OPS 4
Aircraft Technical equipment

1. Introduction

1.1. Aircraft automation and technical equipment may have a direct effect on the likelihood of a level bust. Four types of equipment are concerned. These are:

(a) Barometric altimeters;

(b) Altitude alerters;

(c) Automation; and,

(d) Airborne collision avoidance systems (ACAS).

1.2. Although each of these pieces of equipment can be instrumental in causing a level bust, *correct use of equipment prevents level busts*.

1.3. The overwhelming characteristic of ACAS is its ability to reduce the risk of collision. For this reason, ACAS has been dealt with in full in a separate briefing note.[1]

1.4. Aircraft equipment varies widely according to the age, manufacturer and model; the choice of equipment fitted; and the modification state of the equipment.

1.5. Equipment fitted in states which follow JAR-OPS 1 is governed by regulations. In non-JAR-OPS states, regulatory standards may vary considerably.

2. Barometric Altimeters

Conventional Altimeters

2.1. JAR-OPS[2] requires that aircraft be equipped with two sensitive pressure altimeters calibrated in feet with sub-scale settings, calibrated in hectopascals (or millibars), adjustable for any barometric pressure likely to be set during flight. Not later than 1 April 2002 these altimeters must have counter drum-pointer or equivalent presentation.

2.2. JAA TGL28[3] describes the main types of barometric altimeter presentation in use today. These are: three-pointer; drum-pointer; counter-pointer; and counter drum-pointer.

2.3. Although all commercial air transport aeroplanes operated in JAR-OPS states should now be equipped with primary altimeters featuring the counter drum-pointer presentation, other types of altimeter display may be encountered elsewhere.

2.4. TGL28 explains the shortcomings of the first three types of altimeter which led to the development of the counter drum-pointer instrument.

2.5. The counter drum-pointer presentation is illustrated in Figure 1. In case of doubt, operators should refer to the full description in TGL28.

2.6. JAR-OPS does not specify the type of altimeter display to be fitted as standby equipment, but TGL28 recommends that Operators should use the counter drum-pointer layout.

2.7. TGL28 also recommends that the primary altimeters in use at pilot stations should have similar displays.

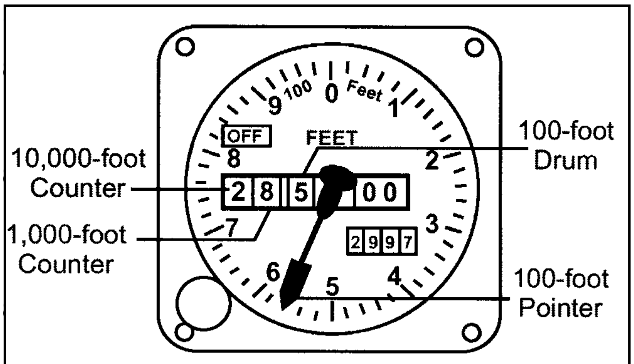

Figure 1

Counter Drum-Pointer Altimeter Display

[1] Briefing Note OPS 5 – Airborne Collision avoidance Systems.
[2] JAR-OPS 1.652(c) – IFR or night operations – Flight and navigational instruments and associated equipment

[3] JAA Administrative & Guidance Material Section Four: Operations, Part Three: Temporary Guidance: Leaflets (JAR-OPS) Leaflet No 28 – Drum-Pointer and Counter/Drum-Pointer Display Altimeters.

Electronic Flight Instrument Displays (EFIS)

2.8. In modern flight decks the altitude displays differ from the conventional altimeter, usually featuring a vertical altitude tape on the right hand side. The rate of climb or descent may be harder to visualise than when using the conventional altimeter, in the same way as reading a digital watch is more error-prone than using an analogue one. In some cases, rate cues such as chevrons have been added to address this problem.

2.9. In particular, JAA TGL11[4] points out that if a vertical speed tape is used and the range of the tape is less than 2,500 ft/min, an ACAS Increase Rate RA cannot be properly displayed.

2.10. Some examples of EFIS altitude displays are shown below to illustrate the wide variety that may be encountered. Each display may have unique aspects requiring specific system knowledge and may require adjustment of the instrument scan to encompass all information.

2.11. With the introduction of new technology there is always opportunity for new errors; flight crews require in depth knowledge of their current displays and operating systems and must be aware that under stress, the human tendency is to revert to a previous or best known mode of operation.

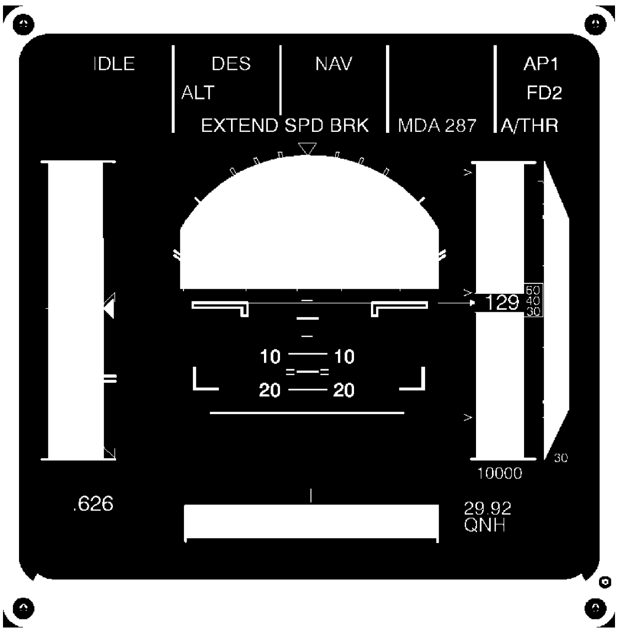

Figure 2a

Figure 2b

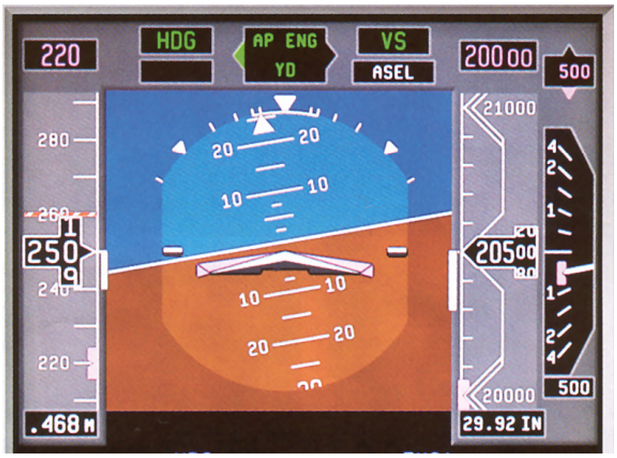

Figure 2c

Figure 2d
(Head-up Guidance System)

4 [JAA Administrative & Guidance Material Section Four: Operations, Part Three: Temporary Guidance: Leaflets (JAR-OPS) Leaflet No. 11: Guidance For Operators On Training Programmes For The Use Of Airborne Collision Avoidance Systems (ACAS)]

3. Altitude Alerter

3.1. JAR-OPS[5] requires that aircraft be equipped with an altitude alerting system (see Figure 3) capable of:

(a) Alerting the flight crew upon approaching a preselected altitude; and

(b) Alerting the flight crew by at least an aural signal, when deviating from a preselected altitude.

3.6. The Swedish CAA report[6] found that the altitude alerter had a positive effect on the avoidance of level busts. They also reported that level busts were significantly less likely to occur on aircraft equipped with aural warnings as well as visual warnings.

3.7. In 2000 the UK CAA published the findings of their level bust working group – "On the Level" and in April 2001 a series of further recommendations was published[7] which are worthy of study.

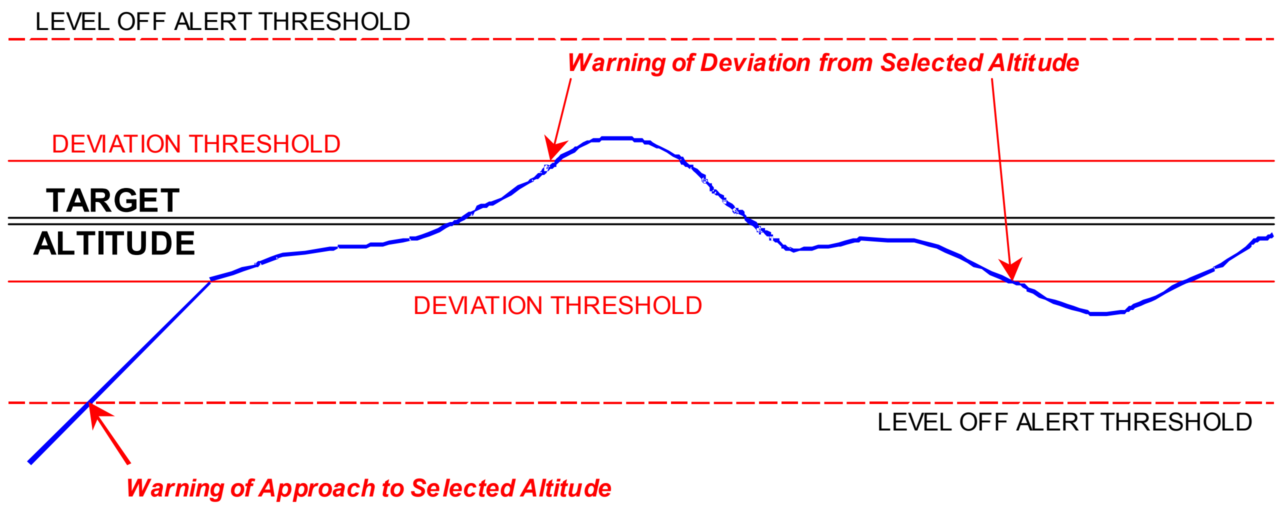

Figure 3.
Approach to or deviation from selected altitude is indicated by a combination of visual and/or aural warnings

3.2. Some altitude alerters are only fitted with visual warnings while others have an aural warning as well as a light.

3.3. Typically, a momentary chime is heard and/or a light comes on at a preset point, usually after the "1000 ft to go" point. The light goes out when the aircraft comes within a specified distance (usually 200 ft – 300 ft) of the preselected altitude.

3.4. If the aircraft deviates by a specified amount (usually 200 ft – 300 ft from the preselected altitude) the light comes on together with an aural tone or a voice message such as "ALTITUDE".

3.5. In 1997 the Swedish Civil Aviation Authority (CAA) reported the results of a survey carried out among major Swedish operators. Their objective was to detect aircraft equipment that had a positive influence on aircraft leveling off at the selected altitude.

4. Automation

8.4. Automatic flight guidance systems (FGS) and flight management systems (FMS) vary widely between aircraft types and even between examples of the same aircraft type. Not only does equipment vary, but the underlying philosophy may differ from one system to another. Unless pilots understand fully the systems fitted to their aircraft, there is a danger of level bust because of incorrect setting or inadequate understanding of mode changes.

[5] JAR-OPS 1.660 – Altitude Alerting Systems

[6] CAP 710 – UK CAA Level Bust Working Group "On the Level" Project Final Report, (the Swedish report is at Attachment 6

[7] CAP 710 – UK CAA Level Bust Working Group "On the Level" Project Final Report and Recommendations Originating from the "On the Level" project.

Factors and Errors

4.1. The following factors and errors can cause an incorrect flight path, which – if not recognised – can lead to a level bust, including controlled flight into terrain:

(a) Inadvertent arming of a mode or selection of an incorrect mode;

(b) Failure to verify the armed mode or selected mode by reference to the flight mode annunciator (FMA);

(c) Entering the incorrect target altitude on the FGS control panel and failure to confirm the entered target on the primary flight display (PFD) and/or navigation display (ND);

(d) Changing the FGS control panel altitude target to any altitude below the final approach intercept altitude during approach;

(e) Preoccupation with FGS or FMS programming with consequent loss of situational awareness;

(f) Inadequate understanding of mode changes (e.g. mode confusion or automation surprises);

(g) Inadequate task sharing and/or inadequate crew resource management (CRM), preventing the pilot flying (PF) from monitoring the flight path; and,

(h) Engaging the AP or disengaging the AP when the aircraft is in an out-of trim condition.

Operating Philosophy

4.2. Operation of the FGS and FMS must be monitored at all times by:

(a) Cross checking the FGS engagement status and mode of operation on the FMA;

(b) Stating and checking the selected altitude (Alt Sel) value; and,

(c) Monitoring the result of FGS operation by cross-reference to the basic flight displays.

4.3. The PF should always use the most appropriate guidance and level of automation for the task.

4.4. If doubt exists about the aircraft's flight path or airspeed control, no attempt should be made to reprogram the automated systems. Revert to a lower level of automation or hand fly with raw data until time and conditions permit reprogramming the FGS or FMS.

4.5. If the aircraft does not follow the intended flight path, check the FGS engagement status. If engaged, the FGS must be disconnected using the AP-disconnect switch to revert to hand-flying with reference to raw data.

4.6. When hand-flying for any other reason, the FD commands should be followed; otherwise, the FD command bars should be cleared from the PFD.

4.7. FGS systems must not be overridden manually, except under conditions set forth in the aircraft operating manual (AOM) or quick reference handbook (QRH).

4.8. Use an appropriate instrument scan for automatic flight that gives more emphasis to the FGS engaged status and FMA.

Recommendations

4.9. Before engaging the FGS, ensure that:

(a) The modes selected for FD guidance are correct; and,

(b) The FD command bars do not show large flight-path correction commands. If large corrections are commanded, hand-fly the aircraft to centre the FD command bars).

4.10. Before taking action on the FGS control panel check that the knob or push-button is the correct one for the desired function.

4.11. After each action on the FGS control panel, verify the result of the action by reference to the FMA and to other PFD/ND data or by reference to the flight path and airspeed.

4.12. Monitor the FMA and call all mode changes in accordance with SOPs.

4.13. When changing the altitude entered on the FGS control panel, cross-check the selected-altitude readout on the PFD.

4.14. No attempt should be made to analyse or to correct an anomaly by reprogramming the FGS or the FMS until the desired flight path or altitude is restored.

4.15. If at any time the aircraft does not follow the desired flight path, do not hesitate to revert to a lower (more direct) level of automation. For example:

(a) Revert from FMS to selected modes;

(b) Disengage the AP and follow FD guidance;

(c) Disengage the FD, select the flight path vector and fly raw data or fly visually (if in visual meteorological conditions); and/or,

(d) Disengage the A/THR and control the thrust manually.

5. Resources

OtherLevel Bust Briefing Notes

5.1. The following Level Bust Toolkit Briefing Notes contain information to supplement this discussion:

OPS 1 – Standard Operating Procedures;

OPS 2 – Altimeter Setting Procedures;

OPS 5 – Airborne Collision Avoidance Systems.

Access to Resources

5.2. Most of the resources listed may be accessed free of charge from the Internet. Exceptions are:

ICAO documents, which may be purchased direct from *ICAO*;

Certain Flight Safety Foundation (FSF) Documents, which may be purchased direct from *FSF*;

Certain documents produced by the Joint Aviation Authorities, which may be purchased from *JAA*.

Regulatory References

5.3. Documents produced by regulatory authorities such as ICAO, JAA and national aviation authorities are subject to amendment. Reference should be made to the current version of the document to establish the effect of any subsequent amendment.

JAR-OPS 1.650 & 1.652 – Flight and Navigational Equipment & Associated Equipment;

JAR-OPS 1.660 – Altitude Alerting System.

Training Material & Incident Reports

FSF Accident Prevention No 4/1997: MD83 Descends Below Minimum Descent Height;

NASA Technical Memorandum 92/7 – Altitude Deviations: Breakdown of an Error Tolerant System;

Report by the Norwegian Air Accident Investigation Bureau into an Airprox between an Airbus A310 and a Boeing 737 at Oslo in February 2002.

Other Resources

FSF Digest 11/98 – "Killers in Aviation": Facts about Controlled Flight Into Terrain Accidents;

FSF Digest 6/93 – Research Identifies Common Errors behind Altitude Deviation;

FSF Digest 6/99 – Transition to Glass: Pilot Training for High technology Aircraft;

FSF Accident Prevention 12/95 – Different Altimeter Displays and Crew Fatigue … ;

NASA: Murphi Busts an Altitude – A Murphi Anaysis of an Automation Surprise;

NASA: Pilot-Autopilot Interaction – A Formal Perspective;

UK CAA CAP 710 – "On the Level" and associated recommendations.

This briefing note has been prepared by the Safety Improvement Sub-Group (SISG) of EUROCONTROL to help prevent level busts. It is one of 14 briefing notes that form a fundamental part of the European Air Traffic Management (EATM) Level Bust Toolkit.

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