International Civil Aviation Organization

FIFTEENTH MEETING OF THE
ASIA/PACIFIC AIR NAVIGATION PLANNING AND
IMPLEMENTATION REGIONAL GROUP (APANPIRG/15)
Bangkok, Thailand, 23 to 27 August 2004

Agenda Item 2.4 : Other Air Navigation Matters

ICAO REQUIREMENTS FOR THE OPERATION OF NEW LARGER AIRCRAFT

(Presented by the Secretariat)

SUMMARY

The introduction of the Airbus A380 presents new challenges for operators of both existing airports and airports currently being planned and/or constructed.

This paper describes the actions taken by ICAO to assist States in addressing some of the issue of operations of the New Larger Aeroplanes (NLA), in particular compliance with the requirements of Annex 14 *Aerodromes* Vol I. *Aerodrome Design and Operations*.

The paper also highlight pertinent issues having an impact on the NLA operations such as those related to facilitation, capacity and security.

Relevant websites related to the subject have also been included as references.

1. HISTORY

1.1 At the 36th Meeting of the International Industry Working Group (IIWG/36) held in Miami, Florida, United States, from 20 to 22 October 1993, three major aircraft manufacturers i.e. the Airbus Industries, Boeing and Douglas Aircraft Company outlined plans for the introduction of aeroplanes larger than the Boeing 747-400 – currently the largest passenger aeroplane in commercial service – capable of carrying more than 500 passengers.

1.2 In response to a request from the Airports Council International (ACI) in December 1993, ICAO commenced work on the NLA specifications and to develop appropriate Annex 14 requirements. These specifications were required on an urgent basis as they would aid States and airports in their evaluation of the impact of such large aeroplanes on the existing ground infrastructure and in planning for necessary developments.

1.3 The information documented by the three aircraft manufacturers during the following IIIWG/37 meeting held in Vienna, Austria from 15 – 17 June 1994 indicated that all of them were studying the possibility of introducing early in the next century, aircraft capable of carrying more than

600 passengers and that these aircraft could have a maximum wing span of around 80m against the 64.5m of the B747- 400. Furthermore, there were indications that these aircraft were unlikely to be equipped with foldable wings, and as a result they can pose serious compatibility problems at aerodromes designed to support the operation of aircraft no larger than the B747-400.

1.4 At the IIWG/43 held in Seattle in 1995, ICAO was requested to progress the task with a degree of urgency as States required a lead time of four to five years to plan the necessary development activities. It was felt that an amendment to Annex 14, Vol.I containing new specifications be developed and made available in 1999.

1.5 As agreed by the ICAO Air Navigation Commission, the Airport Design Study Group (ADSG) was requested to assist ICAO in developing the relevant specifications. At the first meeting of the ADSG in 1995, a new aerodrome reference Code F to cover aeroplanes with wing spans from 65m up to 80m and outer main gear wheel span from 14m to 16m was developed. In subsequent meetings in 1996 and 1997, all other specifications related to airport physical characteristics for Code F aircraft were developed. Appropriate contributions came from the Obstacle Clearance Panel (OCP) as a culmination of the work assigned to the OCP by the Commission on the subject of the obstacle free zone (OFZ) for aeroplanes with wing spans greater than 65m.

1.6 In May 1998, amendment proposal to Annex 14 Vol I introducing a new aerodrome reference Code F for NLA, after review by the Commission, were sent to States and International Organizations for consultations. The majority of replies supported the proposed amendment. After further review, the proposed Amendment 3 to Annex 14 Vol I were adopted by the Council in March 1999.

1.7 Subsequent to the new Code letter F specifications becoming applicable on 4 November 1999, ICAO has been requested by industry to explore ways to develop operational guidance in order to accommodate Code F aircraft at existing airports which were not designed for such large aircraft.

1.8 Wherever an existing airport could not be readily modified for a new generation of aeroplanes, suitable local operational measures were developed to accommodate the new aircraft. The standard practice among airport planners and engineers is to evaluate the existing airport infrastructure vis-à-vis the Annex 14 requirements and plan the necessary modifications

1.9 In certain cases, such modification may not be considered practicable. In such cases, in order to ensure that the required level safety levels are met, States should carry out appropriate aeronautical studies to evaluate the suitability of existing facilities and to determine the need for operational procedures, alternate measures and operating restrictions to meet the safety objectives of Annex 14 Vol I provisions.

1.10 In order to assist States in this regard, ICAO has developed a new Circular with the main intent of bringing together in one document all the relevant issues of concern with necessary cross references to the appropriate ICAO provisions so that States may benefit from this in their efforts to develop their aerodromes appropriately for the safe operations of the NLAs at existing aerodromes.

2. DISCUSSION

A380 airplane characteristics for airport planning

2.1 A 200-page Manual on the characteristics of the only NLA currently expected to enter commercial service in 2006 viz., the Airbus A380 can be found in the following website:

http://www.airbus.com/product/a380_planning.asp

2.2 A comparison of the critical figures between the A380 and B747-400 having an effect on airports operations are show below:

	Airbus A380-100	**Boeing 747-400**
Passengers	**555 (33%)**	**416**
Wingspan	**79.75 m (24%)**	**65 m**
Length	**72.6 m (2%)**	**70 m**
Height	**24 m (24%)**	**19.6 m**
Fuselage Width	**7.14m**	**6.5m**
Maximum take- off weight	**560 tons (40%)**	**400 tons**

Amendment 3 to Annex 14 Vol I

2.3 Annex 14 – *Aerodromes*, Vol.I – *Aerodrome Design and Operations* contains provisions on aerodrome design and operations for the evaluation and development of new areas of existing airports as well as for designing new aerodromes, interrelated through a combination of aerodrome reference Code numbers and letters that are based on aircraft performance and dimensions.

2.4 Amendment 3 specifications have been developed to facilitate the planning of new airports and new facilities at existing airports, for the largest aeroplane dimension in any given aerodrome reference Code, a method intended to accommodate any future aircraft variant within the specific Code element. These specifications were not developed for a specific aircraft because they would soon become outdated when the next generation aircraft came into commercial service.

2.5 Amendment 3 to Annex 14 Vol. I containing, *inter alia*, provisions for NLAs was adopted by the ICAO Council at the 7th meeting of its 156th Session on 5 March 1999 with an applicability date on 4 November 1999. A new aerodrome reference Code letter F to cover aeroplanes with wing span from 65m up to but not including 80m and an outer main gear wheel span from 14m up to but not including 16m was established. Separately, specifications for aerodrome rescue and fire fighting for aeroplanes with maximum fuselage widths in excess of 7m and lengths greater than 76m, Code letter 10, had already been developed and included in the Annex.

2.6 Amendment 3 contains, amongst others, the following requirements relevant to NLAs:

2.6.1 **Aerodrome reference code letter F :** For aeroplanes with a wingspan of 65m up to but not including 80m and an outer main gear wheel span off 14m up to but not including 16m.

2.6.2 **Runway width:** The runway width is based on the aeroplane's outer main gear wheel span and a clearance on either side required to accommodate the probability of a lateral deviation of an aeroplane due to many factors during landing or take-off operations. A 60 m wide runway is deemed necessary for operational reasons to permit safe landing in adverse meteorological conditions such as cross winds, contaminated runway surface and the use of crab angle approaches.

2.6.3 **Overall width of runway and its shoulders:** The data on take-off thrust exhaust velocity contours of the engines planned to be used for NLAs indicate the need for an overall width of 75 m to prevent:

a) erosion of soil beyond the runway; and

b) the possibility of foreign object damage to the outboard engines.

2.6.4 **Objects on runway strips:** The provisions in § 3.3.7 of the Annex have been modified to take into account the revised width of the obstacle-free zone for Code letter F aeroplane operations as recommended by the Obstacle Clearance Panel at its eleventh meeting. No fixed object, other than visual aids required for air navigation purposes and satisfying the relevant frangibility requirement in Chapter 5 shall be permitted on a runway strip within 77.5m of the runway centre line of a PAI, PAII or PAIII runway category where the code number is 4 and the code letter is F.

2.6.5 **Taxiways:** Taxiway width has traditionally been related to the outer main gear wheel span and the permissible wheel-to-pavement edge clearance for a given Code letter. The existing clearance of 4.5 m for Code letter E has been retained for Code letter F, and the resulting width of taxiways is 25 m.

2.6.6 **Overall width of taxiway and shoulders:** The overall width of 60 m in §3.9.1 is based on the engine exhaust data in the breakaway thrust mode to be able to prevent erosion of soil adjacent to the taxiway, to prevent foreign object damage to the engines, and to be able to support the occasional passage of an aeroplane in the event of it running off the taxiway accidentally. Consequently, the 25 m wide taxiways would need to be provided with 17.5 m wide shoulders on either side.

2.6.7 **Taxiway minimum separation distances:** The separation distance between a runway and a parallel taxiway is based on the need for the wing tip of a taxiing aeroplane to be clear of the associated runway strip. The use of this concept (half strip width + half wing span) for Code letter F has led to a separation distance of 190m between the centre lines of an instrument runway and a parallel taxiway, and 115 m for a non-instrument runway. As for the taxiway minimum separation distances in columns 10 to 12 of Table 3-1 of Annex 14 Vol I, these distances are based on existing ICAO methodology of relating the distance to the wing span of the aeroplane, its permissible deviation from the centre line and a safety margin/buffer. It was concluded that the safety margin/buffer for Code letter F need not be as large as it would be if the current method is used. Instead, the existing safety margin for Code letter E was increased in proportion to the increase in the wing span of the Code letter F aeroplane. The resulting distances are 97.5 m between the centre lines of two taxiways, and 57.5 m between a taxiway centre line and an object. In case of the minimum distance between an aircraft stand taxilane and an object, it was felt that a smaller deviation was adequate and thus, a distance of 50.5 m has been proposed. Additionally, a new Note has been added to the Table 3-1 that the minimum distances specified therein ***do not guarantee*** sufficient distance behind a holding aeroplane for another to bypass it on a taxiway behind it.

2.6.8 **Taxiways on bridges:** The current specification in §3.8.19 concerning the width of taxiway bridges was found to be equally applicable for Code letter F as well. Accordingly, the taxiway bridge width for Code letter F will be equal to the corresponding graded portion of the taxiway strip, i.e. 60 m. A new recommendation, replacing the existing Note on the need to provide access by rescue and fire fighting vehicles to an aircraft in distress on a taxiway bridge, has been included.

2.6.9 **Taxiway strips:** The existing specification in §3.10.2 on the width of taxiway strips was deemed adequate for Code letter F aeroplane operations. The proposed 60 m wide graded portion of a taxiway strip for Code letter F is in accordance with the existing principle of it being equal to the overall width of a taxiway and shoulders.

2.6.10 **Aprons:** The current clearance distance of 7.5 m at an aircraft stand for Code letter E was considered adequate for Code letter F.

2.6.11 The pages of Amendment 3 relevant to the Code F aircraft, as contained in a State Letter ref AN 4/1.2.17-99/44 dated 9 April 1999 have been included as Attachment A to this Discussion Paper.

ICAO Circular on New Larger Aeroplane Operations Existing Aerodromes

2.7 ICAO has issued a Circular - a draft Version 4.1 dated 15 March 2004 - in order to provide States with information on the issues concerning aerodrome facilities and services, air traffic management and flight operations which should be considered for accomodating NLA operations at existing aerodromes. The Circular was developed in consultation with the Aerodrome Design Study Group and other appropriate parties.

2.8 The Circular contains information to assist in the understanding of the rationale behind the relevant Annex 14 Vol I Code F provisions as well as those related to flight operations and air traffic management. Additionally, the Circular provides guidance on the development of suitable operational procedures, alternative measures and operating restrictions at existing aerodromes which do not meet the relevant Annex 14 Vol I Code F provisions, so that safety will not be compromised at those aerodromes when used by a specific NLA.

2.9 The Circular also contains suitable references to aeronautical studies conducted by some States and International Organizations which will assist States in carrying out its own safety studies.

2.10 Aerodromes intending to handle aircraft operations requiring Code F facilities as specified in Annex 14 Vol I may, with the approval of the appropriate authority, provide the facilities with clearance less than those specified in the Annex for the operation of A380 aeroplanes, after carrying out aeronautical studies to ensure safety of operations are not impacted. However, facilities meeting Code F requirements should be provided in full on all relevant parts of the movement areas and whenever new construction or major redevelopment of the movement area are undertaken.

2.11 It is important to note that any resulting operational restrictions should be reviewed periodically and only be considered as a temporary alternative to full Annex 14 compliance. The existing guidance materials available in §1 of the *Aerodrome Design Manual* Part 2 – *Taxiways, Aprons and Holding Bays* (Doc 9157) pertaining to the conduct of aeronautical studies for determining the permissible minimum separation distances may be referred to. Each State which accepts aeronautical studies and other safety studies not referenced in Annex 14 Vol I and applies the resulting operational procedures, alternative measures and operating restrictions, is responsible for their application.

2.12 Attention is drawn to the fact that the operational procedures, alternative measures and operating restrictions identified in the Circular are applicable to those NLA for which the critical characteristics are shown in the attached Appendix A of the Circular. Should any of these characteristics change, appropriate studies will be needed to ensure continued safety of operations.

2.13 A copy of the Circular is included as Attachment B to this Working Paper. It can also be accessed by authorised users through the secure website ICAO-NET at www.icao.int/icaonet by selecting the link "Electronic Publications". In using the Circular attention is drawn to the disclaimer that the contents are subject to change, pending editorial revision and further technical input. ICAO accepts no responsibility or liability, in whole or in part, as to the currency, accuracy or quality of information in the Circular nor any consequence of its use.

Current Developments

2.14 It is anticipated that airports in the Asia/Pacific region would be among the major users of the only NLAs currently in production i.e. A380. When it began designing the A380, Airbus surveyed some 81 airports world-wide and 24 (30%) of those were in the Asia/Pacific region.

2.15 Early A380 airports in the Asia/Pacific region were forecasted to be SIN, NRT, SYD in 2006/2007, BKK, HKG, KIX in 2007/2009 and other early potential destinations could be TPE, SEL, DEL, BOM, KUL, MEL, BNE, and AKL.

2.16 The last six (6) years saw a proliferation of a number of mega greenfield airports being constructed and commissioned in the Asia/Pacific region. These include the new Kuala Lumpur International Airport, Hong Kong International Airport, Incheon International Airport, Guangzhou Baiyun, and the soon-to-be completed Suvarnabhumi Airport in Bangkok and Chubu International Airport in Japan. These airports are not expected to face significant problems in accommodating the A380, scheduled for entry into commercial service in 2006.

2.17 As of July 2004, there were 129 firm commitments from the following 11 airlines : Air France (10), Emirates (43), FedEx (10), ILFC (10), Korean Air (5), Lufthansa (15), Malaysian Airlines (6), Qatar Airways (2), Qantas (12), Singapore Airlines (10) and Virgin Atlantic (6).

2.18 The following describes some of the works completed as well currently ongoing at several States and major airports preparing for the operation of the A380:

2.18.1 **UNITED KINGDOM**

Civil Aviation Authority

Information on "Requirements for Code F Facilities and the introduction of A380 aircraft Operations" published by the UKCAA can be found at the website tp://www.caa.co.uk/docs/33/NTL200302.PDF

2.18.2 **UNITED STATES**

Federal Aviation Administration (FAA)

The following Engineering Briefs from FAA provide useful information as follows:

EB63, August 2003: "Use of non-standard 75-foot wide straight taxiway sections for Airbus A380 taxiing operations".

EB65, February 2004: "Minimum requirements to Widen Existing 150' wide runways for Airbus A380 Operations"

The FAA website is: http://www.faa.gov/arp/engineering/briefs/index.cfm?ARPnav=engineer

General Accounting Office (GAO)

This website examines issues related to the costs of upgrading airports in the US to accommodate the NLAs. It has been estimated that it will cost US$2.1 billion to prepare 14 largest airports in the US for the arrival of the A380. Nearly a third of the funds may be spent at LAX which is expected to handle more A380s than any other US city airport because it is the country's gateway for many Asian carriers.

The GAO website is : http://www.gao.gov/new.items/d02251.pdf

2.18.3 **EUROPE**

European Civil Aviation Commission (ECAC)

The NLA forum is hosted by ECAC in order to facilitate the exchange of information relevant to the New Larger Aircraft between States administrations, international organisations, airports, airlines, research organisations and industry.

The web site provides guidance and reference material from States concerning the accommodation of NLAs at existing airports. It sets out some of the possible operational procedures, alternative measures and operating restrictions which could be applied to operations of NLAs, and in particular the A380. It contains suitable references to aeronautical studies conducted by some States which will enable a State to carry out its own studies if unable to meet Annex 14, Volume I requirements.

Of particular interest is the Report on Risk Analysis in Support of Aerodrome Design Rules conducted by the Norwegian CAA in May 2004.

The website can be found at: http://www.ecac-ceac.org/nla-forum/

Other security and facilitation issues

2.19 With the planned commencement of A380 operations in 2006, significant changes will be required to many aspects of the airport infrastructure, in addition to Annex 14 Vol I requirements as described. The introduction of the aircraft will present new challenges for airport and airline security as well as border control.

2.20 Issues for consideration include airport facilities such as the impact on check-in areas, passenger and baggage screening, passenger terminal capacity, aircraft turnaround time, increased passenger risk, embarkation issues, pre-flight security screening, aircraft parking areas, in-flight contingencies and the threat posed by man-portable air defence systems (MANPADS).

2.21 Some of these issues had been discussed during the 12th Session of the ICAO Facilitation Division meeting held in Cairo, Egypt from 22 March to 2 April 2004. The relevant working papers can be found in the ICAO website:

http://www.icao.int/icao/en/atb/fal/FAL12/documentation.htm.

3. ACTION BY APANPIRG

The meeting is invited to:

a) note the information contained in this paper; and

b) call upon States and airport providers to initiate actions for the provision of facilities for the safe operation of the NLAs.

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AMENDMENT No. 3

TO THE

INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES

AERODROMES

ANNEX 14

TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

VOLUME I
AERODROME DESIGN AND OPERATIONS

The amendment to Annex 14, Volume I contained in this document was adopted by the Council of ICAO on **5 March 1999**. Such parts of this amendment as have not been disapproved by more than half of the total number of Contracting States on or before **19 July 1999** will become effective on that date and will become applicable on **4 November 1999** as specified in the Resolution of Adoption.

MARCH 1999

INTERNATIONAL CIVIL AVIATION ORGANIZATION

AMENDMENT 3 TO THE INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

AERODROMES
VOLUME I - AERODROME DESIGN AND OPERATIONS

RESOLUTION OF ADOPTION

The Council

Acting in accordance with the Convention on International Civil Aviation, and particularly with the provisions of Articles 37, 54 and 90 thereof,

1. *Hereby adopts* on 5 March 1999 Amendment 3 to the International Standards and Recommended Practices contained in the document entitled *International Standards and Recommended Practices, Aerodromes - Aerodrome Design and Operations*, which for convenience is designated Annex 14, Volume I to the Convention;

2. *Prescribes* 19 July 1999 as the date upon which the said amendment shall become effective, except for any part thereof in respect of which a majority of the Contracting States have registered their disapproval with the Council before that date;

3. *Resolves* that the said amendment or such parts thereof as have become effective shall become applicable on 4 November 1999;

4. *Requests the Secretary General*:

   a) to notify each Contracting State immediately of the above action and immediately after 19 July 1999 of those parts of the amendment which have become effective;

   b) to request each Contracting State:

      1) to notify the Organization (in accordance with the obligation imposed by Article 38 of the Convention) of the differences that will exist on 4 November 1999 between its national regulations or practices and the provisions of the Standards in the Annex as hereby amended, such notification to be made before 4 October 1999, and thereafter to notify the Organization of any further differences that arise;

      2) to notify the Organization before 4 October 1999 of the date or dates by which it will have complied with the provisions of the Standards in the Annex as hereby amended;

   c) to invite each Contracting State to notify additionally any differences between its own practices and those established by the Recommended Practices, when the notification of such differences is important for the safety of air navigation, following the procedure specified in subparagraph b) above with respect to differences from Standards.

NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT TO ANNEX 14, VOLUME I

1. The text of the proposed amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

~~Text to be deleted is shown with a line through it.~~	text to be deleted
New text to be inserted is highlighted with grey shading.	new text to be inserted
~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

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1.3 Reference Code

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Table 1-1. Aerodrome reference code
(see 1.3.2 to 1.3.4)

Code element 1		Code element 2		
Code number (1)	Aeroplane reference field length (2)	Code letter (3)	Wing span (4)	Outer main gear wheel span[a] (5)
1	Less than 800 m	A	Up to but not including 15 m	Up to but not including 4.5 m
2	800 m up to but not including 1 200 m	B	15 m up to but not including 24 m	4.5 m up to but not including 6 m
3	1 200 m up to but not including 1 800 m	C	24 m up to but not including 36 m	6 m up to but not including 9 m
4	1 800 m and over	D	36 m up to but not including 52 m	9 m up to but not including 14 m
		E	52 m up to but not including 65 m	9 m up to but not including 14 m
		F	[redacted]	[redacted]

a. Distance between the outside edges of the main gear wheels.

[redacted]

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CHAPTER 3. PHYSICAL CHARACTERISTICS

3.1 Runways

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Width of runways

3.1.9 **Recommendation.—** *The width of a runway should be not less than the appropriate dimension specified in the following tabulation:*

	Code letter					
Code number	*A*	*B*	*C*	*D*	*E*	*F*
1[a]	*18 m*	*18 m*	*23 m*	-		-
2[a]	*23 m*	*23 m*	*30 m*	-	-	-
3	*30 m*	*30 m*	*30 m*	*45 m*	-	-
4	-	-	*45 m*	*45 m*	*45 m*	[redacted]

a. The width of a precision approach runway should be not less than 30 m where the code number is 1 or 2.

Note 1.— The combinations of code numbers and letters for which widths are specified have been developed for typical aeroplane characteristics.

[redacted]

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Slopes on runways

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3.1.16 Sight distance

Recommendation.— *Where slope changes cannot be avoided, they should be such that there will be an unobstructed line of sight from:*

— *any point 3 m above a runway to all other points 3 m above the runway within a distance of at least half the length of the runway where the code letter is C, D or E [redacted]*

— *any point 2 m above a runway to all other points 2 m above the runway within a distance of at least half the length of the runway where the code letter is B; and*

— *any point 1.5 m above a runway to all other points 1.5 m above the runway within a distance of at least half the length of the runway where the code letter is A.*

[redacted]

CHAPTER 3. PHYSICAL CHARACTERISTICS

3.1 Runways

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Width of runways

3.1.9 **Recommendation.**— *The width of a runway should be not less than the appropriate dimension specified in the following tabulation:*

	Code letter					
Code number	*A*	*B*	*C*	*D*	*E*	*F*
1[a]	*18 m*	*18 m*	*23 m*	-		-
2[a]	*23 m*	*23 m*	*30 m*	-	-	-
3	*30 m*	*30 m*	*30 m*	*45 m*	-	-
4	-	-	*45 m*	*45 m*	*45 m*	*60 m*

a. The width of a precision approach runway should be not less than 30 m where the code number is 1 or 2.

Note 1.— The combinations of code numbers and letters for which widths are specified have been developed for typical aeroplane characteristics.

Note 2.— Guidance on runway width is given in the Aerodrome Design Manual, Part 1.

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Slopes on runways

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3.1.16 Sight distance

Recommendation.— *Where slope changes cannot be avoided, they should be such that there will be an unobstructed line of sight from:*

— *any point 3 m above a runway to all other points 3 m above the runway within a distance of at least half the length of the runway where the code letter is C, D, E or F;*

— *any point 2 m above a runway to all other points 2 m above the runway within a distance of at least half the length of the runway where the code letter is B; and*

— *any point 1.5 m above a runway to all other points 1.5 m above the runway within a distance of at least half the length of the runway where the code letter is A.*

Note.— Consideration will have to be given to providing an unobstructed line of sight over the entire length of a single runway where a full-length parallel taxiway is not available. Where an aerodrome has intersecting

3.2 Runway shoulders

General

Note.— Guidance on characteristics and treatment of runway shoulders is given in Attachment A, Section 8, and in the Aerodrome Design Manual, *Part 2*.

3.2.1 **Recommendation.**— *Runway shoulders should be provided for a runway where the code letter is D or E, and the runway width is less than 60 m.*

[redacted]

Width of runway shoulders

3.2.2 **Recommendation.**— *The runway shoulders should extend symmetrically on each side of the runway so that the over-all width of the runway and its shoulders is not less than 60 m.*

[redacted]

Slopes on runway shoulders

3.2.3 **Recommendation.**— *The surface of the shoulder that abuts the runway should be flush with the surface of the runway and its transverse slope should not exceed 2.5 per cent.*

Strength of runway shoulders

3.2.4 **Recommendation.**— *A runway shoulder should be prepared or constructed so as to be capable, in the event of an aeroplane running off the runway, of supporting the aeroplane without inducing structural damage to the aeroplane and of supporting ground vehicles which may operate on the shoulder.*

[redacted]

3.3 Runway strips

General

3.3.1 A runway and any associated stopways shall be included in a strip.

Length of runway strips

3.3.2 ~~**Recommendation.**— *A strip should extend before the threshold and beyond the end of the runway or stopway for a distance of at least:*~~ A strip shall extend before the threshold and beyond the end of the runway or stopway for a distance of at least:

— ~~*60 m where the code number is 2, 3 or 4;*~~

— ~~*60 m where the code number is 1 and the runway is an instrument one; and*~~

— ~~*30 m where the code number is 1 and the runway is a non-instrument one.*~~

— 60 m where the code number is 2, 3 or 4;

— 60 m where the code number is 1 and the runway is an instrument one; and

— 30 m where the code number is 1 and the runway is a non-instrument one.

* * * * *

Objects on runway strips

Note.— See 8.7 for information regarding siting and construction of equipment and installations on runway strips.

3.3.6 **Recommendation.**— *An object situated on a runway strip which may endanger aeroplanes should be regarded as an obstacle and should, as far as practicable, be removed.*

3.3.7 No fixed object, other than visual aids required for air navigation purposes and satisfying the relevant frangibility requirement in Chapter 5, shall be permitted on a runway strip:

a) within 77.5 m of the runway centre line of a precision approach runway category I, II or III where the code number is 4 and the code letter is F; or

b) within 60 m of the runway centre line of a precision approach runway category I, II or III where the code number is 3 or 4; or

c) within 45 m of the runway centre line of a precision approach runway category I where the code number is 1 or 2.

No mobile object shall be permitted on this part of the runway strip during the use of the runway for landing or take-off.

3.8 Taxiways

Note.— Unless otherwise indicated the requirements on this section are applicable to all types of taxiways.

General

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3.8.3 **Recommendation.—** *The design of a taxiway should be such that, when the cockpit of the aeroplane for which the taxiway is intended remains over the taxiway centre line markings, the clearance distance between the outer main wheel of the aeroplane and the edge of the taxiway should be not less than that given by the following tabulation:*

Code letter	Clearance
A	*1.5 m*
B	*2.25 m*
C	*3 m if the taxiway is intended to be used by aeroplanes with a wheel base less than 18 m;* *4.5 m if the taxiway is intended to be used by aeroplanes with a wheel base equal to or greater than 18 m.*
D	*4.5 m*
E	*4.5 m*
F	*4.5 m*

Note 1.— Wheel base means the distance from the nose gear to the geometric centre of the main gear.

Note 2.— [illegible] letter is F and the traffic density is high, a wheel to edge clearance greater than 4.5 m [illegible] to permit higher taxiing speeds.

Width of taxiways

3.8.4 **Recommendation.—** *A straight portion of a taxiway should have a width of not less than that given by the following tabulation:*

Code letter	Taxiway width
A	*7.5 m*
B	*10.5 m*

C	*15 m if the taxiway is intended to be used by aeroplanes with a wheel base less than 18 m;*
	18 m if the taxiway is intended to be used by aeroplanes with a wheel base equal to or greater than 18 m.
D	*18 m if the taxiway is intended to be used by aeroplanes with an outer main gear wheel span of less than 9 m;*
	23 m if the taxiway is intended to be used by aeroplanes with an outer main gear wheel span equal to or greater than 9 m.
E	*23 m*
F	*23 m*

[redacted]

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Junctions and intersections

3.8.6 **Recommendation.**— *To facilitate the movement of aeroplanes, fillets should be provided at junctions and intersections of taxiways with runways, aprons and other taxiways. The design of fillets should ensure that the minimum wheel clearances specified in 3.8.3 are maintained when aeroplanes are manoeuvring through the junctions or intersections.*

Note. — [redacted] *Guidance on the design of fillets* [redacted] *is given in the Aerodrome* Design Manual, *Part 2.*

. . . . .

Taxiway minimum separation distances

3.8.7 **Recommendation.**— *The separation distance between the centre line of a taxiway and the centre line of a runway, the centre line of a parallel taxiway or an object should not be less than the appropriate dimension specified in Table 3-1, except that it may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.*

Note 1.— Guidance on factors which may be considered in the aeronautical study is given in the Aerodrome Design Manual, *Part 2.*

Note 2.— ILS/MLS installations may also influence the location of taxiways due to interferences to ILS and MLS signals by a taxiing or stopped aircraft. Information on critical and sensitive areas surrounding ILS and MLS installations is contained in Annex 10, Volume I, Attachments C and G (respectively) to Part I.

Note 3.— The separation distances of Table 3-1, column 10, do not necessarily provide the capability of making a normal turn from one taxiway to another parallel taxiway. Guidance for this condition is given in the Aerodrome Design Manual, *Part 2.*

Note 4.— The separation distance between the centre line of an aircraft stand taxilane and an object shown in Table 3-1, column 12 may need to be increased when jet exhaust wake velocity may cause hazardous conditions for ground servicing.

Table 3-1. Taxiway minimum separation distances

Code letter	Distance between taxiway centre line and runway centre line (metres)								Taxiway centre line to taxiway centre line (metres)	Taxiway, other than aircraft stand taxilane, centre line to object (metres)	Aircraft stand taxilane centre line to object (metres)
	Instrument runways				Non-instrument runways						
	Code number				Code number						
	1	2	3	4	1	2	3	4			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
A	82.5	82.5	-	-	37.5	47.5	-	-	23.75	16.25	12
B	87	87	-	-	42	52	-	-	33.5	21.5	16.5
C	-	-	168	-	-	-	93	-	44	26	24.5
D	-	-	176	176	-	-	101	101	66.5	40.5	36
E	-	-	-	182.5	-	-	-	107.5	80	47.5	42.5
F	-	-	-	[illegible]	-	-	-	[illegible]	97.5	57.5	[illegible]

Note 1.— The separation distances shown in columns (2) to (9) represent ordinary combinations of runways and taxiways. The basis for development of these distances is given in the Aerodrome Design Manual, *Part 2.*

[redacted]

Slopes on taxiways

3.8.8 Longitudinal slopes

Recommendation.— *The longitudinal slope of a taxiway should not exceed:*

— *1.5 per cent where the code letter is C, D, or E* [redacted] *and*

— *3 per cent where the code letter is A or B.*

3.8.9 Longitudinal slope changes

Recommendation.— *Where slope changes on a taxiway cannot be avoided, the transition from one slope to another slope should be accomplished by a curved surface with a rate of change not exceeding:*

- *1 per cent per 30 m (minimum radius of curvature of 3 000 m) where the code letter is C, D or E or F; and*

- *1 per cent per 25 m (minimum radius of curvature of 2 500 m) where the code letter is A or B.*

3.8.10 Sight distance

Recommendation.— *Where a change in slope on a taxiway cannot be avoided, the change should be such that, from any point:*

- *3 m above the taxiway, it will be possible to see the whole surface of the taxiway for a distance of at least 300 m from that point, where the code letter is C, D, or E or F;*

- *2 m above the taxiway, it will be possible to see the whole surface of the taxiway for a distance of at least 200 m from that point, where the code letter is B; and*

- *1.5 m above the taxiway, it will be possible to see the whole surface of the taxiway for a distance of at least 150 m from that point, where the code letter is A.*

3.8.11 Transverse slopes

Recommendation.— *The transverse slopes of a taxiway should be sufficient to prevent the accumulation of water on the surface of the taxiway but should not exceed:*

- *1.5 per cent where the code letter is C, D, or E or F; and*

- *2 per cent where the code letter is A or B.*

. . . . .

Taxiways on bridges

3.8.19 The width of that portion of a taxiway bridge capable of supporting aeroplanes, as measured perpendicularly to the taxiway centre line, shall not be less than the width of the graded area of the strip provided for that taxiway, unless a proven method of lateral restraint is provided which shall not be hazardous for aeroplanes for which the taxiway is intended.

~~3.8.19 bis Recommendation.— Access should be provided for rescue and fire fighting vehicles to intervene in both directions within the specified response time to the largest aeroplane for which the taxiway bridge is intended.~~

~~*Note 1.— Where a width less than the width of the graded area of the strip is provided, consideration will have to be given to access by rescue and fire fighting vehicles.*~~

3.10 Taxiway strips

. . . . .

Width of taxiway strips

3.10.2 **Recommendation.—** *A taxiway strip should extend symmetrically on each side of the centre line of the taxiway throughout the length of the taxiway to at least the distance from the centre line given in Table 3-1, column 11.*

Objects on taxiway strips

Note.— See 8.7 for information regarding siting and construction of equipment and installations on taxiway strips.

3.10.3 **Recommendation.—** *The taxiway strip should provide an area clear of objects which may endanger taxiing aeroplanes.*

Note.— Consideration will have to be given to the location and design of drains on a taxiway strip to prevent damage to an aeroplane accidentally running off a taxiway. Suitably designed drain covers may be required.

Grading of taxiway strips

3.10.4 **Recommendation.—** *The centre portion of a taxiway strip should provide a graded area to a distance from the centre line of the taxiway of at least:*

— *11 m where the code letter is A;*

— *12.5 m where the code letter is B or C;*

— *19 m where the code letter is D; and*

— *22 m where the code letter is E; and*

— *[illegible] letter is F.*

Slopes on taxiway strips

3.10.5 **Recommendation.—** *The surface of the strip should be flush at the edge of the taxiway or shoulder, if provided, and the graded portion should not have an upward transverse slope exceeding:*

— *2.5 per cent for strips where the code letter is C, D, E or F; and*

— *3 per cent for strips of taxiways where the code letter is A or B;*

the upward slope being measured with reference to the transverse slope of the adjacent taxiway surface and not the horizontal. The downward transverse slope should not exceed 5 per cent measured with reference to the horizontal.

3.10.6 **Recommendation.—** *The transverse slopes on any portion of a taxiway strip beyond that to be graded should not exceed an upward ~~or downward~~ slope of 5 per cent as measured in the direction away from the taxiway.*

. . . . .

3.11.7 **Recommendation.—** *If a holding bay, ~~taxi-~~runway-holding position or road-holding position for a precision approach runway code number 4 is at a greater elevation compared to the threshold, the distance of 90 m or 75 m, as appropriate, specified in Table 3-2 should be further increased 5 m for every metre the bay or position is higher than the threshold.*

3.11.8 The location of a ~~taxi-~~runway-holding position established ~~at other than a taxiway/runway intersection~~ in accordance with 3.11.3 shall be such that a holding aircraft or vehicle will not infringe the obstacle free zone, approach surface, take-off climb surface or ILS/MLS critical/sensitive area or interfere with the operation of radio navigation aids.

* * * * *

3.12 Aprons

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Slopes on aprons

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3.12.5 **Recommendation.—** *On an aircraft stand the maximum slope should not exceed 1 per cent.*

Clearance distances on aircraft stands

3.12.6 **Recommendation.—** *An aircraft stand should provide the following minimum clearances between an aircraft using the stand and any adjacent building, aircraft on another stand and other objects:*

Code letter	*Clearance*
A	*3 m*
B	*3 m*
C	*4.5 m*
D	*7.5 m*
E	*7.5 m*
F	[redacted]

When special circumstances so warrant, these clearances may be reduced at a nose-in aircraft stand, where the code letter is D or E [redacted]*:*

a) between the terminal, including any fixed passenger bridge, and the nose of an aircraft; and

b) over any portion of the stand provided with azimuth guidance by a visual docking guidance system.

Note.— On aprons, consideration also has to be given to the provision of service roads and to manoeuvring and storage area for ground equipment [redacted]

3.11.7 **Recommendation.**— *If a holding bay, ~~taxi-~~runway-holding position or road-holding position for a precision approach runway code number 4 is at a greater elevation compared to the threshold, the distance of 90 m [illegible], specified in Table 3-2 should be further increased 5 m for every metre the bay or position is higher than the threshold.*

3.11.8 The location of a ~~taxi-~~runway-holding position established ~~at other than a taxiway/runway intersection~~ in accordance with 3.11.3 shall be such that a holding aircraft or vehicle will not infringe the obstacle free zone, approach surface, take-off climb surface or ILS/MLS critical/sensitive area or interfere with the operation of radio navigation aids.

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3.12 Aprons

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Slopes on aprons

. . . . .

3.12.5 **Recommendation.**— *On an aircraft stand the maximum slope should not exceed 1 per cent.*

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3.12.6 **Recommendation.**— *An aircraft stand should provide the following minimum clearances between an aircraft using the stand and any adjacent building, aircraft on another stand and other objects:*

Code letter	*Clearance*
A	*3 m*
B	*3 m*
C	*4.5 m*
D	*7.5 m*
E	*7.5 m*
F	[illegible]

When special circumstances so warrant, these clearances may be reduced at a nose-in aircraft stand, where the code letter is D or E [illegible]*:*

a) between the terminal, including any fixed passenger bridge, and the nose of an aircraft; and

b) over any portion of the stand provided with azimuth guidance by a visual docking guidance system.

Note.— On aprons, consideration also has to be given to the provision of service roads and to manoeuvring and storage area for ground equipment (see the Aerodrome Design Manual, Part 2, for [illegible]

Insert new text as follows:

3.14 De/anti-icing facilities

Note. — Safe and efficient aeroplane operations are of primary importance in the development of an aeroplane de/anti-icing facility. For further guidance, see the Manual on Aircraft Ground De/Anti-icing Operations.

General

3.14.1 **Recommendation.—** *Aeroplane de/anti-icing facilities should be provided at an aerodrome where icing conditions are expected to occur.*

Location

3.14.2 **Recommendation.—** *De/anti-icing facilities should be provided either at aircraft stands or at specified remote areas along the taxiway leading to the runway meant for take-off, provided that adequate drainage arrangements for the collection and safe disposal of excess de/anti-icing fluids are available to prevent ground water contamination. The effect of volume of traffic and departure flow rates should also be considered.*

Note 1.— One of the primary factors influencing the location of a de/anti-icing facility is to ensure that the holdover time of the anti-icing treatment is still in effect at the end of the taxiing and when take-off clearance of the treated aeroplane is given.

Note 2.— Remote facilities compensate for changing weather conditions when icing conditions or blowing snow are expected to occur along the taxi route taken by the aeroplane to the runway meant for take-off.

3.14.3 **Recommendation.—** *The remote de/anti-icing facility should be located to be clear of the obstacle limitation surfaces specified in Chapter 4, not cause interference to the radio navigation aids and should be clearly visible from the air traffic control tower for clearing the treated aeroplane.*

3.14.4 **Recommendation. —** *The remote de/anti-icing facility should be so located as to provide for an expeditious traffic flow, perhaps with a bypass configuration and not require unusual taxiing manoeuvre into and out of the pads.*

Note. — The jet blast effects caused by a moving aeroplane on other aeroplanes receiving the anti-icing treatment or taxiing behind will have to be taken into account to prevent degradation of the treatment.

Size and number of de/anti-icing pads

Note. — An aeroplane de/anti-icing pad consists of a) an inner area for parking of an aeroplane to be treated, and b) an outer area for movement of two or more mobile de/anti-icing equipment.

CHAPTER 4. OBSTACLE RESTRICTION AND REMOVAL

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4.2 Obstacle limitation requirements

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Amend Table 4-1 as follows:

Table 4-1. Dimensions and slopes of obstacle limitation surfaces — Approach runways

APPROACH RUNWAYS

	RUNWAY CLASSIFICATION									
								Precision approach category		
	Non-instrument Code number				Non-precision approach Code number			I Code number		II or III Code number
Surface and dimensions[a]	1 (2)	2 (3)	3 (4)	4 (5)	1,2 (6)	3 (7)	4 (8)	1,2 (9)	3,4 (10)	3,4 (11)
INNER APPROACH Width	—	—	—	—	—	—	—	90 m	120 m[e]	120 m[e]
. . . . .										
BALKED LANDING SURFACE Length of inner edge	—	—	—	—	—	—	—	90 m	120 m[e]	120 m[e]
. . . . .										

~~[illegible]~~

End of Table 4-1

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Circular on New Larger Aeroplane Operations at Existing Aerodromes

DRAFT Version 4.1 — 15 March 2004

NLACircularVersion4.1.wpd

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FOREWORD

In the early 1990s, the major aeroplane manufacturers had announced that plans were in hand to develop aeroplanes larger than the Boeing B747-400 — currently the largest passenger aeroplane in commercial service — capable of carrying more than 500 passengers.

In response to the stated need for appropriate ICAO provisions to facilitate aerodrome development for such New Larger Aeroplanes (NLA), ICAO undertook a study with the participation of some States, selected international organizations, and aeroplane manufacturers. The results of that study led to Amendment 3 to Annex 14, Volume I, which was adopted by the ICAO Council in March 1999. A new aerodrome reference code letter F to cover aeroplanes with wing spans from 65 m up to but not including 80 m and an outer main gear wheel span from 14 m up to but not including 16 m was established. Consequent new specifications on aerodrome physical characteristics for these aeroplanes were also developed. The new code F specifications in Annex 14, Volume I became applicable from 1 November 1999. Separately, specifications for aerodrome rescue and fire fighting (RFF) for aeroplanes with maximum fuselage widths in excess of than 7 m, and lengths greater than 76 m, RFF category 10, had already been developed and included in the Annex.

Newer generations of aeroplanes generally have an impact on existing aerodrome facilities and services when the dimensions and/or mass of these aeroplanes exceed the design parameters used for planning and developing an aerodrome. Consequently, as such newer and larger aeroplanes entered commercial service, aerodromes evolved by making necessary modifications to comply with the applicable Annex 14 specifications, as updated from time to time.

In certain cases, such modifications may not be considered practicable. In such cases, in order to ensure that a new aeroplane can be safely operated, States should carry out appropriate aeronautical studies to evaluate the suitability of existing facilities and to determine the need for alternative measures, operational procedures and operating restrictions for the specific aeroplane concerned. Some States and international organizations have already undertaken such studies tailored to a specific aeroplane type, to determine if solutions can be developed for those existing aerodromes which may not be able to comply fully with the code F provisions for the introduction of the NLA concerned.

In May 2003, the ICAO Council was presented with a twofold Action Plan developed by the Air Navigation Commission for the introduction of NLA into international civil aviation service, as published in State letter SL AN 4/5.7-03/80, dated 25 July 2003. Firstly, this Circular has been developed to provide States with information concerning aerodrome facilities and services, air traffic management and flight operations, which should be considered for accommodating NLA operations at existing aerodromes. Secondly, a review will be undertaken of the current Annex 14, Volume I, code F provisions, including their underlying basis, considering the results of studies outside ICAO.

It should be understood that Annex 14 contains all the provisions aimed at ensuring the safe operation of NLAs in general. However, each aeronautical study is specific to a particular context and to a particular NLA. Caution should therefore be exercised in considering applicability to other situations and locations. Each State which approves an aeronautical study and its resulting alternative measures, operational procedures and operating restrictions, is responsible for their application. Where operating restrictions are implemented, these should be reviewed periodically and only be considered as a temporary alternative to Annex 14 compliance.

The Circular has been developed in close cooperation with the Air Navigation Commission. Users are invited to express their views and offer comments and suggestions for improvements or additions based on their practical experience when using this information for national planning for introduction of NLA operations at existing aerodromes. These should be directed to the Secretary General of ICAO.

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Chapter 1

INTRODUCTION

1.1 PURPOSE

1.1.1 The Circular provides information on the issues concerning aerodrome facilities and services, air traffic management and flight operations which should be considered for accommodating a NLA at an existing aerodrome. The purpose of this Circular is to assist States in addressing the various aspects of NLA operations at existing aerodromes and to draw the attention of States and aerodrome operators to the impact on existing aerodromes of new larger aeroplanes (NLA) such as the Airbus A380.

1.1.2 The Circular provides guidance on conducting aeronautical studies, including the development of alternative measures, operational procedures and operating restrictions that could, while preserving safety, allow aerodromes which do not meet the relevant Annex 14, Volume I, code F criteria, to accommodate a specific NLA. States remain responsible for deciding what is acceptable as a measure, procedure, or restriction.

1.1.3 The Circular also addresses the impact of new longer aeroplanes such as the Airbus A340-600 and the Boeing B777-300 which, though belonging to aerodrome reference code E, have very long fuselage lengths, causing some problems at existing aerodrome stands, taxiway curves and holding positions. The need for specific study in all such cases and to review the clearances from all relevant angles is emphasized.

1.1.4 In 1999, Amendment 3 to Annex 14, Volume I introduced a new aerodrome reference code letter F, to accommodate aeroplanes with a wing span from 65 m up to but not including 80 m, and outer main gear wheel span from 14 m up to but not including 16 m. The intent of the ICAO aerodrome reference code is to provide a simple method for interrelating the numerous specifications concerning the characteristics of aerodromes so as to provide a series of aerodrome facilities that are suitable for the aeroplanes that are intended to operate at the aerodrome. In light of the above, the specifications in Chapter 3 of the Annex, on physical characteristics, were developed for code F using the existing methodology applied to codes A to E, and based on the data of the aircraft characteristics made available to ICAO. It should be noted that these provisions are generic and intended for the most demanding dimensions in the given aerodrome reference code letter; they were not developed for a specific aircraft type. The standard method of use of these specifications is to evaluate the most demanding aircraft and to establish the aerodrome reference code number and letter using the aircraft performance characteristics and dimensions. The methodology used to develop the Annex 14, Volume I, code F specifications for each aerodrome facility will be found in Chapter 4 of this Circular.

1.1.5 While States are expected to implement the new code F specifications for developing their aerodromes to receive NLAs in general, it is recognized that some States may have difficulties in complying with the new Annex 14, Volume I provisions before the entry into commercial service of a specific NLA at a given location. This Circular has been developed with the main intent of bringing together in one document all the relevant issues, with necessary cross-references to the appropriate ICAO provisions so that States may benefit from this in their efforts to develop their aerodromes appropriately. Information on some issues may not be mature at the time of publication of this Circular and will be issued when available.

1.2 SCOPE

1.2.1 This Circular identifies the issues which are of relevance to the operations of NLAs, including the A380. Notwithstanding the information provided in this Circular, the responsibility of States and aerodrome operators to ensure safety and efficiency remains unchanged. Any information provided herein should be evaluated for applicability and appropriateness in the specific aerodrome environment, and every effort should be made to comply with the Annex 14, Volume I provisions. Safety of operations must be the overriding concern whenever it is contemplated to conduct such operations with lesser clearances than those specified in the Annex.

1.2.2 It should be noted that Article 37 of the Chicago Convention provides that Contracting States undertake, inter alia, to conform with international standards, unless it is found impracticable to fully comply with them. In such a case, immediate notification thereof must be given to the ICAO Council, as provided in Article 38 of the Convention. Furthermore, according to Assembly Resolution A33-14, Appendix D, Associated Practice 3, Contracting States are called upon to notify to the Organization all differences from SARPS, i.e. not only from Standards but also from Recommended Practices. While all such notified differences are published by ICAO in Supplements to the relevant Annexes, Contracting States are also requested to publish them (as well as differences from Procedures) in their Aeronautical Information Publications (AIPs), when significant, as required under paragraph 4.1.2 c) of Annex 15 — *Aeronautical Information Services to the Convention*.

1.2.3 Information is provided on the various issues concerning aerodrome facilities and services which should be considered for accommodating, at existing aerodromes, the operations of NLAs and of the most demanding code E aeroplane such as the Airbus A340-600 and the Boeing B777-300. The known pertinent features of the Airbus A340-600, the A380 the Boeing B777-300 and the B747-Advanced are included. The Circular is also intended to assist in understanding the rationale behind the relevant Annex 14, Volume I provisions, as well as those related to flight operations and air traffic management. Additionally, the Circular provides information on the need to implement, suitable alternative measures, operational procedures and operating restrictions so that safety will not be compromised when operating at existing aerodromes which do not meet the relevant Annex 14, Volume I provisions for such large aeroplanes.

1.2.4 The Circular also contains detailed information on the various factors to be considered in conducting an aeronautical study to assess operation of large aeroplanes at existing aerodromes. Suitable references to studies conducted by some States have been included, which may provide assistance to a State wishing to carry out its own studies, if unable to comply with Annex 14, Volume I provisions. A review of the general scope and applicability of these studies indicates that the results are specific or particular to each aeroplane, to each aerodrome, its pavement surfaces and weather conditions. While these studies may be of assistance to those intending to carry out similar studies, it may not be appropriate to use the results directly where any or some of the factors are different from those used in these studies. Appendix B to this Circular contains references to these studies.

1.2.5 Though the results of a study may help to identify any safety-related aspects, States and aerodrome operators may wish to consider the potential impact on aerodrome capacity and movement rates. At many aerodromes, congestion is a critical issue. Authorities may therefore wish to link the studies to simulations of ground movement traffic flows, including NLA, as a gate-to-runway system, to identify any possible impact of operating an NLA on aerodrome capacity, and to develop trade-off options on a cost/effective basis. Nevertheless, safety should always be given due priority.

1.2.6 The Circular also draws attention to the need for reconsideration of emergency plans to deal with incidents involving larger aeroplanes, and consequential aspects of rescue and fire fighting.

1.2.7 Aircraft design and certification issues are not directly addressed in this Circular. However national certification requirements may impact facilities, services, or aerodrome infrastructure requirements.

1.2.8 During the early stages of introduction of the NLA, and where it is expected that frequency of movements will remain low, States may take the decision to consider the statistical implications of such frequency of movements on safety, in deciding on measures to be implemented.

1.2.9 Aerodromes intending to handle operations of a given NLA may, with approval of the appropriate authority, provide the facilities with clearances less than those specified in Annex 14, Volume I, after carrying out aeronautical studies to ensure safety of operations is preserved for that specific aeroplane. However, facilities meeting code F requirements should be provided in full on all relevant parts of the movement area whenever new constructions or major redevelopment are undertaken. When planning such construction or redevelopment, it may be prudent to consider the requirements of future aeroplane types needing facilities in excess of code F. Guidance in this respect is given in the *Aerodrome Design Manual*, Parts 1 and 2. Long term perspective planning to cater to future needs and the ability of the ground infrastructure to be modified quickly without disruption of ground operations and without compromising safety, would be advisable.

1.2.10 If NLA operations are contemplated on runways narrower than the 60 m recommended in Annex 14, Volume I, due considerations should be given to all factors affecting safety, including:

a) the type certification of the NLA concerned in accordance with Annex 8 (see Chapter 5, paragraph 5.1.2 of this Circular);

b) the use of possible mitigation measures discussed in Chapter 4, Section 4.1.2; and

c) local conditions and other operational factors.

1.2.11 Attention is drawn to the fact that the alternative measures, operational procedures and operating restrictions identified in this document are applicable to those NLA for which the critical characteristics are shown in Appendix A hereto. Should any of these characteristics change, appropriate studies will be needed to ensure continued safety of operations.

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Chapter 2

IMPACT OF NEW LARGER AEROPLANE CHARACTERISTICS ON AERODROME INFRASTRUCTURE

2.1 INTRODUCTION

2.1.1 The aim of this chapter is to relate the characteristics of NLA with aerodrome dimensions, facilities and services in movement areas. When preparing to accommodate NLA, any dimension that exceeds those of aeroplanes commonly using the facility should be taken into consideration. This chapter provides a comprehensive, but not exhaustive checklist of relevant items. Specific details of certain anticipated new aircraft types are in the Appendix hereto.

2.1.2 The following broad NLA characteristics are addressed:

a) NLA dimensions;

b) landing gear characteristics, weights and Aircraft Classification Number (ACN) values;

c) engine data;

d) maximum passenger and fuel carrying capacities; and

e) flight performance, including wake vortex.

2.2 NLA CHARACTERISTICS

2.2.1 Fuselage length

2.2.1.1 Fuselage length may influence:

a) dimensions of aprons, passenger gate, terminal areas, and holding bays;

b) dimensions of aircraft maintenance and repair services facilities;

c) aerodrome category for Rescue and Fire Fighting (RFF): Overall length of the most critical aeroplane is one of the two Annex 14 criteria to determine aerodrome category for RFF;

d) ground movement and control (e.g. reduced clearance behind a longer aeroplane holding at an apron or a runway holding position to permit the passing of another aeroplane) and;

e) de-icing facilities.

2.2.2 Fuselage width

2.2.2.1 The fuselage width will influence the aerodrome category for RFF. Maximum fuselage width of the most critical aeroplane is one of the two Annex 14 criteria to determine aerodrome category for RFF.

2.2.3 Fuselage height

2.2.3.1 The fuselage height may influence:

a) Location of holding position: Fuselage height is one of the Annex 14 criteria used to determine the location of the runway holding position (including tail height and distance from the nose to the highest part of the tail) of the critical aeroplane which shall be clear of the runway obstacle free zone (OFZ);

b) passenger gate and terminal area, in terms of upper deck access; and

c) dimensions of aircraft maintenance facilities.

2.2.4 Tail height

2.2.4.1 The tail height may influence:

a) location of holding position (see 2.2.3 above);

b) ILS sensitive areas: in addition to the tail height of the critical aircraft, tail composition, tail position and obstacle density (but also fuselage height and length) should be taken into account to determine the effect on ILS sensitive areas;

c) dimensions of aircraft maintenance services;

d) de-icing/anti-icing facilities; and

e) aeroplane parking position (in relation to aerodrome obstacle limitation surfaces).

2.2.5 Wing span

2.2.5.1 The wing span would influence:

a) taxiway separation distances (including runway-taxiway separation distances);

b) dimensions of the obstacle free zone (OFZ);

c) location of runway holding position (due to the impact of wing span on OFZ dimensions);

d) dimensions of aprons and holding bays;

e) shoulder dimensions;

f) wake turbulence;

g) selection of gates;

h) aerodrome maintenance services (e.g. snow removal to ensure adequate emergency vehicle to aircraft clearance);

i) dimensions of aerodrome or aircraft maintenance facilities; and

j) equipment for disabled aeroplane removal.

2.2.6 Wing tip vertical clearance

2.2.6.1 The wing tip vertical clearance may influence:

a) taxiway separation distances with height limited object;

b) aprons and holding bays clearances with height limited object;

c) aerodrome maintenance services (e.g. snow removal); and

d) airfield signage clearances.

2.2.7 Cockpit view

2.2.7.1 The relevant geometric parameters to assess the cockpit view are cockpit height, cockpit cut-off angle and corresponding obscured segment.

2.2.7.2 The cockpit view may influence:

a) runway visual references;.

b) runway sight distance;

c) taxiing operations on straight and curved sections;

d) markings and signs on runways, taxiways, aprons and holding bays; and

e) lights: In low visibility conditions, the number and spacing of visible lights when taxiing may depend on the cockpit view.

2.2.8 Pilot-eye position to nose landing gear and main landing gear distances

2.2.8.1 The design of taxiway curves is based on the cockpit-over-centre line concept. Pilots eye position to nose landing gear and main landing gear distances may influence:

a) taxiway fillets;

b) dimensions of aprons and holding bays; and

c) dimensions of turn pads.

2.2.8.2 The increased wheelbase dimensions of newer generation longer aeroplanes (A340-600, B-777-300) require a specific study to ascertain the adequacy of existing fillets and when designing other new facilities.

2.2.9 Landing gear design

2.2.9.1 The aeroplane landing gear design is such that the overall mass of the aeroplane is distributed so that the stresses transferred to the soil through a well-designed pavement are within the soil's bearing capacity. The landing gear layout also has an effect on the manoeuvrability of the aeroplane. The various factors that would impact an aerodrome pavement system are discussed hereafter.

2.2.10 Outer main gear wheel span

2.2.10.1 Outer main gear wheel span may influence:

a) runway width;

b) dimensions of turn pads;

c) taxiway width;

d) taxiway fillets; and

e) dimensions of aprons and holding bays.

2.2.11 Wheelbase

2.2.11.1 The wheelbase may influence dimensions of turn pads, taxiway fillets, and dimensions of aprons and holding bays.

2.2.12 Main gear steering system

2.2.12.1 The main gear steering may influence dimensions of turn pads, dimensions of aprons and holding bays.

2.2.13 Maximum aircraft mass

2.2.13.1 The maximum mass may influence:

a) design of pavements and underground structures;

b) mass limitation on existing bridges, tunnels and culverts under runways and taxiways;

c) disabled aircraft removal; and

d) wake turbulence.

2.2.14 Landing gear geometry, tire pressure and ACN values

2.2.14.1 Landing gear geometry, tire pressure and ACN values may influence design of airfield pavement, and design of runway shoulders.

2.2.15 Engine data

2.2.15.1 Engine characteristics

2.2.15.1.1 The engine characteristics that may be of interest are the following:

a) number of engines;

b) locations of engines;

c) vertical clearance of engines;

d) engine thrust; and

e) exhaust velocity.

2.2.15.1.2 The number and location of engines may influence:

a) runway shoulder width (jet blast and ingestion issues during take-off and landing);

b) taxiway shoulder width (jet blast and ingestion issues during taxiing);

c) bridge width (jet blast under the bridge);

d) dimensions and location of fences;

e) location of signs;

f) characteristics of runway and taxiway edge lights; and

g) snow removal procedure.

2.2.15.2 Engine exhaust velocities

2.2.15.2.1 The relevant exhaust velocities to be considered are at take-off thrust, breakaway thrust, thrust required during turning and idle thrust.

2.2.15.2.2 Engine exhaust velocity contours may influence:

a) runway shoulder width;

b) taxiway shoulder width;

c) bridge width;

d) blast fence dimensions and blast pads (including blast protection near turn pads), or overall blast limitations whilst manoeuvring;

e) location and structural integrity of signs;

f) characteristics of runway and taxiway edge lights;

g) separation between subsequent or proximate aircraft, ground service personnel or vehicles; and

h) snow removal procedures.

2.2.15.3 Engine thrust reverse

2.2.15.3.1 The engine thrust reverse system may influence the runway and shoulder width (lateral excursion, jet blast and ingestion issues during take-off and landing).

2.2.16 Maximum passenger and fuel carrying capacities

2.2.16.1 The maximum passenger and fuel carrying capacities may influence:

a) passenger terminal facilities;

b) fuel storage and distribution;

c) aerodrome emergency planning; and

d) aerodrome rescue and fire fighting.

2.2.17 Flight performance

2.2.17.1 The relevant parameters to be considered are:

a) approach attitude on glide slope;

b) approach speed;

c) start of visual segment;

d) autoland and manual modes; and

e) flight handling qualities.

2.2.17.2 The flight performance (autoland and manual) may influence:

a) runway width;

b) obstacle free zone;

c) runway-taxiway separation;

d) runway visual reference;

e) markings and signs on runways;

f) lighting in low visibility conditions;

g) flight safety and aircraft certification; and

h) wake turbulence.

2.2.18 Technology evolution

2.2.18.1 The technology evolution may influence:

a) runway and shoulder width;

b) taxiway and shoulder width;

c) aircraft certification criteria;

d) obstacle free zone and balked landing surface (OPS/AIR);

e) in flight phase (OPS/AIR); and

f) environment aspects (ATM).

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Chapter 3

METHODOLOGY FOR CONDUCTING AERONAUTICAL STUDIES

3.1 INTRODUCTION

3.1.1 This chapter outlines a safety analysis methodology[1] that is used in Chapter 4 of this Circular to assess the operational requirements and infrastructure needs for the accommodation of NLA at existing aerodromes.

3.1.2 If the level of aerodrome infrastructure is at least equal to that specified for code F aircraft in Annex 14, Volume I, these NLAs can be accommodated without alternative measures, operational procedures and operating restrictions.

3.1.3 Annex 14, Volume I permits the use of aeronautical studies in a few specific areas, namely taxiway minimum separation distances and penetration of certain obstacle limitation surfaces by existing objects. For example, paragraph 3.8.7 (Recommended Practice) envisages that it may be permissible to operate with lower taxiway minimum separation distances than those specified in Annex 14, Volume I, Table 3-1 at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect safety or significantly affect the regularity of aeroplane operations. Each State which approves an aeronautical study and its resulting alternative measures, operational procedures and operating restrictions, is responsible for their application. The *Aerodrome Design Manual* (Doc 9157), Part 2, Chapter 1, paragraphs 1.2.28 to 1.2.65 contain detailed guidance for conducting such aeronautical studies.

3.1.4 A safety analysis has been developed which is divided into four steps. For each infrastructure item to be evaluated, the analysis includes the Annex 14 requirements, hazard identification and analysis, risk assessment and possible mitigation measures.

3.1.5 However, the Circular does not include definitive conclusions for each infrastructure item. It will be the responsibility of airport operators and appropriate authority (States) to initiate aeronautical studies and to endorse conclusions from the safety analysis, taking into consideration the characteristics of the aeroplane to be operated, the local conditions and their own legal, regulatory and other requirements.

3.1.6 Appendix B contains a list of references to existing studies that may assist States and airports in developing their aeronautical studies, in accordance with Chapters 3 and 7. However it should be remembered that each study is specific to a particular context, and to a particular NLA, and caution should be exercised in considering applicability to other situations and locations. Inclusion of these references does not imply any ICAO endorsement or recognition of the findings, which remains a matter for the respective State to decide.

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[1] It should be noted that this is not the only way of conducting such an analysis, and that there are other appropriate methods: for the sake of consistency, it is advised that a single method be adopted as much as possible for all aerodrome infrastructure items.

3.2 OBJECTIVES AND SCOPE

3.2.1 According to the *Aerodrome Design Manual*, Part 2, the prime objective of an aeronautical study is the assessment of the adequacy of protection provided by the existing aerodrome layout for the operation of critical aeroplane with respect to:

a) collision with another aircraft, vehicle or object;

b) run-off from paved surfaces; and

c) engine damage from ingestion of foreign objects.

3.2.2 The areas of concern, which this assessment will address, relate to specific functional requirements in terms of:

a) distance between centre lines of runway and taxiway;

b) distance between centre lines of taxiway and parallel taxiway;

c) distance between centre line of taxiway and object;

d) distance between centre line of aircraft stand taxilane and object;

e) runway and taxiway dimensions, surface and shoulders; and

f) protection of engines against damage from foreign objects.

3.3 BASIC CONSIDERATIONS

3.3.1 It is recommended that an initial evaluation of the level of compliance with code F provisions in Annex 14, Volume I should be documented first and then the remaining areas of concern identified before proceeding with the aeronautical study.

3.4 SAFETY ANALYSIS ASPECTS

3.4.1 Risk assessment and possible mitigation measures

3.4.1.1 Hazard analysis to be applied in this context is the identification of undesirable events and hazards linked to an infrastructure item using experience and operational judgement. The analysis should cover:

a) accident causal factors and critical events based on a simple causal analysis of available accident and incident databases; and

b) accident severity with a simple consequences analysis, based on experience and accident database analysis.

3.4.1.2 The severity level of an incident/accident ("minor", "major", "hazardous" or "catastrophic") may be deduced from its consequences ("Effect on aircraft and occupants").

3.4.1.3 Careful consideration should be given by the relevant authorities to the classification of levels of risk. States should implement suitable risk assessment models. Examples of models are given in Appendix B. Advisory Material Joint-AMJ JAR 25.1309, containing material similar to US FAA Advisory Circular AC25.1309-1A (21 June 1988) defines "Catastrophic" as "Failure Conditions which would prevent Continued Safe Flight and Landing".

3.4.1.4 Risk assessment models are commonly built on the principle that there should be an inverse relationship between the severity of an incident and its probability. The appropriate level of safety for each type of incident can be specified in either quantitative (identification of a numerical probability) or qualitative (comparison with an existing situation) terms. A quantitative risk assessment may be problematic and not always relevant. In some cases, a probabilistic approach is possible and numerical target levels of safety can be used. In other instances, a qualitative analysis is more relevant with — for instance — the objective of providing a level of safety equal or better than the one offered to a code E aeroplane on a code E-compliant infrastructure.

3.4.2 Risk assessment process

3.4.2.1 Once each undesirable event is identified and analysed in terms of causes and consequences, the main remaining question is: "Are all identified risks under control?." The method for the evaluation of the level of risk is strongly dependent on the nature and mechanism of the hazards. Depending on the nature of the risk, three methods can be used to evaluate whether it is under control:

a) *Method type "A"*:

   For certain hazards, risk assessment strongly depends on specific aeroplane performance and handling qualities. The safety level is dependent upon aeroplane performance, handling qualities and infrastructure characteristics. Risk assessment, then, could be based on the aeroplane design, certification, simulation results and accident analysis.

b) *Method type "B"*:

   For other hazards, the aeroplane behaviour is not really linked with specific aeroplane performance and handling qualities, and can be calculated from existing aeroplane measurements. Risk assessment, then, could be based on statistics (e.g. deviations) from existing aeroplane operations or on accident analyses; development of generic quantitative risk models can be well adapted.

c) *Method type "C"*:

   In this case, a "risk assessment study" is not needed : a simple geometric argument may be sufficient to calculate NLA infrastructure requirements, without waiting for certification results or using statistics from existing aeroplane operations.

3.4.2.2 The understanding of the risks is the basis for the subsequent evaluation of alternative measures, operational procedures and operating restrictions needed to safely operate an NLA on existing infrastructure.

3.4.2.3 Where possible, the result of the risk assessment should be the establishment of alternative measures, operational procedures and operating restrictions to mitigate risks for the non-compliance of aerodrome facilities with ICAO code F requirements. These alternative measures, operational procedures and operating restrictions should be regarded as minimum conditions to achieve uniformity between similar operations at different airports. However, specific local conditions at an aerodrome may prohibit the provision or application of the minimum conditions. In this case additional control measures should be implemented in order to provide an acceptable level of safety.

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Chapter 4

AERODROME FACILITIES AND SERVICES

4.1 FACILITIES

4.1.1 Introduction

4.1.1.1 Newer generations of aeroplanes generally have an impact on existing aerodrome facilities and services when the dimensions and/or mass of these aeroplanes exceed the design parameters used for planning and developing the aerodromes. Due to their specific dimensions, the aerodrome infrastructure and operations may be affected. This is not only the case with the future NLAs such as the Airbus A380 and the proposed Boeing B747-Advanced or existing ones (Lockheed C5 and Antonov AN124) but also with recent and new aeroplanes within the well established code E. The new Airbus A340-600 as also the Boeing B777-300ER are within the upper boundaries of code E but require changes to many aspects of the aerodrome infrastructure due to their long fuselage length and the associated long wheelbase, i.e. the nose wheel gear to main landing gear distance.

4.1.1.2 This chapter describes the effect of these NLAs on the aerodrome infrastructure. The following items that may be affected by the introduction of NLAs are:

a) runways and shoulders;

b) runway strip and runway end safety area;

c) taxiways and shoulders;

d) bridges, tunnels and culverts under taxiways;

e) taxiway minimum separation distances; and

f) aprons and holding bays.

4.1.1.3 For each infrastructure item the following is presented:

a) **The ICAO SARPs**: (Standards and Recommended Practices) contained in Annex 14, Volume I, and guidance material in the Aerodrome Design Manual are described. Where possible, information and formula used to elaborate the ICAO provisions are given.

b) **Hazard identification and analyses**: where it is impossible or not practicable for aerodromes to adapt their infrastructure to the ICAO Annex 14, Volume I, code F provisions for the operation of a given NLA, an aeronautical study will be required to show that operation of the specific type within existing facilities is possible without compromising safety. For this reason a number of possible hazards are identified.

c) **Risk assessment** and possible mitigation measures related to the specific infrastructure item are given as a guideline. Information on risk assessment methods is contained in paragraph 3.4.2 of this Circular.

4.1.1.4 A reference list of studies is provided in Appendix B. Subject to cautions and guidance elsewhere in this Circular, these studies and results may assist authorities in developing their aeronautical studies. Inclusion of references in this Circular to studies conducted outside of ICAO does not imply ICAO endorsement. They are provided solely for the information of the reader. Any application of the results of the studies listed in the references to any ongoing studies remains a matter for decision by the appropriate authorities.

4.1.2 Runway and shoulders

4.1.2.1 Runway width

4.1.2.1.1 Annex 14, Volume I, paragraph 3.1.9 recommends that the width of a runway should not be less than 45 m where the code letter is E, and 60 m where the code letter is F.

4.1.2.1.2 Guidance in the *Aerodrome Design Manual* (Doc 9157), Part 1, *Runways*, indicates that, primarily the runway width is related to the outer main gear wheel span and the clearance required on either side of the outer main gear wheels when the aeroplane is centred on the runway centre line, as shown in the following formula:

Runway width = TM+2 x C

where TM = outer main gear wheel span and C= clearance between the outer main gear wheel and the runway edge.

The guidance in Doc 9157, Part 1 states that other factors of operational significance indicate that it might be advisable, for planning purposes, to consider a width of up to 60 m. The rationale for this was to have a margin for factors such as wet or contaminated runway pavement, cross wind conditions, crab angle approaches to landing and aircraft controllability during aborted take-off.

4.1.2.2 Hazard identification and analysis

4.1.2.2.1 The main hazard linked to available runway width is from structural damage associated with an aircraft running off the runway, during take-off, rejected take-off, or landing phase.

4.1.2.2.2 The main causes and accident factors are:

a) for take-off:

1) Aircraft (asymmetric spin-up and/or reverse thrust, malfunctioning of control surfaces, hydraulic system, tires, brakes, nose gear steering, aft CG);

2) Power plant (engine failure, foreign object ingestion);

3) Surface conditions (standing water, snow, runway friction coefficient);

4) Weather conditions (Heavy rain, cross wind, strong/gusty winds, visibility); and

5) Human factors (crew, maintenance, balance, payload security).

b) for landing:

1) Aircraft (malfunctioning of landing gear, control surfaces, hydraulic system, brakes, tires, nose gear steering);

2) Power plant (reverse and thrust lever linkage);

3) Surface conditions (standing water, snow, runway friction coefficient);

4) Weather conditions (Heavy rain, cross wind, strong/gusty winds, thunderstorms/wind shear, visibility);

5) ILS localizer signal quality/interference; and

6) Human factors (hard landings, crew, maintenance).

4.1.2.2.3 An analysis of lateral runway excursion reports shows that accident mechanisms are not the same for take-off and for landing. Mechanical failures are, for instance, a frequent accident factor for excursion during take-off, while bad weather conditions are more often associated with landing incidents. Engine reverse thrust system malfunction has also been a factor in a significant number of landing veer-offs (see Appendix B).

4.1.2.2.4 Lateral runway excursion hazard could be classified as major to catastrophic risk depending on the aircraft speed. According to the available reports, there were no code E aircraft fatal accidents due to runway excursion alone reported from 1980 to 2000.

4.1.2.2.5 A review of this accident/incident database also revealed that only 1.3 per cent of the total number of on-board fatalities from 1980 to 1998 occurred after lateral runway excursions. However, it should be noted that a large percentage of excursions result in serious damage or operational implications.

4.1.2.3 Risk assessment and possible mitigation measures

4.1.2.3.1 The lateral runway excursion risk is clearly linked to specific aircraft characteristics, performance/handling qualities, controllability in response to such events as aircraft mechanical failures, pavement contamination and cross-wind conditions. This type of risk comes under the category for which risk assessment is mainly based on aircraft performance and handling qualities. Aircraft type certification is one of the key factors to be considered in order to ensure that this risk is under control.

4.1.2.3.2 For use of runways narrower than the 60 m width recommended by Annex 14, Volume I, all factors affecting safety should be taken into account including the certification of the specific aircraft type and local conditions[2]. The approval of the appropriate authority should be sought. Possible mitigation

[2] Attention should be given to the crosswind performance of the aircraft on various runway surface conditions

measures for operation of a given NLA on runways which do not meet Annex 14, Volume I, code F specifications, are:

a) paved inner shoulders of adequate bearing strength to provide an overall width of the runway and its (inner) shoulders of 60 m;

b) provision of inset runway edge lights (in lieu of elevated lights);

c) provision of outer paved/stabilized shoulders with adequate bearing shoulders strength to provide an overall width of the runway and its shoulder of 75 m; and

d) provision of additional runway centre line guidance.

4.1.2.3.3 Aerodromes with runways narrower than 60 m should also take into account the possibility that certain NLAs are unable to make a 180 degree turn on that runway. When there is no proper taxiway to the end of the runway, the provision of a suitable runway turn pad is recommended.

4.1.2.4 Runway shoulder width

4.1.2.4.1 Annex 14, Volume I, paragraph 3.2.2 recommends that runway shoulders should be provided for a runway where the code letter is F. Furthermore, runway shoulders should extend symmetrically on each side of the runway so that the overall width of the runway and its shoulders is not less than 75 m where the code letter is F.

4.1.2.4.2 Runway shoulders are intended to provide a transition from the full strength pavement to the runway strip. In the event of an aeroplane running off a runway, the shoulders should be capable of withstanding the occasional passage of the aeroplane that has the most demanding pavement loading impact, operating at the aerodrome. Shoulders also provide erosion protection for the areas beyond the pavement, thereby reducing consequent foreign object damage.

4.1.2.5 Runway shoulder strength

4.1.2.5.1 Annex 14, Volume I recommends:

Paragraph 3.2.5: A runway shoulder should be prepared or constructed so as to be capable, in the event of an aeroplane running off the runway, of supporting the aeroplane without inducing structural damage to the aeroplane and of supporting ground vehicles which may operate on the shoulder.

4.1.2.5.2 *Aerodrome Design Manual*, Part 1 states that:

Paragraph 5.2.2: The shoulder of a runway should be prepared or constructed so as to minimize any hazard to an aeroplane running off the runway.

Paragraph 5.2.3: In some cases, the bearing strength of the natural ground may be sufficient, without special preparation, to meet the requirements for shoulders.

Paragraph 5.2.4: Attention should also be paid when designing shoulders to prevent the ingestion of stones or other objects by turbine engines.

Paragraph 5.2.5: In case of special preparation, visual contrast between runway and runway shoulders may be needed.

4.1.2.6 Hazard identification and analysis

4.1.2.6.1 Runway shoulders have three main functions:

a) to support occasional aircraft incursions without inducing structural damage to the aeroplane;

b) to provide jet blast protection and to prevent engine ingestion; and

c) to support ground vehicle traffic (RFF vehicles in particular).

4.1.2.6.2 Potential hazards associated with runway shoulder characteristics (width, soil type, bearing strength) are:

a) aircraft damage that could occur, due to inadequate bearing capacity, after incursion onto runway shoulder;

b) shoulder erosion causing ingestion of foreign objects by jet engines due to unsealed surfaces; and

c) difficulties for RFF services to access a damaged aircraft on the runway due to inadequate bearing strength or width.

4.1.2.6.3 Main causes and accident factors are:

a) runway centre line deviations (see runway excursion risk);

b) power plant characteristics (engine height, location and power); and

c) inadequate shoulder width, soil type, and bearing strength.

4.1.2.6.4 The specific NLA issues of concern to the RFF vehicle traffic are:

a) aeroplane wing span, engine position, escape chute extension length; and

b) shoulder width and bearing strength.

4.1.2.6.5 Certification requirements define the impact of foreign object damage (FOD) risks on aircraft tires and engines as potentially major. Delay in RFF operations could be classified as major to catastrophic. Sudden deceleration resulting from heavy braking, or due to aircraft damage can cause injuries that could be classified as major or catastrophic.

4.1.2.7 Risk assessment and possible mitigation measures

4.1.2.7.1 The hazards listed above are dependent on the relationship between the shoulder width, the bearing capacity and the critical characteristics of the aeroplane (overall mass, gear width and configuration, wingspan, outer engine position). Possible mitigation measures are:

a) **Prevention of damage to aircraft after incursion onto runway shoulder**. To prevent structural damage to aircraft in case of veer-off from a runway which does not meet Annex 14, Volume I specifications for a code F aircraft, hard shoulders to ensure at least an overall width of the runway and its inner paved shoulders of 60 m should be provided to allow pilots to steer the aircraft back onto the runway. The thickness and composition of shoulder pavements would need to be such as to withstand the occasional passage of the aeroplane that has the most demanding pavement loading impact, operating at the airport, as well as the full load of the most demanding airport emergency vehicle. The impact of an NLA on pavements should be assessed and, if required, existing runways and taxiways (if allowed to be used by these heavier aeroplanes) may need to be strengthened by providing a suitable overlay. Similarly, the existing shoulders also need to be evaluated for adequacy.

b) **Jet blast issue**. Information about outer engine position and jet blast velocity contour at take-off is needed to calculate the required width for jet blast protection. Jet blast velocity data is available on the respective manufacturers Web sites. Lateral deviation from runway centre line should also be taken into account. Regarding the risk of ingestion of foreign objects by the outer engines, additional data on ingestion tendency in front of these engines at take-off thrust are, in theory, needed before drawing any conclusions. Nevertheless, a comparison with the respective geometry of current large aircraft operations on existing runways helps to provide a better understanding of the issue. The dimension to be considered should include the margins between outer engine axis and edge of shoulder, and the distance from the outer engine to the ground.

c) **RFF vehicles intervention**. Operational experience with current large aircraft on existing runways suggests that an overall width of the runway and its shoulders of 75 m may be adequate for occasional RFF vehicle traffic in order to permit intervention to NLA (code F) at least as easily as for the current code E aircraft on a code E runway. However the longer extension of upper deck escape chutes may reduce the margin between the shoulder edge and the extremity of these escape slides and reduce the supporting surface available to rescue vehicles. Additional ICAO guidance material is under development, and will be issued later.

4.1.3 Runway strip and runway end safety area

4.1.3.1 Runway strip and runway end safety area are based on the runway length classification and instrument approach classification. The runway strip is intended to provide an area free of fixed and moving objects in order to permit safe landing and take-off of aeroplanes using the runway. Particularly, the graded portion of the runway strip is provided to minimize the damage to an aeroplane in the event of a veer-off during a landing or take-off operation. It is for this reason that Annex 14, Volume I requires objects to be located away from this portion of the runway strip unless they are needed for air navigation purposes and are frangibly mounted.

4.1.3.2 The runway end safety area is provided to prevent accidents/incidents due to aircraft undershooting/overshooting the runway. ICAO Accident/Incident Reporting (ADREP) data for the 10 year period (1987 - 1997) have shown that in the area extending to a distance of 300 m from the runway threshold, 21 per cent of the overrunning aircraft were destroyed while nearly 48 per cent sustained substantial damages. Collision hazard after runway excursion could be classified as major to catastrophic risk. Hence the need to provide adequate runway end safety areas, as specified in Annex 14, Volume I.

4.1.3.3 The dimensions of the Runway End Safety Area is dependent on the width of the runway. According to the requirements in Annex 14, Volume I, this is aircraft size dependent as the minimum requirement is 120 m (2 x 60 m runway width) for code F aircraft and 90 m (2 x 45 m runway width) for code E aircraft. In most cases, the width of the runway end safety area is greater than the minimum required in Annex 14, Volume I.

4.1.4 Taxiway and shoulders

4.1.4.1 Width of straight taxiway

4.1.4.1.1 Annex 14, Volume I, paragraph 3.8.1 specifies that taxiways should be provided to permit the safe and expeditious surface movement of aircraft. Furthermore paragraph 3.8.3 recommends that the minimum clearance between outer main wheel and taxiway edge should be at least 4.5 m for code letters D, E, and F. Additionally, paragraph 3.8.4 specifies that the width of a straight portion of a taxiway should not be less than:

— 23 m where code letter is E; and
— 25 m where code letter is F

4.1.4.1.2 Guidance material in the *Aerodrome Design Manual* (Doc 9157), Part 2 indicates in paragraph 1.2.7 and Table 1-1 the formula for determining the width of a taxiway as follows:

Taxiway width = 2 x clearance distance from wheel to pavement edge plus max. outer main gear wheel span for the code letter.

Using the above formula, the taxiway width for:

code E: 2 x 4.5 m + 14 m = 23 m; and
code F: 2 x 4.5 m + 16 m = 25 m.

4.1.4.2 Hazard identification and analysis

4.1.4.2.1 The hazard arises from a lateral taxiway excursion on a straight section. The taxiway should be sufficiently wide to permit smooth traffic flow while facilitating aircraft steering control.

4.1.4.2.2 The causes of a taxiway excursion are:

a) mechanical failure (hydraulic system, brake, nose gear steering);

b) adverse surface conditions (standing water, loss of control on ice-covered surface, friction coefficient);

c) loss of taxiway centre line visual guidance (markings and lights covered by snow or inadequately maintained); and

d) human factors (including directional control, orientation error, pre-take-off workload).

4.1.4.2.3 Consequences are potentially major. In practice, according to the common accident/incident lateral taxiway excursions databases, no taxiway excursion on a straight section with passenger injuries have been reported for the last 20 years. However consideration should be given to the greater potential impact of a larger aircraft deviation in terms of blocked taxiway or disabled aircraft removal.

4.1.4.3 Risk assessment and possible mitigation measures

4.1.4.3.1 Loss of control due to mechanical failure, surface conditions and loss of visual taxiway guidance system are factors that should be considered while deciding on the taxiway width.

4.1.4.3.2 The risk linked with pilot precision and attention is a key issue since it is heavily related to the margin between the outer main gear wheel and the taxiway edge. This risk is a generic one. All functioning aeroplanes respond reliably to pilot directional inputs when taxiing at ordinary speeds. NLA behaviour could be deduced from observations of existing large aircraft types (see Appendix B).

4.1.4.3.3 Optional studies could include:

a) the use of taxiway deviation statistics to calculate NLA taxiway excursion probability depending on taxiway width. The impact of taxiway guidance systems, weather and surface conditions on taxiway excursion probability should be assessed whenever possible. Several taxiway deviation trials have already been conducted, and additional trials are being conducted at a number of aerodromes to determine the extent of deviation from the taxiway centre line during taxiing of large aircraft. (See references in Appendix B); and

b) the ease of visibility of the taxiway from the cockpit, taking into account the visual reference cockpit cut-off angle.

4.1.4.3.4 Possible mitigation measures for operations of NLAs on taxiways narrower than those recommended in Annex 14, Volume I, are:

a) provision of taxiway centre line lights;

b) on-board taxi camera systems to assist taxi guidance;

c) reduced taxi speed;

d) provision of taxi side stripe markings (and taxiway edge lights);

e) enhanced snowbank clearance (engine positions); and

f) use of alternative taxi routes.

4.1.4.3.5 Special attention should be given to the offset of centre line lights in relation to centre line markings. Especially during winter conditions, distinction between markings and offset lights could be difficult.

4.1.4.4 Taxiway curves and intersections

4.1.4.4.1 Annex 14, Volume I, paragraph 3.8.5 recommends provision of suitable curves to ensure that when the cockpit remains over the taxiway centre line, the outer main wheel edge maintains a 4.5 m clearance from taxiway edge.

4.1.4.4.2 *Aerodrome Design Manual*, Part 2 contains related guidance in paragraphs 1.2.9 and 1.2.22 and Table 1-3.

4.1.4.5 Hazard identification and analysis

4.1.4.5.1 Any hazard will be the result of a lateral taxiway excursion on a curved section.

4.1.4.5.2 The causes of such an event could be classified as the same as for a taxiway excursion on a straight taxiway section. The use of cockpit-over-centre line steering technique on curved taxiway will result in track-in of the main landing gears from the centre line. The amount of track-in depends on the radius of the curved taxiway and the cockpit-to-main landing gear distance.

4.1.4.5.3 Consequences are the same as for lateral taxiway excursions on straight sections.

4.1.4.6 Risk assessment and possible mitigation measures

4.1.4.6.1 The required width of curved portions of the taxiways is related to the clearance between the outer main wheel and the taxiway edge on the inner curve. The hazard is related to the combination of outer main gear wheel span and the distance between nose gear/cockpit and main gear. Consideration may need to be given to the effect of jet blast from a turning aircraft on airfield signs and other objects nearby.

4.1.4.6.2 Though the outer main gear wheel span of certain aircraft place them in code E, the effect of the longer wheelbase on taxiway junctions will require wider fillets.

4.1.4.6.3 Possible mitigation measures for operation of NLA on taxiway curves and sections not conforming to Annex 14, Volume I specifications are:

a) widening existing fillets or providing new fillets;

b) reduced taxi speed; and

c) provision of taxiway centre line lights and taxi side stripe markings (and taxiway edge lights).

4.1.4.6.4 Special attention should be given to the offset of centre line lights in relation to centre line markings. Especially during winter conditions distinction between markings and offset lights could be difficult.

4.1.4.7 Taxiway shoulders

4.1.4.7.1 Annex 14, Volume I, paragraph 3.9.1 recommends that the overall width of taxiway and shoulders on straight portion should be:

— 44 m where code letter is E
— 60 m where code letter is F.

These dimensions are based on current information regarding the width of the outer engine exhaust plume for breakaway thrust. These are the minimum widths considered necessary for taxiway shoulders as detailed in paragraph 4.1.4.7.2. Furthermore, in paragraph 3.9.2, it is recommended that the surface should be so prepared as to resist erosion and ingestion of the surface material by aeroplane engines.

4.1.4.7.2 The guidance material in the Aerodrome Design Manual, Part 2, paragraphs 1.6.1 and 1.6.2 envisages that the shoulders are intended to protect an aeroplane operating on the taxiway and to reduce the risk of damage to an aeroplane running off the taxiway.

4.1.4.8 Hazard identification and analysis

4.1.4.8.1 Taxiway shoulders have four main functions:

a) to prevent jet engines that overhang the edge of a taxiway from ingesting stones or other objects that might damage engine or cause jet blast damage to following aircraft;

b) to prevent erosion of the area adjacent to the taxiway;

c) to support occasional aircraft incursions without inducing structural damage to the aeroplane; and

d) to support RFF vehicles.

4.1.4.8.2 The factors leading to reported problems are:

a) power plant characteristics (engine height, location and power);

b) taxiway shoulder width, nature of surface and its treatment; and

c) taxiway centre line deviation factors, both from the expected minor wander from tracking error and the effect of main gear track-in in the turn area while using the cockpit-over-centre line steering technique.

4.1.4.8.3 Ingestion immediately prior to take-off could be classified as a major safety risk, whereas during taxiing, it could be classified as minor. Infrastructure requirements relative to jet blast and engine ingestion should consider the increased engine span and performance.

4.1.4.9 Risk assessment and possible mitigation measures

4.1.4.9.1 Information on engine position and jet blast velocity contour at breakaway thrust mode enables an assessment of jet blast protection requirements during taxiing operations to be made. A lateral deviation from taxiway centre line should be taken into account, particularly in the case of a curved taxiway and the use of cockpit-over-centre line steering technique.

4.1.5 Bridges, tunnels and culverts under taxiways

4.1.5.1 Taxiway on bridges

4.1.5.1.1 Annex 14, Volume I, paragraph 3.8.19 specifies: "The width of that portion of a taxiway bridge capable of supporting aeroplanes, as measured perpendicularly to the taxiway centre line, shall not be less than the width of the graded area of the strip provided for that taxiway, unless a proven method of lateral restraint is provided which shall not be hazardous for aeroplanes for which the taxiway is intended."

4.1.5.1.2 Annex 14, Volume I, paragraph 3.8.20 also specifies that access should be provided for RFF vehicles to intervene in both directions within the specified response time to the largest aeroplane for which the taxiway is intended.

4.1.5.1.3 Annex 14, Volume I: paragraph 3.8.20, and *Aerodrome Design Manual*, Part 2, paragraph 1.4.4 specify that if aeroplane engines overhang the bridge structure, protection of adjacent areas below the bridge from engine blast may be required.

4.1.5.2 Hazard identification and analysis

4.1.5.2.1 The following hazards are related to the width of taxiway bridges:

a) landing gear leaving the load-bearing surface;

b) deployment of an escape slide beyond the bridge, in case of an emergency evacuation;

c) lack of manoeuvring space for RFF vehicles around the aeroplane;

d) jet blast to vehicles, objects or personnel below the bridge;

e) structural damage to the bridge due to aeroplane mass exceeding the design load; and

f) damage to aeroplane due to insufficient clearance of engines, wings or fuselage from bridge rails, lights or signs.

4.1.5.2.2 The causes of such an event could be:

a) mechanical failure (hydraulic system, brake, nose gear steering);

b) surface conditions (standing water, loss of control on ice-covered surface, friction coefficient);

c) loss of visual taxiway guidance system (markings and lights covered by snow);

d) human factors (e.g. directional control, disorientation, pre-departure workload);

e) insufficient clearance between the outer wheels of the main gear and the edge of the bridge;

f) position of the extremity of the escape slides; and

g) undercarriage design.

4.1.5.2.3 The main causes and accident factors for jet blast effect below the bridge are:

a) power plant characteristics (engine height, location and power);

b) bridge blast protection width; and

c) taxiway centre line deviation factors (see taxiway excursion risk).

4.1.5.2.4 These hazards would be classified as “major” to “catastrophic”.

4.1.5.3 Risk assessment and possible mitigation measures

4.1.5.3.1 Hazard prevention mechanisms could be based on the critical dimensions of the aeroplane relative to the bridge width. However, before permitting use of taxiway bridges of narrower width than those specified in Annex 14, Volume I, States should evaluate the operational feasibility of doing so.

4.1.5.3.2 For RFF intervention, it is necessary to ensure that the vehicles have access to both sides of the aircraft, to fight any fire from the best position, and allowing for wind direction as necessary. A wingspan of 80 m will in all cases exceed the width of a bridge. However, according to the experience of some aerodromes, it may be feasible to use another bridge nearby for access to the “other” side of an aircraft rather than an increased bridge width. This may be practicable only where bridges are paired (parallel taxiways) or when there is a service road in the vicinity. The surface on the bypass routes would need to be stabilised where it is unpaved.

4.1.5.3.3 For jet blast protection to vehicle traffic under/near the bridge, the requirement for protection should be at least consistent with the overall width of the taxiway and its shoulders.

4.1.5.3.4 For weight capacity limitations, some alternative procedures may be required. Where an existing bridge does not have the capability to support the weight of an NLA, either alternate routes may be used, or a new bridge should be constructed.

4.1.5.3.5 In any case, the bridge width should be compatible with the deployment of escape slides. If the width of the bridge do not meet this criterion, it should be ensured that the available blast protection provides a safe and quick escape route.

4.1.5.3.6 The existing underground structures such as box culverts, bridges and pipe crossings all need to be evaluated for their structural capability in view of the significant increase in the all-up mass of the given

NLA. If inadequate, suitable strengthening measures, if economical and technically feasible, would need to be implemented. Otherwise, alternate taxi routes should be established that would have suitably designed underground structures where needed.

4.1.5.3.7 Possible mitigation measures for operation of a given NLA on taxiway bridges which do not meet Annex 14, Volume I, code F specifications are:

a) where feasible, strengthen existing bridges;

b) provide a proven method of lateral restraint to prevent the aeroplane from veering off the full bearing strength of the taxiway bridge; and

c) alternative path/bridge for RFF vehicles subject to its feasibility from an RFF point of view.

4.1.6 Taxiway minimum separation distances

4.1.6.1 Runway to parallel taxiway separations

4.1.6.1.1 Annex 14, Volume I, paragraph 3.8.7, Table 3-1, columns 5 and 9 specify, for code F, a minimum distance between the centre lines of a runway and the associated parallel taxiway of 190 m for instrument runways and 115 m for non-instrument runways. It may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly effect the regularity of operations of aeroplanes. See Note 2 to Table 3-1, and Notes 2, 3 and 4 to paragraph 3.8.7 of Annex14, Volume I.

4.1.6.1.2 *Aerodrome Design Manual*, Part 2: paragraph 1.2.19, Table 1-5 clarifies that the runway/taxiway separation is based on the principle that the wing tip of an aeroplane taxiing on a parallel taxiway should be clear of the runway strip.

The runway to taxiway separation distance = 1/2 wing span + 1/2 strip width.

For code E: 1/2 x 65 m + 1/2 x 300 m = 182.5 m
For code F: 1/2 x 80 m + 1/2 x 300 m = 190 m

4.1.6.1.3 *Aerodrome Design Manual*, Part 2 has related guidance in paragraph 1.2.46 to 1.2.49. Furthermore, attention is drawn to the need to provide adequate clearance at an existing airport in order to operate a new larger aeroplane with the minimum possible risk.

4.1.6.2 Hazard identification and analysis

4.1.6.2.1 The potential hazards associated with runway and parallel taxiway separation distances are:

a) collision risk between an aeroplane in flight and an object (fixed or mobile) on the aerodrome;

b) collision risk between an aeroplane leaving the runway and an object (fixed or mobile) on the aerodrome or collision risk between an aircraft which runs off the taxiway into the runway strip; and

c) ILS signal interference due to a taxiing or stopped aeroplane.

4.1.6.2.2 The first two hazards are potentially catastrophic and the third one is potentially major.

4.1.6.2.3 Main causes and accident factors are:

a) human factors (crew, ATS);

b) weather conditions (visibility);

c) aircraft mechanical failure (engine, hydraulic system, flight instruments, control surfaces, auto pilot, etc.);

d) surface conditions (standing water, loss of control on ice-covered surface, friction coefficient);

e) lateral veer-off distance;

f) aeroplane position relative to navaids, especially ILS; and

g) aeroplane size and characteristics (especially wing span).

4.1.6.2.4 Common accident/incident databases deal with lateral runway excursions and do not include accident reports relative to in-flight collision and ILS signal interference. Therefore, the causes and accident factors specific to the local environment and identified above for runway separation issues are mainly supported by local aerodrome experience. The huge variety and complexity of accident factors for collision risk should be emphasized.

4.1.6.3 Risk assessment and possible mitigation measures

Collision between an aircraft in flight and an object (fixed or mobile) on the aerodrome

4.1.6.3.1 The ICAO Obstacle Clearance Panel is conducting a study on NLA balked landing operations. Some simulation tests are still to be done before analyses and final conclusions for all aircraft operating modes (Autoland, Flight Director and visual approach conditions) are reached.

Collision between an aircraft veering off the runway and an object (fixed or mobile) on the aerodrome

4.1.6.3.2 The *Aerodrome Design Manual*, Part 2, paragraph 1.2.19 states “Separation distances are based on the concept of the wing tip of an aircraft centred on a parallel taxiway remaining clear of the strip”.

4.1.6.3.3 As such, the following options may be considered:

a) place a restriction on the wing span of aircraft using the parallel taxiway if continued unrestricted runway operation is desired;

b) conduct a local study for any impact on ILS signal; and

c) in deciding whether to approve unrestricted operations, consider the expected frequency of potentially limiting NLA operations.

4.1.6.3.4 The minimum distance between the centre lines of a runway and a parallel taxiway may need to be increased beyond those specified in Annex 14, Volume I, Table 3-1, taking into account the location of the holding position, the length of the most demanding aircraft at the holding position, and the minimum distance (as per Table 3-1, column 11) needed for an aircraft to taxi behind it safely[3].

4.1.6.3.5 In some complex aerodrome layouts, a specific study may be needed to evaluate the situations where existing taxiways are permitted to be used by a code F aeroplane.

4.1.6.3.6 A review of present taxi operation procedures and guidance technologies may be needed. Mitigation measures may require some surface movement restrictions, alternative operational procedures or additional guidance systems.

4.1.6.3.7 In addition, Annex 14, Volume I, section 2.9 advises effective control of runway surface friction characteristics, reliable wind reporting, and where applicable, reporting of runway surface friction characteristics. Aircraft operators could apply operational restrictions according to conditions.

ILS signal interference by a taxiing or stationary aircraft

4.1.6.3.8 ILS signal distortion risk should be assessed on a case-by-case study basis taking into account specific aerodrome layout and traffic density. Individual case studies could benefit from several ongoing generic studies dealing with current code E and expected code F aircraft geometry effects on ILS safety area.

4.1.6.4 Parallel taxiway separation

4.1.6.4.1 Annex 14, Volume I, paragraph 3.8.7, Table 3-1, column 10 specifies the minimum distance between the centre lines of two parallel taxiways should be 97.5 m where the code letter is F. It may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly effect the regularity of operations of aeroplanes.

4.1.6.4.2 *Aerodrome Design Manual*, Part 2, paragraph 1.2.13 to 1.2.15, Table 1-1 and 1-4, Figure 1-4 clarifies that this minimum separation distance is equal to the wing span plus max lateral deviation plus increment.

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[3] Additional guidance material on minimum separation distances will be included in the revised *Aerodrome Design Manual*, Part 2 (4th edition)

for code E: 65 m + 4.5 m + 10.5 m = 80 m;
for code F: 80 m + 4.5 m + 13 m = 97.5 m

4.1.6.5 Taxiway/apron taxilane to object separation

4.1.6.5.1 Annex 14, Volume I, paragraph 3.8.7, Table 3-1, column 11 specifies that the minimum distance between a code F taxiway centre line and an object should be 57.5 m. It may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly effect the regularity of operations of aeroplanes.

4.1.6.5.2 Paragraph 3.10.3 also envisages that the taxiway strip should provide an area clear of objects which may endanger an aircraft.

4.1.6.5.3 *Aerodrome Design Manual*, Part 2, paragraphs 1.2.13 to 1.2.18, Table 1-1 and 1-4, Figure 1-4 states that:

Separation = 1/2 wing span + max lateral deviation + increment

for code E: 1/2 x 65 m + 4.5 m + 10.5 m = 47.5
for code F: 1/2 x 80 m + 4.5 m + 13 m = 57.5 m

4.1.6.6 Aircraft stand taxilane to object separation (including service road)

4.1.6.6.1 Annex 14, Volume I, paragraph 3.8.7, Table 3-1, column 12, specifies a minimum separation distance between the taxilane centre line and an object to be 50.5 m. Note 4 to this paragraph envisages that this distance may need to be increased if jet exhaust wake velocity is likely to be hazardous for ground servicing personnel and equipment.

4.1.6.6.2 *Aerodrome Design Manual*, Part 2, paragraphs 1.2.13 to 1.2.17, Tables 1-1 and 1-4, Figure 1-4 indicate that:

Separation = 1/2 wing span + max. lateral deviation + increment

for code E: 1/2 x 65 m + 2.5 m + 7.5 m = 42.5
for code F: 1/2 x 80 m + 2.5 m + 8 m = 50.5 m

See paragraphs 1.2.61 and 1.2.62 of the Aerodrome Design Manual, *Part 2*.

4.1.6.7 Hazard identification and analysis

4.1.6.7.1 The separation distances during taxiing are intended to limit the risk of collision between two aeroplanes (taxiway/taxiway separation) and between an aeroplane and an object (taxiway/object, taxilane/object separations).

4.1.6.7.2 A review of commonly used databases reveals that information relative to collision on taxiing is limited as few such incidents have been recorded as serious incidents. However, the causes of such an event could be classified as:

a) mechanical failure (hydraulic system, brake, nose gear steering);

b) surface conditions (standing water, loss of control on ice-covered surface, friction coefficient);

c) loss of visual taxiway guidance system (markings and lights covered by snow); and

d) human factors (directional control, temporary loss of orientation, etc.).

4.1.6.7.3 Consequences of collision on taxiing are potentially major.

4.1.6.8 Risk assessment and possible mitigation measures

4.1.6.8.1 Operational experience of existing code E aeroplanes, under favourable conditions, shows that deviations do not increase with aeroplane size. It is therefore expected that taxiway deviations by NLA will not be significantly different from code E aeroplanes. This has yet to be confirmed by actual operational experience with NLAs. That is why the permissible deviation of code F aeroplanes in Annex 14, Volume I, paragraph 3.8.3 is the same as for code E aeroplanes.

4.1.6.8.2 Taxiway deviation statistics may be used to assess the collision risk between two aircraft or between an aircraft and an object. Several taxiway deviation studies are available or in progress on different aerodromes world-wide (JFK, ANC, AMS, LHR, CDG, FRA & SYD. Final reports are expected in 2004).

4.1.6.8.3 Possible mitigation measures for operation of NLA on taxiways which do not meet the taxiway minimum separation distances specified in Annex 14, Volume I, Table 3-1 for code F are:

a) reduced taxiing speed;

b) provision of taxiway centre line lights;

c) provision of taxi side stripe markings (and taxiway edge lights);

d) special taxi routing for new larger aeroplanes;

e) restrictions on aircraft (wing span) allowed to use parallel taxiways during NLA operations;

f) restrictions on vehicles using service roads adjacent to a designated new larger aeroplane route;

g) use of “follow me” guidance; and

h) reduced spacing between taxiway centre line lights.

Note.— Special attention should be given to the offset of centre line lights in relation to centre line markings. Especially during winter conditions distinction between markings and offset lights could be difficult.

4.1.6.9 Aprons — Clearance distances on aircraft stands

4.1.6.9.1 Annex 14, Volume I, paragraph 3.12.6 recommends that the minimum distance between the aeroplane and an obstacle should be at least 7.5 m except in the following special circumstances at a nose-in stand, this may be reduced:

a) between terminal (including fixed passenger boarding bridge) and aircraft nose; and

b) over any portion of stand provided with azimuth guidance by a visual docking guidance system.

4.1.6.10 Hazard identification and analysis

4.1.6.10.1 The existing aprons on most of today's airports were not designed with code F aircraft in mind. Consequently, the safety margins tend to get reduced when used by such larger aeroplanes.

4.1.6.10.2 The causes of a collision between aeroplane and obstacle on apron or holding bay could be classified as:

a) mechanical failure (hydraulic system, brake, nose gear steering);

b) surface conditions (standing water, ice-covered surface, friction coefficient);

c) loss of visual taxi guidance system (docking system out of service,...); and

d) human factors (directional control, orientation error, …).

4.1.6.10.3 Consequences of collision on apron or holding bay are potentially major.

4.1.6.11 Risk assessment and possible mitigation measures

4.1.6.11.1 Collision hazard during taxiing depends more on human factors than on aeroplane performance (all functioning aeroplanes respond reliably to pilot directional inputs when taxiing at ordinary speeds) . Therefore, the expected NLA behaviour could be inferred in part from existing aircraft behaviour. Nevertheless, caution should be exercised with regard to the implications of significantly increased wingspan of NLAs.

4.1.6.11.2 Reduced separation at the gate is possible where azimuth guidance by a visual docking guidance system is provided.

4.1.6.11.3 Some operational restrictions may be required. Adequate clearances behind parked or holding aeroplanes will be required, noting the increased length of code F, and some new longer code E aircraft.

4.1.7 Pavement design

4.1.7.1 The increased mass and/or gear load of the NLAs would require adequate pavement support. Existing pavements would need to be evaluated for adequacy due to differences in wheel loading, tire pressure, and undercarriage design. Bridge, tunnel and culvert load bearing capacities may be a limiting factor, requiring some operational procedures. These may require alternative taxi routings where the ACN of the aeroplane exceeds the PCN or the maximum loads of the concerned NLA exceed those used in the design of the underground structures.

4.1.7.2 Mitigation measures may restrict aircraft with higher ACNs to specific taxiways, bridges or runways. These operational procedures may slow down movement of other aircraft on the ground.

4.1.7.3 To facilitate flight planning, various aerodrome data are required to be published. One such data is concerning the strength of pavements, which is one of the factors required to assess whether the aerodrome can be used by an aeroplane of specific all-up mass. ICAO has established the aircraft classification number-pavement classification number (ACN-PCN) method of reporting pavement strength. Annex 14, Volume I, paragraphs 2.6.1 to 2.6.8 contain the requirements in this regard.

4.1.7.4 The *Aerodrome Design Manual*, Part 3 — *Pavements* (Doc 9157) contains guidance on reporting pavement strength using the ICAO ACN/PCN method.

4.1.7.5 Criteria should be established to regulate the use of a pavement by an aircraft with an ACN higher than the PCN reported.

4.2 AERODROME OPERATIONAL SAFETY SERVICES

4.2.1 Aerodrome emergency planning

4.2.1.1 General

4.2.1.1.1 Annex 14, Volume I, paragraph 9.1.1 requires the establishment of an aerodrome emergency plan appropriate to the nature of aircraft operations and other activities at the aerodrome. It provides for the coordination of the actions to be taken in an emergency occurring at an aerodrome or in the vicinity. Prior to the introduction of a given NLA, the plan will need to be reviewed. Guidance material may be found in the *Airport Services Manual*, Part 7.

4.2.1.1.2 The introduction of aircraft able to carry as many as 30 per cent more passengers than existing code E aircraft, including upwards of 200 passengers on full length upper deck, requires some additional consideration in terms of emergency planning. The main issues involve the size of the airframe, and the potential numbers of passengers or casualties to be handled by the emergency services. Fuel quantities will exceed those of existing code E aircraft, and some fuel tank locations may be different. In areas of difficult terrain or water, additional specialized rescue capability will be needed.

4.2.1.1.3 Aircraft with a significant upper deck passenger capacity and longer escape chutes will pose new challenges to RFF services in terms of the areas to be protected during the evacuation phase. Additional extinguishing agent, and possibly additional, or enhanced intervention vehicles may be required, as will a means of communicating with the pilot-in-command. Furthermore, consideration should be given to the need for special equipment for accessing the upper deck to facilitate emergency evacuation of injured or handicapped persons. Studies on the above issues are in progress.

4.2.1.1.4 Key issues associated with the introduction of NLA will be to:

a) provide aircraft information and briefing before the first flight, including a crash chart and dimensional drawings;

b) provide briefing and training on doors and systems;

c) revise emergency plans;

d) conduct a task analysis for staffing; and

e) upgrade services to meet Category 10 requirements.

4.2.1.2 Critical considerations

4.2.1.2.1 The following critical considerations will need to be addressed (see *Airport Services Manual*, Doc 9137, Part 7):

a) assessment and testing of the aerodrome emergency plan in order to be able to respond to an emergency within a distance of 1000 m from the threshold of each operational runway or within the aerodrome boundary;

b) potential for simulation to assist in testing the revised plan (e.g. desk top computer based etc);

c) medical requirements at an aerodrome commensurate with the number of passengers on board;

d) capacity of terminal building facilities to handle increased numbers of friends and relatives;

e) scene management to take account of additional passenger numbers;

f) additional transportation needs;

g) liaison with local hospitals so that they can cope with the potential increase in casualties;

h) the implication of NLA-specific incidents on the ramp/stand or parking areas;

i) implications of any hazardous materials used in the specific aircraft's construction, and an analysis should be conducted to ensure safe working practices; and

j) aircraft recovery plan will need updating for significantly larger aircraft.

4.2.1.3 Tactical issues for external and internal situations

4.2.1.3.1 The following issues will need to be considered:

a) aircraft configuration (number of decks, exit locations, cabin crew rest area locations and cargo hold layout etc.);

b) sill height of the upper deck for access and egress for Rescue and Fire Fighting personnel who may need to enter the aircraft, including forcible entry, where necessary;

c) upper deck escape slide deployment and safe egress area will be greater than for current code E aeroplane;

d) enhanced command and control procedures appropriate to the aircraft type and size;

e) fuel capacity, including location of tanks and fuel pumps;

f) for internal fires, airport authorities may consider the use of Positive Pressure Ventilation (PPV)[4] systems;

g) holds, and capacity of on-board extinguishing systems;

h) aircraft size, including the gross mass for recovery planning; and

i) adequacy of communications between emergency response teams and the pilot in command.

4.2.1.4 Appropriate level of service and equipment

4.2.1.4.1 The aerodrome will need to conduct a task resource analysis and generic assessment that should consider the provision of specific resources, trained personnel and rescue equipment commensurate with the level of NLA operations. Critical situations should be identified and addressed accordingly.

4.2.2 Rescue and fire fighting services

4.2.2.1 General

4.2.2.1.1 The introduction of NLA and the evolutionary growth of existing types present new challenges to RFF services. In particular, the greater airframe surface area and the need to protect a large number of passengers exiting from more than one deck may require revised procedures, increased quantities of extinguishing agents, specific training for cabin staff and emergency crews, direct communications between the pilot-in-command and the emergency services, and strategies for access to an upper deck as appropriate. Rescue crews should be prepared for larger numbers of passengers transiting the protection area during evacuation.

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[4] A Positive Pressure Ventilation System introduces breathable air into a smoke-filled fuselage.

4.2.2.1.2 Egress for passengers from, and access by emergency crews to double-deck aircraft under emergency conditions, including the possible need for equipment to access the upper deck, has been identified as a significant issue. The specifics of dealing with certain NLAs will be addressed separately. In the meanwhile, attention is drawn to the ICAO *Airport Services Manual*, Part 1 — *Rescue and Fire Fighting* (Doc 9137), Chapter 12, section 12.3.

4.2.2.1.3 Aerodrome operators planning to refit or replace existing emergency vehicles should consider making provision to accommodate any projected increase in size of aircraft types and the consequential requirement for additional agent capacity during the planned service life of that equipment.

4.2.2.1.4 In the early stages of introduction into service, new aircraft types such as the A380 may be expected to regularly serve major aerodromes currently supporting B747 operations. These aerodromes will need to take steps to provide as necessary for the additional requirements of these aeroplanes.

4.2.2.1.5 The most important factors bearing on the effective rescue in a survivable aircraft accident are the training received, the effectiveness of the equipment and the speed with which personnel and equipment, designated for rescue and fire fighting purposes, can be put into use.

4.2.2.1.6 Detailed guidelines are given in the *Airport Services Manual*, Part 1 — *Rescue and Fire Fighting* (Doc 9137).

4.2.2.2 **Level of protection to be provided**

4.2.2.2.1 The A380 falls into ICAO Aerodrome RFF Category 10 due its fuselage width (8 m), though not its overall length. Other projected aircraft type stretches may lift them into a higher category. The A380 has the capability to deploy 3 upper deck slides on each side compared to 1 for the B747. For double-deck aeroplanes, the increased number and longer extension of upper deck slides widens the area around the aeroplane to be protected in the event of an evacuation. Specific requirements, in this regard, are under consideration by ICAO and will be issued when available.

4.2.2.2.2 Quantities of extinguishing agents specified in Annex 14, Volume I, Table 9-2 to meet the requirements in a particular aerodrome category, have been based on the size of the median aeroplane in the group. To meet the needs of future aeroplane type derivatives, calculations should take into account actual aeroplane dimensions. Where the largest aeroplane regularly operating at an aerodrome exceeds the size of the median aeroplane in a given category, the actual quantities of agents required for that aeroplane should be calculated and provided as per the guidance in the *Airport Services Manual*, Part 1.

4.2.2.2.3 4.2.2.2.3 The ability of modern extinguishing agents to achieve a more rapid knockdown is under review and may have some future impact on recommended quantities of agent to be carried. Conversely, environmental pressures may limit extensive use of certain types of agents in the future. Further studies are in progress.

4.2.2.3 RFF and emergency planning training issues

4.2.2.3.1 Rescue and fire fighting personnel should receive specific training relevant to NLA. The on-station training programme will need to take account of the size and type of the NLA and be appropriate to the risk. Double-deck aircraft will bring new challenges in terms of human factors and procedures.

4.2.2.3.2 Emergency response training for the introduction of NLA will require cooperation between airframe manufacturers, aircraft operators, airport authorities and emergency services. Attachment A to Annex 14, Volume I, paragraph 16.2 draws attention to the need for familiarization with aircraft types. Several useful training sources are available, and airport operators may wish to note the increasing use of "e-learning" packages in general as a valuable tool.

4.2.3 Disabled aircraft removal

4.2.3.1 The disabled aircraft removal plan established for an aerodrome will need to be updated to include the specific requirements for removal of a disabled NLA. The aeroplane size and mass (see Appendix A) are critical factors that should be considered in updating this plan.

4.2.3.2 Aircraft operators having regular scheduled flights to/from an aerodrome should present a plan to the airport authorities concerned, outlining their procedures for removing a disabled aircraft. Airport authorities will incorporate this in their aerodrome emergency plans, as well as the details of coordination with various agencies in this regard.

4.2.3.3 Guidance on removal of disabled aircraft, including recovery equipment, is contained in the *Airport Services Manual*, Part 5 — *Removal of Disabled Aircraft* (Doc 9137). At present a recovery manual for the Airbus A380 has not yet been published. Specific technical requirements and related procedures are currently being discussed among aircraft manufacturers, aircraft operators and aerodrome operators, within the IATA Disabled Aircraft Recovery Working Group; relevant information will be made available in due course.

4.2.4 Aerodrome maintenance services

4.2.4.1 With the introduction of NLA such as the A380, aerodrome maintenance or reconstruction programs will need to ensure that the specific aircraft requirements in terms of increased aircraft mass, wheelbase and wing span, the wider location of the outboard engines, and possible jet blast to temporary structures, are taken into account. The wing tip track-in whilst negotiating turns will also need to be considered. Where the specific requirements exceed those of current code E aircraft, special arrangement may be necessary.

4.2.4.2 Snow removal programs will need to ensure clearance of snow banks to the full width of the code F facilities, and noting the wing tip and wheel track-ins during turns. With the increased mass of NLA, particular attention to the reporting of surface conditions, notably surface friction will be necessary. Aerodrome surface inspections will need to take the wider engine span and wheelbase into account.

4.2.4.3 Specific instructions will be required to be given to contractors or maintenance staff in terms of control of safety and work in progress. General guidance is given in the *Airport Services Manual*, Part 9 — *Airport Maintenance Practices* (Doc 9137).

4.3 OBSTACLE LIMITATION SURFACES

4.3.1 Obstacle free zone

4.3.1.1 The inner approach surface, inner transitional surface, and balked landing surface define a volume of airspace in the immediate vicinity of a precision approach runway that is known as the obstacle free zone (OFZ). This zone shall be kept free from fixed objects other than lightweight and frangibly mounted aids to air navigation and from transient objects such as aircraft and vehicles when the runway is being used for Cat II or Cat III ILS approaches.

4.3.1.2 For code F operations, the OFZ on a precision approach runway is designed to protect an aeroplane with a wing span of 80 m on a precision approach below a height of 30 m. Annex 14, Volume I, Table 4-1 defines the obstacle limitation surfaces for approach runways. With regard to code F:

a) the width of the inner horizontal surface has been increased from the code E dimension of 120 m to 155 m. The inner approach surface begins 60 m from the threshold and extends to 900 m. It has a slope of 2 per cent;

b) the inner transitional surface has a slope of 33.3 per cent; and

c) the length of the inner edge of the balked landing surface has been increased from the code E dimension of 120 m to 155 m. The distance from the threshold, or runway end (whichever is less) is 1 800 m. The divergence (each side) is 10 per cent and the slope is 3.33 per cent.

4.3.1.3 The dimensions of the obstacle free zones may have an impact on other airfield items such as the position of holding points.

Note.— The dimensions of the OFZ are currently under review by the Obstacle Clearance Panel of the Air Navigation Commission.

4.4 VISUAL AIDS

4.4.1 Markings and signs

4.4.1.1 Location of existing aerodrome signs

4.4.1.1.1 Generally, existing signs should suffice for NLA operations at most aerodromes that will receive these aeroplanes.

4.4.1.1.2 ICAO Annex 14, Volume I, Table 5.4 specifies the distances from the edge of runways and taxiways at which signs may be located. This distance may need to be increased to ensure that similar clearance is obtained for NLA operations. With an increased distance from the taxiway edge, the angle of signs relative to the taxiway may have to be considered.

4.4.1.1.3 Due to aircraft engine clearance and engine thrust issues, operation of NLA may affect the structural integrity and/or location of the existing signs. Therefore signs along some taxiways may have to be strengthened or relocated in order to perform their intended functions, as they may be subjected to excessive jet blast.

4.4.1.2 Additional signs

4.4.1.2.1 The NLA may be limited to operating along specific taxiway routes. Where ATC procedures require NLA movement along specific taxiway routes, these may need to be identified by additional information signs. All signs should meet existing Annex 14, Volume I requirements for size, colour and luminosity.

4.4.1.2.2 Additional signs may be required along service roads that run adjacent to or across an NLA designated taxiing route, to alert drivers or vehicles to the potential exposure to excessive jet blast.

4.4.1.2.3 Where separations between taxiways are insufficient to allow simultaneous NLA-NLA or NLA-other aircraft operations, air traffic control procedures may be required to control aircraft movement. These procedures may require signs to indicate positions for aircraft to hold. This may also apply to new longer (code E) aircraft.

4.4.1.3 Information and mandatory instruction markings

4.4.1.3.1 Additional information and mandatory instruction markings may be required to identify NLA-permitted taxi routes, speed restriction areas, prohibited movement areas and specific NLA holding positions. These markings will need to be easily distinguished to eliminate confusion between NLA and other aircraft.

4.4.2 Lights

4.4.2.1 Existing lights

4.4.2.1.1 Lights may be liable to the effects of jet blast. Elevated runway and taxiway edge lights may have to be replaced with inset units. Where inset runway edge lights are used, they should meet the requirements of Annex 14, Volume I, paragraph 5.3.9.8.

4.4.2.1.2 The increased mass of the NLA may also create higher wheel loadings. The strength of all lights and fittings over which the NLA may pass may have to be checked for adequacy.

4.4.2.2 Additional lights

4.4.2.2.1 Where taxiways have been widened to allow for the NLA, additional stop bar lights and intermediate holding position lights may be required at runway-holding and intermediate holding positions. This may also apply to runway guard lights.

4.4.2.2.2 Additional stop bars and runway guard lights may be required if runway-holding positions are relocated or new positions provided.

4.4.2.2.3 If NLA are permitted to operate on taxiways that do not meet the Annex 14, Volume I, code F provisions, such taxiways may require additional centre line lights to increase the conspicuity of the taxiway centre line. In addition, the edges of these taxiways may need to be provided with taxiway edge lights.

4.4.2.3 PAPI/APAPI

4.4.2.3.1 It is expected that the eye-to-wheel height of the NLA would comply with the requirements of Annex 14, Volume I, Chapter 5, Table 5.2. As such, the PAPI units are not likely to be affected. However, the position of the engines may mean that PAPI units sited closest to the runway edge could be subject to greater jet blast. This should be monitored on a regular basis to ensure that the setting angles are not distorted and the lenses are kept clean.

4.5 GROUND SERVICING OF AEROPLANES

4.5.1 Fuelling of aircraft (to be issued later)

4.5.2 Aeroplane de-icing/anti-icing facilities

4.5.2.1 The increased mass, wing span and surface area of NLA will require some reconsideration of the adequacy of the de-icing/anti-icing facilities to accommodate them.

4.5.2.2 Particular attention will be needed to:

a) adequate space on the pad to ensure a clear paved area of no less than 3.8 m to facilitate the movement of de-icing/anti-icing vehicles (See Annex 14, Volume I, paragraph 3.14.5);

b) sufficient clearance between pad and adjacent manoeuvring areas taking the NLA dimensions into consideration;

c) surface markings to ensure wing tip clearance from obstructions and other aircraft, especially if another NLA is also to be accommodated on the pad;

d) load bearing capacity of the existing structure;

e) greater quantities of de-icing/anti-icing agent required;

f) containment of excess run-off of de-icing/anti-icing agent;

g) turning circle capabilities of NLA;

h) jet blast implications, especially in static breakaway and turns, including the risk of possible degradation of agent caused on smaller aircraft nearby; and

i) revision of pad management procedures in terms of the respective positioning and exiting of NLA versus smaller aircraft types.

4.5.2.3 Requirements may where de-icing operations are conducted on the stand as opposed to a remote facility.

4.5.3 Ramp handling equipment and services (to be issued later)

4.5.4 Training of personnel (to be issued later)

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Chapter 5

AIRCRAFT OPERATIONS

5.1 AIR OPERATOR CERTIFICATION

5.1.1 Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*, paragraph 3.1.9 recommends a runway width of 60 m for code F aeroplanes, and paragraph 3.2.3 specifies 75 m overall width of runway and shoulders. For code E aeroplanes, the recommended runway width is 45 m, and the overall width of the runway and shoulders is 60 m.

5.1.2 Compliance with Annex 8 — *Airworthiness of Aircraft*, requires the manufacturer to demonstrate that the aeroplane is controllable within the runway to be used. Annex 8 — *Airworthiness of Aircraft*, Part III B, Sub-part B. *Flight*, B.2.5 *Take-off* requires an aeroplane to be capable of taking off assuming the critical engine to fail, the remaining engines being operated within their take-off power or thrust limitations. Standard B.3.2.2 Controllability on the ground (or water) requires the aeroplane to be controllable on the ground (or on the water) during taxiing, take-off and landing under the anticipated operating conditions. Standard B 3.2.3 requires the aeroplane to be controllable in the event of sudden failure of the critical engine at any point in the take-off, when the aeroplane is handled in the manner associated with the scheduling of take-off paths and accelerate-stop distances. It is understood that during the type certification process, consideration is given to the following criteria separately and, where appropriate, in combination:

— maximum crosswind component
— runway surface (dry, wet, contamination)
— failure conditions including sudden engine failure
— critical aeroplane loading (gross weight, center of gravity)
— autoland operations, when applicable

The manufacturer will provide in the flight manual, information on minimum runway width and the critical crosswind component under all anticipated operating conditions as defined in Annex 8, Part I — *Definitions*.

5.1.3 During air operator certification, the State of the Operator will need to review the availability of the facilities and services specified in Annex 14, Volume I, and may need to consider specific alternative measures, operational procedures and operating restrictions referred to in Chapter 4 of this Circular, to preserve a level of safety acceptable to the State of the Operator in the event that the provisions of Annex 14, Volume I cannot be fully complied with. While establishing these alternative measures, operational procedures and operating restrictions, States should review the information in the flight manual regarding minimum runway width and critical crosswind component under all anticipated operating conditions.

5.1.4 Normal requirements concerning operators' emergency evacuation demonstrations apply to NLAs. However, because of the number of passengers carried by NLAs and the height of the upper deck exits above the ground, special precautions may be needed to minimize the risk of passenger injuries likely to occur during the conduct of emergency evacuation demonstrations required for operator certification.

5.1.5 Taxi cameras can assist the flight crew in preventing the wheels of the aeroplane from leaving the full-strength pavement during normal ground manoeuvring. For dispatch to an aerodrome with runways having a width less than that specified in Annex 14, Volume I and that are not provided with suitable taxiway fillets or a taxiway of the width specified in Annex 14, the taxi camera system may, in some cases, have to be required because the aeroplane may need to carry out turns of 90 degrees or more, including a 180-degree turn after landing, and to taxi into position for take-off.

5.1.6 Particular care may be needed while manoeuvring on runways and taxiways having a width less than that specified in Annex 14, Volume I to prevent the wheels of the aeroplane from leaving the pavement while avoiding the use of large amounts of thrust that could damage runway lights and signs, and cause erosion of the runway strip. Affected runways and taxiways should be closely inspected, as appropriate, for the presence of debris which may be deposited during 180 degree turns on the runway after landing, and while taxiing into position for take-off.

5.2 FLIGHT PROCEDURES DESIGN

5.2.1 Obstacle limitation surfaces

5.2.1.1 The significance of any existing or proposed object within the aerodrome boundary in the vicinity of the aerodrome is assessed by the use of two separate sets of criteria defining airspace requirements. The first of these comprises the obstacle limitation surfaces particular to a runway and its intended use specified in Annex 14. The broad purpose of these surfaces is to define the Volume of airspace that should ideally be kept free from obstacles in order to minimize the dangers presented by obstacles to an aircraft, either during an entirely visual approach or during the visual segment of an instrument approach. The specifications and dimensions of the various obstacle limitation surfaces are contained in Chapter 4 of Annex 14, Volume I, and guidance on the functions of these surfaces is given in the *Aerodrome Services Manual*, Part 6 — *Control of Obstacles*. The second set of criteria comprises the surfaces described in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS), Volume II — *Construction of Visual and Instrument Flight Procedures*. The PANS-OPS surfaces are intended for use by procedure designers for the construction of instrument flight procedures and for specifying minimum safe altitudes/heights for each segment of the procedure.

5.2.2 Obstacle free zone (OFZ) issues

5.2.2.1 ICAO Annex 14, Volume I defines OFZ as: “The airspace above the inner approach surface, inner transitional surfaces, and balked landing surface and that portion of the strip bounded by these surfaces, which is not penetrated by any fixed obstacle other than a low-mass and frangibly mounted one required for air navigation purposes”.

5.2.2.2 Runways require a space free of obstacles, termed obstacle free zones (OFZ), to provide enough airspace to safely execute take-offs, landings, balked landings, and missed approaches. The shape of an OFZ is determined by aircraft dimensions and performance and runway width. The OFZ covers the entire runway to the surface and inclines upward from the surface over adjacent taxiways and other ground movement areas. Also accounted for in the design of an OFZ is the spacing between the runway and taxiway, and the physical characteristics of taxiing aircraft. Having a clearly defined OFZ allows air traffic planners to permit or prohibit certain types of aircraft and procedures (e.g. the OFZ may restrict the use of simultaneous landing/take-offs and taxi operations). The design philosophy on taxiways parallel to runways is to protect against the intrusion of a wing tip into a runway strip. Given the tail height and wingspan of a given NLA, the OFZ of some aerodromes may be penetrated. The State concerned may then elect to either restrict operations or to conduct an appropriate aeronautical study that will determine the necessary alternative measures, operational procedures and operating restrictions. However, it should be noted that Annex 14, Volume I does not provide for an aeronautical study regarding OFZ.

5.2.2.3 The obstacle free zone during approach, landing, take-off, and taxi operations may need to be expanded, or the operation of NLA restricted, depending on the distance between taxiways and runways relative to the wing span and tail height of NLA, the published missed approach procedures, the balked landing/go-around procedures, and the performance characteristics of the NLA concerned.

5.2.2.4 Annex 14, Volume I (Standard), paragraph 4.2.8 and Table 4-1 (including table footnote "e") extends the width of the inner approach surface and balked landing surface from 120 m for code E aircraft to 155 m for code F. However, some existing code E aerodromes may experience problems in implementing the provisions of Annex 14, Volume I for code F aircraft. Solutions for these airports should be determined from an operational safety point of view. Consequently, as an operational mitigation, the ICAO Obstacle Clearance Panel (OCP) undertook a Balked Landing Study, published under Circular 301-AN/174, *New Larger Aeroplane — Infringement of the Obstacle Free Zone: Operational Measures and Aeronautical Study*. An overview can be found in Appendix C to this Circular. The attention of States and operators is drawn to this document.

5.2.3 Aircraft speed categorization

5.2.3.1 ICAO PANS-OPS describes aircraft speed categories which are used for OCA/H calculations and the promulgation of aircraft category related minima.

5.2.3.2 Amendment 12 to PANS-OPS, Volume II introduces a new speed category into flight procedure design calculations in support of the introduction of NLA, designated D_L. This speed category recognizes aircraft with a wing span of 80 m and a vertical distance between the flight path of the wheels and the glide path antennas to be 8 m. The new category avoids applying excessive penalties and operational minima to category "D" aeroplanes.

5.2.3.3 Available software for the design of instrument approach procedures such as the PANS-OPS Obstacle Assessment Surfaces (OAS) and the PANS-OPS software (CD101) incorporates D_L into the calculations.

5.3 ENVIRONMENTAL ASPECTS

5.3.1 As NLAs will have to be certified against the latest Annex 16 noise and emission standards, it is not anticipated that any environmental issues specifically attributed to NLAs will be identified. However, the introduction of a significantly increased aircraft size might generate wide interest amongst environmental groups.

5.3.2 Though operations by expected NLA types will be few to start with, consideration should be given to the projected growth and the local, longer-term, environment impact. The necessary overall environmental assessment should also take into account the improved efficiency which is entailed by the increased payload per NLA movement and the better performance of NLAs compared to older models still in operations.

5.3.3 The following should be taken into account by the appropriate authorities, aerodrome and aircraft operators:

a) aircraft noise;

b) aircraft engine emissions;

c) aircraft fuelling;

d) aircraft maintenance and operations;

e) aircraft de-icing; and

f) aerodrome infrastructure.

Detailed Guidance on the environmental aspects of these subjects is provided in the *Airport Planning Manual*, Part 2 — *Land Use and Environmental Control* (Doc 9184).

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Chapter 6

AIR TRAFFIC MANAGEMENT ISSUES

6.1 INTRODUCTION

6.1.1 Wake vortices are present behind every aeroplane, but are particularly generated by larger transport aeroplanes. They are heavily influenced by the specific aeroplane aerodynamics. Categorization for NLAs such as the A380 in terms of wake turbulence, together with a fuller understanding of the impact of a such aeroplanes on following traffic are currently being reviewed by industry and regulators through a group of experts working under the joint auspices of the United States Federal Aviation Administration (FAA), the Joint Aviation Authorities (JAA) and the European Organisation for the Safety of Air Navigation (EUROCONTROL). The outcome will be reported when complete.

6.1.2 The implications of the increased mass, an advanced wing design and any approach speed differences (e.g. compared to code E aircraft), may require a review of current wake turbulence procedures.

6.1.3 Wake turbulence categories and non-radar wake turbulence longitudinal separation minima are contained in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444), Chapter 4, Section 4.9 and Chapter 5, Section 5.8, respectively. Wake turbulence radar separation minima, details of which can be found in Chapter 8, are in some cases as high as 6 nautical miles. Guidance material with a description of wake vortices and their effect on aircraft is contained in the *Air Traffic Services Planning Manual* (Doc 9426).

6.2 GROUND MOVEMENT AND CONTROL (To be issued later)

6.3 TRAINING OF ATM PERSONNEL (To be issued later)

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Chapter 7

AERONAUTICAL STUDIES

7.1 SCOPE AND APPLICABILITY

7.1.1 An aeronautical study is a study of an aeronautical problem to identify possible solutions and select a solution that is acceptable for a given aeroplane at a given location without compromising safety. Such a study includes a systematic identification and analysis of safety hazards and an assessment of risks and possible mitigation measures.

7.1.2 An aeronautical study is conducted to assess, for a given aeroplane at a given location, the impact of deviations from some Standards and Recommended Practices (SARPs) specified in Annex 14, Volume I, to estimate the effectiveness of each solution and to recommend alternative measures, operational procedures and operating restrictions to compensate for the deviation and to ensure safe operations of the aeroplane concerned[5]. For the purposes of this Circular, the generic requirement for an aeronautical study is to assess how aerodromes can accommodate a specific NLA in a safe and efficient manner, including the development of alternative measures, operational procedures and operating restrictions which might be required at aerodromes where Annex 14, Volume I, code F provisions cannot be met.

7.1.3 Each aeronautical study is likely to be different and would be in a specific and defined context. Therefore the applicability of the results of an earlier aeronautical study performed in a different context will require due consideration and acceptance by the respective State, either through the performance of a dedicated aeronautical study, or an appropriate validation process[6].

7.1.4 The following guidance should be considered a general example that could be followed when performing an aeronautical study (or a validation process), but keeping in mind that the effort and budget required for its performance should remain commensurate with its objectives and purpose. The guidance is intended to lead readers through the various steps in the aeronautical study process, but allowing readers to form their own conclusions.

7.2 APPROVAL OF AN AERONAUTICAL STUDY AND OTHER PRACTICAL MATTERS

7.2.1 It is necessary, when establishing the scope of the aeronautical study, to identify the sources of those requirements and hence the competent authority responsible for approving the aeronautical study. The authority may apply various procedures for validation or acceptance of the items that are submitted. Though in most cases the final aeronautical study approval process is based on the approval of the appropriate validation case, some interim review may be needed.

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[5] In this context there have been a number of taxiway deviation studies conducted, but few aeronautical studies.

[6] A State which validates an aeronautical study presented by one airport operator may decide that the conclusions of this aeronautical study are applicable to other airports within its jurisdiction.

7.2.2 It is therefore essential to accurately define the objectives and processes to be followed, and to document them as appropriate in the study plan.

7.3 DEFINING THE SCOPE OF THE AERONAUTICAL STUDY

7.3.1 The first step consists of identifying the scope of the study, considering the relevant ICAO and other guidance materials, and should include:

a) level of compliance with ICAO SARPs;

b) identification of all other items to be included in the study;

c) identification of those areas of interest relevant to the items to be addressed;

d) the assumptions on which the aeronautical study will be based and the list of the specific NLA characteristics (see Chapter 2 and Appendix A) which may have an impact on the issues at stake for the different items;

e) international specifications, national or local regulations, and any other requirements; and

f) any additional criteria and definition of methods of assessment which are needed to clarify and demonstrate conformance to particular requirements.

7.4 STUDY PLAN

7.4.1 The following steps may provide a framework for a uniform structured process:

a) introduce, and develop a background statement to the requirement;

b) specify roles, responsibilities and competence;

c) identify sources of the requirements;

d) specify the manner in which the study is to be conducted;

e) clearly define the study objectives, together with any specific control and approvals mechanisms;

f) identify the process for fault identification, change management and issue resolution;

g) define any process validation methodology, including approvals;

h) specify measures to archive results and data; and

i) specify resources to be used, and scheduling plan.

7.4.2 As stated previously, this comprehensive structure should be considered only as a guideline and not as a mandatory requirement.

7.4.3 To facilitate the aeronautical study, a State or organization may elect to draw on existing studies or guidance material to assist them. In doing so, it will be necessary to:

a) define particular local requirements and consider how these may impact the study plan and the conclusions;

b) consult only relevant sources of information;

c) consult the authority responsible for the previous study and obtain appropriate details, or permissions;

d) evaluate the information; and

e) develop and validate the study tasks using relevant information.

7.4.4 Appendix B provides a list of relevant studies and existing material as well as addresses of web sites where other validated information can be found[7].

7.4.5 However, it should be emphasised that no two situations are likely to be identical and therefore considerable caution should be exercised when attempting to apply an existing study or solution to a different location or situation.

7.5 RECOMMENDATIONS AND CONCLUSIONS

7.5.1 The result of the aeronautical study should demonstrate that the objectives outlined above in the scope of the study have been fully met, and will contain a recommendation for acceptance or rejection. The report structure may consist of:

a) executive summary;

b) introduction and overview;

c) sources of requirements;

d) aeronautical study plan overview;

e) aeronautical study tasks summary reports;

f) compliance with requirements;

[7] The list and addresses are provided for the assistance of the reader, and does not signify ICAO endorsement of any study, process, or conclusion.

g) other outstanding information or issues; and

h) conclusions.

7.6 AERONAUTICAL INFORMATION SERVICE (AIS) DISSEMINATION

7.6.1 States are reminded of their obligation to take the appropriate AIS action in regard to alternative measures, operational procedures and operating restrictions implemented at a particular aerodrome, and, in the context of this Circular, to accommodate a specific NLA.

7.6.2 States are further reminded of the obligation imposed under Article 38 of the Convention by which Contracting States are required to notify the ICAO of any differences between their national regulations and practices and the International Standards contained in Annex 14. (Paragraphs 1.1.4 and 1.2.2 of this Circular refer).

7.7 ICAO SPECIFICATIONS AND GUIDANCE MATERIAL

7.7.1 Currently, Annex 14, Volume I specifically provides for aeronautical studies to be conducted in respect of:

a) Taxiway Minimum Separation Distances: paragraph 3.8.7, but see the "Notes" thereto;

   Guidance material can be found in the *Aerodrome Design Manual*, Part 2 — *Taxiways, Aprons and Holding Bays* (Doc 9157).

b) Obstacle Limitation Requirements: paragraphs 4.2.4, 4.2.5, 4.2.11, 4.2.12, 4.2.20, 4.2.21, 4.2.27, 4.3.1, 4.4.2;

c) Visual Aids for Air Navigation: Table 5.2.c, and paragraphs 5.3.5.44, 5.3.5.45; and

d) Visual Aids for Obstacles: paragraphs 6.1.1.d, 6.1.4.d, 6.1.10, 6.3.8.

7.7.2 Additional guidance material can be found in the *Aerodrome Design Manual* (Doc 9157), Part 2 — *Taxiways, Aprons and Holding Bays*. Depending on the items, domains, alternative measures, operational procedures and operating restrictions which would be addressed by the study, the following may also provide guidance:

a) Doc 8126 — *Aeronautical Information Services Manual*;

b) Doc 8168 — *Procedures for Air Navigation Services — Aircraft Operations*;

c) Doc 9137 — *Airport Services Manual*;

d) Doc 9157 — *Aerodrome Design Manual*;

e) Doc 9184 — *Airport Planning Manual*;

f) Doc 9365 — *Manual on All-Weather Operations*;

g) Doc 9426 — *Air Traffic Services Planning Manual*; and

h) Doc 9476 — *Manual of Surface Movement Guidance and Control Systems (SMGCS)*.

7.7.3 Other material or studies have been developed or are under development outside ICAO, which could serve as reference or background material, thus saving time and effort to States in the performance of a particular aeronautical study. The list is provided for the assistance of the reader, and does not signify ICAO endorsement of any study, process, or conclusion.

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APPENDIX A

NEW LARGER AEROPLANE DIMENSIONS AND OTHER DATA

Table 1: ICAO aerodrome code Letters and corresponding aeroplane dimensions

	Code F	A380-800**	B747-Advanced*	C5	An 124	Code E	A340-600	B747-400ER**	B777-300ER
Wing span	65 m up to but not including 80 m	79.8 m	68.7 m	67.9 m	73.3 m	52 m up to but not including 65 m	63.4 m	64.9 m	64.8 m
Outer main gear wheel span	14 m up to but not including 16 m	14.3 m	12.7 m	11.4 m	8.0 m	9 m up to but not including 14 m	12.6 m	12.6 m	12.9 m

* B747-Advanced is a proposed aircraft (not yet launched) and, therefore, the specifications are subject to change.

** Freighter version values provided where appropriate

Table 2: Aeroplane dimensions

	Code F				Code E		
Aeroplane Dimensions	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
Fuselage length	70.4 m	72.2 m 73.7 m**	70.3 m	69.9 m	73.5 m	68.6 m	73.1 m
Overall length	72.7 m	74.2 m 75.7 m**	75.5 m	69.9 m	75.3 m	70.7 m	73.9 m
Fuselage width	7.1 m	6.5 m	7.1 m	7.3 m	5.6 m	6.5 m	6.2 m
Fuselage height at OEW	10.9 m	10.2 m	9.3 m	10.2 m	8.5 m	10.2 m	8.7 m
Main Deck sill height***	5.4 m	5.4 m	2.7 m	2.8 m	5.7 m	5.4 m	5.5 m
Upper Deck sill height***	8.1 m	7.9 m	7.1 m	7.5 m	-	7.9 m	-
Tail height at OEW	24.1 m	20.1 m	19.9 m	21.0 m	17.4 m	19.6 m	18.7 m
Wing span	79.8 m	68.7 m	67.9 m	73.3 m	63.4 m	64.9 m	64.8 m
Wing span (full fuel)#	-	-	-	-	63.6	64.9 m	-
Wing span (jig) ##	79.8	68.7 m	67.9	73.3	63.4	64.4 m	64.8 m
Wing tip vertical clearance at MTOW	5.3 m	~5.1 m	3.2 m	3.7 m	6.0 m	5.1 m	7.2 m
Wing tip vertical clearance at OEW	6.1 m	~5.7 m	4.0 m	Unknown	6.2 m	5.7 m	7.5 m
Maximum wing tip height at MTOW	7.5 m	~5.1 m	3.2 m	3.7 m	7.6 m	6.7 m	7.2 m

	Code F				Code E		
Aeroplane Dimensions	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
Maximum wing tip height at OEW	8.3 m	~5.7 m	4.0 m	Unknown	7.8 m	7.3 m	7.5 m
Cockpit view at OEW: - Cockpit height - Cockpit cut-off angle - Obscured segment	 7.2 m 20° Max.19.8 m	 8.7 m 18.4° 25.8 m	 8.2 m unknown unknown	 8.3 m unknown unknown	 5.7 m 20° 15.7 m	 8.7 m 18.4° 25.8 m	 5.9 m 21° 14.6 m
Taxi camera	Yes	No	No	No	Yes	No	Yes
Pilot-to-nose landing gear distance	2.1 m	2.3 m	5.0 m	2.4 m	4.3 m	2.3 m	3.6 m
Pilot-to-main landing gear distance	31.8 m	28.4 m 29.9 m**	27.2 m	25.3 m	37.4 m	26.4 m	34.2 m

~ symbol indicates "approximate"

* B747-Advanced is a proposed aircraft (not yet launched) and, therefore, the specifications are subject to change.

** Freighter version values provided where appropriate

*** Highest door at OEW

\# For aircraft with large winglets (significant wing and winglet deflection with full fuel)

\#\# For aircraft without winglets, reference frequently made to "jig" span, i.e. the span as measured in the manufacturing jig (straight wing without 1G droop).

Table 3: Landing gear geometry

	Code F				Code E		
Landing gear geometry	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
Weights							
MRW	562 t 602 t**	4232 t 437 t**	381 t	405 t	369 t	414 t	341 t
MTOW	560 t 600 t**	422 t 435 t**	379.6 t	398 t	368 t	413 t	340 t
MLW	386 t 427 t**	296 t 333 t**	288.4 t	330 t	256 t	296 t 302 t**	251 t
Landing gear dimensions							
Wheel track	12.5 m	11.0 m	7.9 m	6.3 m	10.7 m	11.0 m	11.0 m
Outer main gear wheel span	14.3 m	12.7 m	11.4 m	8.0 m	12.6 m	12.6 m	12.9 m
Wheelbase	29.7 m	26.1 m 27.6 m**	22.2 m	22.9 m	33.1 m	24.1 m	30.6 m
Main gear steering system***	Yes	Yes	Yes	Yes	No	Yes	Yes

	Code F				Code E		
Landing gear geometry	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
ACN - Flexible							
FA	63 66**	63 65**	29	51	70	61	62
FB	69 73**	71 72**	33	60	75	69	69
FC	83 87**	88 90**	40	77	89	85	86
FD	111 116**	111 114**	56	107	119	108	117
ACN - Rigid							
RA	55 58**	61 62**	29	35	62	59	64
RB	68 72**	71 72**	34	48	72	69	82
RC	89 94**	83 85**	44	73	84	81	105
RD	110 117**	94 97**	55	100	98	92	127

Discussions on the value of alpha factor is ongoing. Aircraft footprints and ACN curves are available in Section 7 of the respective “Airplane Characteristics for Airport Planning” document in the manufacturers Web site (Appendix B).

* B747-Advanced is a proposed aircraft (not yet launched) and, therefore, the specifications are subject to change.

** Freighter version values provided where appropriate.

*** There are two types of main landing gear steering system – post steering with all wheels steered (747, C5 and An 124), aft-axle steering (aft two wheels out of 6-wheel gear, e.g. A380-800 and 777). The effect of main gear steering system on turn center location is shown in the Section 4.3 of the respective “Airplane Characteristics for Airport Planning” document in the manufacturer Web site (Appendix B).

Table 4: Minimum pavement width required for U-turn (in ascending order)

Code	Aircraft	U-turn width	Wheelbase	Track (to outside tire edge)
E	747-400	152' (46.3 m)	79.0' (24.1 m)	41.3' (12.6 m)
D	MD11	161 (49)	81.2 (24.7)	41.2 (12.6)
F	747-Adv	163' (49.7)	85.6 (26.1)	41.3 (12.6)

Code	Aircraft	U-turn width	Wheelbase	Track (to outside tire edge)
F	747F-Adv	171' (52.1)	90.6 (27.6)	41.3 (12.6)
E	777-300	185 (56.5)	100.4 (30.6)	42.3 (12.9)
E	A340-600	186 (56.7)	109 (33.2)	41.3 (12.6)
F	A380-800	216 (65.7)	97.5 (29.7)	47 (14.3)

Assumes symmetric thrust and no braking

Note that U-turn width does not have much relationship with code letter.

Table 5: Engine data

	Code F				Code E		
Engine data	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
Number of engines	4	4	4	4	4	4	2
Bypass ratio	8.7	~9	8.0	~5.7	7.5	~5	~7
Engine Thrust	70 klb 77 klb**	65-67 klb	41 klb	52 klb	56 klb	56-63 klb	115 klb
Engine span (CL to CL)	51.4 m	41.7 m	37.7 m	37.9 m	38.5 m	41.7 m	19.2 m
Engine vertical clearance at MTOW	1.1 m (inner) 1.9 m (outer)	0.7 m 1.4 m	2.5 m 1.7 m	3.5 m 3.1 m	0.5 m 1.6 m	0.7 m 1.4 m	0.9 m
Reverse system	Only inboard thrust reversers	Yes	Yes	Yes	Yes	Yes	Yes

~ symbol indicates "approximate"

Jet blast velocity contours are available in Section 6 of the respective "Airplane Characteristics for Airport planning" document in the manufacturers' Web site (Appendix B).

* B747-Advanced is a proposed aircraft (not yet launched) and, therefore, the specifications are subject to change.

** Freighter version values provided where appropriate.

Table 6: Maximum passenger and fuel carrying capacities

	Code F				Code E		
Maximum passenger and fuel carrying capacities	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
3-class reference layout	555	450	-	-	380	416	365
Maximum passenger carrying capacity	~800	~650	-	-	~475	~620	550
Wing fuel tank capacity (litres)#	287 000	Similar to B747-400ER	186 000	350 000	131 000	138 924	78 206
Tail empennage fuel tank capacity (litres)#	23 000	Similar to B747-400ER	0	0	8 300	12 490	0
Centre fuel tank capacity (litres)#	0	Similar to B747-400ER	0	0	56 000	64 973	103 077
Maximum fuel carrying capacity (litres)	310 000	Similar to B747-400ER	186 000	350 000	194 878	228 538*** 204 333**	181 283

~ symbol indicates "approximate"
* B747-Advanced is a proposed aircraft (not yet launched) and, therefore, the specifications are subject to change.
** Freighter version values provided where appropriate.
*** B747-400ER is standard with one body fuel tank; optional second body fuel tank will increase fuel volume by 12 151 litres.
# Data shown are approximate

Emergency exits locations are available in Section 7 of the respective "Airplane Characteristics for Airport Planning" document in the manufacturers Web site (Appendix B).

Table 7: Landing incidence/attitude and final approach speed

	Code F				Code E		
Landing incidence/attitude and final approach speed At MLW and forward cg	**A380-800**	**B747-Advanced***	**C5**	**An 124**	**A340-600**	**B747-400ER**	**B777-300ER**
Approach attitude at 3° glide slope	~1°	~3°	Unknown	Unknown	3.5°	3.0°	~3°
Approach speed	~145 kt	~157 kt	~135 kt	~124 kt	154 kt	157 kt	~150 kt
Start of visual segment	290 ft				338 ft		

~ symbol indicates "approximate"
747-Advanced, 777-300ER and A380-800 data are estimated values.
B747-Advanced is a proposed aircraft (not yet launched) and, therefore, the specifications are subject to change.

Technology evolution

Possible NLA design features that may impact aerodrome elements

There has been a steady progress over past decades in aviation technology, enhancing the accuracy and reliability of aircraft operations. These technologies, along with improvements in airport infrastructure and improved operational procedures of airports and aircraft have contributed to the overall aviation safety. A review that was carried out by a members State showed that the rate went down from 3.5 fatal accidents per million flights for the first generation of modern aeroplanes (e.g. B707) to 1.6 for the second generation aeroplanes (e.g. DC-10, A300) and to 0.5 for the third generation aeroplanes (e.g. B777, A340). Listed below are recent technology features already available on existing aircraft models as well as those that may become available in the near future for a possible integration in the NLA, such as the A380. This is not an exhaustive list nor is it intended to define the required technology improvements for the NLA. Technology features below are grouped under the relevant airfield elements.

Runway and shoulder width:

— **Nose wheel steering augmentation system**: Provides reduced steering angle with increasing ground speed: This may reduce the likelihood of nose wheel skidding.

— **Two stage lift dumping**: in the event of uneven gear touchdown at landing, the spoilers provide partial lift dumping to ensure all gears achieve ground contact prior to full spoiler deployment. This may ensure that antiskid operation do not result in asymmetric braking problems.

— Back up nose wheel hydraulic power source

Taxiway turn fillet

— **Taxi cameras** (not mandatory for dispatch): cameras are valuable in the pilot training phase, but are considered to be of little use in the field. Pilot self-learning of oversteer turning technique on taxiway turns and for runway U-turn through use of cameras (correct visual cues acquired) has been confirmed by A340-600/777-300 experience to give excellent pilot skills.

Taxiway and shoulder

— **Aerodrome taxi navigation guidance**: A precision type guidance system based on differential GPS or visual sensors can give tracking guidance to an accuracy of less than one m from the taxiway centre line. This can prevent inadvertent deviation such as under poor visibility.

OFZ/runway width and other OPS/AIR aspects

— **Track guidance**: for Go-Arounds and especially in case of balked landings, instead of a track capture at Go-Around engagement, a computation can be performed based on the direction over the last 15 seconds as already available on some aircraft. This may provide a much more accurate guidance and prevent from some unsuitable tracks, coming for example from gusts or strong crosswinds.

— **Vertical display**: this feature allows a dynamic situation assessment (aircraft position, safe altitude, display of terrain and vertical flight path), which reduces the likelihood of Controlled-Flight-into-Terrain. In the context of the flight safety foundation (US) approach and landing accident reduction activities, it was found that inadequate situational awareness was a factor in 51 per cent of approach-and-landing accidents analysed.

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APPENDIX B

BIBLIOGRAPHY

LIST OF REFERENCES AND AERONAUTICAL STUDIES ASSOCIATED WITH NLA OPERATION

Subject to cautions and guidance elsewhere in this Circular, the following references may assist authorities in developing their own aeronautical studies. Inclusion of references to studies conducted outside of ICAO does not imply ICAO endorsement. They are listed solely for the information of the reader. Any application to ongoing studies remains a matter for decision by the appropriate authorities.

Page B-2 contains an example of how to classify risks and severity levels.

1. ICAO Annex 14, Volume I
2. Aerodrome Design Manual, Part 1, Runways
3. Aerodrome Design Manual, Part 2, Taxiways, Aprons and Holding Bays
4. Notice to Aerodrome Licence Holders, 2/2003, CAA UK 5.
5. Statistical Extreme Value Analysis of Taxiway Centre line Deviations for 747 Aircraft at JFK and ANC airports, August 2003, Boeing.
6. Statistical analysis of aircraft deviations from taxiway centre line, Taxiway Deviation Study at Amsterdam Airport Schiphol, 1995, Boeing Computer Services
7. Aircraft Deviation Analysis at Frankfurt Airport, June 2002, Frankfurt Airport
8. Runway Lateral Deviations during Landing, Study with Flight Recorder Systems on Board, CAA-France
9. Common Agreement Document (CAD) of the A380 Aerodrome Compatibility Group, December 2002, CAA-France, CAA-UK, CAA-Netherlands, CAA-Germany, ACI, IATA[8].
10. Obstacle Free Zone, FAA Balked Landing Study, United States, FAA, 20031.ICAO Annex 14, Volume I
11. Analysis of Runway Lateral Excursions from a common accident/incident database (source: ICAO, FAA, Airbus, Boeing), June 2003, Airbus
12. Update on the Taxiway Deviation Studies at JFK July 2002, ACI-NA
13. Test of Load Bearing Capacity of Shoulders, 2003, CAA-France and Airbus
14. Reduced Separation Distances for code F Aircraft at Amsterdam Airport Schipol, 2001, Amsterdam Airport Schipol
15. A380 and Localizer Multipaths, June 2003, Paris Airport Authority
16. Obstacle free zone position for A380 operations, October 2003, Paris Airport Authority

AEROPLANE CHARACTERISTICS DATABASES

1. Boeing Web site: www.boeing.com/airports
2. Airbus Web site: www.airbus.com/customer/technical.asp#

[8] The CAD shows a practical example of the application of the methodology in this Circular to a specific NLA, the Airbus A380. It develops alternative measures for the A380 which are supported by the CAAs of the sponsoring States.

EXAMPLE OF CLASSIFICATION OF RISKS

Careful consideration should be given by the relevant authorities to the definition of the safety objectives for each levels of risk. The following table may be used to classify the probability and security levels based on the principle that there should be an inverse relationship between the severity of the effect of a failure and the probability of its occurrence (risk tolerability).

<table>
<tr><td>Effect on aircraft and occupants</td><td colspan="2">Normal</td><td>Nuisance</td><td colspan="2">• Slight reduction in safety margins
• Slight increase in crew workload
• Inconvenience to occupants</td><td colspan="2">• Significant reduction in safety margins
• Significant increase in crew workload
• Passenger injuries</td><td colspan="2">• Large reduction in safety margins
• Physical distress or higher workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely
• Serious or fatal injury to a small number of occupants</td><td colspan="2">• Multiple fatalities
• Loss of the aeroplane</td></tr>
<tr><td>Numeric probability</td><td>10</td><td>10^{-1}</td><td>10^{-2}</td><td>10^{-3}</td><td>10^{-4}</td><td>10^{-5}</td><td>10^{-6}</td><td>10^{-7}</td><td>10^{-8}</td><td>10^{-9}</td><td>10^{-10}</td></tr>
<tr><td>FAR</td><td colspan="5"><--------------- PROBABLE ---------------></td><td colspan="4"><-----------IMPROBABLE -----------></td><td colspan="2">EXTREMELY IMPROBABLE</td></tr>
<tr><td>JAR-25</td><td colspan="3"><----- FREQUENT------></td><td colspan="2">REASONABLY PROBABLE</td><td colspan="2">REMOTE</td><td colspan="2">EXTREMELY REMOTE</td><td colspan="2"></td></tr>
<tr><td>Classification of severity level</td><td colspan="5"><------------------- MINOR ----------------></td><td colspan="2">MAJOR</td><td colspan="2">HAZARDOUS</td><td colspan="2">CATASTROPHE</td></tr>
</table>

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APPENDIX C

OBSTACLE FREE ZONE — BALKED LANDING STUDY OVERVIEW

OVERVIEW OF NLA BALKED LANDING SIMULATION STUDY

1. INTRODUCTION

1.1 A two-year study was conducted by the United States Federal Aviation Administration (FAA) investigating the balked landing scenario for new larger aeroplanes (NLA) using B747-400 aircraft technology. The FAA Balked Landing Study Program specifically focused on the risk analysis/probability of collision during a balked landing by an NLA. The outcome of the study consisted of:

a) Iso-probability contours used to assess the impact of obstacles based on their distance from the runway centre line at any specific point along the length of the runway;

b) data projecting excursions (lateral displacement from centre line) for NLA based on a wide range of flight profiles;

c) how to address aerodrome elevation; and

d) other elements that may be identified as operationally pertinent to the risk analysis of existing aerodromes.

1.2 This section contains a summary of the report of that study. It should be noted that the study assumed that the aeroplane guidance system is in “ground track hold” mode with the engagement of “go-around”. This becomes a special condition, which does not conflict with Annex 14.

2. STUDY OUTLINE

2.1 Over 200 000 computer simulations were conducted using the FAA Airspace Simulation and Analysis for Terminal Instrument Procedures (TERPS) (ASAT). ASAT was developed to investigate missed approach procedures in the terminal airspace using highly accurate computer representations of the aircraft and the airspace/aerodrome environment. A complete integrated aircraft configuration simulation model of the B747-400 was obtained from the Boeing Airplane Systems Laboratory in support of the study. (The model is the engineering version of the flight simulator data package, as provided to the simulator vendors, and satisfies all criteria for the qualification of flight simulators as specified in the ICAO *Manual of Criteria for the Qualification of Flight Simulators* (Doc 9625)).

2.2 The study followed the outline for an aeronautical study as prescribed in section 1.2.32 of the ICAO *Aerodrome Design Manual* in support of the consideration for the probability of collision. The purpose of this study was to assess the impact of the balked landing on the definition of the obstacle free zone (OFZ) for aircraft with a wing span up to 80 m using collision risk methodology. In accord with the ICAO collision risk model (CRM), the value of 1×10^{-7} defined the Target Level of Safety (TLS) and was, therefore, the criterion used to define the risk of collision between an aircraft on the approach and another aircraft, vehicle, or object on the ground. Iso-probability contours of 10^{-7} were constructed from the simulation flight track data to serve as a basis for evaluating the OFZ definition. The iso-probability contours were constructed at various locations along the flight path of a balked landing beginning at some range point before runway threshold (e.g. 4 200 m) and continuing along the length of the runway after threshold (e.g. 200 m past threshold). A detailed report is available upon request.

3. SIMULATOR SESSION ON THE NASA AMES B747-400 FLIGHT SIMULATOR

3.1 Flight simulator sessions were conducted at the NASA Ames Research Center in a full-motion, B747-400 simulator. Airline pilots were monitored as they performed balked landing procedures under controlled experimental conditions. For these tests, the go-arounds were initiated by one of the following situations:

a) simulated air traffic control command issued when the aircraft reached a specified altitude;

b) runway incursion by another aircraft at the holdbar;

c) vehicle/pedestrian deviation; and

d) active arriving and departing traffic on the runway.

3.2 All landing scenarios used a strong crosswind component. By testing airline pilots under extreme operational conditions, it was hoped that one could generalize the study results to balked landings outside the testing environment. Pilot response time data was used as input to Monte Carlo simulations.

3.3 Examination of the NASA Ames simulator data suggested that the Monte Carlo computer simulation should focus on autopilot controlled balked landings. Compared to manual control with flight director, the autopilot controlled balked landings exhibited smaller lateral deviation from the runway centre line at all aerodrome elevations considered in the simulator study, namely, at sea level, 760 m, 1 600 m, and 2 240 m. The (Monte Carlo) computer simulations conducted the balked landings at two aerodrome elevations, namely, at sea level (4 m) and at 1 980 m to correspond to the piloted simulator study. All approaches in the Monte Carlo simulation were conducted in autoland mode utilizing the pilot response time distributions as determined from examination of NASA Ames B747-400 Flight Simulator Data.

4. CONSTRUCTION OF 10^{-7} ISO-PROBABILITY CONTOURS

4.1 An analysis was made of wind data and the instrument landing systems at 40 existing aerodromes worldwide that were considered likely to host a new larger aircraft according to marketing forecasts by manufacturers. The analysis assumed that ILS critical and sensitive areas were protected. The results of the analysis were used to define composite models of the wind and instrument landing systems representative of the conditions found at the various aerodrome locations. The composite models served as input to the computer simulations.

4.2 Examination was made of an immense amount of simulation generated flight track data at various perpendicular planes or tiles located at intervals along the flight path. Iso-probability contours were constructed at each tile location using the lateral and vertical distributions centered on the extended runway centre line. These contours were based on the location of the center-of-gravity (C.G.) of the aircraft and were, at times, oval in shape. The iso-probability contour at the threshold is shown in Figure 1-1. The lateral component of the contour does not vary significantly with aerodrome elevation due to the tracking capabilities of the autopilot system. The vertical component of the contour is affected by the atmospheric density while executing the go-around manoeuvre (at higher altitudes the aircraft is flying faster and producing less lifting force so it travels farther down the runway before beginning to climb).

4.3 The lower curve in Figure 1-1 is the lower half of the oval curve corrected for semispan and wheel location of the aircraft. The value of semispan used was 40 m (i.e. a total span of 80 m) with the flight path of the bottom of the wheel located 7.3 m below the horizontal plane of the C.G. point. The lower half of the curve is that part of the curve below the median of the vertical distribution. Therefore, the probability of some part of the aircraft being below the lower curve is less than 1×10^{-7}. At some tile locations past runway threshold, the ground plane crosses the lower curve. This indicates that some aircraft are expected to touch wheels on the runway. It does not indicate that they have impacted the ground or crashed. The ends of the lower curve indicate the maximum distance from runway centre line, for a probability of 1×10^{-7} that we would expect to find an aircraft wing tip.

5. STUDY FINDING

5.1 The simulation studies, for autoland approaches, found that the maximum distance from runway centre line that one would expect to find an aircraft wing tip is contained within ±50 m on either side of the centre line. This result is contained within the dimensions of the balked landing surface found in Table 4-1 of Annex 14, Volume I, where the code number is 4 and the code letter is E. To ensure ILS signal integrity for NLA operations using autoland see the ICAO *Manual of All-Weather Operations* (Doc 9365-AN/910), section 5.2.13. These findings are part of an aeronautical study conducted by the United States. A follow on study involving use of the aircraft flight director will be included in the ICAO Balked Landing Study Circular, due to be published later in 2004. This study includes a validation with an adapted A340 research simulator and also includes the use of an A340-600 engineering model to study the effects of fly-by-wire steering.

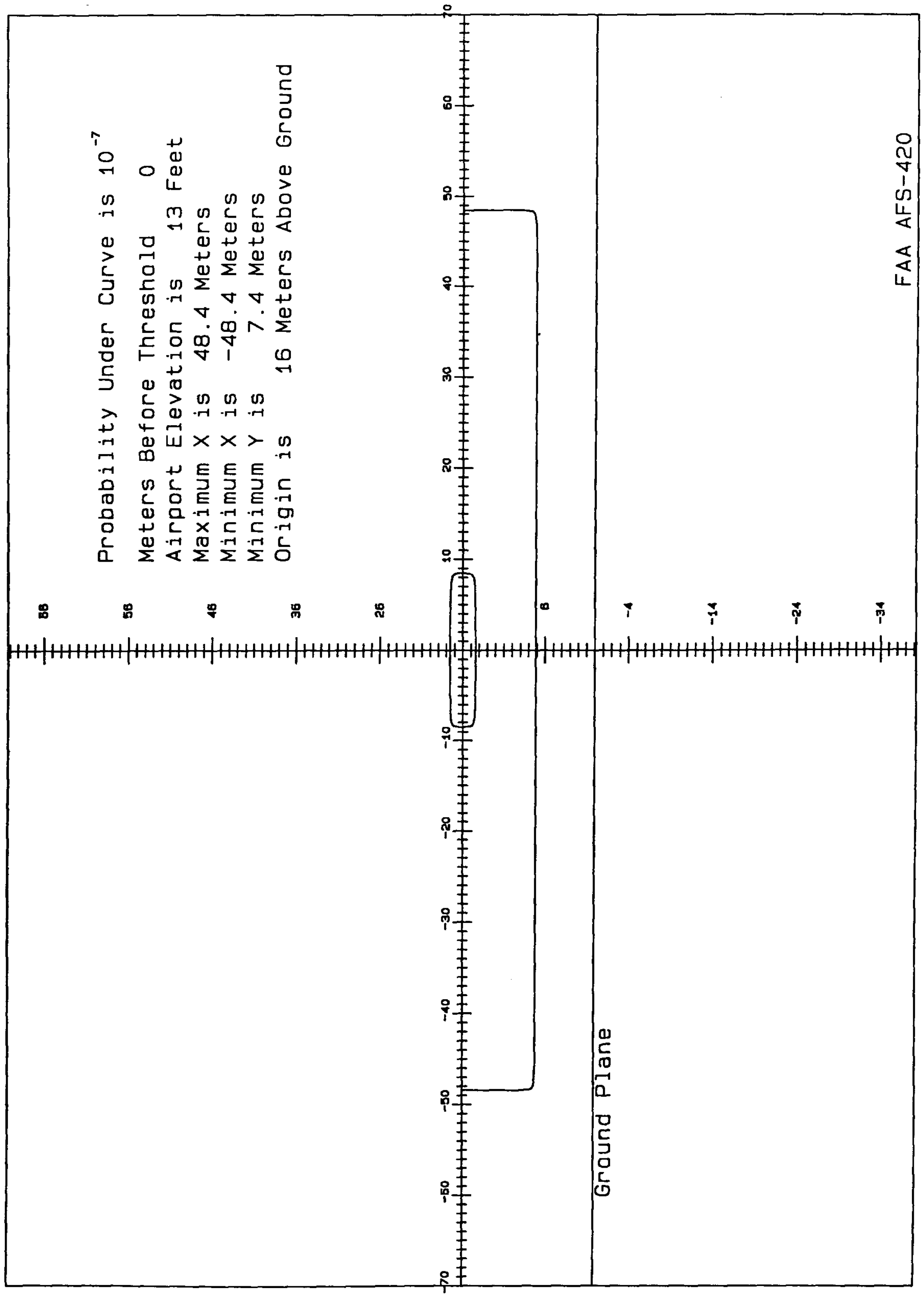

Figure 1-1. The iso-probability contour at runway threshold

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