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Estimation of Total Error in Altimetry

RATIONALE

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INTRODUCTION

In the field of altimetry, and more generally in the field of air data, it has been customary to specify accuracies in the form of tolerances on specific functions. For example, the specification for an altimeter or air data computer might say that for a particular test condition, the instrument would have a tolerance of ± 100 ft for scale error, 50 ft for hysteresis, 50 ft for friction, 20 ft for temperature, etc. Because scale error is the most obvious, and usually the largest of the errors, mistaken assumptions have often been made that scale error alone is a sufficient measure of the accuracy of an instrument, or even of a whole system.

Some of those in the field have advocated that tolerances should be lumped; that is that test procedures should be devised so that for a particular test point, the equipment should be tested so that it would be exposed to all of the pertinent sources of error, and a single numerical limit be set on the net of all of them. This concept has been mooted for many years, but has never found full acceptance.

There remains a need for some means to know the width of the total band of error or uncertainty so that it can be stated that a particular aircraft will be within so many feet of being at its assigned altitude, and that there is good confidence (say, $\pm 3\sigma$ or 99.7%) in the statement.

The need for this information is to be able to establish standards of vertical separation between aircraft and standards of equipment performance in order to operate safely with those vertical separation standards.

INTRODUCTION (Continued)

In the 1950s and 60s, air carriers flying the North Atlantic were anxious for economic reasons to fly at 1000 ft, rather than 2000 ft separations. Studies were made by the Air Transport Association (ATA), and four of the resulting reports were eventually used as the bases for SAE documents (References 11, 13, 14, and 15). The International Civil Aviation Organization (ICAO) has sponsored on-going studies of the problem by its Panel on Vertical Separation of Aircraft, later renamed Review of the General Concept of Separation Panel (RGCSP). In 1982, the Federal Aviation Administration (FAA) asked the Radio Technical Commission for Aeronautics (RTCA) to form a Special Committee (SC-150) to develop a Minimum System Performance Standard (MSPS) to prepare for reduction of vertical separation to 1000 ft above Flight Level (FL) 290.

This Report suggests methods of estimating total error for four flight regimes, as originally considered in Area Navigation (RNAV) studies. More specifically, it suggests starting with the limits of probable error (i.e., tolerances) of contributing types of error and arriving at overall limits of probable error or uncertainty. It also provides for starting with known or measured contributing errors and arriving at an overall error, and for the situation where the available information consists of a mixture of tolerances and known errors.

The Traffic Alert and Collision Avoidance System (TCAS) program does not yet call for specific efforts to improve the accuracy of altimetry. "A Field Study of Mode C Altimetry Accuracy in the General Aviation Fleet" (Reference 22) shows that it is presently adequate up to 3900 ft. At high altitudes however, non-servoed pressure altimeters are less accurate than at low, and at high speeds airframe static pressure (position) errors become more significant. In the investigation of reports of apparent malfunction or false warning of TCAS equipment at high altitudes and/or speeds, where the accuracy of altimetry is suspect, the procedures of this AIR and of RTCA SC-150's "Minimum System Performance Standards for Vertical Separation above Flight Level 290" (Reference 23) should be useful.

Altitudes in this report are in terms of feet. Altitudes may some day be stated in meters or other units, but that day is further into the future than the adoption of other SI units. References 17 and 18 contain backgrounds on this question.

1. SCOPE:

AIR1608 ESTIMATION OF TOTAL ERROR IN ALTIMETRY proposes a method of estimating overall error of altimetry in order to provide a basis for safe vertical separation of aircraft.

2. REFERENCES:

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4. "Altimetry", Special Committee 70, Paper 215-58/DO-88, Radio Technical Committee for Aeronautics, Washington, November 1958. (Reprinted April 1978.)
5. "Survey of Altitude Measuring Methods for the Vertical Separation of Aircraft", Gracey, Technical Note D-738, National Aeronautics and Space Administration, Langley Field, March 1961.
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8. "Survey of the Errors of Pressure Measuring Instruments in Relation to Air Traffic Separation Standards", Anderson, Technical Report 65262, Royal Aircraft Establishment, Farnborough, December 1965. (AD 478915)
9. "Specifying the Calibration of Static Pressure Systems for the Safe Use of 1000 Foot Vertical Separation Standard in North Atlantic Jet Traffic", Reich and Anderson, Technical Report 66156, Royal Aircraft Establishment, Farnborough, May 1966.
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16. "Implications of Altimetry System Errors for Collision Avoidance Systems", Mundra, Technical Report MTR-7232, Mitre Corporation, McLean, May 1977.
17. "Problems in Worldwide Standardization of the Units of Height Measurement", Gilsinn, Report FAA-EM-78-2, Federal Aviation Administration, Washington, February 1978. (AD A051150)
18. "SI Units of Measurement in Aviation (Together with Non-Linear Units of Altitude)", Anderson, Engineering Report F-1856, United Airlines, San Francisco, September 1978. (No text; a collection of references.)

2. (Continued):

19. "Estimation of Total Error in Altimetry", Anderson, Engineering Report F-1870, United Airlines, San Francisco, March 1979. (Draft of Society of Automotive Engineers Aerospace Information Report 1608.)
20. "Measurement of Aircraft Speed and Altitude", Gracey, Reference Publication 1046, National Aeronautics and Space Administration, Hampton, May 1980. Also published by John Wiley, New York, May 1982.
21. "Height Indication by Pressure Altimeters", Anderson, Engineering Report F-1588, United Airlines, San Francisco, July 1980.
22. "A Field Study of Mode C Altimetry Accuracy in the General Aviation Fleet", Cohen, Report MTR-86W231, Mitre Corporation, McLean, March 1987.
23. "Minimum System Performance Standards for Vertical Separation Above Flight Level 290", Special Committee 150, Radio Technical Commission for Aeronautics, Washington, Fifth Draft, January 1988. [More drafts expected before publication as an RTCA DO- ____ document.]

3. GROUPING OF ERRORS:

Cursory discussions of accuracy of altimetry are usually concerned with the errors peculiar to one aircraft and its equipment, or in the case of collision probability studies, two aircraft. While this is not invalid, neither is it complete. There are additional sources of error that are common to all aircraft in a locality, others that are common to a type of aircraft, and still others related to the manner of operation of the aircraft.

3.1 Errors Common to all Aircraft in a Given Locality:

Aircraft below 18,000 ft and receiving their QNH altimeter setting number from a single source are all equally dependent on the accuracy of that source. If there are errors in the QNH transmitted, all aircraft using it will be flying too low or too high by the same amount. This may increase the risk of long or short landings or of hitting obstructions on the ground, but should not increase the risk of collision between two aircraft.

3.2 Errors Pertaining to Aircraft of a Type:

One of the steps on certification of an aircraft type is flight calibration of the static system of one or more of the first few aircraft. It has been recommended that at least three aircraft be calibrated (Reference 12). It is usual that the flight test results are a series of data points with some scatter, and that a fair curve, or family of fair curves is drawn through the scatter field. The fair curve then is published in the government-approved Flight Manual as applicable to all aircraft of that type. Subsequent aircraft of the type will thus be subject to whatever errors or uncertainties there were in the original calibration.