

# FLIGHT TESTING



Flight testing includes many tasks, but calibrating your pitot-static system ought to be high on the list.

## FINDING TAS FROM GPS DATA

If you do the math right and use proper flying technique during test runs, you can arrive at an accurate number.

BY KEVIN HORTON

### How fast does your aircraft go?

You could grab your trusty E-6B and use your airspeed indicator (ASI) reading, pressure altitude and outside air temperature (OAT) to calculate true airspeed (TAS). But if you are flying an Experimental/Amateur-Built aircraft, you may not know what the static source position error is. And your ASI probably has instrument error. What is a guy to do? The GPS is the answer. We can use the groundspeed information from the GPS to calculate TAS, as long as we are careful to use a method that is mathematically sound.

### What Not to Do

Many folks intuitively believe that the average of GPS groundspeeds from runs on the four cardinal compass headings will equal the TAS. Sorry, but that is wrong! It only works if the wind is zero. To help understand the source of the error, let's imagine an aircraft flying at a TAS of 100 knots. The wind is 20 knots from the west. The pilot flies on headings of 000, 090, 180 and 270 and records the GPS groundspeed. When he is heading west, into wind, the groundspeed will be 80 knots. Heading east, the groundspeed will be 120 knots. So

far, so good. The average is 100, the same as the TAS. But what happens on the north and south legs?

On the north leg, the wind triangle (Figure 1) shows that with the wind at 90° to the heading, the track arrow is longer than the heading arrow—the groundspeed is 102 knots on both the north and south legs. The groundspeeds on the N, E, S and W legs are 102, 120, 102 and 80, for an average of 101 knots. The TAS was 100 knots, so clearly the average of groundspeeds on the four cardinal headings is not equal to the groundspeed. The error is low if the

Finding TAS *continued*

wind speed is low, but the error increases quickly as the wind speed increases.

If instead of flying the four cardinal headings the pilot flies four cardinal tracks, there is still an error. Only this time, because the pilot needs to turn into the wind to force the track to be north and south, the groundspeeds on those legs are less than the TAS, and the average of the four groundspeeds is 99 knots (Figure 2).

**Math Works!**

Mathematically sound methods have been published that rely on GPS groundspeed data from three legs with headings 90° apart, i.e. three sides of a square box (Horseshoe Heading Technique, David Rogers, 2002). See the Resource list at the end of the story for more information on methods. An accurate method that relied on data from three legs on tracks 90° apart was also published in this magazine (“Is Your Speed True” by David Fox, February 1995). Both of these methods work, but the one requiring legs on specific headings relies to a certain extent on the accuracy of the magnetic compass. Further, both methods require that the pilot take care to accurately fly the correct headings or tracks.

**Doug Gray’s Method**

Doug Gray, an Australian RV-6 builder, developed a very useful method that can use GPS data from three legs on arbitrary tracks (“Using GPS to Accurately Establish True Airspeed,” Doug Gray, 1998). The inputs are the GPS groundspeed and track on each leg, and the outputs are the TAS, wind speed and wind direction. Secondary outputs are the headings on each leg, which can be used to check the accuracy of the compass. Gray’s method has the advantages that it does not rely on magnetic compass accuracy, nor does it require the pilot to accurately fly a target heading or track. However, each leg must be on a constant heading long enough for the GPS groundspeed and track calculations to stabilize.

Figure 1.

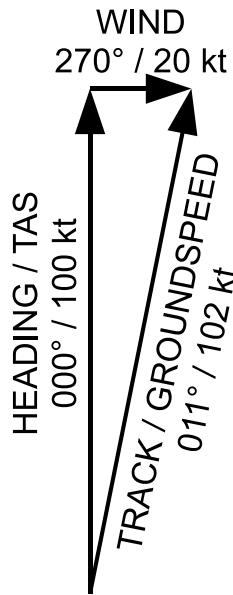
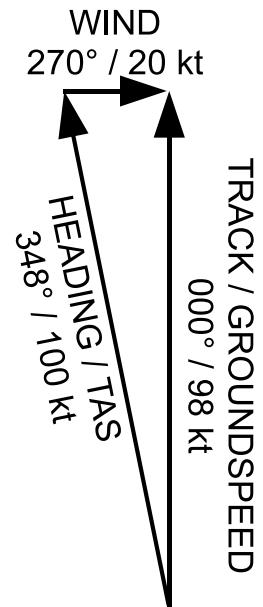


Figure 2.



The test card.

**TAS FROM GPS DATA**

**FLIGHT INFO**

Date:  
Aircraft Reg:  
Aircraft Model  
Pilot:  
Observer:  
Weight at Take Off:  
Fuel at Take Off:

**TEST CONDITIONS**

Time:  
Target IAS:  
Target Altitude:  
Flap Position:  
Power (RPM & MP):

**TEST PROCEDURE**

1. Set altimeter to 29.92.
2. Find smooth air altitude that will allow the target speed to be obtained in level flight.
3. Do four runs at each speed, with the headings separated by approximately 90
4. Ensure that the IAS and altitude are the same for each run. IAS is more important than altitude. If necessary to adjust the IAS, altitude errors of ± 50 ft are acceptable.
5. Record fuel remaining, indicated airspeed and altitude, GPS track, ground speed and OAT for each run.

**DATA**

| Fuel | IAS | Altitude | GPS Track | GPS G/S | OAT | Remarks |
|------|-----|----------|-----------|---------|-----|---------|
|      |     |          |           |         |     |         |
|      |     |          |           |         |     |         |
|      |     |          |           |         |     |         |
|      |     |          |           |         |     |         |

**NOTES**

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## Static Source Position Error

The purpose of the static system is to measure the free-stream ambient pressure, that is, what the ambient pressure was before the aircraft came along and disturbed the air. Measuring the free-stream ambient pressure is a bit of a trick because the aircraft causes the airflow to accelerate and decelerate as it passes by. Bernoulli's Law tells us that the pressure will change as the speed of the air changes, so it is difficult to find a position on the airframe where the local pressure is the same as the free-stream ambient pressure. The difference between the pressure sensed by the static port and the free-stream static pressure is called the static source position error.

Airspeed indicators determine airspeed by measuring the difference between the pitot and static pressures. Thus, if the static pressure has an error, the indicated airspeed will be in error. This error also affects the altimeter.

Manufacturers of modern type-certificated aircraft conduct flight testing on the prototype to determine the static source position error along with the resulting airspeed and barometric altitude errors. The amount of the error depends on the shape of the aircraft and the location of the static port. All examples of a type-certificated aircraft design are supposed to be identical, so the static source position error is assumed to be the same for each type. This information will be found in charts or tables in the Pilot's Operating Handbook or Aircraft Flight Manual. But every example of an Experimental/Amateur-Built aircraft is unique, even if it was built from a kit, due to normal variations in tolerance and builder modifications (e.g., replacing Van's blind rivet static port with a flush static port). So the static source position error cannot be assumed to be the same for all examples of these aircraft.

—K.H.

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### NTPS Spreadsheet

The National Test Pilot School was using another GPS-based method when I was there for a refresher course in 2001. I introduced NTPS instructor Greg Lewis to Gray's approach, and the NTPS quickly recognized its superiority over other methods of calculating TAS from GPS data and made a clever addition to this method: They gather data on four legs and use the redundant data to provide a data quality check. The NTPS's spreadsheet does four TAS calculations using data from different combinations of three of the four legs. If the data is good, all four calculations should yield similar TAS and wind. But if there is a problem with the data, the four TAS and wind calculations will vary, and all data from those four legs should be discarded. The data could be bad for many reasons: error recording GPS data, actual TAS not the same on all four legs, data recorded before the calculated GPS groundspeed and track had fully stabi-

|   | A          | B     | V            | W               | X            |
|---|------------|-------|--------------|-----------------|--------------|
| 1 | Point 1    |       | <u>Vwind</u> | <u>Wind dir</u> | <u>Vtrue</u> |
| 2 | Vg         | Track | (kts)        | (deg)           | (kts)        |
| 3 | 178        | 178   | 5.3          | 195             | 183.0        |
| 4 | 185        | 82    | 3.6          | 182             | 184.4        |
| 5 | 188        | 355   | 5.1          | 163             | 183.0        |
| 6 | 184        | 265   | 6.4          | 178             | 184.4        |
| 7 | <u>ave</u> |       | 5.1          | 179.2           | 183.7        |
| 8 | std dev    |       |              |                 | 0.8          |

Figure 3: an excerpt of the test results.

lized, aircraft heading changing instead of being constant and poor air quality due to turbulence or wind variations.

The spreadsheet has three tabs. The "Three Legs" tab is for calculating TAS with data from three legs, using Gray's method. This tab also has notes that explain the abbreviations used in all tabs. The "Four Legs" tab employs the four-leg variation of Gray's method (See excerpt in Figure 3). Four GPS groundspeeds are put in the Vg column, and

the four GPS tracks are put in the Track column. The four calculated winds and TASs (Vtrue) are shown to the right, with the average TAS and wind below. The std dev (standard deviation) value below the average TAS is a measure of how much the four TAS calculations differ. Small standard deviation values indicate good quality data. Ideally, the standard deviation would be 0.5 or less, and the data should certainly be thrown out if it is greater than 1.0. The last tab,

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PEC, is used to calculate pitot-static error corrections, which will be the subject of a future article.

### Flight-Test Details

This flight test requires extremely smooth air. Choose a test area that should have minimal traffic. The pilot will be working hard to accurately fly the aircraft, so it would be helpful to carry an observer, if possible, to record the data and to help keep a watch for other aircraft. The use of an autopilot should give better quality data and help reduce pilot workload.

There are two usual purposes for conducting this type of flight test: determining TAS versus power or as part of a static-system position error flight test. Future articles will provide expanded coverage of both these subjects. The flight test for static system position error is easier to conduct than the one for power versus TAS, as the power can be varied as required to stabilize at the target IAS. It is important that the IAS for each leg be as close as possible to

the target IAS, as the analysis method assumes all legs are at exactly the same TAS. The altitude should be close to the target altitude, but it may be varied  $\pm 50$  feet from the target if necessary to achieve exactly the target IAS.

If the purpose of the test is TAS versus power, then the power cannot be varied, and the pilot must be patient on each leg to allow the aircraft to slowly accelerate to the stabilized IAS. Note the IAS on each leg, and ensure that they are all the same.

### Conclusion

If you are going to take the time and burn the fuel to gather GPS data to calculate TAS, you might as well use a method that actually works. Take the time to download the NTPS spreadsheet. It can be opened using Microsoft Excel, the free OpenOffice for Windows, Linux or OS X, or NeoOffice for OS X only). Use the four-leg method described above, as it allows the quality of the data to be checked. May your aircraft fly faster than you expected! †

## RESOURCES

David Rogers' Horseshoe Heading Technique  
[www.nar-associates.com/technical-flying/horseshoe\\_heading/horseshoehead\\_screen.pdf](http://www.nar-associates.com/technical-flying/horseshoe_heading/horseshoehead_screen.pdf)

Doug Gray's "Using GPS to Accurately Establish True Airspeed"  
[www.kilohotel.com/rv8/rvlinks/doug\\_gray/TAS\\_FNL4.pdf](http://www.kilohotel.com/rv8/rvlinks/doug_gray/TAS_FNL4.pdf)

NeoOffice (for OS X only)  
[www.neooffice.org](http://www.neooffice.org)

NTPS GPS PEC.xls Spreadsheet  
[www.ntps.edu/Files/GPS%20PEC.XLS](http://www.ntps.edu/Files/GPS%20PEC.XLS)

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\*Find direct links to these sites at [www.kitplanes.com](http://www.kitplanes.com).

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