# Towards a Common Transition Altitude

## A Flight Deck Perspective

*An evaluation of the impact on flight crew workload, flight deck procedures*
*and safety implications of utilising a common transition altitude in European airspace.*

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# Executive summary

This study evaluates the impact on flight crew workload, flight deck procedures and safety implications of utilising a common transition altitude in European airspace.

Examining the related documentation, it can be seen that the International Civil Aviation Organisation (ICAO) advocates the implementation of a common transition altitude for an ICAO region. The International Federation of Air Line Pilots' Associations (IFALPA) clearly favours a common transition altitude because it finds a diversity in transition altitudes operationally unsatisfactory. IFALPA prefers a round number (10.000 ft or 20.000 ft) for this common transition altitude.

In order to identify the safety aspects related to altimeter setting procedures several studies were examined: the Approach and Landing Accident Reduction (ALAR), Controlled Flight Into Terrain (CFIT) and the "on the level" project (CAP 710).

Due to the variety of transition altitudes, increased vigilance from the flight crew is necessary to ensure that the correct altimeter setting is used. Altimeter mis-settings or omissions might occur when the transition needs to be performed during a period of high flight deck workload. Multiple transition altitudes do pose a safety risk. An obvious solution to reduce the safety risk is the introduction of a common transition altitude over an area as wide as possible.

Altitude awareness is a safety critical factor. A common flight deck procedure or cross-check that eliminates or reduces the altimeter setting errors needs to be established. Flight deck procedures and Instrument Flight Rules (IFR) flight operations that have an impact on or interfere with altimeter setting procedures were examined. The optimal solution is to incorporate the altimeter setting in an associated action that is linked to a Standard Operating Procedure (SOP). This procedure needs to be performed at a well-defined moment and therefore a fixed value for the transition altitude is necessary; hence the need to introduce a common transition altitude. By incorporating the altimeter setting action into a Standard Operating Procedure, a supplementary safety net can be introduced.

It should be clearly understood that altimeter setting is an important procedure that involves not only a physical action, but also a mental process. Altimeter setting is sometimes forgotten during periods of high flight deck workload. In order to determine this workload during the various phases of flight, a survey was conducted. This survey illustrates that, in terms of flight deck workload, a transition altitude below 10.000 ft should be avoided.

To identify the advantages/disadvantages of the various proposed common transition altitudes, three bands were identified: low (below 10.000 ft), medium (around 10.000 ft) and high (well above 10.000ft). For each of these the benefits of a common transition altitude are listed.

The low altitude band is not suitable as a common transition altitude because it is located where the workload during climb and descent is the highest. It also interferes with several procedures that require a number of flight deck actions to be performed and therefore resetting the altimeter might easily be forgotten.

The medium altitude band has clear advantages. It coincides with a period of acceptable workload and setting the altimeter could be incorporated into existing procedures that need to be performed at this time. Also, the majority of initial approach fixes found in the European airspace are set below this altitude band and there is no interference with most IFR flight operations procedures. Only a few high altitude airports within the European airspace need an exception regarding transition altitude. This is acceptable because operating into these airports already requires special training and/or briefing.

A 10.000 ft transition altitude has clear advantages. Firstly, this altitude is already used for the triggering of associated actions and Standard Operating Procedures. Secondly, a transition altitude at 10.000 ft could eliminate the frequent occurrence of altitude miss-hearings with the

10.000/11.000 ft pairing.

The high altitude band also has advantages, certainly in respect of flight deck workload, but to a lesser extent than the medium altitude band. The major drawbacks are: the setting of the altimeter comes too late after take-off and could easily be forgotten; during descent the altimeter setting information might be outdated.

The final conclusion of this study proposes the introduction of a common transition altitude. This altitude should be 10 000 ft throughout European airspace.

## Definitions

***Aerodrome.*** A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

***Aerodrome elevation.*** The elevation of the highest point of the landing area.

***Aeronautical Information Publication (AIP).*** A publication issued by or with the authority of a State and containing aeronautical information of a lasting character essential to air navigation.

***Aircraft.*** Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth’s surface.

***Air traffic.*** All aircraft in flight or operating on the manoeuvring area of an aerodrome.

***Air traffic control clearance.*** Authorization for an aircraft to proceed under conditions specified by an air traffic control unit.

*Note 1.— For convenience, the term “air traffic control clearance” is frequently abbreviated to “clearance” when used in appropriate contexts.*

*Note 2.— The abbreviated term “clearance” may be prefixed by the words “taxi”, “take-off”, “departure”, “en-route”, “approach” or “landing” to indicate the particular portion of flight to which the air traffic control clearance relates.*

***Air traffic control instruction.*** Directives issued by air traffic control for the purpose of requiring a pilot to take a specific action.

***Air traffic control service.*** A service provided for the purpose of:

a) preventing collisions:

b) expediting and maintaining an orderly flow of air traffic.

***Air traffic control unit.*** A generic term meaning variously, area control centre, approach control unit or aerodrome control tower.

***Air traffic management.*** The aggregation of the airborne functions and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations.

***Air traffic service (ATS).*** A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

***Altitude.*** The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).

***Area navigation (RNAV).*** A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

***ATIS.*** The symbol used to designate automatic terminal information service.

***Automatic terminal information service (ATIS***). The automatic provision of current, routine information to arriving and departing aircraft throughout 24 hours or a specified portion thereof:

***Cruising level.*** A level maintained during a significant portion of a flight.

***Elevation.*** The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

***Final approach.*** That part of an instrument approach procedure which commences at the specified final approach fix or point, or where such a fix or point is not specified,

a) at the end of the last procedure turn, base turn or inbound turn of a racetrack procedure, if specified; or

b) at the point of interception of the last track specified in the approach procedure; and ends at a point in the vicinity of an aerodrome from which:

1) a landing can be made; or

2) a missed approach procedure is initiated.

***Flight crew member*****.** A licensed crew member charged with duties essential to the operation of an aircraft during a flight duty period.

***Flight information region (FIR).*** An airspace of defined dimensions within which flight information service and alerting service are provided.

***Flight level.*** A surface of constant atmospheric pressure which is related to a specific pressure datum, 1013.2 hectopascals (hPa), and is separated from other such surfaces by specific pressure intervals.

*Note 1.— A pressure type altimeter calibrated in accordance with the Standard Atmosphere:*

*a) when set to a QNH altimeter setting, will indicate altitude;*

*b) when set to QFE altimeter setting, will indicate height above the QFE reference datum;*

*c) when set to a pressure of 1 013.2 hPa, may be used to indicate flight levels.*

*Note 2.— The terms "height" and "altitude", used in Note 1 above, indicate altimetric rather than geometric heights and altitudes.*

***Height.*** The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

***Human Factors principles.*** Principles which apply to aeronautical design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

***Human performance*****.** Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

***IFR.*** The symbol used to designate the instrument flight rules.

***IFR flight.*** A flight conducted in accordance with the instrument flight rules.

***Inciden*****t.** An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

*Note.— The type of incidents which are of main interest to the International Civil Aviation Organization for accident prevention studies are listed in the ICAO* Accident/Incident Reporting Manual *(Doc 9156).*

***Instrument approach procedure.*** A series of predetermined manoeuvres by reference to flight instruments with specified protection from obstacles from the initial approach fix, or where applicable, from the beginning of a defined arrival route to a point from which a landing can be completed and thereafter, if a landing is not completed, to a position at which holding or en-route obstacle clearance criteria apply.

***Level.*** A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level.

***Missed approach procedure.*** The procedure to be followed if the approach cannot be continued.

***NOTAM.*** A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

***Pressure-altitude.*** An atmospheric pressure expressed in terms of altitude which corresponds to that pressure in the Standard Atmosphere.

***Standard instrument arrival (STAR).*** A designated instrument flight rule (IFR) arrival route linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commenced.

***Standard instrument departure (SID).*** A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of a flight commences.

***Transition altitude.*** The altitude at or below which the vertical position of an aircraft is controlled by reference to altitudes.

***Transition layer.*** The airspace between the transition altitude and the transition level.

***Transition level.*** The lowest flight level available for use above the transition altitude.

***VFR.*** The symbol used to designate the visual flight rules.

***VFR flight.*** A flight conducted in accordance with the visual flight rules.

## Acronyms

| | |
|---|---|
| AIP | Aeronautical Information Publication |
| ALAR | Approach and Landing Accident Reduction |
| ASR | Air Safety Report |
| ASRS | Air Safety Reporting System |
| ATC | Air Traffic Control |
| ATIS | Automatic Terminal Information System |
| ATM | Air Traffic Management |
| CAA | Civil Aviation Authority |
| CAST | Commercial Aviation Safety Team |
| CDA | Continuous Descent Approach |
| CFIT | Controlled Flight Into Terrain |
| CRM | Cockpit Resource Management |
| Doc | Document |
| ECA | European Cockpit Association |
| ECAC | European Civil Aviation Conference |
| ECAM | Electronic Centralized Aircraft Monitoring |
| EFFRA | Engine Failure Flap Retraction Altitude |
| EFIS | Electronic Flight Instrument System |
| EUR | European Region |
| FAA | Federal Aviation Administration |
| FAF | Final Approach Fix |
| FAR | Federal Aviation Regulation |
| FIR | Flight Information Region |
| FL | Flight Level |
| FMS | Flight Management System |
| FOM | Flight Operations Manual |
| FSF | Flight Safety Foundation |
| ft | feet (unit for height/altitude) |
| hPa | hectopascal (standard unit for pressure) |
| ICAO | International Civil Aviation Organization |
| IFALPA | International Federation of Airline Pilots' Associations |
| IFR | Instrument Flight Rules |
| ILS | Instrument Landing System |
| In.Hg | Inches of Mercury |
| ISA | International Standard Atmosphere |
| JSIT | Joint Safety Implementation Team |
| m | meter (standard unit for length) |
| METAR | Aviation routine weather report |
| NAM | North American Region |
| NLR | Netherlands National Aerospace Laboratory |
| NM | Nautical Miles |
| NOTAM | Notices to Airmen |
| OAT | Outside Air Temperature |
| OPS | Operations |
| PANS | Procedures for Air Navigation Services |
| QFE | Field Elevation Atmospheric Pressure |
| QNE | Sea Level Standard Atmosphere Pressure (1013 hPa) |
| QNH | Sea Level Atmospheric Pressure |
| RAN | Regional Air Navigation |
| RNAV | Area Navigation |
| RQRD | Required |
| SID | Standard Instrument Departure |
| SOP | Standard Operating Procedure |
| STAR | Standard Terminal Arrival Route |
| V2 | Take Off Safety Speed |
| VFR | Visual Flight Rules |

# 1 Related documentation

## 1.1 ICAO references

### 1.1.1 Procedures For Air Navigation Services – Aircraft Operations (Doc 8168-OPS/611, Vol. 1)-Flight Procedures

*Chapter 1; Basic requirements*

1.1.2 Transition altitude

1.1.2.1 A transition altitude shall normally be specified for each aerodrome by the State in which the aerodrome is located.

1.1.2.1.1 Where two or more closely spaced aerodromes are so located as to require co-ordinated procedures, a common transition altitude shall be established. This common transition altitude shall be the highest of the transition altitudes that would result for the aerodromes if separately considered.

1.1.2.1.2 As far as possible a common transition altitude should be established:

a) for groups of aerodromes of a State or all aerodromes of that State;
b) on the basis of an agreement, for aerodromes of adjacent States, States of the same flight information region, of two or more adjacent flight information regions or one ICAO region; and
c) for aerodromes of two or more ICAO regions when agreement can be obtained between these regions.

1.1.2.1.3 The height above the aerodrome of the transition altitude shall be as low as possible but normally not less than 900 m (3000 ft)

1.1.2.1.4 The calculated height of the transition altitude shall be rounded up to the next full 300 m (1000 ft).

1.1.2.2 Notwithstanding the provisions in 1.1.2.1, a transition altitude may be established for a specified area, when so determined on the basis of regional air navigation agreements.

1.1.2.3 Transition altitudes shall be published in aeronautical information publications and shown on the appropriate charts.

### 1.1.2 PANS - ATM (Doc 4444 / ATM 501)

*Chapter 4; General Provisions for Air Traffic Services*

4.10 ALTIMETER SETTING PROCEDURES

4.10.1 Expression of vertical position of aircraft

4.10.1.1 For flights in the vicinity of aerodromes and within terminal control areas the vertical position of aircraft shall, except as provided for in 4.10.1.2, be expressed in terms of altitudes at or below the transition altitude and in terms of flight levels at or above the transition level. While passing through the transition layer, vertical position shall be expressed in terms of flight levels when climbing and in terms of altitudes when descending.

4.10.1.2 When an aircraft which has been given clearance to land is completing its approach using atmospheric pressure at aerodrome elevation (QFE), the vertical position of the aircraft shall be expressed in terms of height above aerodrome elevation during that portion of its flight for which QFE may be used, except that it shall be expressed in terms of height above runway threshold elevation:

a) for instrument runways, if the threshold is 2 metres (7 feet) or more below the aerodrome elevation, and
b) for precision approach runways.

4.10.1.3 For flights en route the vertical position of aircraft shall be expressed in terms of:

a) flight levels at or above the lowest usable flight level;
b) altitudes below the lowest usable flight level; except where, on the basis of regional air navigation agreements, a transition altitude has been established for a specified area, in which case the provisions of 4.10.1.1 shall apply.

4.10.2 Determination of the transition level

4.10.2.1 The appropriate ATS unit shall establish the transition level to be used in the vicinity of the aerodrome(s) concerned and, when relevant, the terminal control area (TMA) concerned, for the appropriate period of time on the basis of QNH (altimeter sub-scale setting to obtain elevation when on the ground) reports and forecast mean sea level pressure, if required.

4.10.2.2 The transition level shall be the lowest flight level available for use above the transition altitude established for the aerodrome(s) concerned. Where a common transition altitude has been established for two or more aerodromes which are so closely located as to require coordinated procedures, the appropriate ATS units shall establish a common transition level to be used at any given time in the vicinity of the aerodrome and, when relevant, in the TMA concerned.
*Note.— See 4.10.3.2 regarding the determination of the lowest usable flight level(s) for control areas.*

4.10.3 Minimum cruising level for IFR flights

4.10.3.1 Except when specifically authorized by the appropriate authority, cruising levels below the minimum
flight altitudes established by the State shall not be assigned.

4.10.3.2 ATC units shall, when circumstances warrant it, determine the lowest usable flight level or levels for the whole or parts of the control area for which they are responsible, and use it when assigning flight levels and pass it to pilots on request.
*Note 1.— Unless otherwise prescribed by the State concerned, the lowest usable flight level is that flight level which corresponds to, or is immediately above, the established minimum flight altitude.*
*Note 2.— The portion of a control area for which a particular lowest usable flight level applies is determined in accordance with air traffic services requirements.*
*Note 3.— The objectives of the air traffic control service as prescribed in Annex 11 do not include prevention of collision with terrain. The procedures prescribed in this document do not therefore relieve the pilots of their responsibility to ensure that any clearance issued by air traffic control units is safe in this respect, except when an IFR flight is vectored by radar. See Chapter 8, 8.6.5.2.*

4.10.4 Provision of altimeter setting information

4.10.4.1 Appropriate ATS units shall at all times have available for transmission to aircraft in flight, on request, the information required to determine the lowest flight level which will ensure adequate terrain clearance on routes or segments of routes for which this information is required.
*Note.— If so prescribed on the basis of regional air navigation agreements, this information may consist of climatological data.*

4.10.4.2 Flight information centres and ACCs shall have available for transmission to aircraft on request an appropriate number of QNH reports or forecast pressures for the FIRs and control areas for which they are responsible, and for those adjacent.

4.10.4.3 The flight crew shall be provided with the transition level in due time prior to reaching it during descent. This may be accomplished by voice communications, ATIS broadcast or data link.

4.10.4.4 The transition level shall be included in approach clearances when so prescribed by the appropriate authority or requested by the pilot.

4.10.4.5 A QNH altimeter setting shall be included in the descent clearance when first cleared to an altitude below the transition level, in approach clearances or clearances to enter the traffic circuit, and in taxi clearances for departing aircraft, except when it is known that the aircraft has already received the information.

4.10.4.6 A QFE altimeter setting shall be provided to aircraft on request or on a regular basis in accordance with local arrangements; it shall be the QFE for the aerodrome elevation except for:

a) non-precision approach runways, if the threshold is 2 metres (7 feet) or more below the aerodrome elevation, and
b) precision approach runways, in which cases the QFE for the relevant runway threshold shall be provided.

4.10.4.7 Altimeter settings provided to aircraft shall be rounded down to the nearest lower whole hectopascal.
*Note 1.— Unless otherwise prescribed by the State concerned, the lowest usable flight level is that flight level which corresponds to, or is immediately above, the established minimum flight altitude.*
*Note 2.— The portion of a control area for which a particular lowest usable flight level applies is determined in accordance with air traffic services requirements.*
*Note 3.— See Foreword, Note 2 to paragraph 2.1.*

### 1.1.3 Air Traffic Services Planning Manual (Doc 9426-AN/924)

*Part II; Section 5; Chapter 1; Altimeter Setting Procedures.*

1.1 Establishment of the transition altitude

1.2 The basic principles for the establishment of the transition altitude are contained in Introduction

1.2.1 Altimeter setting procedures are contained in the *Procedures for Air Navigation Services – Aircraft Operations (Doc 8168, Volume I)* and the *Regional Supplementary Procedures (Doc 7030).* These documents should be used by States when specifying their altimeter setting procedures including the establishment of minimum flight levels, transition altitudes and methods for determination of transition levels.

1.2.2 The basic method used in providing adequate separation between aircraft and adequate terrain clearance during all phases of flight is based on a number of basic principles. Those principles are outlined below:

a) during flight, when at or below a fixed altitude (called the transition altitude), an aircraft is flown at altitudes determined with the aid of an altimeter set to sea level pressure(QNH) and its vertical position is expressed in terms of altitude;
b) during flight above the transition altitude an aircraft is flown along the surfaces of constant atmospheric pressure based on an altimeter setting of 1013,2 hPa (1013,2 mb). Throughout this phase of flight, the vertical position is expressed in terms of flight levels; Where no transition altitude has been established for the area, aircraft in the en-route phase shall be flown at a flight level;
c) when climbing, the change in reference from altitude to flight levels is made at the transition altitude and when descending the change from flight level to altitude is made at the transition level;
d) during any phase of a flight adequate terrain clearance may be maintained in any of several ways, depending upon the facilities available in a particular area. The recommended methods in the order of preference are:
    1) the use of current QNH reports from an adequate network of QNH reporting stations;
    2) the use of such QNH reports as are available, combined with other meteorological information such as forecast lowest mean sea level pressure for the route or portions thereof;
    3) where relevant current information is not available, the use of the lowest altitude values of flight levels which have been derived from climatological data;
e) during the approach to land, terrain clearance may be determined by using the QNH altimeter setting (giving altitude) or, under specified circumstances a QFE setting (giving the height above the point to which the QFE is related, e.g. the runway threshold).

1.1.3 The method provides sufficient flexibility to permit variation in detailed procedures which may be required to account for local conditions, without deviating from the basic procedures.

1.2.3 Doc 8168 Volume I, Part VI.
Preferably a common transition altitude should be established for groups of aerodromes, aerodromes in adjacent States or for a specified area when so determined on the basis of a regional air navigation agreement.

1.2.4 The selection of a transition altitude will be governed by the following factors:
a) the amount of traffic operating in the lower airspace;
b) the types and performance categories of aircraft;
c) the ratio of level flights to those climbing and descending in the same airspace;
d) the terrain configuration;

e) the departure and arrival procedures including noise abatement procedures;
f) variation in the route distances involved and thus variation in cruising levels required;
g) the rate of change in barometric pressures and the range of fluctuation along air traffic services (ATS) routes within a certain area;
h) the infrastructure for the provision of area QNH; and
i) the existence of other aerodromes in the vicinity.

The ICAO reference material gives the States a rather broad choice to determine the transition altitude.

The paragraph 1.1.2.1.3 PANS-OPS, Aircraft Operations, Volume I, states that *the height above the aerodrome of the transition altitude shall be as low as possible but normally not less than 900 m (3000ft).* Therefore most of the transition altitudes found in the ECAC airspace are altitudes below 10,000 ft. Only in mountainous areas transition are altitudes higher than 10.000 ft found. The airport of Sion, Switzerland has the highest transition altitude, 16.000 ft. Some States publish transition altitudes below 3000 ft.

Paragraph 1.1.2.1.4 states that *the calculated height of the transition altitude shall be rounded up to the next full 300 m (1000 ft).* Several discrepancies can be found, e.g. Belgium (4500 ft), Croatia (9500 ft), Clermont-Ferrand and Bastia airport (5500 ft and 6200 ft respectively).

Several airports have different transition altitudes depending on direction, e.g. Lugano airport has 2 different transition altitudes (6000 ft and 8500 ft).

## *1.2 IFALPA/ECA policy*

The International Federation of Air Line Pilots' Associations (IFALPA) represents in excess of 100.000 pilots and flight engineers in more than 90 countries world-wide. The mission of IFALPA is to be the global voice of airline pilots, promoting the highest level of aviation safety world-wide and providing services, support and representation to all of its Member Associations. The European Cockpit Association (ECA) is the regional sister organisation of IFALPA.

IFALPA mirrors its policies with the ICAO annexes, PANS-OPS and PANS-ATM documents. IFALPA strongly supports the introduction of a common transition altitude. The IFALPA policy relates to the applicable ICAO PANS-OPS, Volume I, Part VI, Chapter 1, Basic Requirements and reads as follows:

> IFALPA is in agreement with the evident underlying intent throughout section 1.1.2 to eventually establish common transition altitudes over wide areas of the world. However, IFALPA also finds that the language of many of the subsections of 1.1.2 has an effect counter to the underlying intent, in that it supports the wide diversity of transition altitudes around the world. This diversity is operationally unsatisfactory for IFALPA as it gives rise to serious flight operational problems and even airmisses. IFALPA recommends the establishment of a common transition altitude within each State and, where possible, within each ICAO region. Given that standardisation is an essential goal in itself and having regard to the basic requirement to apply the standard altimeter setting of 1013,2 hPa in the maximum possible airspace, a standard transition altitude must, of necessity, take account of the appropriate terrain configuration, availability of reliable area QNH, character of air traffic and performance characteristic of modern aircraft. To reduce diversity and introduce a rational system that respects of the performance and modes of operation of present aircraft equipment, the choice of transition altitudes should be limited to 10.000 or 20.000 feet.

# 2 Present environment

## 2.1 History of the transition altitude introduction in Europe

The rise in traffic during the late fifties and the advent of the jet aircraft (Comet, Caravelle and the Boeing 707), together with the presence of military jet aircraft, introduced problems with vertical separation. The new jets were travelling at speeds twice the previous generation. The use of QNH as the vertical reference was no longer satisfactory because of transition problems at the boundaries of designated QNH areas between aircraft operating at adjacent levels but in opposite direction. Also the frequent change of altimeter settings as the flight progressed was no longer feasible. ICAO introduced a new system of altimetry for use during the enroute portion of flight. It was based on the use of a standard altimeter setting of 1013,2 hPa, and the corresponding altitudes were called flight levels. At the higher altitudes, in order to compensate for the inaccuracies of the altimeter system, it was decided to increase the separation between aircraft from 300 m (1000 ft) to 600 m (2000 ft). The introduction of this system throughout the European area was decided at the Fourth Regional Air Navigation (RAN) Meeting for the European Mediterranean Region, which was held early in 1958 at Geneva, Switzerland. For aircraft landing and departing, the QNH or QFE setting would be used. During the en-route portion of the flight, the aircraft would all use the same altimeter setting, QNE or 1013,2 hPa. Hence all the aircraft would use the same reference setting and vertical separation would therefore be assured. Throughout Europe, different transition altitudes were established. The USA and Canada however applied a common transition altitude of 18.000 ft.

## 2.2 Multiplicity of transition altitudes

The altimeter setting procedures can be found in the States' Aeronautical Information Publication (AIP), section ENR 1.7. A limited review of the applicable altimeter setting procedures was conducted. Various differences were noted.

Some countries apply the concept of Altimeter Setting Region, e.g. the UK and the Netherlands. The UK for instance is divided into different Altimeter Setting Regions for each of which the National Meteorological Office calculates the lowest forecast QNH (Regional Pressure Setting) for each hour. These values are available hourly for the period H+1 to H+2 and may be obtained from all the aerodromes having an Air Traffic Service, from the London, Manchester and Scottish ACC´s or by telephone to any of these agencies.

The Netherlands has it's airspace divided into four Altimeter Setting Regions. The QNH of the airports of Schiphol, Maastricht, Aachen and of two off-shore platforms is used. VFR and IFR traffic have a different transition altitude (3500 ft and 3000 ft respectively).

Belgium uses the term Regional QNH as sole reference for the enroute portion of a flight below the transition altitude. This means that the lowest value is taken from a certain number of reporting stations.

Switzerland is divided into three Altimeter Setting Regions: Zurich, Geneva and Ticino.

Norway includes the ICAO table for the altimeter correction when operating in extreme cold temperatures. It does not apply the Altimeter Setting Region concept. For terrain clearance, the QNH of the nearest aerodrome along the route should be used. These are available from all the controlled aerodromes and from aerodromes where flight information services (AFIS) are provided.

Belgium and Germany have one value for the transition altitude, although Belgium uses 4500 ft which doess not conform with ICAO PANS-OPS (Doc 8168-Ops/611, Volume I- Flight Procedures) Part VI, 1.1.2.1.4 *The calculated height of the transition altitude shall be rounded up to the next full 300 m (1 000 ft).*

Not all the countries have a transition layer of minimum 1000 ft. France has a transition layer that varies between 0 and 299 m (0 and 999 ft).

The multiplicity of not only the transition altitudes, but also the differences in State applications make the European environment very complex. Non-uniformity of the transition altitude and the associated procedures can give rise to confusion for the flight crew.

As conclusion it can be stated that a common transition altitude and the associated procedures would vastly reduce the number of errors.

From a flight crew perspective this situation is far from ideal. Normally, every pilot needs to be aware of the local procedures that are in force of the airport he/she is operating into. However from a practical point this is unrealistic. Few pilots will consult the national Aeronautical Information Publication (AIP) before commencing the flight. The information that the flight crew gets is based upon company documentation. The differences are so diverse that for the flight crew it is impossible to have a thorough knowledge of the local procedures that are in force. A uniformly applied transition altitude across Europe would vastly improve the flight crew awareness regarding these procedures and consequently, safety.

# 3 Safety issues

## *3.1 Level bust*

The UK CAA conducted a study the results of which are captured in CAP710 “On the level”. This project ran from early 1998 to the end of 1999. Its aim was *to identify, monitor and analyse common causal and circumstantial factors for UK level busts and to make appropriate recommendations for safety improvements.* The findings were summarised under five headings:

- Standard instrument departures (SID´s)
- Auto-pilot problems
- Altimeter Setting
- Pilot handling
- Standard Operating Procedures (SOP´s)

Level busts, in the category “altimeter settings” are defined as aircraft climbing to a flight level without first setting the altimeter to the Standard Pressure setting and aircraft descending to an altitude without resetting the altimeter to a QNH value.

The report states: *in the UK the altitude at which the crews have to change altimeter setting from QNH to Standard Pressure corresponds to the period of highest workload in the cockpit.*

The recommendation reads: *the transition altitude should be raised to a significantly higher value (e.g. 18,000 ft) and ultimately this should be common throughout Europe.*

Another issue raised in this study was *that in the UK most SID´s end on an altitude but some end on a flight level. This requires an altimeter setting change during a period of often intense workload.* The recommendation reads: “*consideration should be given to ensuring that all SID´s end on an altitude”.* We can also remark that the Heathrow departures all end at the transition altitude, giving rise to possible mis-setting of altimeter reference. A search of a number of SID´s throughout Europe revealed that the first stop altitude varies from either an altitude below the transition altitude, at the transition altitude or an initial flight level. This can give rise to confusion and mis-setting of the altimeter reference setting and thus lead to a level bust.

## *3.2 ALAR*

The Flight Safety Foundation (FSF) Approach and Landing Accident Reduction (ALAR) Task Force was established as a follow-up to the activities on CFIT and ALAR that started in 1991. These initiatives were conducted in co-operation with the International Civil Aviation Organisation and the International Air Transport Association. Important recommendations to prevent CFIT accidents were published in FSF publications. The ALAR objectives are to reduce the Approach and Landing Accidents by 50% within 5 years of issuing the final recommendations in 1999.

Airbus Industries published a brochure called “Getting to Grips with Approach and Landing Accident Reduction”. It provides operational recommendations and guidelines to implement the conclusions and recommendations of the Flight Safety Foundation CFIT and ALAR Task Force and the U.S. Commercial Aviation Safety Team (CAST)-Joint Safety Implementation Team (JSIT) for ALAR. This brochure contains 8 chapters and is tailored for Airbus operators. Chapter 3 deals with *Altimeter and Altitude Issues.*

Several key points in this chapter make reference to altimeter setting issues. It is stated that *the incorrect setting of the altimeter reference often is the result of one 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 ALAR brochure also points out the problems associated with variable transition altitudes: *depending on the airline's / flight crew's usual area of operation, changing from fixed transition altitudes to variable transition altitudes may result in a premature or late setting of the altimeter reference. An altitude constraint (expressed in terms of FL in climb or expressed in terms of altitude in descent) may advance or delay the change of the altimeter reference and cause crew confusion.*

This is clearly an argument to introduce a common transition altitude.

The awareness of altimeter setting changes due to prevailing weather conditions is discussed, especially the operation into areas with low Outside Air Temperature (OAT).

Anotherpoint of interest of this study is the flight level or altitude confusion. The ALAR brochure highlights the possible confusion that can exist between FL 100 and FL 110 (or between 10.000 ft / 11.000 ft). Readback, hearback errors lead to confusion because of these similar sounding phrases. This item will be an argument for the possible selection of the value of the transition altitude. The ALAR study and brochure delivers arguments in favour of a common transition altitude.

## *3.3 CFIT*

The Netherlands National Aerospace Laboratory (NLR) published a report on factors associated with Controlled Flight Into Terrain (CFIT) accidents involving commercial operators. The report focused on 156 CFIT accidents that occurred from 1988 through 1994.

The accident records suggest that accidents rarely have a single cause but, instead, are the result of a series of contributory factors. One of the causal factors in CFIT is altimeter setting error. Incorrect altimeter settings can lead to level busts, approach and landing accidents and CFIT. According to the NLR CFIT study: "*The incorrect setting or reading of the barometric altimeter has been associated with 3,2% of the investigated CFIT accidents*" (this is 20% of the accidents where related data was known). One knows about the accidents, one knows about some incidents, but no one can guess about the numerous occurrences, not leading to fatalities but slumbering and waiting for the right combination to make the worst happen.

The loss of vertical altitude awareness has been proven to be a major cause of CFIT accidents. During the last decade, various "Altitude Awareness Programs" have been set up by many airlines. Reporting systems now focus on the detection of those underlying smaller incidents that did not lead to disaster by pure luck or the coincidental combination of factors. Errors associated with the use of the barometric altimeter and its settings remain a problem that is compounded by language, non-standard phraseology and the use of different units of measurement (In.Hg or hPa). They all contribute to a possible loss of altitude awareness.

Standardisation and the creation of Standard Operating Procedures (SOP's) are a powerful tool to eliminate errors. However, it is difficult to develop SOP's in an environment that is not standardised. A special report of the Flight Safety Foundation, investigating approach-and-landing and controlled flight into terrain accidents concludes: "*Because transition altitudes and transition levels vary by country and terminal area, pilots should exercise increased vigilance to ensure the proper altimeter reference is set*".

## *3.4 Altimeter errors*

The accuracy of the altimeter systems onboard aircraft are subject to errors. Errors related to the non-standard temperatures of the atmosphere, non-standard atmospheric pressure, aircraft static pressure systems and the instrument error.

# 4 Meteorological issues

## 4.1 Cold temperatures

The pressure altimeter systems are calibrated for International Standard Atmosphere (ISA). Variations in air temperatures from the ISA results in errors. Any deviation from the (ISA) will therefore result in an erroneous reading on the altimeter. The altimeter error may be significant under conditions of extremely cold temperatures. When the temperature is lower than ISA, the altimeter reading will be higher than the actual altitude. As a result, the pilot may not be aware that the aircraft is below the safety altitude. A correction needs to be applied (approximately 4% for every 11 °C difference that the average temperature of the air column between the aircraft and the ground differs from the average temperature of the ISA for the same air column). A table with the corrections that need to be applied can be found in PANS-OPS, Vol. I, Part III, Chapter 3.5.4.5.2. *(Example: Aerodrome temperature –30°C; Height of altimeter setting source 1500 ft; results in a value to be added by the pilot to the published altitude: 240 ft.)*

## 4.2 Mountain waves

Mountain waves can result in altimeter errors due to the effect of the pressure drop. This can result in an altimeter error by as much as 3000 ft (A.I.P. Canada, AIR 1.5.8). In mountainous area, the obstacle clearance margin is increased to compensate for this phenomenon.

## 4.3 Low and high pressure regions

When using a particular QNH value, the indicated altitude might become erroneous when the altimeter setting is not updated along the route. This can result in a change of up to 800 ft for each 400 NM distance in extreme cases of steep pressure gradient. However, average change in QNH along the route is much lower.

## 4.4 Conclusion

It is important to understand all possible altimeter errors. Altimeter errors can lower the real height of the transition altitude above the surrounding terrain below acceptable safety margins. Particularly low transition altitudes can cause a safety risk, because the flight crew may be given a false indication of true height above terrain.

# 5 IFR Flight operations

## 5.1 Altimeter setting information

The flight crew can get the altimeter setting information from the Automatic Terminal Information System (ATIS) or on first contact with ATC. If the flight crew reports the receipt of the ATIS message, he/she needs to include the QNH thereby allowing ATC to check whether the flight crew has the correct QNH value.

At top of descent the QNH and the transition level are available from the ATIS or are communicated to the flight crew by ATC. The QNH value is again transmitted to the flight crew when he/she is cleared down to an altitude below the transition level (*e.g. descend to altitude 4000 feet QNH 1021*). During the approach, which is a period of high workload, this altimeter setting information may be misheard or not set at all, causing a potentially unsafe situation. Resetting the altimeter during a period of less workload would reduce the potential for errors.

## 5.2 First Stop Altitudes on Standard Instrument Departures

A review of a number of Standard Instrument Departures (SID´s) has shown a broad range of initial or first stop altitudes. Some are low and below the transition altitude, some coincide with the transition altitude while others are situated above the transition altitude and hence expressed in flight levels. On a number of SID´s there are no altitude restrictions

The first stop altitude is of the utmost importance when performing the SID. It will be briefed before departure and it will add to the workload when a level off needs to be performed at lower altitudes. This workload will be compounded with ATC instructions and flight deck tasks. When the first stop altitude coincides with the transition altitude, a potentially hazardous situation might result. As an example: if the flight crew changes to QNE and levels off at the first stop altitude, a level bust will result if the QNH value is higher than 1013,2 hPa.

It should be clear that an altimeter setting change at low altitudes increases the already high workload. Different transition altitudes at different airports further complicates this and will therefore increase the possibility of mis-setting the altimeter. Safety would be improved by having all the first stop altitudes below the transition altitude.

## 5.3 Noise abatement procedures

Two types of noise abatement procedures are defined by ICAO, procedure A and B. Procedure A results in noise relief during the latter part of the procedure whereas procedure B provides relief during that part of the procedure close to the airport. The procedure selected for use will depend on the noise distribution required and the type of aeroplane involved.

Description of the noise abatement procedures:

- *Procedure A*
  *Take-off to 450 m (1500 ft) above aerodrome elevation:*
    *Take-off power*
    *Take-off flap*
    *Climb at V2 + 20 to 40 km/h (V2 + 10 to 20 kt)(or limited by body angle)*
  *At 450 m (1500 ft):*
    *Reduce thrust to not less than climb power*
  *450 m (1500 ft) to 900 m (3000 ft):*
    *climb at V2 + 20 to 40 km/h (V2 + 10 to 20 kt).*
  *At 900 m (3000 ft)*
    *Accelerate smoothly to en-route climb speed with flap retraction on schedule.*

- *Procedure B*
  *Take-off to 300 m (1000 ft) above aerodrome elevation:*
  *Take–off power/thrust*
  *Take-off flap*
  *Climb at V2 + 20 to 40 km/h (V2 + 10 to 20 kt)*
  *At 300 m (1000 ft)*
  *Maintaining a positive rate of climb, accelerate to zero flap minimum safe manoeuvring speed (Vzf) retracting flap on schedule:*
  *thereafter, reduce thrust consistent with the following:*
    a. *for high by-pass ratio engines reduce to normal climb power/thrust;*
    b. *for low by-pass ratio engines, reduce power/thrust but not less than necessary to maintain the final take-off engine-out climb gradient; and*
    c. *for aeroplanes with slow flap retracting reduce power/thrust at an intermediate flap setting;*
  *thereafter, from 300 m (1000 ft) to 900 m (3000 ft):*
  *continue climb at not greater than Vzf + 0 km/h (Vzf + 10 kt)*
  *At 900 m (3000 ft)*
  *Accelerate smoothly to en-route climb speed*

The noise abatement procedures are in force at the majority of the major European airports. Either of the procedures will be used depending on the vicinity of populated areas. These noise abatement procedures do increase the flight crew workload, as these need to be performed at a critical phase of the flight and close to the ground. Thrust and configuration changes are involved at precisely described altitudes. If the transition altitude coincides with one of the noise abatement altitudes, this can cause confusion and a possible omission of an action that needs to be performed at a critical stage of the departure. It is therefore advisable to have a transition altitude situated well above all the noise abatement procedure altitudes, so that the critical actions associated with resetting of the altimeters and the noise abatement procedures, can be dealt with separately.

### *5.4 RNAV and Continuous Descent Arrivals*

Continuous Descent Arrivals (CDA) were developed to save fuel during the arrival phase. The intention is to have the arriving aircraft execute a continuous descent without having to level-off. The engines remain at idle during the descent resulting in fuel saving and noise reduction. With the advent of RNAV procedures, the arrival procedures will be matched with the continuous descent profiles. The onboard FMS can be programmed to fly the arrival profile accurately not only in the horizontal but also in the vertical plane. In order to have an exact reference for the vertical plane, it is advantageous to have the QNH reference so that the exact height that has to be lost during the approach can be constantly monitored by the flight crew.

Ideally, CDA’s should be commenced as high as possible but this may not be feasible due to ATC operational constraints. An intermediate height would be feasible. It would also be better to have the altitude reference set to the QNH value at the start of the continuous descent. Then the entire descent could be made by reference to this value and the necessary descent and approach checklists could be completed. It should be noted that during a continuous descent the trigger for the crew to change the altimeter setting is lost. Therefore, it is preferable to have the QNH value set at the start of the continuous descent.

### *5.5 Altimeter Setting Regions/Regional QNH*

During en-route flight below the transition altitude, the QNH altimeter setting is used to ensure adequate terrain clearance. As the flight may not receive the QNH related to an aerodrome, it has to use a particular QNH value that is consistent for the flight. In certain European States the concept of the regional QNH is applied. For a certain region, e.g. a FIR, several values of the QNH are measured. The lowest value of the QNH will be used as the regional QNH. This value will be taken in order to provide the best margin for terrain clearance. When the aircraft uses the regional QNH and is flying at an altitude determined by the semi-circular system, it will apply the same reference as the other aircraft thus ensuring vertical separation (in the UK, outside Controlled Airspace, the Quadrantal Rule is in force for traffic operating at/below FL 245. Above FL 250 the Semi-circular rule is in force). When transitioning between regions that apply different QNH settings, the flight crew needs to get the regional QNH value before or upon entry in order to have the same reference setting to ensure vertical separation with the other traffic flying along the levels determined by the semi-circular system. This could be done upon first contact with the ATS unit. Frequent resetting of the altimeter increases workload for the flight crew. So it would be advisable to implement larger regions that apply the same QNH. The major drawback of greater regions is that the altitude error related to an incorrect QNH value could become greater.

A system whereby the flight crew uses the altimeter setting provided by ATC along the route could also be used. This system is used in the US and Canada. It is a straightforward system and does not induce separation infringements. The FAA order imposes an altimeter setting from a station along the route of flight within 100 NM if one is available. The ATS unit shall issue the setting of the nearest reporting station along the route of the flight. It is also normal that the setting of an adjacent station would be communicated to the flight crew during periods that a steep pressure gradient exists. This means that the flight crew can use the most current setting for their position.

In Canada the following rule for the en-route flights applies: *during flight the altimeter shall be set to the current altimeter setting of the nearest station along the route of flight or, where such stations are separated by more than 150 NM the nearest station to the route of flight.*

Smaller regions would imply more frequent altimeter setting changes and are therefore less desirable. The gain in accuracy would be outstripped by the increase in workload for the flight crew.

By raising the transition altitude, more flights would be using the enroute altimeter reference system. From a flight crew perspective it is preferable to make small changes while transiting the regional QNH setting airspace than to change from a QNH to a QNE setting when en-route and transiting between regions that have a different transition altitudes. This could mean that a flight uses the regional QNH altimeter setting in one region and then has to change to QNE setting in the adjacent region because it will be transiting above the transition altitude in the next region/sector. For safety and workload reasons, multiplicity in transition altitudes is clearly undesirable.

The number of flights at lower cruising altitudes is very low compared with the total amount of traffic. Nevertheless the effect of a common transition altitude on flight deck workload has to be considered. Flight crew cruising below the transition altitude have to deal with altimeter setting changes when transiting through different pressure gradients. While the average pressure gradient in Europe is rather low, there are cases where it can reach higher values. This is why flight levels were introduced when fast jet-traffic was introduced. For low flying traffic, the regional QNH can decrease the number of altimeter setting changes along the route.

Frequent altimeter setting changes are less disruptive  for crews of slower aircraft . In the choice of a transition altitude, it is particularly important to consider the jet traffic because of the high transit speeds through differing pressure gradients.

The change of altimeter setting from one QNH value to another is less time consuming, and requires less mental adjustment, compared with the switching from an altitude to a level and vice versa. The altitude awareness and mental picture for the flight crew does not change when resetting the altimeter by a few hectopascal. Moreover, altimeter cross-checks are not required in this case.

On the other hand, the constant changing and reversing between altitude and flight level is far more time consuming and adverse to safety. A common transition altitude eliminates this risk.

# 6 Flight Deck Procedures

## *6.1 Phases of flight*

### 6.1.1 Preflight

At the preflight stage, the crew shall gather all the necessary information in order to plan the flight. The meteorological information is not only required, but also indispensable in order to create the awareness of altimeter setting changes with the prevailing weather conditions (extreme cold or warm fronts, steep frontal surfaces, semi-permanent or seasonal low pressure areas). The altimeter setting (and unit) at the departure and destination is derived from METAR information and usually noted for later independent cross-check with the ATIS.

Information on transition altitudes can be found in the AIP or the equivalent private airway manuals. The transition altitude will be included in the departure briefing together with other relevant altitudes.

### 6.1.2 Instrument setup

The QNH is set on all altimeters (normally 2 plus 1 standby). Basically, two altimeter checks are performed at this stage. First the mechanism check enables the test of the correct movement of needles and drums. A comparison between the different altimeters on the flight deck is made. This check is not performed on electronic systems. Secondly the accuracy check is performed at or near the runway threshold. A comparison is made between each altimeter and the published threshold elevation.

### 6.1.3 Taxi

At start of taxi, the preset QNH is compared with the reported QNH given by the control tower. In the absence of this information (uncontrolled aerodromes), the altimeters are set to the published airport elevation. The approximate QNH is derived from this setting.

### 6.1.4 Climb

When reaching the transition altitude, after announcing, both pilots set the altimeter to QNE value. It should be noted that other flight procedures such as acceleration towards climb speed prevail. Whenever a transition altitude coincides with other duties which demand priority, the altimeter setting will be done initially by the pilot non-flying, and when workload permits, by the pilot flying. This is an important deterrent to levelling off in close proximity to the transition altitude (see section 5.2).

It is important to note that there is no ATC instruction or other reminder that triggers the altimeter setting change, unlike during the arrival stage. This action depends solely on the recall of the flight crew and should therefore be well prepared before departure.

After the setting of QNE, the barometric altimeters (2 main and 1 standby instrument) are cross-checked by the flight crew. Both the setting and the altitude indication are compared. Some airline’s standard operating procedures ask for a repetition of this check at 10.000, 20.000 and 30.000 ft.

### 6.1.5 Cruise below transition altitude

Flights cruising at an altitude below 18.000 ft are a minority of the total traffic volume in European airspace. The number of altimeter settings that have to be performed depends on the pressure gradient of the area that is overflown and of the dimension of the altimeter setting regions. Each frequency change is accompanied with an update of the altimeter setting. Since altimeter settings normally differ only by one or two hPa, this resetting does not require as much

attention as a transition between QNH and QNE reference settings. In the former case, altimeter cross-checks, as described in 6.1.4 are not performed.
Altimeter settings should be provided by ATC, at first contact with each sector. This is not systematically done. It is important to understand that the omission of altimeter setting information, intended to limit communications often leads to the opposite effect when crews have to request that information. This leads to a significant increase in communications and can be avoided by systematically providing the information.

### 6.1.6 Descent

Prior to descent, the transition level and the expected altimeter setting are obtained from the ATIS or the appropriate ATS unit.

Contrary to climb, the altimeter setting action is triggered by the ATC clearance to descend to an altitude while flying at a flight level. This ATC clearance includes the new altimeter setting which can be set immediately. This results in fewer omissions, provided that the descent is started without delay. According to PANS-OPS Vol I, Chapter 1, 1.4.3.1., the altimeter may be set before passing the transition level, provided that level flight above transition altitude is not anticipated. This early setting is normally done to avoid omission and mis-settings.

During descent a cross-check of all barometric altimeters is made, regarding setting and indication. At 2500 ft above ground, when the radio altimeters start indicating, a comparison with the barometric altimeter can be made. During precision approaches, when flying on the correct vertical profile, the altimeter reading can be compared with the published altitudes. In this way, the temperature errors and altimeter setting errors can be discovered before they become critical. This check is not possible on non-precision approaches, since there is no vertical guidance available.

### 6.1.7 Missed approach

A missed approach is a very intense maneuver. The flight crew should be prepared to start a missed approach at all times during the approach phase. But the missed approach rate is rather low (1/300) and therefore the crew is less familiar with this maneuver. During the missed approach, the crew has to perform every single action performed during a normal take off and departure but in much less time. Departure routes are much longer and better prepared and fully programmed in the FMS. During a missed approach extra attention and concentration is needed. Therefore it is clear that altimeter resetting should be avoided. For the same reasons as mentioned in chapter 5.2., it is safety critical that missed approach procedures should be designed entirely below the transition altitude.

### 6.1.8 Conclusion

The altimeter setting is briefed, discussed and executed many times during the succeeding flights of a duty period. Omissions and mis-settings happen very often. This usually has no consequences because the error is discovered in time by ATC, flight crew cross-checks and safety nets. The altimeter setting errors are “under-reported” and prove to be a dormant danger for level bust and CFIT. It is recognized by Airbus and Flight Safety Foundation that the use of variable settings and the changing from fixed to variable transition altitudes may result in premature or late setting of the altimeter reference.

## *6.2 Workload*

The altimeter setting procedure consists of multiple actions, especially during descent. After the setting of the altimeter instrument itself, some checks are performed. The value is compared with the expected value, obtained during pre-flight or in flight through weather broadcasts. Both altimeters are cross-checked. This is a co-ordinated action which requires the simultaneous attention of both crew members. The approach minima may have to be adjusted accordingly. This is a thinking process that requires considerable amount of attention.

After the altimeter setting for the approach is performed, the mental altitude awareness process can start taking place. The focus starts to shift towards the approach and landing. It is at this stage that temperature errors start to get the attention of the crew.

It can be concluded that an altimeter setting comprises more than a single action and should be performed well outside the critical phases of flight, where this can more easily be done with the proper safeguards.

## *6.3 Flight crew briefings*

Flight crew briefings can be divided into 2 categories, take-off and approach briefings. A briefing will cover the necessary actions that will be performed and ensure that all the crewmembers are aware of the actions and procedures that are about to happen and in what sequence. During the take-off briefing the following items are discussed:

- Who will be the pilot flying
- Flap setting
- Reduced or full Take-off thrust
- Taxi routing
- Performance limitation
- Runway condition
- Non-normal actions, e.g. engine failure procedure, holding altitude, obstacles in the departure route, overweight landing , landing runway, ...
- First stop altitudes
- Transition altitude
- Safety altitudes (MSA, Minimum Enroute Altitude, obstacles, ...)

The transition altitude and the First Stop Altitude are related items. These values need to be reminded by the crewmembers throughout the departure phase. In case of multiple sectors that need to be performed by a crew on a typical day in the European airspace, this might lead to confusion and possible misinterpreting of the transition altitude. Therefore it is recommended to use a common transition altitude.

The approach briefing will cover the following items :

- Aircraft status (any malfunctions, inoperative items, performance related items, aircraft weight)
- Fuel status (fuel remaining, available holding fuel, minimum diversion fuel)
- ATIS review (runway in use, STAR, altimeter setting, transition level, weather)
- NOTAMS review affecting the approach guidance, taxi, works in progress)
- Altitudes review (Safe altitudes, initial approach altitude, glide slope intercept altitude, outer marker altitude, minima, threshold altitude and go around altitude)
- Review of the approach elements
- Runway lighting, length and width.
- Taxiway and apron particularities

The transition level is broadcast by the ATIS (Automatic Terminal Information System). It is mentioned during the briefing and compared with the approach charts in order to have a mental picture of the vertical altitude reference. Again, an altitude figure needs to be remembered, which is unique for every approach and not common throughout Europe.

A common transition altitude would trigger this automatically as the aircraft descends through the uniformally applied transition level.

## *6.4 Use of FMS*

The introduction of (Flight Management System) FMS opened a lot of possibilities in terms of prediction and planning. To make those predictions, it is necessary to provide the FMS with all the required data, such as QNH and transition altitude. The FMS mainly uses this data for calculation of the vertical profile and for the automation of cabin pressurization during descent. Another feature is to provide a warning to the flight crew when the transition altitude has been crossed (climb or descent) and the altimeters have not been set. In all cases, the altimeter setting is still performed separately. However, a caution can be generated when the setting does not agree with the value in the FMS. This creates a safety-net.

The advantage of FMS is that the input of the parameters can be done well in advance, during a period of low workload such as cruise or in the preflight phase.

### *6.5 Standard Operating Procedures and Associated Actions*

Many studies show that airlines with established, well thought out and implemented standard operating procedures (SOP) have consistently safer operations. Clear, concise, and understandable SOP’s need to be developed by each airline. Through these procedures and behaviours, the airline sets the standards that the flight crews are required to follow.

Standard operating procedures (SOP´s) have also been established by aircraft manufacturers. According to Airbus Industries their SOP´s are designed to:

- Reflect the Airbus Industries flight deck design philosophy and operating philosophy;
- Promote optimum use of aircraft-type design features; and,
- Apply to a broad range of airline operations and environments.

SOP´s should identify and describe the standard tasks and duties of flight crew for each phase. Associated actions are actions or action blocks that are triggered by a certain event or procedure.

During the climb phase, at 10,000 ft, several tasks are executed. The Airbus SOP´s contain the following actions:

- LAND light ……………………………………………….OFF
- SEAT BELTS …………………………………………….AS RQRD
- EFIS option……………………………………………..ARPT
- ECAM MEMO…………………………………………….REVIEW
- RAD NAV page……………………………………....CHECK
- SEC F-PLN page……………………………………..AS RQRD
- OPT/MAX ALT..............................................................CHECK

An associated action could be to reset the altimeter setting to standard setting. Therefore the passage of 10.000 ft triggers a block of actions as described in the relevant SOP´s and it could also initiate the altimeter setting if the transition altitude were at this altitude.

The same reasoning could be applied during descent. The 10.000 ft passage during descent gives rise to another clearly described action block:

- LIGHTS.............................................................................ON
- SEAT BELTS..................................................................AS RQRD
- EFIS option.....................................................................CSTR
- ILS pushbutton.................................................................AS RQRD
- RAD NAVAIDS..............................................................SELECTED/IDENTIFIED
- NAV ACCURACY..........................................................CHECK

The altimeter setting could also be included in this list. At this time during the approach phase, the workload is not very high.

It is also worth r noting that the change in altimeter setting during the approach requires a mental process. The correct altimeter setting is of the utmost importance and therefore the necessary time frame needs to be taken into account. When further into the approach, the time needed to properly identify and set the altimeter is sometimes not available. This might result in a potentially hazardous situation.

The 10.000 ft passage is also the altitude that indicates the end (during climb) or beginning (during descent)of the *sterile cockpit concept*. It is mandated by the FAA through the FAR-Part 121-542. European operators have mandated it through the inclusion of the concept into their respective Flight Operations Manual (FOM).

10.000 ft there is also the speed limit boundary. The aircraft will either accelerate during departure or decelerate to 250 knots during descent.

It can therefore be concluded that this altitude passage triggers similar actions during climb and descent. It is the only altitude during an entire flight that has this special feature.

### 6.6 Altimeter cross-checks and associated safety nets

Altimeter cross-checks are performed during climb out and descent. They are intended to compare the different altimeter systems and to detect possible altimeter system errors and mis-settings. These altimeter cross-checks also have a safety net included. Not only are the values of the altimeter systems compared but they are also checked for their correct reference value setting. During climb-out both altimeters need to be reset to the QNE setting when passing through the transition altitude. The altimeters are cross-checked for their QNE setting and a comparison is made in order to detect possible errors or mis-settings. During descent the same actions are performed. An additional check is performed during the approach phase to determine which altimeter should be used for the minima call-out.

With a high transition altitude, the flight crew could be given more than one altimeter setting during descent. Different ATC units will issue the altimeter setting when the aircraft descends and executes the approach and landing. An advantage is that a gross altimeter mis-setting could be avoided due to the frequently passed information on the altimeter setting during the descent. The flight crew would detect a previously mis-set altimeter and so the error would be corrected. A drawback, however, would be that the altimeter setting value issued at an early stage of the descent might differ from the final QNH setting to be used during the approach stage of the flight. This could happen with rapidly falling pressure associated with the passage of a frontal system. If the QNH setting is not updated during descent, the resulting QNH setting might be outdated when the approach phase is commenced, leading to a potentially dangerous situation.

During climb out the situation is different. With a high transition altitude the altimeter setting could be forgotten because the attention of the flight crew has shifted to the tasks that need to be performed during the cruise. Changing the altimeter setting could easily be forgotten. This again highlights the fact that the resetting of the altimeter systems needs to be incorporated into an associated action that accompanies a Standard Operating Procedure.

Used in conjunction with an SOP the safety net function is greatly improved. However, to incorporate the altimeter reset into a SOP or an associated action, implies that the transition altitude needs to be common. A common transition altitude is therefore essential from a safety viewpoint. A high value for the common transition altitude has, as previously explained, certain drawbacks. A medium altitude (around 10 000 ft) is, for this reason, the most preferred. It coincides with an altitude above which, during climb out, the workload of the flight crew is lowered and the attention is shifted towards other aspects of the flight, e.g. cruise flight management, checking of the elementary aircraft systems, fuel managementand initial contact with the cabin crew after take off.

During descent, the workload of the crew increases greatly and the altimeter cross-checks could be done in a hasty manner, thus bypassing the safety net function.

This aspect should not be underestimated as it consists of a mental process that needs a certain amount of time. Distraction or interference with other tasks is detrimental to safety.

As a conclusion it can be stated that by introducing a common transition altitude and incorporating the altimeter setting into a standard procedure, safety is improved.

### 6.7 Special QFE procedure

QFE values are available to flight crew in approach when requested. Altimeters set to QFE indicate the height above threshold and consequently read zero upon landing. If using QFE procedures, during descent and prior to arrival at the Final Approach Fix (FAF), the flight crew uses the QNH setting for intermediate level-off. This setting is set on the standby altimeter.

Upon arrival at the FAF, the flight crew starts using the QFE setting which is already set on their primary altimeters. If a missed approach is commenced, the flight crew should revert to QNH (on the standby altimeter) for level-off.
It was believed that the advantage of the QFE system is the standardization of approaches with regard to altitudes seen by flight crews from the FAF until landing. Especially for Category I precision approaches, which have minimums of 200 ft above ground, each approach no matter what the airport elevation is, will appear the same to flight crews, concerning minimum altitude.
Very few airlines still use the QFE procedure. The last US carrier (American Airlines) using this procedure abandoned its use in 1999. Although the use of QFE does not depend on the transition altitude, it adds to the possible confusion between the different altimeter settings. The workload is extremely high, especially in combination with a low transition altitude.

### *6.8 Abnormal and emergency procedures*

Abnormal procedures (e.g. flap problem) and emergency procedures (e.g. engine fire) result in a condition of high workload on the flight deck. First the aircraft needs to be flown and the abnormality or emergency needs to be identified and the necessary actions/checklists need to be performed. An evaluation of the problem and the further course of action will be determined. The normal checklists will be performed when the abnormal/emergency situation is stabilised. If the aircraft climbs through the transition altitude, a reset of the altimeters might easily be overlooked due to the increased level of workload of dealing with the primary tasks. A task prioritisation has to be done and the crew will focus on the abnormal/emergency situation. The normal actions/checklists will be secondary. If the crew decides to perform a turn back and land at the departure airport, maintaining the same altimeter setting would be advantageous. This means that a reasonably high transition altitude would lower the workload and reduce the possible errors that could be introduced with an altimeter setting change. When a low transition altitude is applicable and an abnormal/emergency situation arises, the crew will need to perform two altimeter setting changes when passing through the transition altitude during climb out and again when returning to the departure airport. This again doubles the potential for error.

An important emergency procedure is the emergency descent procedure. This procedure is applied when a loss of pressurisation (sudden decompression due to structural damage) necessitates a rapid descent to a lower altitude. The altitude that the pilot has to descend to varies according to company policy. A 14.000 ft minimum is a regulatory requirement regarding oxygen requirement for passengers. 10.000 ft is used by various companies. In either case the pilot executing the emergency descent has to take into account the safety altitudes. The most important point is that the terrain clearance has to be taken into account. So a reset to a QNH value applicable for the routing should be used when determining a safe level-off altitude. A low transition altitude would therefore be unfavourable. A higher transition altitude would favour incorporation of the altimeter resetting in the flight crew actions when performing the emergency descent manoeuvre, thus leading to fewer errors regarding altimeter settings. It should also be noted that this procedure is one of extremely high workload and the actions that need to be performed are executed in a drill-wise manner.

### *6.9 Training issues*

Introducing a common transition altitude will have an effect on the way procedures are trained, especially the altimeter setting actions. Currently, setting the altimeters is not incorporated in a procedure or an associated action because of the numerous different transition altitudes. So it is also impossible to train the crews in order to obtain a uniformly applied procedure. With the introduction of a common transition altitude, the altimeter resetting could be integrated in a standard operating procedure or an associated action. Therefore, more emphasis could be put on the exact execution of this procedure and the net result might be a reduction in altimeter resetting errors or mis-settings. Also the training of abnormal/emergency procedures could be improved as the setting of the altimeters would occur at a defined standard altitude. This subject was elaborated in section 6.8.

For airports requiring a high transition altitude, an exception could be envisaged. As operating into these airports requires special training or briefing, a different transition altitude than the common transition altitude for these special cases does not pose a great problem. The differences can be emphasised during these briefings or simulator training prior to operating into these airports.

# 7 Altimeter setting errors

## 7.1 Comparison between NAM and EUR region

Because the US has a common transition altitude, it might be interesting to have a look into some altimeter setting related accidents. However comparison with EUR is very difficult because of the difference in accident databases and available statistical data. It can however be concluded that altimeter setting remains a contributing factor in some accidents. Most of the accidents involve non-precision approaches or loss of situation awareness. Communication problems are at the base of most altimeter setting errors (AA MD83, Bradley International, 1995).

European flight crews might be used to the complexity of the European mixed transition altitudes. For flight crew used to a common transition altitude, (Japan, US, Canada and others) special altitude awareness is needed in the EUR environment (IDN 1851, B707, Azores CFIT, 1989). Attention is given to this during the training of long haul pilots in the US. Non European flight crews will benefit the most from the introduction of a common transition altitude.

## 7.2 Altimeter mis-setting or omission

Primary errors in modern cockpits can be categorised into four types: information errors (slips), decision-making errors (mistakes), task prioritisation allocation errors (CRM-type errors) and equipment malfunctions. The first three types are considered as human errors while the last is equipment related. “Contributory factors” are another element of the error classification scheme. Depending on the amount of information, available for each incident, contributory factors such as fatigue, workload, and weather are identified.

The lack or loss of situational awareness, particularly the loss of vertical situational awareness, is a causal factor in 50 % of approach-and-landing accidents (ALAR study FSF). Operators on international routes are exposed to different measurement standards in terms of:

- Altitude measurement (feet and meters)
- Altitude reference setting units (hPa or In.Hg)
- Barometric reference (QNH, QNE or QFE)
- Environmental conditions (low OAT operation, rapid pressure changes)
- Radio altimeter setting and callouts (DH)
- GPS altitude

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

- High workload
- Deviation of normal tasking
- Interruptions and distractions
- Absence of effective cross-check and back-up between crew members
- Communication (read-back/hear-back)

Standardisation is the key to preventing these system induced errors.

## 7.3 Altitude Deviations by Altitude Pairing

Air safety reports (ASR’s) are an important source of information to discover trends in safety related occurrences. ASR’s are voluntarily submitted, and thus cannot be considered a measured random sample of the full population of events. The number of ASRS may comprise over half of all the altitude deviations which occur, or it may be just a small fraction of total occurrences. It is clear from ASR statistics that they represent a lower measure of the true number of events which are occurring (J. Reason).

In 1992, the FAA started a human factors study of altitude deviations. The reports indicated that certain altitude clearances are more likely to be misinterpreted than others. This finding emerged after analyses of 191 ASR's reports between 1987 and 1990. The reported altitude misinterpretations were grouped by altitude pairings. It was found that 38 percent of all the reports involved misinterpretations of the 10.000 ft/11.000 ft altitude pair. The next largest category accounted for less than 5 percent of the total deviations in the data set. The conclusion here is that it is very easy to confuse one-one thousand with one-zero thousand.

Tthe cause of this specific problem is not clear. Nevertheless this specific it could be solved partially by setting the transition altitude at exactly 10.000 ft. This would cause a bigger difference in the pronunciation of "ten-thousand feet" against "flight level one-one-zero". The change from levels to altitudes (or vice versa) would create a clear distinction between the two numbers. Eleven thousand feet would simply not exist.

### *7.4 Read-back and hear-back*

Each incident or accident could have more than one primary error type and more than one source. If a pilot makes a read-back error and the controller makes a hear-back error, the altimeter setting will be wrong. Reasons for read-back/hear-back errors are confusing call signs, one pilot not being in the loop because of other duties (taking ATIS, making public address calls), slips of mind and tongue, expectation of something, heavy workload and blocked transmission. Establishing transition altitudes at high worload points should be avoided.

### *7.5 Altitude Altimeter setting units and unusual values*

Uniformity in the use of altimeter reference units is desirable. Guidelines to reduce the risk associated with the use of different altimeter-setting units or with the use of unusual low or high altimeter settings have been established. All digits as well as the unit should be indicated. A transmission such as "altimeter setting six seven" can be interpreted as 28.67, 29.67, 30.67 in.Hg or as 967 hPa. Note that the use of in.Hg. is more prone to errors than the use of hPa.

### *7.6 Transposing of information*

Built in cross-checks can fail. For example the controller could issue a clearance to an altitude coincident with an altimeter setting, followed by a frequency change. The flight crew can perform a correct read-back but transpose the numbers of the frequency with the altimeter setting when inserting the numbers on the altimeter and the frequency selector.

Taking another aircraft's clearance is also an example of error in information processing. This is known as "slips". Slips are errors of action (as opposed to errors of intention) and occur in relatively familiar environments during automatic, well-learned behaviours, and are associated with some levels of distraction. Mistakes are likely to occur when the decision requires the simultaneous consideration of more than two or three variables.

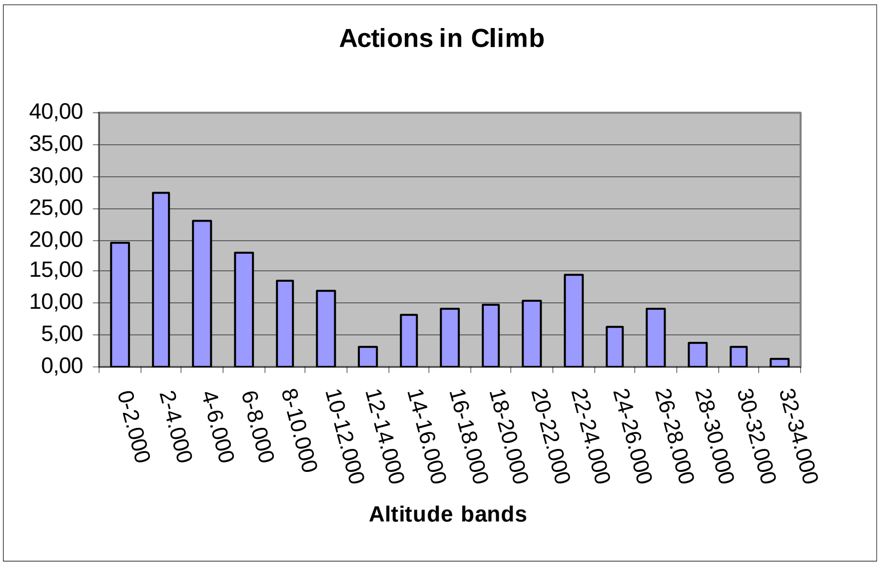
# 8 Workload

Transition altitude and altimeter setting are strongly related. A transition altitude where the workload is high can be the cause of an increase in errors.

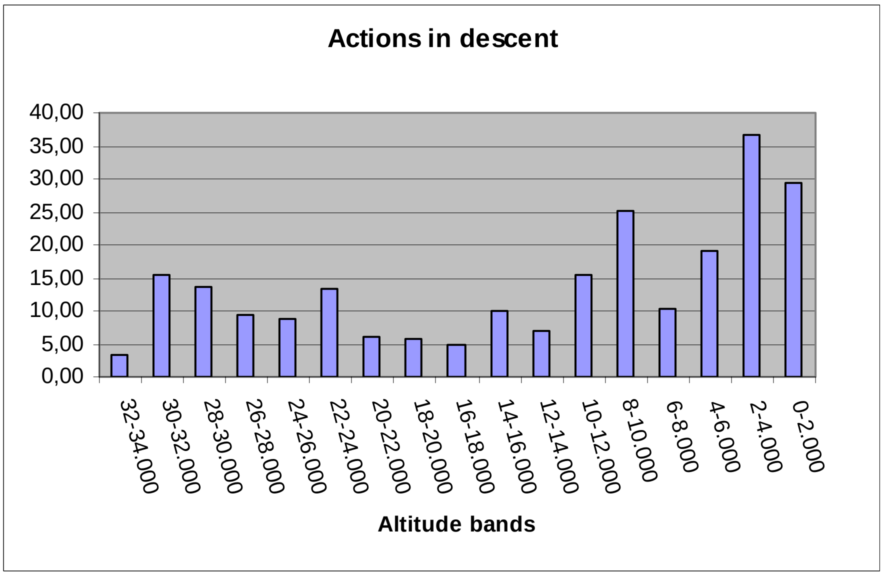
## *8.1 Workload survey*

Little information was found on the spread of flight deck workload versus altitude, or phase of flight. The workload during cruise is much lower and less critical than during landing and take-off. It is interesting to know where the turning point between low and high workload can be situated. Obviously, the transition altitude should not fall in the middle of a high workload phase or a critical phase of flight.

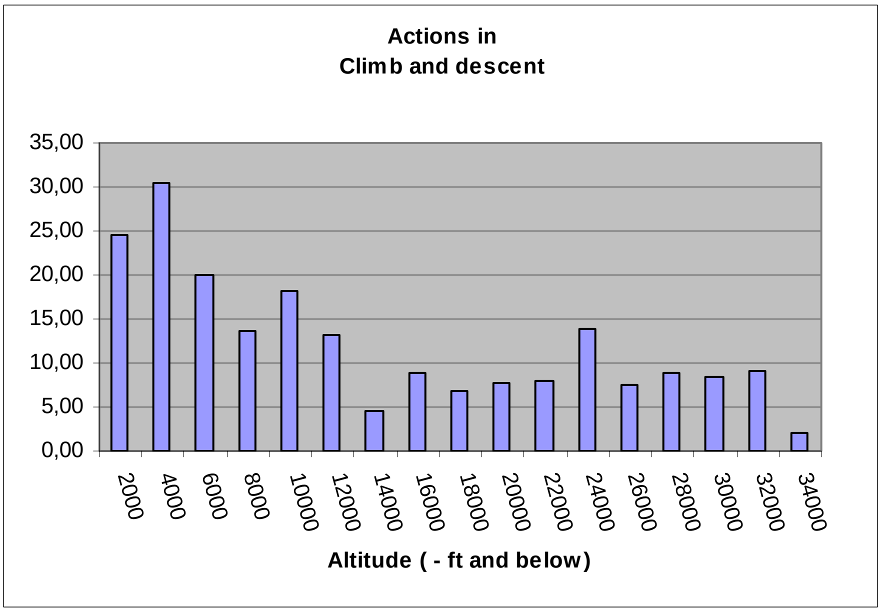
A survey was carried out on a limited number of flights. The departure and destination altitude was near sea level in all cases. An experienced airline pilot monitored ten flights from the jumpseat position. All actions of the captain and co-pilot were registered. Those actions were divided into groups of similar actions, and by altitude band of 2000 ft. A weight was allocated to each specific group of actions. Afterwards the total weight of actions was calculated for each altitude band. A mean value was calculated for the ten flights during climb and descent. These values are plotted below in relation to the altitude bands.



It is important to note that actions are registered and not workload. Other functions (mental actions) should be added in order to reach a total picture. The altitudes are cockpit readings, related to QNH below the transition altitude and to QNE above. The value of the Y-axis is a mean weight of actions. Therefore, a comparison can be made between the climb and descent graphs. In climb peak values are observed between 2000 and 6000 ft. The first band below 2000 ft is smaller because the take off and initial departure route is very well prepared before the flight. The overall departure workload is lower than for arrival because of this preparation. A departure contains less “surprises” for the flight crew. The aircraft is flying away from the problems. Below 10.000 ft, most companies apply the “sterile cockpit” concept: only primary tasks are performed; no papers, no cabin interference, no company calls,… While the actions below 10.000 ft are considered as critical, above 10.000 ft a lot of less critical actions that were previously delayed are now performed. The “associated actions“ triggered at 10.000 ft are an important part of the 10-12.000 ft band. An increase in workload can be observed between 18.000 and 24.000 ft. This is dominated by ATC calls, frequency changes and associated route changes. It is possible that the change from lower to upper airspace can be partly responsible for this increase.



In descent, a similar picture emerges. The overall workload is 22 % higher. This is because the preparation for the climb could be done in the pre-flight, while the arrival preparation must be done during the last part of the cruise and the descent. Arrivals contain more uncertainties than departures. The same increase in workload is observed around the 22-24.000 ft band. The associated actions triggered by the 10.000 ft are now performed between 10.000 and 8000 ft. This explains why the peak value is now situated just below the 10.000 ft (opposite to the climb-associated actions). Again below this altitude, the sterile cockpit concept is in force. Actions from that moment on should be considered as critical.



A transition altitude is the same for both climb and descent. Therefore both results can be combined into one graph. Because of the above mentioned “associated actions” around 10.000 ft, the transition altitude should not be lower than 10.000 ft. The higher workload in the 8-12.000 ft band is not an objection, because most of the actions there are grouped associated actions. Every action below must be seen as critical and should be free from interference.

### *8.2 Between stress, fatigue and boredom*

It is generally accepted that people perform less well when fatigued or stressed. Cambridge experiments show that pilots' flying deteriorates under fatigue: courses and heights are less accurately maintained, fuel checking was liable to be forgotten, there was a strong tendency to become focussed on one particular instrument, and pilots thought they were doing well, while in fact they were performing badly.

Much of what goes on in our mind and much of our memory is banished to the lower part of consciousness. Only the distillation of conscious processing remains. With these neatly packed parts of experience and knowledge, the events and problems are tackled as they occur. It has been shown that the human brain can only hold about nine items in memory at one time. The human being is unable to process or even retain all the information and experiences that overload the working environment.

Automation has undoubtedly had a beneficial effect on safety. On the debit side of increased automation has come a loss of proficiency. A marked skill loss has been noticed in pilots who regularly use automatic equipment. Disturbing as well is that there could be "the tendency to breed inactivity or complacency". This is a natural human reaction to insufficient stimuli. Advanced flight deck automation will be more tolerant of error, but will increase boredom. The flight crew could start making mistakes without even realizing it for hours. Mistakes in a technically complicated environment may stay a long time hidden in the system, and before getting noticed their consequences will have increased significantly. The right trigger at the right time is able to get the pilot back in the loop.

Those triggers are not always foreseen. When flying a flight level and getting the clearance to "Descent to 8000 ft on QNH 995", a clear trigger to reset the altimeter is given. This same clearance, but with a condition like "after passing" or "when ready, descent to 8000 ft on QNH 995" does not contain this trigger. Because the action is delayed, the reset of the altimeter is an item that must be put in our memory (nine items maximum) until execution can take place. But it is known that the information in the brain's memory is forgotten with the passage of time and with the inflow of additional information. A standard instrument departure that contains an initial level off altitude above the transition altitude is another example of the complete absence of trigger. As the altimeter cannot be set at the moment of receiving the clearance (before departure, the altimeter must be set to QNH) it is up to the pilot's memory to recall for the reset of the altimeter.

Altimeter setting for very high transition altitudes might fall in a lower stress environment. This is not always advantageous. At a certain point in climb, altitude awareness for the pilot becomes less important. The mind is focussed on the enroute portion of the flight. The workload graphs (above) show an increase related to the entrance into the higher airspace with its specific requirements. At that point, altitude awareness is not one of the majors concerns any more. In descent, the transition altitude could trigger the altitude awareness on the flight deck. In this respect a transition altitude of 18.000 ft might be too high, especially for lower elevation airports (majority of the cases).

# 9 Disadvantages of a multiplicity of transition altitudes

9.1 The current environment with a multiplicity of transition altitudes and its associated procedures does not conform with the ICAO recommendations. ICAO advocates the establishment of a common transition altitude.

9.2 IFALPA opposes the diversity of transition altitudes because it is operationally unsatisfactory and has a negative impact on safety.

9.3 A lack of altitude awareness, the increased vigilance required and altimeter setting errors have led to level busts, CFIT and approach and landing accidents. The multiplicity of transition altitudes may have contributed to these accidents.

9.4 Transiting between aispace with different transition altitudes requires multiple altimeter setting changes between QNH and QNE. This leads to confusion and is a safety risk.

9.5 Due to the multiplicity of transition altitudes it is impossible to include the altimeter setting procedures into SOP's. The associated safety net function might be lost.

9.6 The flight deck briefing needs to be adapted to each different transition altitude. A common transition altitude would allow uniformity in briefings.

9.7 Flight deck emergency procedures can benefit from a common transition altitude, because of the inclusion of the altimeter setting action into a fixed procedure. Uniformly applied procedures can be trained more efficiently.

# 10 Evaluation of common transition altitude values

| ***Benefits*** | ***Disadvantages*** |
|---|---|
| ***10.1 Low (below 10.000 ft)*** | |
| ▪ Consistent with existing ICAO text | ▪ Flight deck workload too high<br>▪ Multiple exceptions needed (high elevation aerodromes)<br>▪ Conflict with IFR flight procedures |
| ***10.2 Medium (around 10.000 ft)*** | |
| ▪ IFALPA policy<br>▪ Acceptable flight deck workload<br>▪ Above noise abatement and other IFR flight procedures<br>▪ Elimination of the 10.000/11.000 ft misinterpretation (only for transition altitude 10.000 ft)<br>▪ Existing SOP's at 10.000 ft (only for transition altitude 10.000 ft) | ▪ Few exceptions needed (high elevation aerodromes) |
| ***10.3 High (above 10.000 ft)*** | |
| ▪ Acceptable flight deck workload<br>▪ Above noise abatement and other IFR flight procedures | ▪ No exceptions needed (high elevation aerodromes)<br>▪ Introduction of 10.000/11.000 ft misinterpretation<br>▪ Frequent altimeter updates necessary during descent<br>▪ Late trigger for altimeter setting during climb |

## 11 Conclusion

The multiplicity of transition altitudes and the national rules and procedures make the European environment very complex. This can lead to a lack of altitude awareness and altimeter mis-settings and is operationally unsatisfactory. Consequently, increased vigilance from the flight crew is required. A common transition altitude will enable the development of altimeter resetting procedures, which can then be incorporated into a standard operating procedure. This will create a supplementary safety net for normal and abnormal/emergency procedures and will have a positive effect on the way altimeter setting procedures are trained. There will be a definite improvement in safety by introducing a common transition altitude.

Altimeter setting and its associated cross-checks are safety critical actions and should be performed during a period of acceptable workload.

When looking at altitudes below 10.000 ft as proposals for a common transition altitude, very few advantages can be found. Although ICAO suggests a transition altitude should be as low as possible, because of flight deck workload a low transition altitude should be avoided. Below 10.000 ft, the altimeter setting procedure interferes with other flight deck actions that need to be performed during this critical phase of flight.

The conducted survey on flight deck workload indicates that a transition altitude at 10.000 ft or above is acceptable. This is valid for the climb and descent profile. Furthermore, as these altitudes are situated above most IFR flight procedures, there is no conflict between critical flight deck actions and the altimeter setting procedure.

From a flight crew perspective, 10.000 ft is the most preferred altitude because it has clear advantages. Standard operating procedures already exist and are ideal to accommodate the altimeter setting actions. The misinterpretation of the 10.000 ft/11.000 ft altitude pair will be eliminated when the common transition altitude is fixed at 10.000 ft. This can be considered as an additional safety benefit. The only disadvantage of this altitude is the need for exceptions regarding high elevation airports. However, their number is limited and special training is already required before operating into these restricted airports. This specific training can emphasize the non-standard transition altitude.

Establishment of a common transition altitude has a clear safety benefit. All altitudes within the 10.000 – 20.000 ft band are acceptable as common transition altitude with a strong preference for the 10.000 ft value.

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