

**Using AeroPod™ for CdA measurement**  
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## Introduction

Aerodynamics is important in cycling. Very simply put, for the same amount of power, the more “aero” you are, the faster you will go. So, improving the aerodynamics of your ride position and equipment is like adding more power and speed to your ride, without pedaling any harder!

A measurement called CdA quantifies how “aero” you are. The better you understand what CdA is, how to measure it, and how to improve it, the better you will be able to get the most out of your bike, your equipment, and your riding.

This document will guide you through the basics of AeroPod CdA measurement and analysis. We encourage you to take a few minutes to understand more about what CdA is, how AeroPod measures CdA, how to use CdA while on the road, how to use Isaac software to analyze CdA, and most importantly, how to use CdA to help you improve your cycling.

For information regarding attaching AeroPod to your bike, and pairing AeroPod to your ANT+ sensors, please consult the **AeroPod Installation Instructions**, included with your AeroPod.

## The Basics of Aerodynamics and CdA

Every cyclist knows that one way to climb hills faster is to reduce the total weight of bike and rider.

When riding on the flats, wind and aerodynamics are critical.

A quantitative measure of aerodynamics is a single number called “CdA” (see Appendix for a more detailed discussion of CdA). The lower your CdA number is, the more aero you are. The more “aero” you are, the less influence wind will have in opposing your forward motion and, watt-for-watt, the faster you will go.

*So, just as lower weight is important for faster hill climbing, lower CdA is important for faster riding on the flats.*

Weight is measured easily with a scale, but aerodynamic CdA measurements are not so easy. Traditionally, CdA has been measured in wind tunnels or velodromes, where the cyclist tries different ride positions, different bike setups, different wheels or helmets. The objective is to make changes that reduce CdA.

**AeroPod makes it possible to measure CdA on your day-to-day bike routes, in real time, while you are riding.**

### *CdA and cycling*

Reducing your CdA number is an important objective for improved cycling performance, particularly on the flats. When you see wheel sets with deep-dish rims, aero helmets with pointy shapes, or cyclists riding in a time trial position, you know that low CdA is the objective.

Here are just a couple of examples of how you can lower your aerodynamic CdA (see the Appendix for a more detailed discussion of CdA):

- 1) Reduce the frontal area exposed to the wind (make “A” smaller). For example, you can make your frontal surface area smaller by riding in a tuck:
  - Hoods (riding more upright → more exposed area): typical CdA is 0.36 to 0.40
  - TT (riding more aero → less exposed area): typical CdA is .21 to 0.26
- 2) Make your bike equipment more “aero” (make “Cd” smaller). For example, wearing a tighter-fitting cycling bib/jersey reduces CdA substantially:
  - Hoods, t-shirt and casual shorts: typical CdA is 0.50 to 0.70
  - Hoods, cycling bib and jersey: typical CdA is 0.36 to 0.40

In real life, competitive cyclists work to reduce frontal surface area *and* reduce drag. CdA is a single number that encompasses the net effect of these changes. In fact, a major purpose of

CdA testing is to find the optimum *combination* of ride position and equipment that reduces your CdA, without sacrificing your power output.

As you adjust your ride position and equipment, AeroPod will quantify the aerodynamic differences—on the road, without going to a wind tunnel.

## **AeroPod CdA Technology**

Understanding how AeroPod measures CdA will help you obtain more consistent, accurate results for your CdA testing, and how to make best use of AeroPod’s “live” CdA measurements.

### *1. AeroPod uses both applied and opposing force measurements*

- Applied forces are measured by the direct force power meter (DFPM) on your bike. DFPM *applied force* measurements are transmitted wirelessly to AeroPod
- The cyclist’s applied power overcomes the opposing forces caused by wind, hills, acceleration and friction.
- The *opposing forces* of wind, hills, acceleration, and friction are measured by AeroPod’s sensors:
  - The opposing force due to hills and bike acceleration are based on real-time measurements from AeroPod’s accelerometer
  - Wind speed is measured in real time by AeroPod’s pitot tube and wind sensor.
  - The opposing force of friction is determined from the Coefficient of Rolling Resistance ( $C_{rr}$ ).  $C_{rr}$  is determined from tire type, tire inflation, and road type, which are user inputted during first setup of AeroPod. AeroPod assumes  $C_{rr}$  is a constant value that does not change during the bike ride.
- When the correct value of CdA is known, the opposing forces measured by AeroPod will equal to the applied forces measured by the DFPM (Newton’s 3<sup>rd</sup> Law)

### *2. How AeroPod measures CdA*

AeroPod measures and “knows” all of the factors needed to make opposing forces equal applied forces, EXCEPT CdA:

- To convert AeroPod’s wind *speed* measurements into wind *force* measurements, a CdA value must be used in the conversion equation
- *When the correct value of CdA is used for wind force calculation, the total opposing forces measured by AeroPod equals the applied force of the DFPM*

AeroPod compares real-time DFPM applied force readings to real-time opposing force sensor readings and calculates, the correct, real-time value of CdA that causes total opposing forces to equal applied forces.

AeroPod measures CdA every second. So, whenever the rider does something that causes the current, actual CdA to change (for example, by altering ride position), AeroPod updates its calculations and reports the CdA value that keeps opposing forces equal to applied forces.

### 3. *How AeroPod smooths (filters) CdA measurements*

Applied force measurements from the DFPM, and opposing force measurements from AeroPod, vary significantly from second to second—due to the way cyclist power is applied to the bike, and also due to variations in wind speed, bike speed, and slope. This natural variation of power measurement can cause CdA numbers to be “jumpy”.

To smooth out the natural jumpiness of the CdA measurement, AeroPod uses a 60 second filter. If the cyclist does something to cause aerodynamics to change (for example, lowering CdA by moving from the hoods to a time trial position), AeroPod CdA measurement will start to drop quickly, but the full extent of the CdA change will take about 1 minute to be shown.

## AeroPod Initial Setup

See the “**AeroPod Installation Instructions**” to learn how to attach AeroPod to your bike, and pair AeroPod to your ANT+ sensors.

Before starting CdA measurements with AeroPod you’ll need to do these five things:

- 1) Use Isaac software to enter “profile 4” parameters for you and your bike
- 2) Make sure your speed and DFPM sensors are in good condition (good battery, good calibration)
- 3) Pair AeroPod to your speed, cadence, and DFPM  
→NOTE: If you want to record CdA data in AeroPod ride file, do NOT pair your HR strap to AeroPod
- 4) Pair AeroPod to your bike computer display device
- 5) Perform AeroPod calibration ride

### 1. Enter “Profile 4” parameters

Your AeroPod ships from the factory, pre-set to profile 4. **CdA measurement is done ONLY in profile 4.** Profiles 1, 2 and 3 can be used for your other bikes, using AeroPod for power meter measurements.

To enter your parameters, connect AeroPod to Isaac software, then use the command “Device/Setup Device...” to launch the setup wizard. These are the parameters that will be stored into profile 4:

Body weight  
Bike and gear weight  
Normal ride position  
Tire type and road surface

**TIP: We strongly recommend you measure your body weight and the weight of your bike and gear. This will improve the accuracy of AeroPod CdA calculations.**

TIP: Velocomp’s “PowerHouse Bike” app for iOS/Android allows you to set profile 4 parameters from your smartphone, without using Isaac software

### 2. Check your Speed and DFPM sensors

CdA measurements require correct operation of your speed sensor and DFPM power sensor.

**TIP: Before starting CdA tests, we recommend you replace the batteries in your speed sensor and, as appropriate, in your DFPM power sensor.**

Additionally, consult the instructions of your DFPM to make sure it is correctly calibrated. If your DFPM calibration is incorrect then you won't be able to achieve accurate or consistent CdA measurements!

### **SPECIAL NOTE: Calibrating an SRM with AeroPod**

SRMs are calibrated very differently from other direct force power meters. When AeroPod is paired to an SRM direct force power meter or other "crank-torque-frequency" power meter, the SRM is automatically calibrated ("PCAL") by AeroPod, each time the SRM is "found" by AeroPod. **MAKE SURE TO FOLLOW THIS "WAKE UP" PROCESS EVERY TIME YOU RIDE WITH AN SRM:**

- A. Spin the crank to awaken the SRM
- B. Spin the wheel to awaken the speed sensor
- C. *Let the bike crank sit motionless for 5 seconds*
- D. Awaken AeroPod from sleep
- E. When AeroPod detects that it is paired to a "crank-torque-frequency" power meter (i.e. SRM), AeroPod automatically starts the PCAL process
- F. During the PCAL process, AeroPod light flashes green
- G. If the AeroPod one-time calibration ride has not been completed (Step 5), when PCAL is successfully completed, AeroPod light turns solid YELLOW
- H. If the AeroPod calibration ride HAS been completed, when PCAL is successfully completed, AeroPod light turns solid green (assuming speed sensor is found), then turns off.
- I. If PCAL is unsuccessful, light turns solid RED, then unit turns off (to rearm PP/AP for auto PCAL)

### 3. Pair AeroPod to your ANT+ sensors

Awaken your speed, DFPM, and (optional) cadence sensors. (You can also pair a HR strap to AeroPod, but if you do, AeroPod ride file will not include CdA data).

**NOTE: When a heart rate (HR) strap is NOT paired to AeroPod, CdA-related data is recorded in the heart rate channel. When a HR strap IS paired to AeroPod, AeroPod will record your HR data, but you will NOT see the CdA-related data.**

To start AeroPod sensor pairing, *press-hold the AeroPod button for 4 seconds until the light flashes green. Release the button when the light flashes green.*

- During pairing, when AeroPod “finds” your DFPM the status light will flash yellow three times.
- If AeroPod finds a (optional) cadence sensor the light will flash red three times
- If your DFPM also measures *cadence*, AeroPod “reads” the cadence signal from your DFPM, and the AeroPod light won’t flash red
- If your DFPM also measures *bike speed*, AeroPod “reads” the speed signal from your DFPM

The pairing process, which can last up to 60 seconds, ends when the light turns solid green, then goes out.

#### 4. Pair AeroPod to your bike computer

At the time of this writing, AeroPod is compatible with these bike computers:

- Garmin bike computers with Connect IQ compatibility: <https://bit.ly/2eh9WFC>
- EverySight Raptor AR glasses [www.eversight.com](http://www.eversight.com)

#### **Garmin**

1. Install the AeroPod CdA Connect IQ app, available here: <https://bit.ly/2C7BLfD>
2. Follow the app installation instructions provided with the link
3. AFTER installing the app on your Garmin, wake up your speed sensor and then wake up AeroPod. AeroPod will be transmitting data after you see its solid green light.
4. Pair AeroPod to your Garmin
5. When your Garmin is receiving AeroPod data, the “wind speed”, “CdA”, “slope”, and “Time Advantage” fields will show as numbers.

#### **Raptor**

1. Wake up your speed sensor and then wake up AeroPod. AeroPod will be transmitting data after you see its solid green light.
2. Follow the instructions provided by the manufacturer to pair Raptor to AeroPod, and to set Raptor display to show CdA measurements

## 5. AeroPod calibration ride

After pairing AeroPod to your sensors, AeroPod is ready for a calibration ride.

**IMPORTANT: Every time you perform a sensor pairing, even when you re-pair AeroPod to the same sensors, AeroPod is “forced” into calibration ride mode.**

**TIP: When you’re “in the field”, doing CdA testing, we suggest you recalibrate AeroPod prior to beginning your measurements, even if you have previously done a calibration ride**

We recommend calibrating AeroPod on a fairly flat road where there is little traffic and the wind is fairly calm.

The AeroPod calibration ride is similar, *but not identical to*, the calibration ride for other Velocomp products:

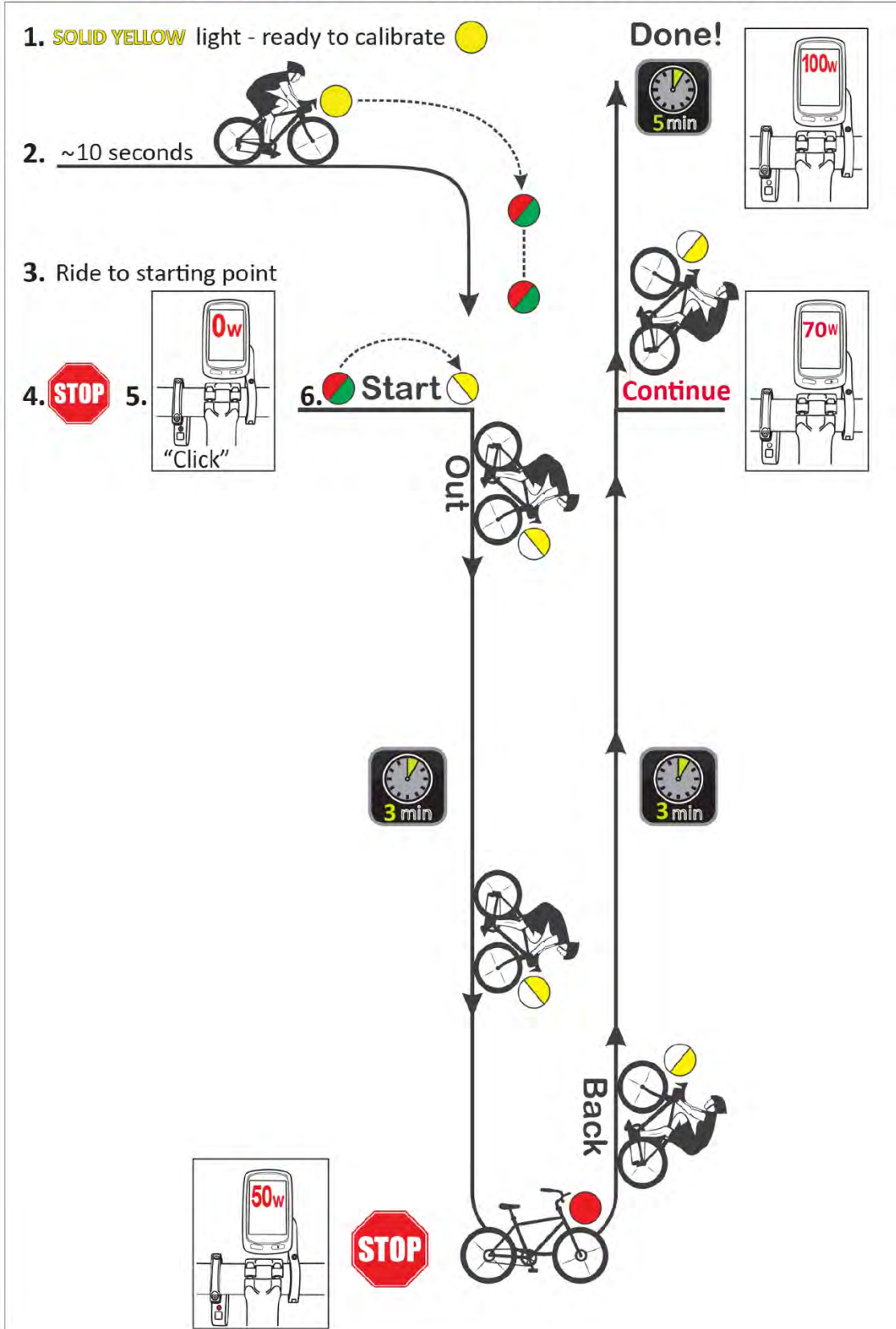
- 1) You will ride “out” for about 3 minutes. Watts rise to 50W
- 2) You will STOP, turn around, and ride back to the starting point. Watts rise to 70W when you reach the starting point.
- 3) **NEW TO AEROPOD:** After you ride back to the starting point, CONTINUE RIDING SOLO FOR ANOTHER 5 MINUTES, IN YOUR NORMAL RIDE POSITION. Watts rise to 100W, then revert to normal.

The next page shows the AeroPod calibration ride pictorially.

**The final 6 minutes of your calibration ride measures and stores your “default” value of CdA; that is, your CdA for your normal ride position.** When you download your ride files into Isaac, this measured value of CdA will be used in your profile.

When the calibration is complete you are ready to start using AeroPod for CdA measurement.

# AeroPod Out and Back Calibration Ride



## Riding with AeroPod

After you've completed your calibration ride, we suggest you continue with a *solo* ride for a few miles, to help you become acquainted with AeroPod measurements and behavior.

- If you're riding with a Garmin with the AeroPod Connect IQ app installed, make sure you show the AeroPod screen. On the AeroPod screen you'll see CdA, ground wind speed, hill slope, Time Advantage, and (we suggest) power.
- If you're riding with Raptor, swipe the temple to show the CdA screen. You'll see, projected on to your field of view, CdA, ground wind speed, hill slope, Time Advantage, and power.

**At the start of any new ride it takes about 90 seconds for the CdA value to "go live".** After the first 90 seconds you will see your live, measured CdA value. If you ride in the position you used during your calibration, the live CdA number you see will be close to the number measured during your calibration ride.

NOTE: If your ride includes lots of turns, speed changes, and stopping, it will take a bit longer for the CdA number to stabilize.

### ***Variation of CdA numbers is normal***

NOTE: Even when you stay in the same ride position for an extended period of time, your "live CdA" will drift somewhat below and above the "normal" value measured during your calibration ride. *This drift is normal*; see pages 20 to 24 for a practical example.

What can cause CdA value to drift, even when you don't change anything about your ride position or equipment?

- Small, natural variations in power measurements, both from your DFPM and from AeroPod
- Surging/coasting. When focusing on CdA, try to pedal at an even level of power, and minimize coasting
- Changes in hill slope, for example from rolling hills
- Drafting/group riding
- Braking
- Sharp turns
- Significant changes in road roughness

After riding some with AeroPod you will get a very good idea of your CdA, and its natural variation as you ride.

## Time Advantage

Time Advantage™ is an exclusive measurement related to CdA.

*What is Time Advantage?*

When you ride a bike, most of the time you're riding in your "normal" riding position.

**DEFINITION:** YOUR "NORMAL RIDING POSITION" IS THE POSITION YOU USED DURING THE AEROPOD CALIBRATION RIDE

As long as you stay in your normal riding position, the total amount of time it takes to complete your ride is unaffected by your riding position; that is, a "normal" riding position results in a "normal" ride time.

Now, suppose you're on a ride and you deviate from your normal riding position; for example, you go into a tuck. If you ride in a tuck with the same level of power, you will go faster because of your more aero ride position. And faster speed means it takes you less time to get to your current position, compared to riding at the same power to the same place, in your normal ride position. *But how much less time?*

Here's another situation: you attack on a hill and stand up to get more power. You know that "standing up" is less aerodynamically efficient and costs you some time to get to the top of the hill. *How much extra time did it take to climb the hill due to aerodynamic inefficiencies?*

A final situation: you've perfected your "normal" ride position using AeroPod. During a long ride, however, you get tired and your ride position becomes a bit sloppy. *How much longer did it take you to complete your ride because your ride position became worse?*

Time Advantage answers all these questions, and more.

**DEFINITION:** AT ANY POINT OF YOUR RIDE, "TIME ADVANTAGE" IS THE CUMULATIVE AMOUNT OF TIME YOU HAVE GAINED (OR LOST), DUE ONLY TO DEVIATIONS FROM YOUR NORMAL RIDE POSITION.

Time advantage is measured in seconds. Suppose you look at your Garmin or Raptor CdA screen at mile 6.2 of your ride and Time Advantage reads + 30 seconds. This means that, at mile 6.2 of your ride, you have been more aero than normal, and you have *gained* 30 seconds of time, *relative to your "normal" riding time for the same power and distance*. If, Alternatively, your Time Advantage reads -15 seconds, you have changed ride positions in a way that has caused you to be *less aero* than normal, and you've *lost* fifteen seconds compared to staying in

your normal riding position.

#### *How are CdA and Time Advantage related?*

If your real-time value of CdA is higher than your normal CdA, you are less aerodynamic compared to your normal riding position. Therefore, for the same amount of applied power, you're less aerodynamic and it takes more time to cover the same distance. Conversely, when your real-time CdA is lower than your normal value you are MORE aerodynamic, and watt-for-watt you'll cover distances in less time.

Time Advantage compares your real-time value of CdA to your baseline, "normal" CdA, moment-by-moment. Using the comparative CdA values between your baseline CdA and your current CdA, AeroPod computes the cumulative amount of time you gain or lose, moment-by-moment, due to deviations from your baseline CdA.

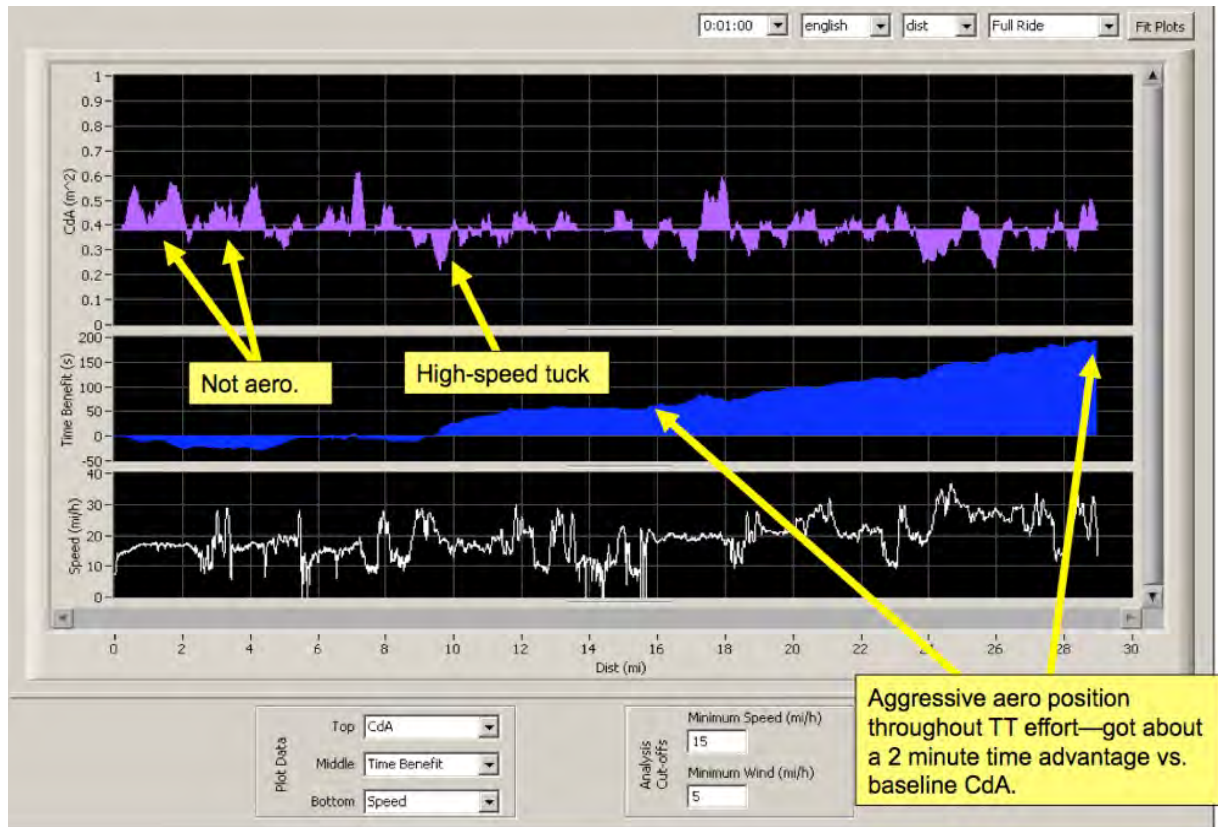
- If you spend most of your time in your "normal" ride position, Time Advantage will be approximately zero
- A positive Time Advantage means you've picked up time due to improved aerodynamics
- A negative Time Advantage means you've lost time due to worse aerodynamics

AeroPod reports the cumulative, net Time Advantage effect of better-and-worse ride positions. Time Advantage is displayed on your Garmin or Raptor screen.

You can view CdA and Time Advantage data, after the ride, when you download your ride to Isaac.

## Time Advantage Graphical Example

Here is a graphical depiction of an actual AeroPod ride with a DFPM, using the “Tools/CdA Analysis...” feature of Isaac (discussed below).



*The top graph shows CdA versus distance. The middle graph shows Time Advantage vs. distance, and the bottom graph shows speed vs. distance*

This ride was about 29 miles long. In the top window, you see in purple the rider’s CdA vs distance. Note that an imaginary horizontal line can be drawn through the purple graph at about CdA = 0.39. The value CdA = 0.39 is this rider’s “normal” CdA value as measured by the AeroPod O&B calibration ride.

For the first 4.4 miles of this ride the rider had CdA measurements that, most often, were above the normal value of 0.39. *A higher-than-normal CdA means the rider was relatively less aerodynamic, and that time was lost due to the relatively poor riding position.* How much time did the high CdA cost? According to the graph, the time lost peaked at -42 seconds at mile 4.4. What does negative 42 seconds mean? It means that if the rider had pedaled equally hard, *but had always stayed in the normal ride position*, then the rider would have arrived at mile 4.4 about 42 seconds sooner. Said differently: at mile 4.4, aerodynamic riding inefficiencies have cost this rider about 42 seconds, as compared to biking in a normal riding position.

At mile 4.4 the rider improves riding position (becoming more “aero”) and CdA drops below his baseline value. *Riding in a more aero position improves the Time Advantage trend; Time Advantage becomes less negative.* In fact, by mile 5.2 the rider is nearly back to zero Time Advantage—meaning the rider at mile 5.2 has neither gained nor lost time due compared to riding the same distance in a normal ride position.

Between miles 6 and 8 there are some high CdA spikes. A high CdA should cause Time Advantage to go more negative, *but Time Advantage curve does not change.* Why? *Time Advantage measurements become less accurate as bike speed and wind speed drop.* Accordingly, AeroPod does not record changes in Time Advantage when bike speed is below 15 mph or when net opposing wind speed is below 5 mph (caused typically by tailwinds). In this example, the rider is just below the 15 mph threshold between miles 6 and 8, so Time Advantage does NOT change.

Just after mile 8 the rider goes into a tuck and his bike speed increases to nearly 30 mph. The rider gains a tremendous amount of Time Advantage: between mile 9.5 and 10 the gain is about 35 seconds! *The faster you’re riding, the more Time Advantage you get from a more “aero” riding position.*

The rider continues the tuck until about mile 11.5. At this point Time Advantage is 50 seconds overall since the beginning of the ride.

Between mile 11.5 and 16 Time Advantage remains flat at about 50 seconds. This is due to low bike speeds of around 10 mph, a result of hill climbs. *At low bike speeds aerodynamic forces don’t affect Time Advantage significantly.*

At mile 16 the rider goes into an aggressive tuck and really picks up the pace, too. Between mile 16 and 29 Time Advantage increases by an ADDITIONAL 150 seconds, so that, by the end of the ride, total Time Advantage is about 200 seconds.

What does 200 seconds of Time Advantage mean? **It means that, by becoming more aero, the rider finished 200 seconds (3 minutes, 20 seconds) faster than riding in the “normal” riding position for the entire ride!**

AeroPod gave this rider feedback about the quality of riding position, AND quantified the Time Advantage of aerodynamic improvements.

## Using AeroPod CdA on your day-to-day rides

On your everyday rides, AeroPod helps you understand your aerodynamics, and quantifies the time advantage implications of your CdA.

1. Try to find a ride position that allows you to keep high power output but reduces CdA. Watch both your power output and your CdA.
2. On longer rides, watch the trend of your CdA, to see if it becomes higher as you become more fatigued
3. If you're doing a Time Trial, make Time Advantage work for you. The more positive the Time Advantage number is, the more aero you are!
4. On hills your CdA doesn't matter as much. Pay more attention to CdA when you're riding on the flats

It's important to remember that CdA and Time Advantage measurements are meaningful ONLY when you are riding solo, and you are riding on road surfaces whose roughness is not changing.

After completing your ride, you can download your AeroPod ride file into Isaac software for more detailed analysis.

## Using AeroPod for CdA Testing

One of the very special things you can do with AeroPod is measure, improve, and optimize your ride position and equipment aerodynamics.

The idea in CdA testing is to perform a controlled set of tests, on a specially-chosen ride route, where you measure the CdA of your equipment and ride positions, then quantify and compare CdA data from each of your tests. Your tests will help you figure out the best combination of equipment and ride positions for your style of riding and your cycling objectives.

When doing CdA testing you will be comparing *multiple* measurements from *multiple* tests. **Because you're doing comparisons, and because CdA is sensitive measurement, you need to set up and perform the tests in a careful manner:**

1. Test route. Ride the SAME route for each test. A one mile loop without abrupt turns, or an out-and-back route at least one mile long in each direction, works well.
2. Solo ride. CdA testing does not work when riding in a group.
3. Tire pressure. Make sure your tires are fully inflated. Different tire pressures on different days will cause CdA test measurements to vary
4. Warm up. Ride for 5-10 minutes before starting your tests. This will allow you and your sensors to temperature stabilize
5. Check calibrations. We recommend doing an AeroPod O&B calibration prior to riding.
6. Test time length. We recommend each test should be 6-10 minutes.
7. Consistent road surface. The surface must NOT change on your route (for example, patches of chip seal on an otherwise smooth road)
8. Ground wind speed. Average wind speed should be less than 10 mph. If you're doing out-and-back testing, it's best if the winds are not "cross winds".
9. Avoid gusty winds. You want to test in conditions where winds are consistent. Do NOT test when winds are gusty. Do NOT test on roads where there is a lot of road traffic (cars cause wind gusts)
10. Temperature. Try to do your testing where temperatures remain reasonably constant. Remember: DFPMs are temperature sensitive...
11. Total Test Length. Try to complete your testing in a few hours.

Here are a few hints that will help you get the most out of your tests:

1. Change only one variable per test. For example, do NOT change your bike helmet *and* your ride position in the same test. Maybe you'll get a different CdA, but you won't know how much of the change was due to the helmet, and how much because of the ride position!
2. Be organized! If you're doing equipment testing, have your gear laid-out at your starting point, so you can easily swap equipment at the end of each test

3. Take notes! It's super-easy to forget what exactly it is you tested. Write down your test variables at the end of each test, and any test notes (such as: a big truck created a wind gust, half way through my last test)
4. If you're using Raptor glasses, touch the temple at the end of each test. This action places a lap marker in your AeroPod ride file, making it easier to analyze CdA later-on with Isaac software

After completing your tests, you can download your ride into Isaac software for more detailed analysis.

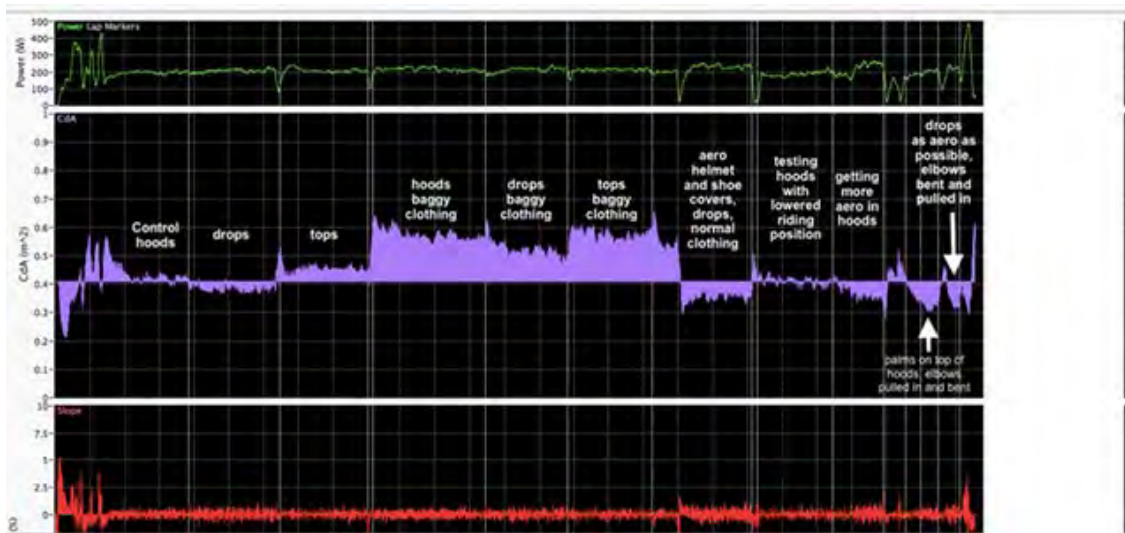
### A Real-Life Example of CdA Testing

One of our CdA beta users performed a very interesting set of tests, comparing clothing, equipment, and ride position, quantifying the effects of each on aerodynamics.

He did his riding on an outdoor track, methodically performing each of his tests.

He liked seeing his CdA while riding: "It was great being able to see the list CdA results as I rode. I was able to tweak positions while riding...[it helped me learn] more intuitively."

After completing his tests, he downloaded his data into Isaac (see next section for details about using Isaac), then used the "Tools/Analyze CdA" function in Isaac to display and quantify his measurements (remember: he saw these CdA numbers in the field, too!):

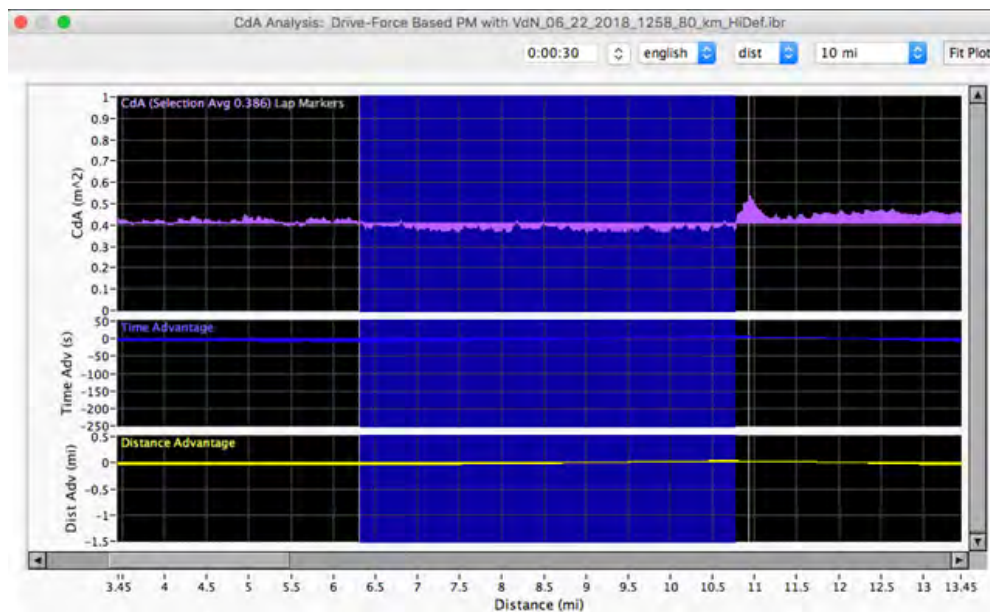


CdA Testing

Purple is CdA; his "normal" CdA is about 0.4

In the graph above you see vertical lines. These are "lap markers" in the ride file, denoting where each test began. The data between any two lap markers is the test. The user inserted information stating what was being tested.

In Isaac, CdA is quantified simply by highlighting the relevant test lap. For example, the CdA of the "drops" section is 0.386 (shown in upper left corner of window of the graph below)



Measured CdA of drops position (0.386)

Here are the measured CdAs of all tests:

- control hoods .419
- drops, normal clothing .386
- tops .452
- hoods, baggy clothing .568
- drops, baggy clothing .516
- tops, baggy clothing .572
- drops, normal clothing, aero helmet, shoe covers .354
- hoods, lowered riding position .408 hoods,
- more aero position .371 hoods,
- elbows pulled in .321
- drops, aero as possible, elbows bent and pulled in .326

Our rider was able to optimize, on-the-road, his aerodynamics, and to quantify some of the benefits of different equipment. For example, when holding the “drops” riding position, by adding an aero helmet and shoe covers, he improved his aerodynamics by about  $0.032 = (0.386 - 0.354)$ ; that is, his aero helmet and shoe covers LOWERED his CdA by 0.032

It’s also obvious that baggy clothing is BAD NEWS for aerodynamic performance... ☺

## Using Isaac Software to Analyze CdA Data

**NOTE: THIS SECTION ASSUMES YOU HAVE INSTALLED ISAAC SOFTWARE AND ARE FAMILIAR WITH ITS OPERATION. YOU CAN FIND ISAAC INSTRUCTIONS HERE:**

ISAAC SOFTWARE DOWNLOAD:

<https://velocomp.com/isaac-software-installation/>

ISAAC SOFTWARE INSTALLATION:

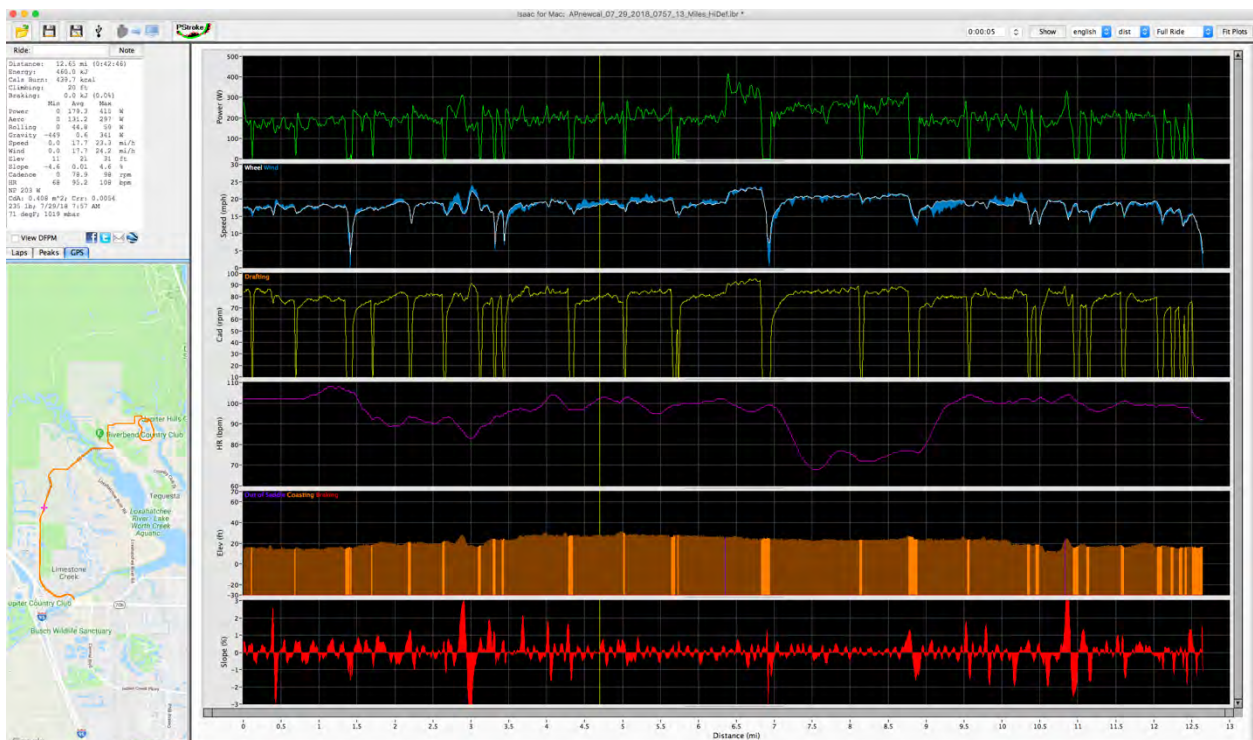
<http://www.velocompforum.com/viewtopic.php?f=12&t=4505>

ISAAC USER MANUAL: <http://velocompforum.com/viewtopic.php?f=12&t=4010>

Once you've finished your on-the-road CdA testing, you can download your AeroPod ride file.

### Example

Here is a recent AeroPod ride.



**In this ride, AeroPod was NOT paired to a heart rate strap, so the HR channel (purple graph) shows a number related to the rider's live CdA data:**

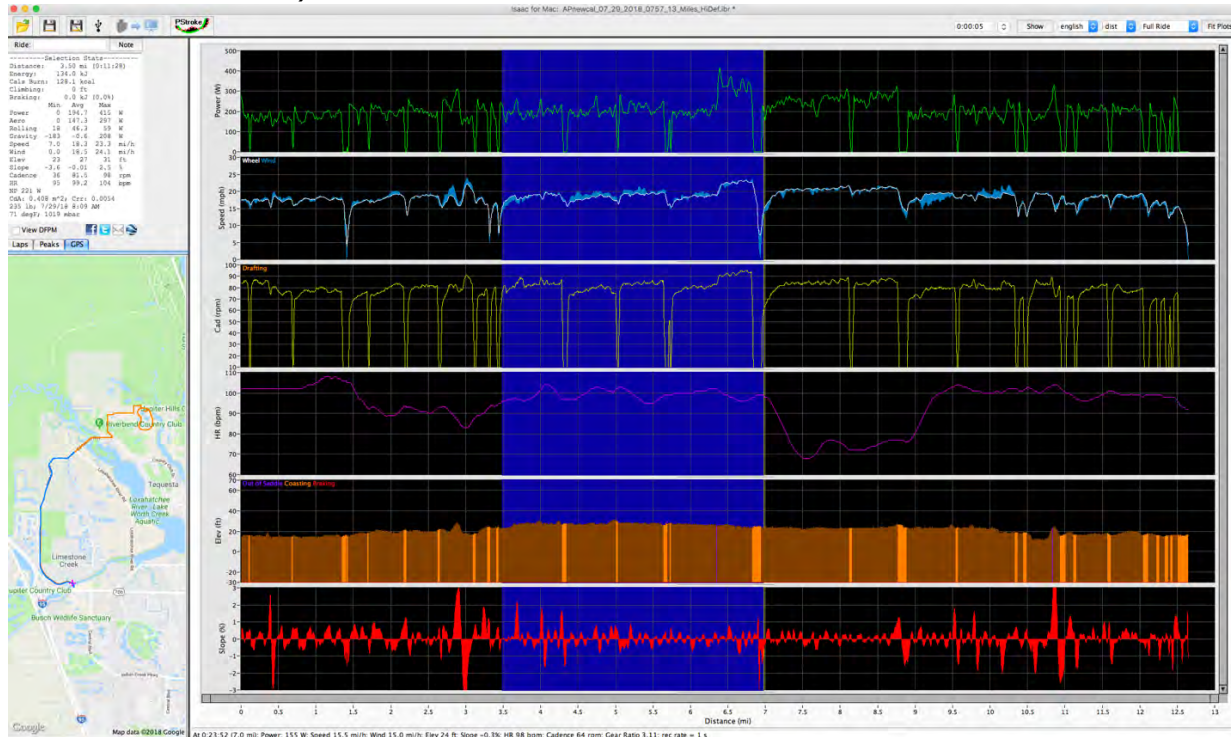
**(CdA = HR reading \* 4 / 1000)**

For example, a HR “reading” of 100 translates to a CdA measurement of 0.400

In this ride, for the first 7 miles the cyclist stayed in the “hoods” position. Beginning at mile 3 the rider had a good course for CdA measurement (fewer stops and turns).

**If you haven’t paired a HR strap to your AeroPod,** it is possible to determine, from the main window, the average CdA, as follows:

- 1) Highlight the section where you want to get average CdA (in this example, between mile 3.5 and 7)



- 2) The “Selection Stats” to the left of the graphs show the averages for this section, including the average HR, which is related to the average CdA

Ride:		Note
-----Selection Stats-----		
Distance:	3.50 mi (0:11:28)	
Energy:	134.0 kJ	
Cals Burn:	128.1 kcal	
Climbing:	0 ft	
Braking:	0.0 kJ (0.0%)	
Power:	Min Avg Max	
Aero:	0 194.7 415 W	
Rolling:	18 46.3 59 W	
Gravity:	-183 -0.6 208 W	
Speed:	7.0 18.3 23.3 mi/h	
Wind:	0.0 18.5 24.1 mi/h	
Elev:	23 27 31 ft	
Slope:	-3.6 -0.01 2.5 %	
Cadence:	36 81.5 98 rpm	
HR:	95 99.2 104 bpm	
NP 221 W		
CdA:	0.408 m <sup>2</sup> ; Crr: 0.0054	
	235 lb; 7/29/18 8:09 AM	
	71 degF; 1019 mbar	
<input type="checkbox"/> View DFPM <span style="float: right;"> </span>		

← average HR = 99.2

- 3) The "Selection Stats" window shows that the average "HR" for this section was 99.2; to convert average HR to average CdA, multiply by 4 and divide by 1000; the rider's CdA on the hoods, for this section, was  $99.2 * 4 / 1000 = \mathbf{0.397}$

### **How CdA changes: from hoods position to TT position to hoods**

Notice that, between mile 7 and 9, the "HR/CdA" reading drops precipitously. Why? At mile 7, the rider moved from the hoods into the time trial position, becoming more aero. Then, at mile 9, the rider moves back to the hoods, and HR/CdA increases, back to the "hoods" HR/CdA value from the earlier part of the ride.

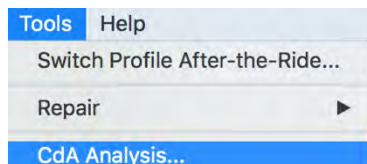
Note that, when the rider changes positions at mile 7, it takes 60 seconds for the reported HR/CdA value to completely reflect the effect of moving from hoods to TT position. Why? The HR/CdA value is smoothed (filtered) in AeroPod, making the CdA number less "jumpy".

*The "HR/CdA" readings reported are the actual measurements AeroPod made during the ride.*

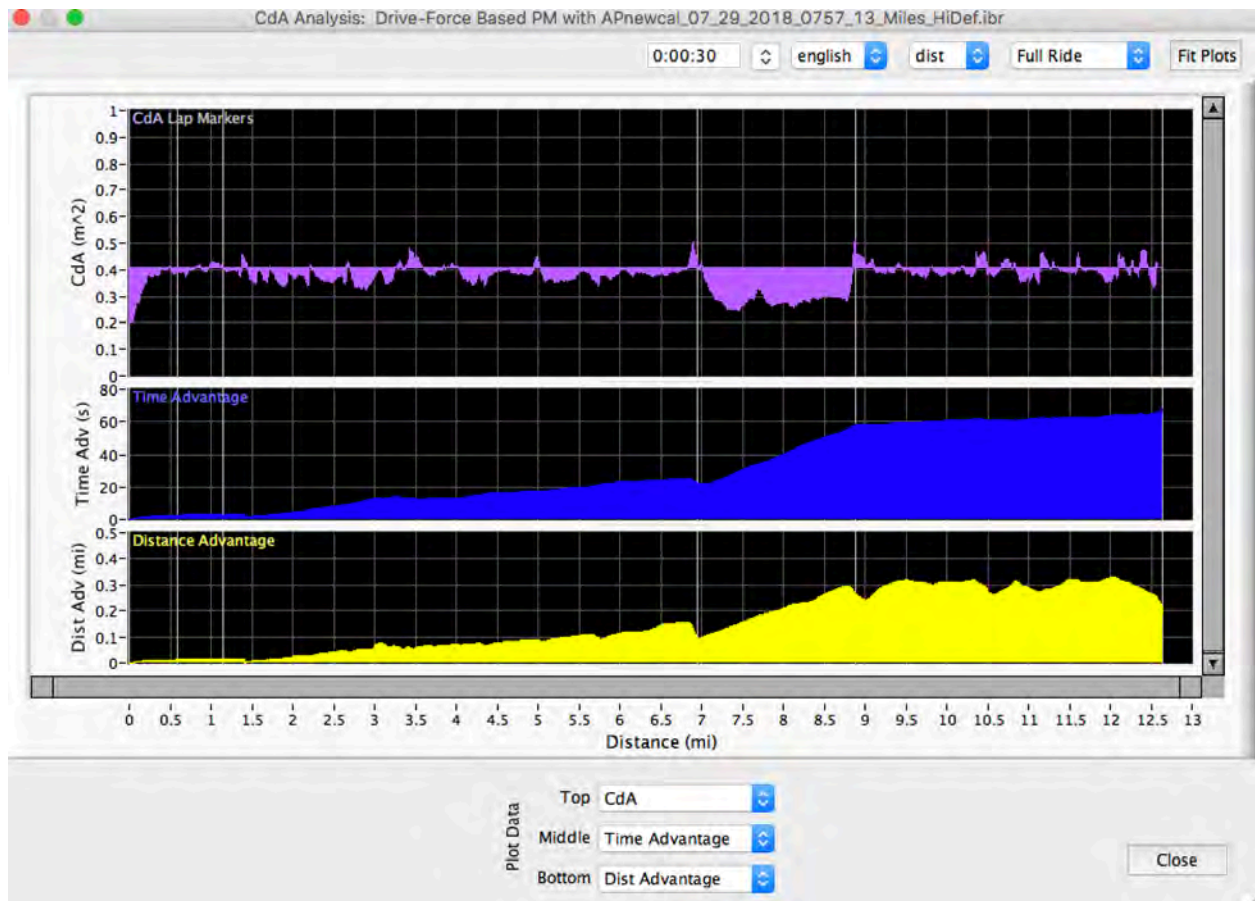
### **Using Isaac to determine CdA readings**

Isaac software uses actual ride data to compute CdA after the ride.

To access this feature, use the "Tools/CdA Analysis..." command to view and analyze your CdA data:



A window like this will appear (this window's data is from our ride example):



The CdA Analysis window shows CdA vs distance (or time, by changing the top right menu item); Time Advantage, and Distance Advantage. The parameters plotted can be selected in the drop-down menus below the graphs.

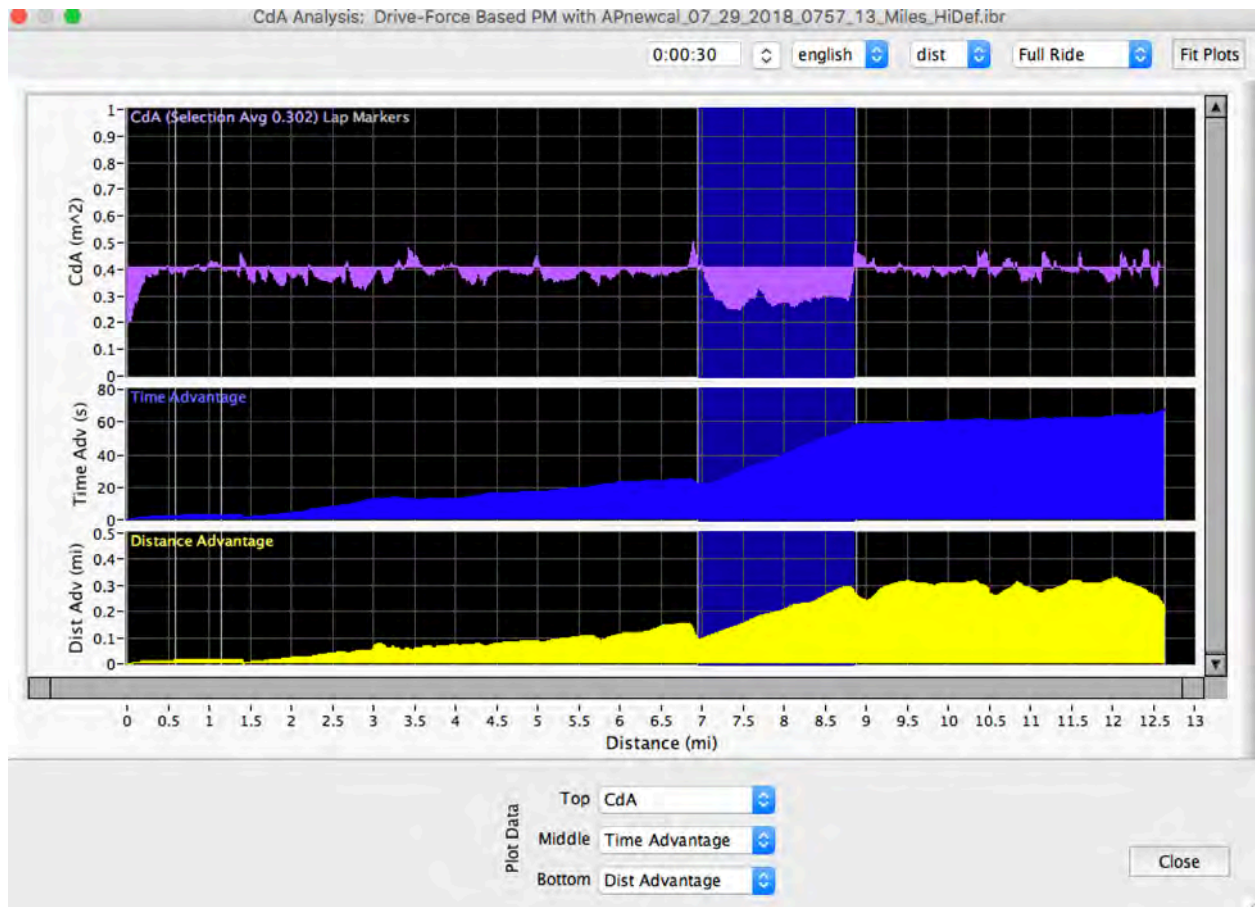
**NOTE:** THE CdA and Time Advantage vs. time graph numbers in the graph are similar to the corresponding numbers displayed on your Garmin or Raptor *during your ride*.

Note that, in the graph above, there are vertical lines. These are lap markers. In this example, these markers were placed by touching the temple on the side of Raptor. You can manually place lap markers in the ride file by right clicking on the main window graph, wherever you want markers to be placed.

### How to measure CdA in the CdA Analysis window

Between mile 7 and 9, the rider moved from the hoods ride position to the time trial position. We have already determined the rider's CdA, in the hoods position, is about 0.398. What is the rider's CdA in the time trial position?

To find out, highlight the area between the lap markers at mile 7 and 9:



In the top left corner of the window, the CdA for this section is shown: 0.302. So, the rider's CdA in the time trial position is much more aero than the hoods position!

Note also that, between mile 7 and 9, Time Advantage increased by about 40 seconds (from 20 seconds to 60 seconds). The benefit of the time trial position was that, by riding in the time trial position, the cyclist gained 40 seconds compared to riding on the hoods!

## POWER METER COMPARISON

If you'd like to see how your Device and your DFPM power measurements compare moment-by-moment, select Tools/Power Meter Comparison. The following graph will appear:



*AeroPod power is shown in white, and DFPM power is shown in green*

Notice that, for the ride example we've been using, that AeroPod and DFPM power are essentially identical everywhere except between mile 7 and 9. This is because rider has set up AeroPod with a "normal" value of CdA that reflects riding on the hoods. When the default CdA value used in AeroPod power calculations reflects the rider's normal ride position, AeroPod and DFPM power readings will be extremely close.

Between mile 7 and 9, where the rider shifts out of the normal hoods position and into the more aerodynamic TT ride position, AeroPod and DFPM power measurements are considerably different; AeroPod power measurements are about 50W higher than DFPM. One way to think about this is that, by becoming more aero, the rider effectively adds the benefit of 50W compared to riding in the normal position.

## TIPS AND TROUBLESHOOTING

Here are some things that you might see, especially as you get to know more about AeroPod and CdA measurements

- I don't see CdA data on my bike computer; I see dashes (---) in the power/CdA/Time Advantage/wind speed/slope fields
  1. Make sure AeroPod is "on" (solid green light when button is pushed)
  2. Make sure DFPM is working
  3. Make sure AeroPod is paired to your bike computer
  4. Ride for a few seconds; this often causes normal readings to begin (--- go to numerical readings)
- When I change ride positions, my CdA and Time Advantage values doesn't change immediately
  1. CdA measurements are smoothed over a period of 60 seconds. When you do something that causes you to become more (or less) aero, the CdA value will begin to change in a few seconds, but the full extent of the CdA change won't be evident until about 90 seconds has elapsed
  2. Time Advantage is related to CdA, so Time Advantage measurements will also lag by about 60 seconds.
- My CdA values vary, even when I stay in the same ride position
  1. This is normal. Some CdA variation around the "correct" value is expected
  2. Riding at a constant level of power reduces CdA variation
  3. Sharp turns, braking, drafting, sharp acceleration can cause CdA to vary
- My CdA number changes somewhen I ride on different road surfaces
  1. This is normal. CdA reported by AeroPod will change when road surface type changes, because road surface changes cause rolling resistance (Crr) to change. AeroPod *assumes* Crr does not change
- My CdA number changes when I ride the same roads on different days
  1. Make sure to inflate your tires to the same pressure prior to every ride. Different tire pressures cause Crr (and, consequently, CdA) to vary
  2. Make sure you have "warmed up" your DFPM and have re-calibrated it.
  3. Temperature variations from day to day can cause CdA measurements to change
  4. Make sure air movement over the pitot tube is not obstructed or blocked
- My Time Advantage information seems "off"
  1. When you ride in your "normal" position Time Advantage should not change much
  2. With Raptor, you can reset TA to "0" by tapping the temple (lap marker)
  3. If Time Advantage changes, even when riding in normal position, then do a new calibration ride
  4. It is normal for Time Advantage measurements to lag by about 60 seconds

- When testing, I don't see significant changes in CdA when I change "x" ("x" is changing to a different piece of equipment, or to a different ride position)
  1. It's easier to measure small CdA changes when you test at higher speeds—22 mph or more
  2. Make sure AeroPod and your DFPM have been calibrated correctly
  3. Especially when making minor changes to your aero setup, don't expect to see significant changes in CdA. The more "minor" your change is, the more important it is to get calibrations correct, and to perform testing according to the recommendations in this document.
  4. Small differences are more easily detected over longer testing periods—10 to 15 minutes.
  5. A "rule of thumb" is that a CdA change of .001 reflects a 1 watt difference between applied and opposing power readings. This is a small difference in power readings.
- My CdA numbers seem way too high (or low)
  1. Make sure your DFPM is properly calibrated. AeroPod assumes your DFPM is working properly and that its wattage numbers are "correct".
  2. If your DFPM is reading high, then AeroPod will report CdA numbers that are too high.
  3. If your DFPM is reading low, then AeroPod will report CdA numbers that are too low.

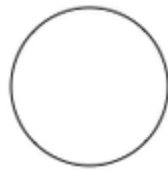
## APPENDIX: What is “CdA”?

The single number “CdA” is actually comprised of two components: your “frontal surface area (A)” —that is, the surface area your body and bike present to the wind in the direction of travel; and the “coefficient of drag (Cd)”, a number quantifying the benefit you get from making the wind flow more smoothly around you and the bike.

In fact, CdA is the product of these two numbers:

$$CdA = Cd \times A$$

To show how these two factors interrelate, here is a simple example. Suppose you put a round, flat disk in a wind tunnel, exposed to the wind. Viewed from the front the disk looks like this:



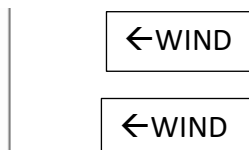
Round disk, frontal surface area  $A = 1$

Let’s suppose we set the diameter of the round disk so that it has a frontal surface area of “1”. So, “A” = 1

Wind is now blown against the disk. The “frontal surface area” the wind encounters when hitting the disk is “1”.

*But to know how much force the wind actually exerts on the disk, we also need to know its coefficient of drag.*

What is the Cd of a round, flat disk? From a side view, flat disk has no depth, so it looks like a thin sliver:



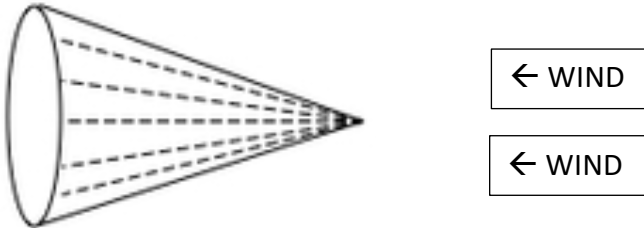
As it turns out, the Cd of a round, flat disk is 1.17. So, the CdA of our round, flat disk is

$$CdA_{\text{flatdisk}} = 1 \times 1.17 = 1.17$$

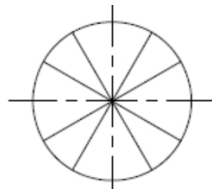
**“1.17” is the CdA used to calculate in wind forces acting on a flat disk with area “1”.**

How can we make a round disk, with a frontal surface area of “1”, more aerodynamic?

*One way is to turn the disk into a cone that points into the wind.*



Note that, looking at the cone directly from its front, *it still looks like a round disk with frontal surface area = 1*



CONE VIEWED FROM THE FRONT—FRONTAL SURFACE AREA IS STILL “1”

However, ***the conical shape improves the flow of wind around the disk, reducing Cd.***

*In fact, if the “angle” of the cone is 60 degrees, the Cd is reduced from 1.17 to 0.50.*

***So,  $CdA_{cone} = 1 \times 0.50 = 0.50$ .***

***A cone with a frontal surface area of “1” is more than a 50% lower than a round, flat disk of with the same are!***

So, a round, flat disk becomes more “aero” by adding a conical aero shape in front of it!

### Summary

CdA encompasses two factors: frontal surface area, and coefficient of drag. Lower CdA is “better”. Cyclists can alter their ride position to reduce frontal surface area, and use aero-optimized equipment to reduce their coefficient of drag.