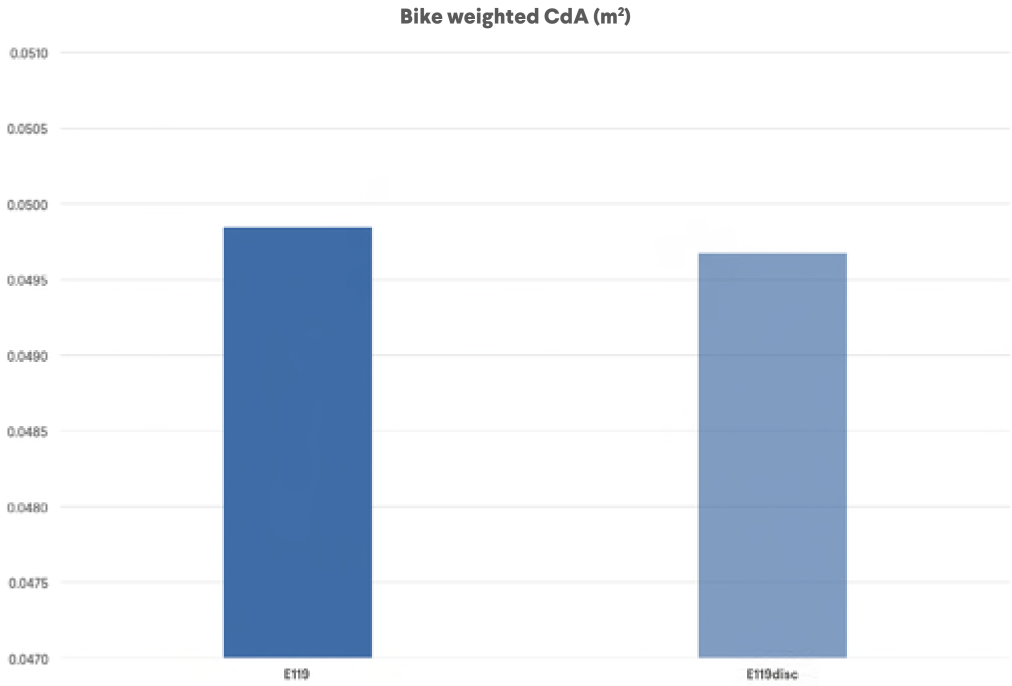
The results of this test session on the track show that the main goals of the new **E119 Tri+ Disc** have been achieved: a bike designed to perform in real IM riding conditions, focused on rider ease of use and fit adjustability, the full integration of disc brakes and storage elements, and the enhanced compatibility for newer, aero-optimised components, such as wheelsets.
The **10W** aero advantage of the new bike shows that our approach to optimizing for these real-world conditions, and delivering rider-focused additions such as the integrated bento box and toolkit, updated cockpit, and enhanced stopping power of discs, resulted in a clear advancement over the previous-generation **E-119**.

While we see the increasing uptake in disc-equipped triathlon bikes on the market, we are also aware that many athletes remain concerned about the aero penalty of these brakes. We are pleased to be able to offer the first integrated disc brakes on the market, eliminating this penalty while providing our athletes with the increased confidence and braking power of discs. It was our goal to be able to offer a bike that achieves this level of aero integration and, at the same time, prioritises the practical race-day needs of triathletes.

5.2 Effects of yaw

One point which is not addressed within this paper is the effect of yaw. We can rely on **CFD** data to give an answer to this question. During bike development we performed extensive **CFD** analysis on different regions of the bike: fork, disc brakes, cockpit, frame, etc. All the analyses were performed with different yaw orientations between 15° and -15° resulting in **CdA** for each yaw angle. To obtain one figure to compare the different designs together, the data at each yaw angle is weighted and the result is summed. This gives an average bike **CdA**, in that the bike will have this **CdA** during an "average" ride. The weighting is performed with SwissSide data (Ref 4 and 5) which was selected by the team at **Argon 18** for the integrity and quality of the methodology. Results of bike **CdA** only are shown on following graph. The analyses were performed with the rider (not pedalling). We can see that taking into account the yaw angles shows no difference between the **E-119 Tri+** and **E-119 Tri+ Disc**, despite use of disc brakes and the new capabilities of the disc bike (less 0.1% difference over bike + rider **CdA**).

Figure 11 > **Weighted CdA results from CFD**



5.3 Monitoring rider position

One point raised by the tests performed is the need to better monitor rider position during tests, to avoid discrepancies between results. The outlier data point of wheelset B is a good example. We suspect a change of rider position for this test, but have no absolute proof of it. Having a method of taking pictures of the rider at each lap, for example, would provide better accuracy for future tests undertaken at the track, especially when we want to measure such small differences.

5.0 DISCUSSION

5.4 Speed sensor

The analysis of speed raw data showed some unphysical data drops coming from the speed sensor, so speed data required slight corrections. This was not noticed previously on the road, and is probably caused by the fact that the sensor uses a magnetometer, which is disturbed by the high angle of the rider turns on the banked track.

5.5 E-118 Tri+ vs. E-119 Tri+ Disc

Why should you ride a **E-119 Tri+ Disc** instead of the **E-118 Tri+**? Tests results show that for the "naked bike" configuration, the **E-118** disc and **E-119** disc perform the same. But when you put the two bikes in the full IM context, the gap widens, and not just in terms of aero advantage. The design intention of the **E-118** was focused more on short course triathlon or time trial (it is UCI legal), or for riders who are looking for a very aggressive fit. It features a low, long, narrow basebar, no integrated nutrition or storage, and no front hydration mount. The **E-119 Tri+ Disc** has a more adjustable cockpit, wider basebar, nutrition capacity, hydration mounts, and our new extension bars, all without an aero penalty. Estimations based on our track test data show a **2W** advantage for the **E-119 Tri+ Disc** (for a rider with 0.266m^2 CdA and 300W power), with a full IM setup.

References

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Ref 2: Drivetrain efficiency data, https://www.cyclingabout.com/drivetrain-efficiency-difference-speed-between-1x-2x/

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Ref 4: Yaw average data method comparison, https://www.slowtwitch.com/Tech/Real_World_Yaw_Angles_5844.html

Ref 5: Yaw average data from SwissSide, https://www.swissside.com/blogs/news/the-swiss-side-instrumented-bike

Ref 6: Notio, https://notio.ai

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E-119 TRI+ DISC