Level Bust Briefing Notes
Air Traffic Management

ATM 4
Airspace & Procedure Design

1. Introduction

1.1. The proper planning and design of routes, holding patterns, airspace structure and ATC sectorisation in both terminal and en-route airspace can be effective in reducing the likelihood of level bust incidents. The converse is also true: poorly designed airspace can create situations where a level bust incident is more likely to occur within an air traffic management (ATM) system.

1.2. In an ideal world, airspace design would make it possible for arriving, departing and en-route flights to operate so that they did not have to cross one another, or climb and descend through each other's levels. Furthermore, approach and take-off flight paths would be free of obstacles. Unfortunately, however, this "ideal" design environment is seldom possible, which means that airspace designers need to take steps to reduce the likelihood of level busts by applying several basic principles.

2. General Principles

2.1. As far as possible, arrival and departure routes within a Terminal Airspace should be segregated from each other, both vertically and laterally, thus reducing controller workload; This means that:

(a) Arrival and departure routes should be designed so that aircraft are not required to fly on reciprocal tracks (This can be achieved by ensuring that exit and entry points of the Terminal Airspace are not located in the same place, and that specialised arrival and departure routes are provided to connect the En Route ATS Route system with the Terminal Airspace);

(b) Where it is necessary for arrival and departures routes to cross, the crossing point should be selected taking into account aircraft flight profiles, so that arriving and departing flights will not have a restricting effect upon each other. (To this end, a comprehensive and accurate evaluation of aircraft performance is needed as regards the aircraft operating within the Terminal Airspace, and account needs to be taken of possible nuisance ACAS alerts);

(c) Space permitting, departure routes should be designed clear of holding areas.

2.2. When SIDs and STARs are published with level restrictions, these restrictions should be unambiguously depicted on published charts.

2.3. The application of obstacle clearance criteria in the design of instrument approach and holding procedures by PANS-OPS specialists should strive for simplicity of design. This means that long and complex procedures involving several altitude changes or step clearances should be avoided.

2.4. To the extent possible, lateral and vertical dimensions of ATC sectors should be designed so as to avoid ATC having to provide stepped level clearances, especially over short distances.

2.5. Where use is made of functional sectorisation as a means of sharing ATC workload in a Terminal Airspace, the vertical areas of responsibility of each sector should be unambiguously described in local ATC instructions.

2.6. Where airspace restrictions or reservations are established above or below controlled airspace, it is essential that adequate buffers (dependent on the activity conducted therein) be established above/below these airspace restrictions or reservations, in order to ensure that ATS can provide an adequate margin of safety.

3. ICAO & EUROCONTROL Provisions

3.1. ICAO PANS-OPS[1] provides criteria for the design of instrument approach, holding and departure procedures. PANS-OPS provisions also cover en-route procedures where obstacle clearance is a consideration.

[1] ICAO Doc. 8168, Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS)

3.2. Similarly, ICAO PANS-ATM[2] provides procedures for air navigation services, whose basic tenets form the basis of airspace design.

3.3. Both these ICAO Procedures documents amplify International Standards and Recommended Practices contained in ICAO Annexes 2, 4 and 11 – *see Paragraph 8.4: Regulatory References.*

3.4. For its part, EUROCONTROL guidance material for airspace design and PANS-OPS Procedure design has also been published. The main references include the *EUROCONTROL Manual for Airspace Planning*[3] and *Guidance Material for the design of Terminal Procedures for Area Navigation* (DME/DME, GNSS, Baro-VNAV and RNP RNAV). (Edition 3.0, March 2003).

4. Influencing Factors

4.1. Changes to local airspace can impact greatly on airspace users. In most countries, a mix of commercial, military and general aviation is encountered, with many operators competing for the same airspace.

4.2. The increase in world-wide air traffic means that frequent extensions and adaptations of airspace and its organisation (routes and sectors) are required, but the need to maximise safety should always be the highest priority.

4.3. The design of routes, holding patterns, airspace structures and delineation of ATC sectors is influenced by a variety of factors:

(a) The extent of the navigation, communication and surveillance infrastructure;

(b) Terrain surrounding the aerodrome;

(c) Other ATS routes;

(d) Prohibited and restricted areas;

(e) Proximity of other aerodromes and other airspace structures;

(f) Requirements to ensure environmental mitigation;

(g) Weather phenomena, especially known areas of disruptive weather conditions.

5. Identified Problems

Standard Instrument Departures

5.1. In their final report[4] the UK CAA level bust working group (LBWG) found that a large number of level busts resulted from pilots climbing above standard instrument departure (SID) step altitudes due to misunderstanding information presented on charts. Almost three-quarters of the “SID busts” involved aircraft climbing above a 3000 ft step altitude and over a third were busts of greater than 1000 ft. The following problems were identified:

(a) The complexity of the presentation means that there is a high chance that certain SID charts may be misinterpreted;

(b) For the most part, SID charts are designed by non-pilots and without pilot input. Factors other than safety can be overriding (e.g. noise). Climbing through the First Stop Altitude (FSA) is a very common cause of a level bust;

(c) Some pilots clearly have difficulty in understanding the English used on SID charts;

(d) Multiple frequency changes are often given during the high workload period following take-off and before reaching FSA. This can cause confusion and distract crews from important monitoring tasks;

(e) A number of SID initial turning points use DMEs that are not located on the airfield. This means that on certain SIDs crews should expect the DME reading to decrease whilst on others the opposite is true.

5.2. The recommendations of the LBWG[5] are specific to the problems identified in the report, but will be of value in developing more general solutions to problems.

5.3. The UK CAA reported that more than half the “SID-busts” investigated for the report involved a particular airport. This enabled them to focus remedial action, which included the following:

(a) Raising awareness of issues with flight crew;

(b) Radio warning to pilots;

(c) Discussion with chart manufacturers; and,

(d) Revising the SIDs.

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[2] ICAO Doc 4444 – Procedures for Air Navigation Services – Air Traffic Management (PANS/ATM);

[3] Note: Section 5 of this manual, entitled ‘Guidelines for Terminal Airspace Design’, is to be replaced by a revised edition at year end 2004.

[4] CAP 710 – Level Bust Working Group "On the Level" Project Final Report

[5] UK CAA: Recommendations Originating from the "On the Level" Project

5.4. Within a year the incident report rate had fallen to zero. Occurrence reporting schemes should be able to identify similar examples, enabling corrective action to be taken.

Non-Precision Approaches

5.5. Most controlled flight into terrain (CFIT) accidents may be viewed as level busts, in that the aircraft descends below the prescribed altitude or approach gradient without the prescribed criteria being met. This usually means that the aircraft descends before the prescribed approach fix is reached or while the aircraft is outside the designated approach path.

5.6. A study[6] carried out for the Flight Safety Foundation (FSF) found that in Europe, the risk involved when flying a non-precision approach was 4.1 times greater than when a precision approach was flown. In Europe, approximately one sixth of all approaches flown are non-precision approaches. Where standard arrival procedures (STARs) were absent, the risk of accident was somewhat greater than when they were available.

5.7. Anecdotal evidence suggests that non-precision approaches are sometimes preferred when a precision approach could have been chosen. The investigation into a recent European fatal accident cited as a contributory factor that "The valid visual minimums at the time of the accident were inappropriate for a decision to use the [non-precision approach]".

5.8. Where descent is to commence at a fix (the usual situation), the fix should preferably be overhead a VOR, a defined distance from an airfield based DME or RNAV position.

5.9. A basic problem with some non-precision approaches is that they specify the descent path by means of a series of "fixes" and corresponding check heights, resulting in a stepped descent rather than a stabilised descent. The establishment of a stabilised approach is considered essential for a safe approach and landing; accordingly, a stepped approach is often intrinsically unsafe.

6. Solutions to Identified Problems

6.1. In addition to following the general principles described above (Section 2) and designing airspace in accordance with ICAO provisions, airspace and procedure designers should follow a structured approach when introducing airspace changes. This means that:

(a) Planning is required, so that problems may be properly identified, stakeholder interests addressed, an impact assessment carried out, and a safety assessment completed. Planning also implies that time-scales and milestones are set, so as to ensure that the airspace changes are affected in an organised manner which reduces the likelihood of design 'solutions' creating operational difficulties for either controllers or pilots;

(b) Changes introduced to existing terminal area procedures as well as SIDs and STARs should be properly validated, prior to implementation;

(c) Sufficient time should be allowed in the planning process to allow for necessary controller and flight crew training .

6.2. When RNAV terminal area procedures are designed (excluding the final approach and missed approach segment), procedures should be designed using P-RNAV criteria in accordance with Guidance Material published by EUROCONTROL.[7].

(a) For RNAV operations which rely on a navigation data base (e.g. P-RNAV), State Aeronautical Information Services, data providers and aircraft operators should take steps to ensure the integrity of navigation data in accordance with guidance material published by EUROCONTROL and the Joint Aviation Authorities (JAA)[8];

(b) When introducing RNAV procedures into Terminal Airspace, both controllers and flight crew should be provided with training so that each may understand the effect on the operating environment of the introduction of P-RNAV. (e.g. the effects of introducing "Open" or "Closed" STARs.)

6.3. At one time the process of airspace design was difficult and laborious, being carried out mostly with paper and pencil using manual calculation. Today, a number of procedure-design tools are available to assist in and speed up the design process. Alternatively, the professional services of

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[6] FSF Digest 3/96 – Airport Safety: A Study of Accidents and Available Approach and Landing Aids

[7] Guidance Material for the design of Terminal Procedures for Area Navigation (DME/DME, GNSS, Baro-Nav and RNP PRNAV) (Edition 3.0. March 2003

[8] Information on the introduction of P-RNAV procedures and requirements for ECAC Terminal Airspace is available at the P-RNAV web-site www.ecacnav.com/p-rnav/default.htm

procedure design specialists may be called on to design procedures.

6.4. Two complementary procedure-design tool systems endorsed by ICAO are available: PD Toolkit and PANS-OPS Software.

6.5. It is essential to ensure the proper training of procedures designers, and that designers have access to the latest innovations, technologies and regulatory criteria. The Australian Civil Aviation Safety Authority (CASA) has produced a manual[9] which outlines standards required for the design of instrument flight procedures and also standards for personnel involved in the design of those procedures. This document lays down Australian licensing requirements for designers.

7. Summary

7.1. Accidents most often happen during departure, or during approach and landing procedures at airports. Analysis of available data suggests that many level busts occur during SIDs. Many CFIT accidents are the result of a level bust during the approach. Careful procedure design can reduce the risk of accidents.

7.2. Where possible, SIDs, STARs and approach procedures, should:

(a) Be standardised;

(b) Be as simple and straightforward as possible;

(c) Avoid step climbs or descents – non-precision approaches should incorporate continuous descent from final approach fix;

(d) Involve a minimum of frequency changes;

(e) Pilots, ATC, airport authorities and other interested parties should be involved in the procedure planning process.

8. Resources

Other Level Bust Briefing Notes

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

OPS 1 – Standard Operating Procedures;

ATM 2 – Reducing Level Busts.

Access to Resources

8.2. 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

8.3. 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.

ICAO Annex 2 – Rules of the Air;

ICAO Annex 4 – Aeronautical Charts;

ICAO Annex 11 – Air Traffic Services;

ICAO Annex 14 Aerodrome Design and Operations;

ICAO Doc 4444 – Procedures for Air Navigation Services – Air Traffic Management (PANS/ATM);

ICAO Doc 7030 – Regional Supplementary Procedures (EUR);

ICAO Doc 8168 – Procedures for Air Navigation Services – Aircraft Operations Volume II (PANS-OPS – Construction of Visual and Instrument Flight Procedures);

ICAO Doc 9157 Aerodrome Design Manual;

ICAO Doc 9368 – Instrument Flight Procedures Construction Manual;

ICAO Doc 9426 - ATS Planning Manual;

ICAO Doc 9554 - Manual Concerning Safety Measures Relating to Military Activities Potentially Hazardous to Civil Aircraft Operations;

EUROCONTROL Manual for Airspace Planning (Edition 2, 2003);

EUROCONTROL Guidance Material for the design of Terminal Procedures for Area Navigation (DME/DME, GNSS, Baro-VNAV and RNP RNAV). (Edition 3.0, March 2003).

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[9] CASA Manual of Standards Part 173 Instrument Flight Procedure Design

Other Resources

- *Eurocontrol: Recommendations of the Level Bust Task Force*;
- *Eurocontrol Safety Letter - CFIT: The Major Risk*;
- *NASA Altitude Deviation Crossing Restriction Altitude Deviations on SIDs & STARs*.

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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in developing these notes, some of which draw on material contained in the

FSF Approach and Landing Accident Reduction (ALAR) Toolkit.