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Technical Comment

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Comment on "Refining Satellite Methods for Pitot-Static Calibration"

Alan Flint*
NASA Johnson Space Center, Houston, Texas 77058
and
Robert J. Niewoehner†
U.S. Naval Academy, Annapolis, Maryland 21402

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Nomenclature

V_{gps} = measured groundspeed, kt
V_T = calculated true airspeed, kt
ψ_{gps} = Global Positional System ground-track azimuth angle (magnetic)

THE subject paper proposed a refined method for using Global Positional System (GPS) ground velocities to more precisely determine true airspeed as a step toward the calibration of pitot-static systems [1]. Specifically, Niewoehner recommended the use of four consecutive legs in a box pattern, flown at constant indicated airspeed, recording GPS groundspeed and ground track on each leg. The true airspeed is then determined by use of a nonlinear least-squares fit of a circle to the four vectors. Three legs would uniquely determine a circle for which the center is the wind vector and the radius is the true airspeed; a fourth leg overdetermines the problem mathematically, requiring a least-squares fit. The residual from the fit provides a quantitative measurement of the quality of the data point, quantifying the precision with which the pilot held indicated airspeed and confirming the stability of the air mass. Significantly, the extra leg requires negligible additional flight time per point while substantially improving the credibility of the result.

The original paper proffered only low-altitude low-speed data gathered from a general aviation airplane. The method has no intrinsic limitation to those flight conditions, but the paper lacked validation at higher Mach numbers or altitudes, or the higher consequent winds.

In 2009, NASA Johnson Space Center modified the static source error correction of one of its T-38N aircraft in an attempt to improve the aircraft's air data accuracy in the transonic region. While the altitude position error of the modified static source error correction was confirmed by a true altitude method, a true airspeed method was needed to verify the total pressure calibration through transonic Mach numbers where isentropic streamlines cannot be presumed. Cost precluded traditional means such as a calibrated pacer, which would have to have come from another agency or center. The GPS method above was trialed as an inexpensive means of quickly validating the calibration with no specialized equipment or instrumentation. The intrinsic measurement of data point quality enhanced its attractiveness.

Table 1 presents sample data from the T-38 flight. All points were performed at 30,000 ft mean sea level (MSL) and Mach numbers ranging from 0.86 to 0.94. The pilot held constant indicated airspeed for each of the four legs, boxing the compass, while the test engineer recorded the ground track and groundspeed provided by a Universal Avionics Wide Area Augmentation System GPS Flight Management System (UNS-1Lw). Each point required approximately 10 s steady on each leg for the GPS speed and track to stabilize.

The true airspeed algorithm was evaluated in flight, using Niewoehner's software [1], providing the true airspeed, the winds, and the rms residual of the circle fit. RMS error values less than 1 kt indicated that the pilot held the indicated airspeed very precisely during each of the four legs and that the air mass was stable throughout the duration of each test point, a detail corroborated by the consistent wind measurement from point to point. All the points met the rms criterion, providing for high test efficiency. Hence, this test extended Niewoehner's methodology to airspeeds and wind values 4 times greater than those documented in the prior paper, and yet with identical tight precisions.

The Federal Aviation Administration recently underscored the importance of reliable, precise, yet inexpensive air data calibration methods, releasing a detailed analysis of design issues believed to be responsible for a string of accidents in the Zodiac light-sport aircraft [2]. While pointing to flutter as the principal cause of the accidents, an erroneous air data calibration was cited as a likely contributing cause. The calibration had been performed using a GPS ground-track method described in advisory circular 23-8B, which is both much less accurate and more time consuming than the method described here [3].

The prior paper's point deserves repeating. GPS velocity methods inexpensively provide a level of precision in air data calibration that was previously only available to programs with complicated instrumentation and expensive test stratagems. Any pilot with even a handheld GPS can quickly and reliably measure the static source error in the airplane they fly, whether a slow or fast mover. Data

Table 1 T-38N: 30,000 ft MSL (29 January 2010)

	Mach = 0.86		Mach = 0.90		Mach = 0.94	
	ψ_{gps}	V_{gps}, kt	ψ_{gps}	V_{gps}, kt	ψ_{gps}	V_{gps}, kt
GPS data						
Leg 1	222	447	223	471	46	626
Leg 2	129	532	320	527	127	580
Leg 3	45	578	45	603	221	494
Leg 4	321	502	127	557	320	546
Least- squares results						
V_T, kt		513		538		560
Wind	238	68	236	68	238	68
RMS error		0.98		0.8		0.07

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*Flight Test Engineer, 2101 NASA Parkway, Mail Code CC3.
†Director of Aeronautics, 590 Holloway Road, Code 11B; niewoehn@usna.edu. Senior Member AIAA.

reduction is easily performed with MATLAB scripts available from the authors.

References

[1] Niewoehner, R. J., "Refining Satellite Methods for Pitot-Static Calibration," *Journal of Aircraft*, Vol. 43, No. 3, May–June 2006, pp. 846–849.
doi:10.2514/1.18976

[2] "Zodiac CH 601 XL Airplane: Special Review Team Report" [online report], Federal Aviation Administration, Jan. 2010, http://eaa.org/news/2010/Zodiac_Review_%20Report.pdf [accessed 5 March 2010].

[3] "Flight Test Guide for Certification of Part 23 Airplanes," Federal Aviation Administration, AC 23-8B, 14 Aug. 2003.