Flight Operations Briefing Notes

Supplementary Techniques

Altimeter Setting - Use of Radio Altimeter

I Introduction

Operators with international routes are exposed to different standards in terms of:

- Altitude measurement, using different units (i.e., feet or meters);
- Altitude reference setting (i.e., baro setting), using different units (i.e., hectoPascal or inch-of-mercury);
- Altitude reference for departure and approach, using QNH or QFE; and,
- Environmental conditions (i.e., rapid atmospheric pressure changes and/or low OAT operation).

This Flight Operations Briefing Note provides a review and discussion of the following aspects, highlighting the lessons learned from incidents / accidents (particularly during approach-and-landing) :

- Barometric-altimeter reference (QNH or QFE);
- Use of different units for altitude measurement and reading (i.e., feet versus meters) and altimeter setting (i.e., In.Hg versus hPa);
- Setting of baro-altimeter bugs (as applicable) and radio-altimeter DH;
- Radio-altimeter callouts; and,
- Low-OAT operation.

II Statistical Data

Deviations from the intended vertical flight profile, caused by omission of an action or by an incorrect action (including errors in setting the altimeter reference), are frequently observed during line operation.

The lack of situational awareness, particularly the lack of vertical situational awareness, is a causal factor in 50 % of approach-and-landing accidents (this includes most accidents involving a CFIT) (Source: FSF Flight Safety Digest Volume 17 & 18 – November 1998 / February 1999).

III QNH or QFE ?

Some operators set the altimeter to QFE, for takeoff and approach-and-landing, in areas of operation where the ATC and the majority of other operators use QNH.

This requires adequate SOPs for altimeter-setting and for conversion of assigned altitudes into heights.

The difference between the QNH and QFE is indicated in approach area chart, e.g. :

- LFBO (Toulouse Blagnac) :
  - " ELEV 499 ft / 152 m (18 hPa) " :
    - QNH 1014 hPa ⟹ QFE = 996 hPa,
    - 3000 ft QNH = 2500 ft QFE.

Pilots should be also aware of possible exceptions, such as airports operating with "**QFE** only" in a country where QNH is used (such exceptions are indicated on the applicable approach chart).

Aircraft fitted with electronic flight instrument systems (EFIS) may be capable of using either QNH / QFE or QNH-only.

IV Altimeter-setting Units

Operators with international routes are exposed to the use of different altimeter setting units:

- Hectopascals (hPa), previously referred to as milibars (mb);
- Inches-of-mercury (in. Hg); or,
- Milimeters-of-mercury (mm.Hg), on earlier eastern-built aircraft.

When in.Hg is used for altimeter setting, unusual barometric pressures such as:

- 28.XX in.Hg (i.e., an unusually low pressure); or,
- 30.XX in.Hg (i.e., an unusually high pressure),

may go undetected when listening to the ATIS or ATC transmissions, resulting in a more usual 29.XX altimeter setting being set.

A 1.00 in.Hg discrepancy in the altimeter setting results in a **1000-ft error** in the intended (actual) altitude, as illustrated by **Figure 1**.

Note

Figure 1, Figure 2 and Figure 3 assume :

- *a 2000 ft airfield elevation; and,*
- *a 4000 ft indicated altitude.*

In **Figure 1**, the actual QNH is an unusually low 28.XX in.Hg but the altimeter setting was mistakenly set to a more usual 29.XX in.Hg, resulting in the actual altitude / height being 1000 ft **lower** than indicated:

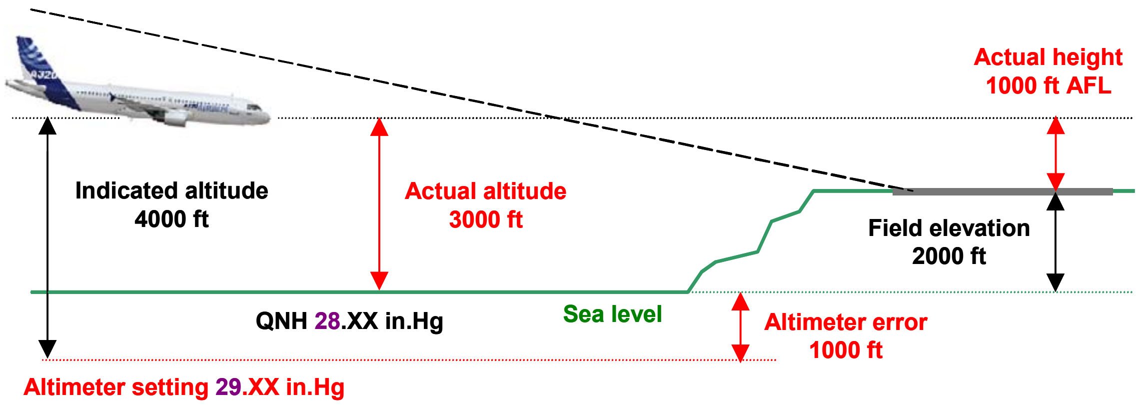

Figure 1

Effect of a 1.00 in.Hg Too-High Altimeter Setting

In **Figure 2**, the actual QNH is an unusually high 30.XX in.Hg but the altimeter setting was mistakenly set to a more usual 29.XX in.Hg, resulting in the actual altitude / height being 1000 ft **higher** than indicated.

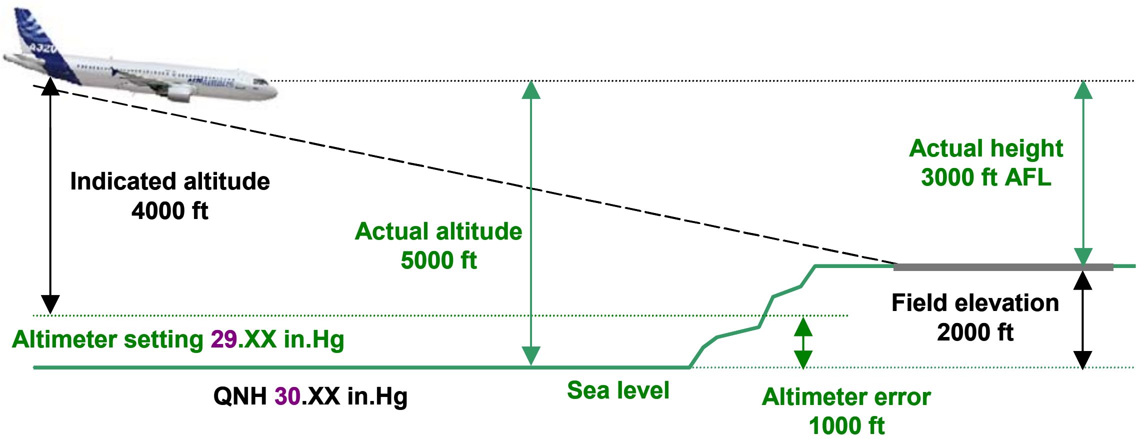

Figure 2

Effect of a 1.00 in.Hg Too-Low Altimeter Setting

Similarly, a 10 hPa error in the altimeter setting would result in a 300 ft error in the actual altitude (i.e., with a 10 hPa too high altimeter setting, flying at a 4000 ft indicated altitude would result flying at a 3700 ft actual altitude).

Confusion between altimeter setting units (i.e. hPa versus in.Hg) leads to similar errors in the actual altitude and actual height above airfield elevation.

In **Figure 3**, an actual QNH of 991 hPa was mistakenly set on the altimeter as 29.91 in.Hg (equivalent to 1012 hPa), resulting in the actual altitude / height being 640 ft **lower** than indicated.

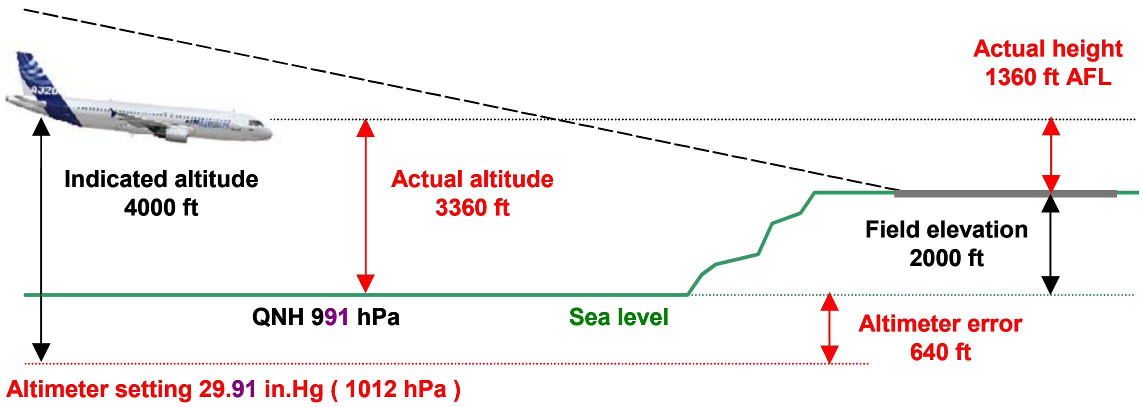

Figure 3

Effect of an Altimeter Setting in in.Hg Instead of hPa

V Setting the Altimeter Reference

In order to eliminate or reduce the risk associated with the use of different altimeter-setting units or with the use of unusual (low or high) altimeter-setting values, the following rules should be used by controllers (when recording the ATIS message or when transmitting the altimeter-setting) and by pilots (when reading back the altimeter-setting):

- All numbers as well as the unit used for the measurement of the atmospheric pressure (e.g., inches or hectoPascals, sometimes abbreviated as "hex") should be indicated in the ATIS' or air traffic controller's transmission.

  For example, an abbreviated transmission, by the air traffic controller, such as "altimeter setting six seven" can be interpreted by the pilots as 28.67, 29.67 or 30.67 in.Hg, or as 967 hPa.

  Accurately indicating both the altimeter-setting unit and the full value of the altimeter setting will prevent confusion or enable the detection and correction of an altimeter-setting error.

- When using inches of mercury (in.Hg), "low" should precede an altimeter setting of 28.XX in.Hg and "high" should precede an altimeter setting of 30.XX in.Hg.

  The U.S. FAA accepts this practice, if deemed desirable by regional or local air traffic services.

VI Use of Metric Altitudes

Using metric altitudes in certain countries (such as the Russian Federation, the Commonwealth of Independent States [CIS] and the People's Republic of China) also requires the use of :

- Metric altimeters; or,
- Conversion tables (i.e., to convert published or assigned altitudes expressed in meters into feet, for setting a target altitude in the FCU ALT window or for reading the altimeter).

VII Changing the Altimeter Setting in Climb or Descent

The transition altitude / level is the altitude / level :

- Above which all aircraft are flying with the altimeter-setting (baro setting) set to the standard (STD) reference (i.e., 1013 hPa / 29.92 In.Hg), and,
- Below which all aircraft are flying with the altimeter-setting set to QNH or QFE.

The transition altitude / level ensure that all aircraft flying within the same airspace fly with the same altimeter reference.

The transition altitude / level can be either:

- Fixed for the whole country (e.g. 18000 ft / FL 180 in the USA); or,
- Variable, depending on QNH (as indicated in the ATIS message), e.g. :
  - LFBO (Toulouse Blagnac) approach charts :
    - " TRANS ALT : 5000' ",
    - " TRANS LEVEL : BY ATC ".

Depending on the airline's / flight crew's usual area of operation, changing from fixed transition altitude / level to variable transition level may cause crew confusion and result in a premature or late setting of the altimeter reference.

VIII Setting of Barometric-altimeter MDA / DA and Radio-altimeter DH

The barometric-altimeter MDA / DA or the radio-altimeter DH should be set in line with Airbus' SOPs or company's SOPs.

Approach	Baro Altimeter	Radio Altimeter
Visual		
Non Precision Approach (Non-ILS Approach)	MDA(H) or DA(H) Note 2	
RNP RNAV Approach	DA(H)	
ILS CAT I	DA(H)	
ILS CAT II ILS CAT III with DH		DH
ILS CAT III with no DH		Note 1

Table 1

Use Barometric Altimeter MDA(H)/DA(H) and Radio Altimeter DH

Note 1

DH set to "- 5 ft" for A300/A310/A300-600 families, "NO" entered on PERF APPR page for other Airbus aircraft families.

Note 2

DA(H), for constant-angle / constant-slope non-precision approaches, as allowed by operational authorities.

IX Radio-altimeter Callouts

Radio-altimeter callouts can be either:

- Announced (verbalized) by the PNF or the Flight Engineer; or,
- Automatically generated by a synthesized voice (e.g., smart callouts).

Callouts should be tailored to the airline' operating policy and to the type of approach.

To enhance the flight crew's terrain awareness, a callout "Radio altimeter alive", should be announced by the first crewmember observing the radio altimeter activation at 2500 ft height AGL.

The radio altimeter reading should then be included in the instrument scanning for the remainder of the approach.

Radio altimeter readings (i.e., feet's AGL) below the Minimum Obstacle Clearance (MOC) values listed below, should alert the flight crew (sources – ICAO-PANS-OPS and US TERPS):

- Initial approach segment (i.e., from IAF to IF) :
  - **1000 ft**;
- Intermediate approach segment (i.e., from IF to FAF) :
  - **500 ft**; and,
- Final approach segment (i.e., after FAF, for non-precision approaches with a defined FAF, until visual references or reaching MAP) :
  - **250 ft**.

Unless the airport features high close-in terrain, the radio-altimeter reading (i.e., height AGL) should reasonably agree with the height above airfield elevation (i.e., height AFE), obtained by :

- Direct reading of the altimeter, if using QFE; or,
- By subtracting the airport elevation from the altitude reading, if using QNH.

X Low OAT Operation

In a standard atmosphere, the indicated altitude (with altimeter set to QNH) provides the true altitude above the Mean Sea Level (MSL) and, therefore, a reliable indication of terrain clearance.

Whenever, the temperature deviates significantly from the standard temperature, the indicated altitude correspondingly deviates from the true altitude (**Figure 4**) :

- Extreme **high** temperature :
  - the true altitude is **higher** than the indicated altitude,

- Extreme **low** temperature :
  - the true altitude is **lower** than the indicated altitude (i.e., 1520 ft true altitude for a 2000 ft indicated altitude, with a – 40° C OAT), thus resulting in a lower-than-anticipated terrain separation and a potential obstacle-clearance hazard.

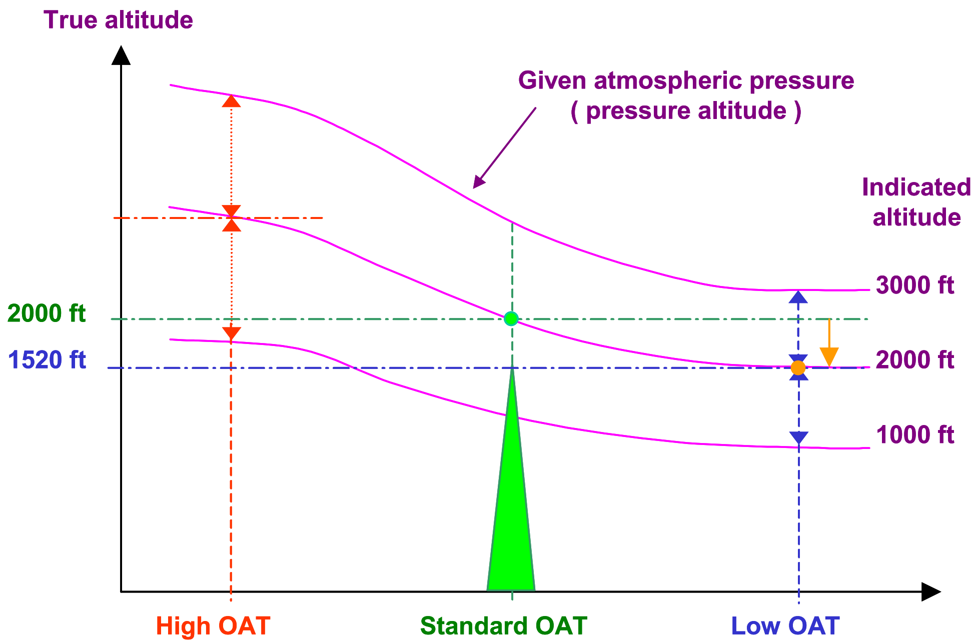

Figure 4

Effect of OAT on True Altitude

As a consequence, when performing an ILS approach – for example - with a published 2000 ft glide-slope interception-altitude and a – 40° C OAT, the glide-slope interception altitude (i.e., altitude selected on FCU) should be **increased by 480 ft** (refer to the example shown on **Table 2**).

The ICAO PANS-OPS, Volume I, provides corrections to be **added** to the published minimum safe altitudes (if using QNH) / heights (if using QFE).

The temperature correction to be added to the indicated altitude (height) is a function of the aerodrome surface temperature (OAT) and of the desired true altitude (height) above the elevation of the altimeter-setting source, as illustrated by **Table 2**.

Aerodrome Temperature °C	Height above the elevation of the altimeter setting source (feet)								
	200	300	400	500	1000	2000	3000	4000	5000
0	20	20	30	30	60	120	170	230	280
-10	20	30	40	50	100	200	290	390	490
-20	30	50	60	70	140	280	420	570	710
-30	40	60	80	100	190	360	570	760	950
-40	50	80	100	120	240	480	720	970	1210
-50	60	90	120	150	300	590	890	1190	1500

(Source – ICAO PANS-OPS)

Table 2

*Low OAT Correction (ft) to be **Added** to Published Altitudes / Heights*

Flying into a low temperature area has the same effect as flying into a low-pressure area; the aircraft is lower than the altimeter indicates.

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These effects are summarized and illustrated in **Table 3**, featuring a well-known aviation golden rule " **Look Out Below !** " :

	From	To	Effect on Altitude
Atmospheric Pressure	**High**	**Low**	**True** altitude is **lower** than **indicated** altitude **!**
OAT	**Warm**	**Cold**	

Table 3

The Golden Rule of Altitude Awareness

In most countries, the pilot is responsible for performing the low-OAT correction, except when under radar control in a radar vectoring area; in this case, the controller normally is responsible for terrain clearance, including accounting for the cold temperature correction (when issuing altitude instructions).

Nevertheless, the operator and/or pilot should confirm this responsibility with the air traffic services of the country of operation.

The temperature correction on altitude affects the following published altitudes, which therefore should be **increased** under low OAT operation:

- MEA;
- Airport sector MSA;
- SID / STAR / Approach segments minimum safe altitude;
- SID / STAR altitude constraints;
- Procedure turn / holding minimum altitude;
- FAF altitude;
- Step-down altitude(s) during a non-precision approach;
- MDA(H) during a non-precision (non-ILS) approach;
- DA(H) during a CAT I ILS approach; and,
- OM crossing altitude during any ILS approach (for altitude check purposes).

For RNAV approaches conducted with Baro-VNAV vertical profile navigation, the minimum published altitudes take into consideration (for recent RNAV procedures only) the effect of low OAT down to a minimum indicated on the approach chart.

As it is not allowed to modify manually the altitude constraints of the FMS vertical flight plan, the use of Baro-VNAV procedures is not permitted when the aerodrome temperature is lower than the published lowest temperature for the procedure (Source: PANS-OPS and TERPS) .

Note

However, a conventional RNAV approach (i.e., LNAV only) is permitted below this temperature if :

- *A corresponding RNAV procedure (i.e. LNAV only) and corresponding MDA(H) is published; and,*
- *The appropriate low-temperature correction is applied to all published altitudes (heights), by the pilot.*

ICAO PANS-OPS does not provide altitude corrections for extreme high temperatures.

Note

When operating under extreme high temperature, the temperature effect on the true altitude may result in a steeper-than-anticipated flight-path angle / vertical speed when performing a constant-angle non-precision approach.

XI Operational and Human Factors Involved in Altimeter-setting Errors

The incorrect setting of the altimeter reference often is the result of one or more of the following factors:

- High workload;
- Deviation from normal task sharing;
- Interruptions and distractions; and,
- Absence of effective cross-check and backup between crewmembers.

The analysis of incident / accident reports identify the following operational and human factors as causes of or contributing factors to altimeter-setting errors :

- Incomplete briefings (i.e., failure to discuss the applicable altimeter-setting unit and the country practice for fixed or variable transitions altitudes / levels);
- Workload during descent / approach;
- Distraction / interruption;

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- Language difficulties (unfamiliar accents, speaking pace, unclear contraction of words, mixed English / local language communications, …);
- Failure to cross-check altimeter-setting information (e.g., ATIS versus TWR messages, PF / PNF cross-check);
- Fatigue;
- Confusion between altimeter-setting units (i.e., in.Hg or hPa);
- Excessive number of instructions given by ATC in a single message;
- Confusion between numbers such as 5 and 9 (i.e., if 9 is pronounced as nine instead of **niner**); and/or,
- Incorrect listening associated with ineffective readback / hearback loop (refer to Flight Operations Briefing Note on **Effective Pilot / Controller Communications**).

XII Company Prevention Strategies and Personal Lines-of-Defense

Adherence to the defined task sharing (for normal or abnormal / emergency conditions) and the use of normal checklists are the most effective lines-of-defense against altimeter-setting errors.

Altimeter-setting errors often result in a lack of vertical situational awareness; the following key points should be considered by **pilots** to minimize altimeter-setting errors and to optimize the setting of the barometric-altimeter MDA(H) / DA(H) or radio-altimeter DH:

- Thorough and effective takeoff and approach / go-around briefing (refer to the Flight Operations Briefing Note **Conducting Effective Briefings**);
- Awareness of the altimeter setting unit in use at the destination airport, e.g. :
  - LFBO (Toulouse Blagnac) approach charts :
    - " Alt Set : hPa ",
- Awareness of rapid QNH / QFE changes due to prevailing weather conditions (i.e., extreme cold or warm fronts, steep frontal surfaces, semi-permanent or seasonal low pressure areas);
- Awareness of the anticipated altimeter setting, using two independent sources for cross-check (e.g., METAR and ATIS messages);
- Effective PF/PNF crosscheck and backup;

- Adherence to SOPs for:
  - Sterile-cockpit rule during taxi, takeoff and descent-approach phases;
  - Change of barometric-altimeters setting in climb and descent, for example:
    - in climb: at the transition altitude; and,
    - in descent: when approaching the transition level and when cleared to an altitude;
  - use of standby-altimeter to cross-check main altimeters;
  - altitude callouts (e.g., approach-fix crossing altitudes);
  - including the radio-altimeter in the instrument scan, when the radio-altimeter is "alive" (i.e., below 2500 ft RA);
  - radio-altimeter callouts; and,
  - setting the barometric-altimeter MDA(H) or DA(H) or the radio-altimeter DH.
- Exercising extra vigilance and cross-check if QFE is used for approach and landing.

The following prevention strategies should be considered by **air traffic controllers** :

- Limiting the number of instructions transmitted in a given message;
- Indicating all the numbers and the unit defining the altimeter setting;
- Adhering to the standard phraseology and pronunciation;
- Adopting the accepted terminology "low" before a 28.XX in.Hg altimeter setting and "high" before a 30.XX in.Hg altimeter setting.

XIII Associated Flight Operations Briefing Notes

The following Flight Operations Briefing Notes also refer to altimeter-setting and altitude issues:

- **Operating Philosophy – SOPs**
- **Conducting Effective Briefings**
- **Effective Pilot / Controller Communications**
- **Managing Interruptions and Distractions**
- **Preventing Altitude Deviations**

XIV Regulatory References

- ICAO Annex 3 – Meteorological Service for International Air navigation, Chapter 4.
- ICAO Annex 5 – Units of Measurement to be used in Air and Ground Operations, Table 3-4, 3.2.
- ICAO Annex 6 – Operations of Aircraft, Part I – International Commercial Air transport – Aeroplane, 6.9.1 c) and Appendix 2, 5.13.
- ICAO Annex 6 – Procedures for Air Navigation Services – Rules of the Air and Air Traffic Services (PANS-RAC, Doc 4444).
- ICAO – Procedures for Air navigation Services – Aircraft Operations (PANS-OPS, Doc 8168), Volume I – Flight procedures - Part VI – Altimeter Setting Procedures - Chapter 3 :
  - New table of temperature corrections to be added to altitude when operating in low OAT conditions.

  The new Part VI – Chapter 3 became effective in Nov.2001 (Amendment 11).
- ICAO - Preparation of an Operations manual (Doc 9376).
- ICAO - Manual of Radiotelephony (Doc 9432).
- ICAO - Human Factors Training Manual (Doc 9683).
- ICAO - Human Factors Digest No.8 – Human Factors in Air Traffic Control (Circular 241).
- UK CAA – CAP 710 – Level Bust Working Group – “ On The level ” – Final Report

XV Industry References

- Eurocontrol - Level Bust website :
  - **http://www.eurocontrol.int/safety/LevelBust_LevelBust.htm**
  - Level Bust Tool Kit

- Flight Safety Foundation website – **http://www.flightsafety.org**
  - Flight Safety Digest – November 2004 – RVSM Heightens Need for Precision in Altitude Measurement

- NASA – ASRS website - **http://asrs.arc.nasa.gov/main.htm**
  - *ASRS Directline* bulletin – Issue No.2 – Oct.1991 – International Altimetry
  - *ASRS Directline* bulletin – Issue No.9 – Mar.1997 – The Low-Down on Altimeter Settings

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