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Operation of New Larger Aeroplanes at Existing Aerodromes

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OPERATION OF NEW LARGER AEROPLANES AT EXISTING AERODROMES

CORRIGENDUM

Please make the following changes to Chapter 1, paragraph 1.15 (page 3):

1.15 If the operation of NLAs is contemplated on runways narrower than the 60 m recommended in Annex 14, Volume I, due consideration should be given to all factors affecting safety, including:

a) the type certification of the NLA concerned in accordance with Annex 8 — *Airworthiness of Aircraft* (see Chapter 5, paragraph ~~5.1.2~~ 5.2 of this circular);

b) the use of possible mitigation measures discussed in Chapter 4, ~~Section 4.1.2~~ Sections 4.5 to 4.24; and

c) local conditions and other operational factors.

FOREWORD

In the early 1990s, the major aeroplane manufacturers 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 these new larger aeroplanes (NLAs), ICAO undertook a study with the participation of several States, selected international organizations and aeroplane manufacturers. The results of that study led to Amendment 3 to Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*, which was adopted by the ICAO Council in March 1999. A new aerodrome reference code letter F to cover aeroplanes with wingspans 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. Aerodrome rescue and fire fighting (RFF) specifications for aeroplanes with maximum fuselage widths in excess of 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 in planning and developing the aerodrome. Consequently, as such newer and larger aeroplanes have entered into commercial service, aerodromes have evolved by making the 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 NLAs into international civil aviation service. First, this circular was developed to provide States with information concerning aerodrome facilities and services, air traffic management and flight operations, which should be considered in accommodating NLAs at existing aerodromes. Second, a review will be undertaken of the current Annex 14, Volume I, code F provisions, including their underlying basis, taking into consideration the results of studies being conducted outside of ICAO.

It should be understood that Annex 14 contains all of 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 its applicability to other situations and locations. Each State that 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 be considered only as a temporary alternative to Annex 14 compliance.

This circular was developed in close cooperation with the Air Navigation Commission. It should be noted that all references in this circular to Annex 14, Volume I, are to the fourth edition which will become applicable on 25 November 2004.

Users are invited to offer comments and suggestions for improvements or additions based on their practical experience in using this information in their national planning for the operation of NLAs at existing aerodromes. These should be directed to the Secretary General of ICAO.

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Chapter 1

INTRODUCTION

PURPOSE

1.1 The purpose of this circular is to assist States in addressing the various aspects of operating NLAs at existing aerodromes and to draw the attention of States and aerodrome operators to the impact on existing aerodromes of new larger aeroplanes (NLAs) such as the Airbus A380. This circular provides information on the issues concerning aerodrome facilities and services, air traffic management and flight operations that should be considered in accommodating NLAs at existing aerodromes.

1.2 This 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 that 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.

1.3 This 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 a very long fuselage, causing some problems at existing aerodrome stands, taxiway curves and holding positions. The need to conduct a specific study in all such cases and to review the clearances from all relevant angles is emphasized.

1.4 In 1999, Amendment 3 to Annex 14, Volume I, introduced a new aerodrome reference code letter F to accommodate aeroplanes with a wingspan 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. 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 on physical characteristics in Chapter 3 of the Annex were developed for code F using the existing methodology applied to codes A to E and based on the aircraft characteristics data 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 using 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 can be found in Chapter 4 of this circular.

1.5 While States are expected to implement the new code F specifications in 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. The main intent of this circular is to bring together in one document all the relevant issues, with necessary cross-references to the appropriate ICAO provisions, to assist States 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.

SCOPE

1.6 This circular identifies the issues that are of relevance to the operation 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 its 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 clearances less than those specified in the Annex.

1.7 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 stipulated 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 Standards and Recommended Practices (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*.

1.8 Information is provided on the various issues concerning aerodrome facilities and services that should be considered in accommodating, at existing aerodromes, the operation 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 also provided. This 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, this 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 that do not meet the relevant Annex 14, Volume I, provisions for such large aeroplanes.

1.9 This circular also contains detailed information on the various factors to be considered in conducting an aeronautical study to assess the 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 their 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.

1.10 Though the results of a study may help to identify safety-related aspects, States and aerodrome operators may also 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 NLAs, as a gate-to-runway system, to identify any possible impact on aerodrome capacity of operating an NLA, and to develop trade-off options on a cost-effective basis. Nevertheless, safety should always be given utmost priority.

1.11 This circular also draws attention to the need to reconsider emergency plans to deal with incidents involving larger aeroplanes, and consequential rescue and fire fighting aspects.

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

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

1.14 Aerodrome operators intending to handle operations of a given NLA may, with approval of the appropriate authority, provide facilities with clearances less than those specified in Annex 14, Volume I, after carrying out aeronautical studies to ensure that the 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 construction or major redevelopment is 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* (Doc 9157), Part 1 — *Runways* and Part 2 — *Taxiways, Aprons and Holding Bays*. 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.

1.15 If the operation of NLAs is contemplated on runways narrower than the 60 m recommended in Annex 14, Volume I, due consideration should be given to all factors affecting safety, including:

a) the type certification of the NLA concerned in accordance with Annex 8 — *Airworthiness of Aircraft* (see Chapter 5, paragraph 5.2 of this circular);

b) the use of possible mitigation measures discussed in Chapter 4, Sections 4.5 to 4.24; and

c) local conditions and other operational factors.

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

Chapter 2

IMPACT OF THE CHARACTERISTICS OF NEW LARGER AEROPLANES ON THE AERODROME INFRASTRUCTURE

INTRODUCTION

2.1 The aim of this chapter is to relate the characteristics of NLAs to aerodrome dimensions, facilities and services in the movement area. When preparing to accommodate an NLA, any dimensions that exceed 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 provided in Appendix A.

2.2 The following broad characteristics of NLAs are addressed:

a) dimensions of NLAs;

b) landing gear characteristics, mass and aircraft classification number (ACN) values;

c) engine data;

d) maximum passenger- and fuel-carrying capacities; and

e) flight performance, including wake vortex.

CHARACTERISTICS OF NLAs

Fuselage length

2.3 The fuselage length may influence:

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

b) the dimensions of aircraft maintenance and repair services facilities;

c) the aerodrome category for rescue and fire fighting (RFF). The overall length of the most critical aeroplane is one of the two Annex 14 criteria to determine the 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.

Fuselage width

2.4 The fuselage width may influence the aerodrome category for RFF. The maximum fuselage width of the most critical aeroplane is one of the two Annex 14 criteria to determine the aerodrome category for RFF.

Fuselage height

2.5 The fuselage height may influence:

a) the location of the runway holding position. The fuselage height is one of the Annex 14 criteria used to determine the location of the runway holding position (including the tail height and the 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 gates and terminal areas, in terms of upper-deck access; and

c) the dimensions of aircraft maintenance facilities.

Tail height

2.6 The tail height may influence:

a) the location of the runway holding position (see 2.3);

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

c) the dimensions of aircraft maintenance services;

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

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

Wingspan

2.7 The wingspan would influence:

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

b) the dimensions of the OFZ;

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

d) the dimensions of aprons and holding bays;

e) shoulder dimensions;

f) wake turbulence;

g) gate selection;

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

i) the dimensions of aerodrome or aircraft maintenance facilities; and

j) equipment for disabled aeroplane removal.

Wing tip vertical clearance

2.8 The wing tip vertical clearance may influence:

a) taxiway separation distances with height limited objects;

b) apron and holding bay clearances with height limited objects;

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

d) airfield signage clearances.

Cockpit view

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

2.10 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.

Distance from the pilot's eye position to the nose landing gear and to the main landing gear

2.11 The design of taxiway curves is based on the cockpit-over-centre-line concept. The distance from the pilot's eye position to the nose landing gear and to the main landing gear may influence:

a) taxiway fillets;

b) the dimensions of aprons and holding bays; and

c) the dimensions of turn pads.

2.12 The increased wheelbase dimensions of newer generation longer aeroplanes (A340-600, B777-300) will require a specific study to ascertain the adequacy of existing fillets and when designing new facilities.

Landing gear design

2.13 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 bearing capacity of the soil. 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.

Outer main gear wheel span

2.14 The outer main gear wheel span may influence:

a) runway width;

b) the dimensions of turn pads;

c) taxiway width;

d) taxiway fillets; and

e) the dimensions of aprons and holding bays.

Wheelbase

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

Main gear steering system

2.16 The main gear steering system may influence the dimensions of turn pads and the dimensions of aprons and holding bays.

Maximum aircraft mass

2.17 The maximum mass may influence:

a) the design of pavements and underground structures;

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

c) disabled aircraft removal; and

d) wake turbulence.

Landing gear geometry, tire pressure and ACN values

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

Engine data

Engine characteristics

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

a) the number of engines;

b) the location of engines;

c) the vertical clearance of engines;

d) engine thrust; and

e) exhaust velocity.

2.20 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) the dimensions and location of fences;

e) the location of signs;

f) the characteristics of runway and taxiway edge lights; and

g) snow removal procedures.

Engine exhaust velocities

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

2.22 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) the location and structural integrity of signs;

f) the characteristics of runway and taxiway edge lights;

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

h) snow removal procedures.

Engine thrust reverse

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

Maximum passenger- and fuel-carrying capacities

2.24 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.

Flight performance

2.25 The relevant parameters to be considered are:

a) approach attitude on glide slope;

b) approach speed;

c) start of the visual segment;

d) autoland and manual modes; and

e) flight handling qualities.

2.26 Flight performance (autoland and manual) may influence:

a) runway width;

b) the OFZ;

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.

Technology evolution

2.27 Technology evolution may influence:

a) runway and shoulder width;

b) taxiway and shoulder width;

c) aircraft certification criteria;

d) the OFZ and balked landing surface;

e) the in-flight phase; and

f) environmental aspects.

Chapter 3

METHODOLOGY FOR CONDUCTING AERONAUTICAL STUDIES

INTRODUCTION

3.1 This chapter outlines the safety analysis methodology[1] that is used in Chapter 4 of this circular to assess the operational and infrastructure requirements for the accommodation of NLAs at existing aerodromes.

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

3.3 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 that 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.

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

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

3.6 Appendix B contains a list of references to existing studies that may assist States and airport operators 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 its applicability to other situations and locations. Inclusion of these references does not imply 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.

OBJECTIVES AND SCOPE

3.7 According to the *Aerodrome Design Manual* (Doc 9157), 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 the 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.

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

a) distance between centre line of runway and centre line of taxiway;

b) distance between centre line of taxiway and centre line of 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.

BASIC CONSIDERATIONS

3.9 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.

SAFETY ANALYSIS ASPECTS

Risk assessment and possible mitigation measures

3.10 Hazard analysis to be applied in this context is the identification, using experience and operational judgement, of undesirable events and hazards linked to an infrastructure item. 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 consequence analysis, based on experience and accident database analysis.

3.11 The severity level of an incident/accident (“minor”, “major”, “hazardous” or “catastrophic”) may be deduced from its consequences (“effect on aircraft and occupants”).

3.12 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 such models are given in Appendix B. Advisory Material Joint-AMJ JAR 25.1309, containing material similar to United States Federal Aviation Administration (FAA) Advisory Circular AC25.1309-1A (21 June 1988) defines "catastrophic" as "failure conditions which would prevent continued safe flight and landing".

3.13 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 terms (identification of a numerical probability) or qualitative terms (comparison with an existing situation). 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 to or better than the one offered to a code E aeroplane on a code E-compliant infrastructure.

Risk assessment process

3.14 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, can be based on aeroplane design, certification, simulation results and accident analysis.

b) *Method type "B"*. For other hazards, risk assessment is not really linked with specific aeroplane performance and handling qualities but can be calculated from existing aeroplane performance measurements. Risk assessment, then, can 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.

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

3.16 Where possible, the result of the risk assessment should be the establishment of alternative measures, operational procedures and operating restrictions to mitigate risks due to 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 aerodromes. However, specific local conditions at an aerodrome may prohibit the provision or application of these minimum conditions. In that case additional control measures should be implemented in order to provide an acceptable level of safety.

Chapter 4

AERODROME FACILITIES AND SERVICES

FACILITIES

Introduction

4.1 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 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 new aeroplanes within the well-established code E. The new Airbus A340-600 as well as 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 and the associated long wheelbase, i.e. the distance from the nose wheel gear to the main landing gear.

4.2 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 strips and runway end safety areas;

c) taxiways and shoulders;

d) bridges, tunnels, and culverts under taxiways;

e) taxiway minimum separation distances; and

f) aprons and holding bays.

4.3 For each infrastructure item the following is presented:

a) *The ICAO SARPs.* The Standards and Recommended Practices contained in Annex 14, Volume I, and the guidance material in the *Aerodrome Design Manual* (Doc 9157) are described. Where possible, information and formulae used to elaborate the ICAO provisions are given.

b) *Hazard identification and analysis.* Where it is impossible or impracticable for aerodromes to adapt their infrastructure to the Annex 14, Volume I, code F provisions for the operation of a given NLA, an aeronautical study will be required to show that the operation of the specific NLA type at existing facilities is possible without compromising safety. For this reason a number of possible hazards are identified.

c) *Risk assessment.* 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 Chapter 3, paragraph 3.14 of this circular.

4.4 A reference list of studies is provided in Appendix B. Subject to the caution and guidance given elsewhere in this circular, these studies and results may assist authorities in developing their own aeronautical studies. Inclusion in this circular of references 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 in States remains a matter for decision by the appropriate authorities.

Runways

Runway width

4.5 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.

4.6 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 × 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 is to have a margin for factors such as wet or contaminated runway pavement, crosswind conditions, crab angle approaches to landing, and aircraft controllability during aborted take-off.

Hazard identification and analysis

4.7 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 the landing phase.

4.8 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 centre of gravity);

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

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

4) weather conditions (heavy rain, crosswind, 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, crosswind, strong/gusty winds, thunderstorms/wind shear, visibility);

5) ILS localizer signal quality/interference; and

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

4.9 An analysis of lateral runway excursion reports shows that the casual factor in aircraft accidents is not the same for take-off and for landing. Mechanical failure is, for instance, a frequent accident factor in excursions 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).

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

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

Risk assessment and possible mitigation measures

4.12 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 crosswind 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.

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

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

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

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

d) additional runway centre line guidance.

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

4.14 At aerodromes with runways narrower than 60 m, operators should also take into account the possibility that certain NLAs may not be able to make a 180-degree turn on such a runway. When there is no proper taxiway to the end of the runway, the provision of a suitable runway turn pad is recommended.

Runway shoulders

Shoulder width

4.15 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.

4.16 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.

Shoulder strength

4.17 Annex 14, Volume I, paragraph 3.2.5, recommends:

> 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.

4.18 The *Aerodrome Design Manual* (Doc 9157), Part 1, states that:

> The shoulder of a runway should be prepared or constructed so as to minimize any hazard to an aeroplane running off the runway (paragraph 5.2.2).
>
> In some cases, the bearing strength of the natural ground may be sufficient, without special preparation, to meet the requirements for shoulders (paragraph 5.2.3).
>
> Attention should also be paid when designing shoulders to prevent the ingestion of stones or other objects by turbine engines (paragraph 5.2.4).
>
> In the case of special preparation, visual contrast between runway and runway shoulders may be needed (paragraph 5.2.5).

Hazard identification and analysis

4.19 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 prevent engine ingestion; and

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

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

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

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.

4.21 The 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.

4.22 The specific issues of concern to RFF vehicle traffic with regard to NLAs are:

a) aeroplane wingspan, engine position, length of the escape chute; and

b) shoulder width and bearing strength.

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

Risk assessment and possible mitigation measures

4.24 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) *Incursion onto the runway shoulder.* To prevent structural damage to an aircraft in the case of veer-off from a runway that 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 will also need to be evaluated for adequacy.

b) *Jet blast.* 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 are available on the websites of the respective manufacturers. Lateral deviation from the runway centre line should also be taken into account. Regarding the risk of ingestion of foreign objects by the outer engines, additional data on the 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 operating on existing runways may provide a better understanding of the issue. The dimensions to be considered should include the margins between the outer engine axis and the edge of the shoulder, and the distance from the outer engine to the ground.

c) *RFF vehicles.* Operational experience with current large aircraft on existing runways suggests that an overall width of the runway and its shoulders of 75 m should be adequate to permit intervention to NLAs (code F) by occasional RFF vehicle traffic at least as easily as for current code E aircraft on a code E runway. However, the longer 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.

Runway strip and runway end safety area

4.25 The 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 the 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.

4.26 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 ten-year period (1987–1997) show 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 damage. Collision hazard after runway excursion can be classified as a major to catastrophic risk, hence the need to provide adequate runway end safety areas, as specified in Annex 14, Volume I.

4.27 The dimensions of the runway end safety area are dependent on the width of the runway. According to the requirements in Annex 14, Volume I, this is dependent on aircraft size. The minimum requirement is 120 m (2 × 60 m runway width) for code F aircraft and 90 m (2 × 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.

Taxiways

Width of a straight taxiway

4.28 Annex 14, Volume I, paragraph 3.9.1, specifies that taxiways should be provided to permit the safe and expeditious surface movement of aircraft. Furthermore, paragraph 3.9.3 recommends that the minimum clearance between the outer main wheel and the taxiway edge should be at least 4.5 m for code letters D, E and F. Additionally, paragraph 3.9.4 specifies that the width of a straight portion of a taxiway should not be less than:

— 23 m where the code letter is E; and

— 25 m where the code letter is F.

4.29 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 × clearance distance from wheel to pavement edge plus maximum outer main gear wheel span for the code letter.

Using the above formula, the taxiway width for code letters E and F would be as follows:

For code E: 2 × 4.5 m + 14 m = 23 m.

For code F: 2 × 4.5 m + 16 m = 25 m.

Hazard identification and analysis

4.30 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.

4.31 The main causes and accident factors are:

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

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

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

d) Human Factors (including directional control, orientation error, pre-departure workload).

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

Risk assessment and possible mitigation measures

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

4.34 The risk associated 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 input when taxiing at ordinary speeds. The expected behaviour of an NLA could be deduced from the observation of existing large aircraft types (see Appendix B).

4.35 Optional studies could include:

a) the use of taxiway deviation statistics to calculate the taxiway excursion probability of an NLA 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.

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

a) the provision of taxiway centre line lights;

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

c) reduced taxi speed;

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

e) enhanced snow bank clearance (engine positions); and

f) the use of alternative taxi routes.

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

Taxiway curves and intersections

4.38 Annex 14, Volume I, paragraph 3.8.5, recommends the 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 the taxiway edge.

4.39 The *Aerodrome Design Manual* (Doc 9157), Part 2, contains related guidance in paragraphs 1.2.9 and 1.2.22 and Table 1-3.

Hazard identification and analysis

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

4.41 The main causes and accident factors are the same as for a taxiway excursion on a straight taxiway section. The use of the cockpit-over-centre-line steering technique on a curved taxiway will result in track-in of the main landing gear from the centre line. The amount of track-in depends on the radius of the curved taxiway and the distance from the cockpit to the main landing gear.

4.42 The consequences are the same as for lateral taxiway excursions on straight sections.

Risk assessment and possible mitigation measures

4.43 The required width of the curved portions of 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 the outer main gear wheel span and the distance between the nose gear/cockpit and the main gear. Consideration may need to be given to the effect on airfield signs and other objects nearby of jet blast from a turning aircraft.

4.44 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.

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

a) the widening of existing fillets or the provision of new fillets;

b) reduced taxi speed; and

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

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

Taxiway shoulders

4.47 Annex 14, Volume I, paragraph 3.10.1, recommends that the overall width of the taxiway and its shoulders on straight portions should be:

— 44 m where the code letter is E; and

— 60 m where the 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 4.48. Furthermore, Annex 14, Volume I, paragraph 3.10.2, recommends that the surface should be so prepared as to resist erosion and ingestion of the surface material by aeroplane engines.

4.48 The guidance material in the *Aerodrome Design Manual* (Doc 9157), 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.

Hazard identification and analysis

4.49 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 the 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.

4.50 The factors leading to reported problems are:

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

b) taxiway shoulder width, the nature of the 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.

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

Risk assessment and possible mitigation measures

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

Bridges, tunnels, and culverts under taxiways

Taxiways on bridges

4.53 Annex 14, Volume I, paragraph 3.9.19, 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."

4.54 Annex 14, Volume I, paragraph 3.9.20, 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.

4.55 Annex 14, Volume I, paragraph 3.9.21, and the *Aerodrome Design Manual* (Doc 9157), 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.

Hazard identification and analysis

4.56 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 the aeroplane mass exceeding the design load; and

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

4.57 The main causes and accident factors are:

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

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

c) loss of the 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) the position of the extremity of the escape slides; and

g) undercarriage design.

4.58 The main causes of 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).

4.59 These hazards can be classified as “major” to “catastrophic”.

Risk assessment and possible mitigation measures

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

4.61 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, allowing for wind direction as necessary. A wingspan of 80 m will in all cases exceed the width of a bridge. However, based on experience at 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 would be practicable only where bridges are paired (parallel taxiways) or when there is a service road in the vicinity. The surface of the bypass routes would need to be stabilized where it is unpaved.

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

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

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

4.65 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 a 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 have suitably designed underground structures where needed.

4.66 Possible mitigation measures for the operation of a given NLA on taxiway bridges that 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) provide an alternative path/bridge for RFF vehicles subject to its feasibility from an RFF point of view.

Taxiway minimum separation distances

Runway to parallel taxiway separations

4.67 Annex 14, Volume I, paragraph 3.9.7, and Table 3-1, columns 5 and 9, specify, for code F, a minimum distance between the centre line of a runway and the centre line of 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 affect the regularity of operations of aeroplanes. See Note 2 to Table 3-1, and Notes 2, 3 and 4 to paragraph 3.9.7 of Annex 14, Volume I.

4.68 The *Aerodrome Design Manual* (Doc 9157), Part 2, paragraph 1.2.19, and Table 1-5, clarify 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 wingspan + 1/2 strip width.

For code E: $1/2 \times 65$ m + $1/2 \times 300$ m = 182.5 m.

For code F: $1/2 \times 80$ m + $1/2 \times 300$ m = 190 m.

4.69 The *Aerodrome Design Manual* (Doc 9157), Part 2, has related guidance in paragraphs 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 an NLA with the minimum possible risk.

Hazard identification and analysis

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

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

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

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

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

4.72 The 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, autopilot, etc.);

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

e) lateral veer-off distance;

f) aeroplane position relative to navigation aids, especially ILS; and

g) aeroplane size and characteristics (especially wingspan).

4.73 Common accident/incident databases deal with lateral runway excursions but do not include accident reports relative to in-flight collisions 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.

Risk assessment and possible mitigation measures

4.74 *Collision between an aircraft in flight and an object (fixed or mobile) on the aerodrome.* 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) can be reached.

4.75 *Collision between an aircraft veering off the runway and an object (fixed or mobile) on the aerodrome.* The *Aerodrome Design Manual* (Doc 9157), 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.” As such, the following options may be considered:

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

b) conduct a local study to determine the impact on ILS signals; and

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

4.76 The minimum distance between the centre line of a runway and the centre line of 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].

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

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

4.79 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 can apply operational restrictions according to conditions.

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3. Additional guidance material on minimum separation distances will be included in the fourth edition of the *Aerodrome Design Manual* (Doc 9157), Part 2.

4.80 *ILS signal interference by a taxiing or stationary aircraft.* The risk of ILS signal distortion should be assessed on a case-by-case study basis taking into account the specific aerodrome layout and traffic density. Individual case studies could benefit from several ongoing generic studies dealing with the effect of current code E and expected code F aircraft geometry on the ILS safety area.

Parallel taxiway separation

4.81 Annex 14, Volume I, paragraph 3.9.7, and Table 3-1, column 10, specify that 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 affect the regularity of operations of aeroplanes.

4.82 The *Aerodrome Design Manual* (Doc 9157), Part 2, paragraphs 1.2.13 to 1.2.15, Tables 1-1 and 1-4, and Figure-1-4, clarify that this minimum separation distance is equal to the wingspan plus maximum lateral deviation plus increment as follows:

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.

Taxiway/apron taxilane to object separation

4.83 Annex 14, Volume I, paragraph 3.9.7, and Table 3-1, column 11, specify 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 affect the regularity of operations of aeroplanes.

4.84 Paragraph 3.11.3 of Annex 14, Volume I, also envisages that the taxiway strip should provide an area clear of objects that may endanger an aircraft.

4.85 The *Aerodrome Design Manual* (Doc 9157), Part 2, paragraphs 1.2.13 to 1.2.18, Tables 1-1 and 1-4, and Figure 1-4, state that:

Separation = 1/2 wingspan + maximum lateral deviation + increment.

For code E: 1/2 × 65 m + 4.5 m + 10.5 m = 47.5 m.

For code F: 1/2 × 80 m + 4.5 m + 13 m = 57.5 m.

Aircraft stand taxilane to object separation
(including service road)

4.86 Annex 14, Volume I, paragraph 3.9.7, and Table 3-1, column 12, specify that the minimum separation distance between the taxilane centre line and an object should be 50.5 m. Note 4 to that 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.

4.87 The *Aerodrome Design Manual* (Doc 9157), Part 2, paragraphs 1.2.13 to 1.2.17, Tables 1-1 and 1-4, and Figure 1-4, indicate that:

Separation = 1/2 wingspan + maximum lateral deviation + increment.

For code E: 1/2 × 65 m + 2.5 m + 7.5 m = 42.5 m.

For code F: 1/2 × 80 m + 2.5 m + 8 m = 50.5 m.

Note.— See paragraphs 1.2.61 and 1.2.62 of the Aerodrome Design Manual *(Doc 9157), Part 2*.

Hazard identification and analysis

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

4.89 A review of commonly used databases reveals that there is limited information relative to collisions when taxiing because few such incidents have been recorded as serious incidents. However, the main causes and accident factors could be:

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

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

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

d) Human Factors (directional control, temporary loss of orientation, etc.).

4.90 The consequences of a collision when taxiing are potentially major.

Risk assessment and possible mitigation measures

4.91 Operational experience with existing code E aeroplanes, under favourable conditions, shows that deviations do not increase with aeroplane size. It is therefore expected that taxiway deviations by NLAs will not be significantly different from those by 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 3.9.3, is the same as for code E aeroplanes.

4.92 Taxiway deviation statistics may be used to assess the risk of a collision between two aircraft or between an aircraft and an object. Several taxiway deviation studies are available or in progress on different aerodromes worldwide (New York-Kennedy, Anchorage, Amsterdam-Schiphol, London-Heathrow, Paris-Charles de Gaulle, Frankfurt and Sydney). Final reports are expected in 2004.

4.93 Possible mitigation measures for the operation of NLAs on taxiways that 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) the provision of taxiway centre line lights;

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

d) special taxi routing for NLAs;

e) restrictions on aircraft (wingspan) allowed to use parallel taxiways during the operation of NLAs;

f) restrictions on vehicles using service roads adjacent to a designated NLA route;

g) the 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, distinguishing between markings and offset lights can be difficult.

Aprons — clearance distances on aircraft stands

4.94 Annex 14, Volume I, paragraph 3.13.6, recommends that the minimum distance between an aeroplane using the stand 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 the terminal (including any fixed passenger boarding bridge) and the aircraft nose; and

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

Hazard identification and analysis

4.95 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.

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

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

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

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

d) Human Factors (directional control, orientation error).

4.97 The consequences of a collision on the apron or holding bay are potentially major.

Risk assessment and possible mitigation measures

4.98 The collision hazard during taxiing depends more on Human Factors than on aeroplane performance (all functioning aeroplanes respond reliably to pilot directional input when taxiing at ordinary speeds). Therefore, the expected behaviour of an NLA could be inferred in part from that of existing aircraft. Nevertheless, caution should be exercised with regard to the implications of the significantly increased wingspan of NLAs.

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

4.100 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 code E aircraft.

Pavement design

4.101 The increased mass and/or gear load of the NLAs will require adequate pavement support. Existing pavements will 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 aircraft classification number (ACN) of the aeroplane exceeds the pavement classification number (PCN), or the maximum loads of the NLA concerned exceed those used in the design of the underground structures.

4.102 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.

4.103 To facilitate flight planning, various aerodrome data are required to be published, such as data concerning the strength of pavements, which is one of the factors required to assess whether the aerodrome can be used by an aeroplane of a specific all-up mass. ICAO has established the 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.

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

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

AERODROME OPERATIONAL SAFETY SERVICES

Aerodrome emergency planning

General

4.106 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 can be found in the *Airport Services Manual* (Doc 9137), Part 7 — *Airport Emergency Planning*.

4.107 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 decks, requires some additional consideration in terms of emergency planning. The main issues involve the size of the airframe and the potential number 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.

4.108 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 agents 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.

4.109 Key issues associated with the introduction of NLAs 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.

Critical considerations

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

a) the assessment and testing of the aerodrome emergency plan in order to be able to respond to an emergency within a distance of 1 000 m from the threshold of each operational runway or within the aerodrome boundary;

b) the potential for simulation to assist in testing the revised plan (e.g. desktop computer);

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

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

e) scene management to account for the additional passenger numbers;

f) additional transportation needs;

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

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

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

j) the updating of the aircraft recovery plan to include significantly larger aircraft.

Tactical issues for external and internal situations

4.111 The following issues will need to be considered:

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

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

c) upper-deck escape slide deployment and a safe egress area, which will be greater than for current code E aeroplanes;

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

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

f) the use of positive pressure ventilation (PPV)[4] systems for internal fires;

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

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

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

Appropriate level of service and equipment

4.112 Aerodrome operators 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 operation of NLAs. Critical situations should be identified and addressed accordingly.

Rescue and fire fighting services

General

4.113 The introduction of NLAs 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.

4.114 Passenger egress from, and emergency crew access to, double-deck aircraft under emergency conditions, including the possible need for equipment to access the upper deck, have been identified as significant issues. The specifics of dealing with certain NLAs will be addressed separately. In the meanwhile, attention is drawn to the *Airport Services Manual* (Doc 9137), Part 1 — *Rescue and Fire Fighting*, Chapter 12, section 12.3.

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

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

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4. A positive pressure ventilation system introduces breathable air into a smoke-filled fuselage.

4.117 The most important factors bearing on an 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.

4.118 Detailed guidelines are given in the *Airport Services Manual* (Doc 9137), Part. 1.

Level of protection to be provided

4.119 The A380 falls into ICAO aerodrome RFF category 10 due to its fuselage width (8 m), though not its overall length. Other projected aircraft-type stretches may warrant a higher category. The A380 has the capability to deploy three upper-deck slides on each side compared to one for the B747. For double-deck aeroplanes, the increased number and longer extension of the 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.

4.120 The quantities of extinguishing agents specified in Annex 14, Volume I, Table 9-2, to meet the requirements of a particular aerodrome category, are 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 the 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* (Doc 9137), Part 1.

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

Training

4.122 Rescue and fire fighting personnel should receive specific training relevant to the 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.

4.123 Emergency response training for the introduction of NLAs will require cooperation between airframe manufacturers, aircraft operators, airport authorities and emergency services. Paragraph 17.2 of Attachment A to Annex 14, Volume I, 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.

Disabled aircraft removal

4.124 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.

4.125 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.

4.126 Guidance on removal of disabled aircraft, including recovery equipment, is contained in the *Airport Services Manual* (Doc 9137), Part 5 — *Removal of Disabled Aircraft*. 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.

Aerodrome maintenance services

4.127 With the introduction of NLAs such as the A380, aerodrome maintenance or reconstruction programmes will need to ensure that the specific aircraft requirements in terms of increased aircraft mass, wheelbase and wingspan; 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 arrangements may be necessary.

4.128 Snow removal programmes will need to ensure clearance of snow banks to the full width of the code F facilities, noting the wing tip and wheel track-ins during turns. With the increased mass of NLAs, 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.

4.129 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* (Doc 9137), Part 9 — *Airport Maintenance Practices*.

OBSTACLE LIMITATION SURFACES

Obstacle free zone

4.130 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.

4.131 For code F operations, the OFZ on a precision approach runway is designed to protect an aeroplane with a wingspan 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.

4.132 The dimensions of the OFZ 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.

VISUAL AIDS

Markings and signs

Location of existing aerodrome signs

4.133 Generally, existing signs should suffice for the operation of NLAs at most of the aerodromes that will receive these aeroplanes.

4.134 Annex 14, Volume I, Table 5-4, specifies the distances from the edge of runways and taxiways at which signs may be located. These distances may need to be increased to ensure that similar clearance is obtained for the operation of NLAs. With an increased distance from the taxiway edge, the angle of signs relative to the taxiway may have to be considered.

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

Additional signs

4.136 NLAs 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.

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

4.138 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 aircraft holding positions. This may also apply to new longer (code E) aircraft.

Information and mandatory instruction markings

4.139 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.

Lights

Existing lights

4.140 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.

4.141 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.

Additional lights

4.142 Where taxiways have been widened to allow for NLAs, 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.

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

4.144 If NLAs 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.

PAPI/APAPI

4.145 It is expected that the eye-to-wheel height of the NLA will comply with the requirements of Annex 14, Volume I, 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.

GROUND SERVICING OF AEROPLANES

Aeroplane de-icing/anti-icing facilities

4.146 The increased mass, wingspan and surface area of NLAs will require some reconsideration of the adequacy of the de-icing/anti-icing facilities to accommodate them.

4.147 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 3.15.5);

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

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

d) the load bearing capacity of the existing structure;

e) the requirement for greater quantities of de-icing/anti-icing agents;

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

g) turning circle capabilities of NLAs;

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

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

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

Chapter 5

AIRCRAFT OPERATIONS

AIR OPERATOR CERTIFICATION

5.1 Annex 14, Volume I, paragraph 3.1.9, recommends a runway width of 60 m for code F aeroplanes, and paragraph 3.2.3 specifies a 75-m overall width for the runway and its shoulders. For code E aeroplanes, the recommended runway width is 45 m, and the overall width of the runway and its shoulders is 60 m.

5.2 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, Part IIIB, 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:

a) maximum crosswind component;

b) runway surface (dry, wet, contaminated);

c) failure conditions including sudden engine failure;

d) critical aeroplane loading (gross weight, centre of gravity); and

e) autoland operations, when applicable.

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

5.3 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. When establishing these alternative measures, operational procedures and operating restrictions, States should review the information in the flight manual regarding the minimum runway width and critical crosswind component under all anticipated operating conditions.

5.4 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.

5.5 Taxi cameras can assist the flight crew in preventing the wheels of the aeroplane from leaving the full-strength pavement during normal ground manoeuvring. The taxi camera system may be required on an aeroplane dispatched 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 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.

5.6 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 that may be deposited during 180-degree turns on the runway after landing and while taxiing into position for take-off.

FLIGHT PROCEDURES DESIGN

Obstacle limitation surfaces

5.7 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, considering its intended use, as 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 *Airport Services Manual* (Doc 9137), 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, Doc 8168), 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.

Obstacle free zone (OFZ)

5.8 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.”

5.9 Runways require a space free of obstacles, termed the obstacle free zone (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 landings/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.

5.10 The OFZ during approach, landing, take-off and taxi operations may need to be expanded, or the operation of NLAs restricted, depending on the distance between taxiways and runways relative to the wingspan and tail height of an NLA, the published missed approach procedures, the balked landing/go-around procedures and the performance characteristics of the NLA concerned.

5.11 Annex 14, Volume I (Standard), paragraph 4.2.8, and Table 4-1 (including table footnote "e"), extend 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 in Circular 301 — *New Larger Aeroplanes — Infringement of the Obstacle Free Zone: Operational Measures and Aeronautical Study*. The attention of States and operators is drawn to that circular, an overview of which can be found in Appendix C.

Aircraft speed categorization

5.12 The PANS-OPS describes the aircraft speed categories that are used for OCA/H calculations and the promulgation of aircraft category-related minima.

5.13 Amendment 12 to PANS-OPS, Volume II, introduces a new speed category, D_L, into flight procedure design calculations in support of the introduction of NLAs. This speed category recognizes aircraft with a wingspan of 80 m and a vertical distance between the flight path of the wheels and the glide path antennas to be 8 m, thereby avoiding the need to apply excessive penalties and operational minima to category "D" aeroplanes.

5.14 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 its calculations.

ENVIRONMENTAL ASPECTS

5.15 Because 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 may generate wide interest amongst environmental groups.

5.16 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 environmental impact. The necessary overall environmental assessment should also take into account the improved efficiency derived from the increased payload per NLA movement and the better performance of NLAs compared to older models still in operation.

5.17 The following should be taken into account by the appropriate authorities and 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* (Doc 9184), Part 2 — *Land Use and Environmental Control*.

Chapter 6

AIR TRAFFIC MANAGEMENT ISSUES

WAKE TURBULENCE ISSUES

6.1 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 of 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, is 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 completed.

6.2 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.

6.3 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 of Doc 4444, are in some cases as high as six 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).

Chapter 7

AERONAUTICAL STUDIES

SCOPE AND APPLICABILITY

7.1 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.

7.2 An aeronautical study is conducted to assess, for a given aeroplane at a given location, the impact of deviations from some of the 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 the safe operation 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 that may be required at aerodromes where Annex 14, Volume I, code F provisions cannot be met.

7.3 Each aeronautical study is likely to be different and will 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].

7.4 The following guidance should be considered as a general example that could be followed when performing an aeronautical study (or a validation process), 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 allow them to form their own conclusions.

APPROVAL OF AN AERONAUTICAL STUDY

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

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

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

DEFINING THE SCOPE OF THE AERONAUTICAL STUDY

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

a) the level of compliance with ICAO SARPs;

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

c) the 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 a list of the specific characteristics of an NLA (see Chapter 2 and Appendix A) that 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 a definition of the method of assessment that is needed to clarify and demonstrate conformance to particular requirements.

STUDY PLAN

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

a) develop a background statement to the requirement;

b) specify roles, responsibilities and competence;

c) identify the 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 approval mechanisms;

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

g) define the validation methodology, including the approval process;

h) specify measures to archive results and data; and

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

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

7.8 To facilitate the aeronautical study, a State or organization may elect to draw on existing studies or guidance material. 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.

7.9 Appendix B provides a list of relevant studies and existing material as well as the websites where other validated information can be found[7]. However, it should be emphasized 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.

RECOMMENDATIONS AND CONCLUSIONS

7.10 The result of the aeronautical study should demonstrate that the objectives outlined in 7.6 have been fully met and should contain a recommendation for the acceptance or rejection of the study. The report structure may consist of:

a) an executive summary;

b) an introduction and overview;

c) the sources of the requirements;

d) an overview of the aeronautical study plan;

e) summary reports of the aeronautical study tasks;

f) compliance with the requirements;

g) other outstanding information or issues; and

h) conclusions.

AERONAUTICAL INFORMATION SERVICE (AIS)

7.11 States are reminded of their obligation to take the appropriate action with regard to the dissemination, via the AIS, of information concerning alternative measures, operational procedures and operating restrictions implemented at a particular aerodrome and, in the context of this circular, to accommodate a specific NLA.

7.12 States are further reminded of the obligation imposed under Article 38 of the Convention by which Contracting States are required to notify ICAO of any differences between their national regulations and practices and the International Standards contained in Annex 14. (Paragraph 1.7 of this circular refers.)

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7. The list and websites are provided for the assistance of the reader and do not signify ICAO endorsement of any study, process or conclusion.

ICAO SPECIFICATIONS AND GUIDANCE MATERIAL

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

a) taxiway minimum separation distances: paragraph 3.9.7 and notes thereto;

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: footnote c to Table 5-2, 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.

7.14 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 to 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 of All-Weather Operations*;

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

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

7.15 Other material or studies that have been developed or are under development outside of ICAO, could serve as reference or background material, thus saving States time and effort in the performance of a particular aeronautical study. A list of aeronautical studies associated with NLA operations can be found in Appendix B. This list is provided for the assistance of the reader and does not signify ICAO endorsement of any study, process or conclusion.

Appendix A

CHARACTERISTCS OF NEW LARGER AEROPLANES

1. DIMENSIONS AND OTHER DATA

Table A-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*
Wingspan	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

* Freighter version values are provided where appropriate.
** B747-Advanced is a proposed aircraft (not yet in service), and therefore the specifications are subject to change.

Table A-2. Aeroplane dimensions

Aeroplane dimensions	*Code F*				*Code E*		
	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 operating empty weight (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
Wingspan	79.8 m	68.7 m	67.9 m	73.3 m	63.4 m	64.9 m	64.8 m

Aeroplane dimensions	*Code F*				*Code E*		
	A380-800	*B747-Advanced**	*C5*	*An 124*	*A340-600*	*B747-400ER*	*B777-300ER*
Wingspan (full fuel)#	—	—	—	—	63.6 m	64.9 m	—
Wingspan (jig)##	79.8 m	68.7 m	67.9 m	73.3 m	63.4 m	64.4 m	64.8 m
Wing tip vertical clearance at maximum take-off weight (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
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 distance from nose landing gear	2.1 m	2.3 m	5.0 m	2.4 m	4.3 m	2.3 m	3.6 m
Pilot distance from main landing gear	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 in service), and therefore the specifications are subject to change.
** Freighter version values are 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 is frequently made to "jig" span, i.e. the span as measured in the manufacturing jig (straight wing without 1G droop).

Table A-3. Landing gear geometry

Landing gear geometry	*Code F*				*Code E*		
	A380-800	*B747-Advanced**	*C5*	*An 124*	*A340-600*	*B747-400ER*	*B777-300ER*
Weight							
• Maximum ramp weight (MRW)	562 t 602 t**	423 t 437 t**	381 t	405 t	369 t	414 t	341 t
• Maximum take-off weight (MTOW)	560 t 600 t**	422 t 435 t**	379.6 t	398 t	368 t	413 t	340 t
• Maximum landing weight (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
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

* B747-Advanced is a proposed aircraft (not yet in service), and therefore the specifications are subject to change.
** Freighter version values are provided where appropriate.
*** There are two types of main landing gear steering systems — post steering with all wheels steered (747, C5 and An 124) and aft-axle steering (aft two wheels out of six-wheel gear, e.g. A380-800 and B777). The effect of the main gear steering system on turn centre location is shown in Section 4.3 of the "Airplane Characteristics for Airport Planning" document on the website of the respective manufacturer (Appendix B).

Note.— Discussions on the value of the alpha factor are ongoing. Aircraft footprints and ACN curves are available in Section 7 of the "Airplane Characteristics for Airport Planning" document on the website of the respective manufacturer (Appendix B).

Table A-4. Minimum pavement width required for U-turns (in ascending order)

Code	*Aircraft*	*U-turn width m (ft)*	*Wheelbase m (ft)*	*Track (to outside tire edge) m (ft)*
E	747-400	46.3 (152)	24.1 (79)	12.6 (41.3)
D	MD11	49 (161)	24.7 (81.2)	12.6 (41.3)
F	747-Adv	49.7 (163)	26.1 (85.6)	12.6 (41.3)
F	747F-Adv	52.1 (171)	27.6 (90.6)	12.6 (41.3)
E	777-300	56.5 (185)	30.6 (100.4)	12.9 (42.3)
E	A340-600	56.7 (186)	33.2 (109)	12.6 (41.3)
F	A380-800	65.7 (216)	29.7 (97.5)	14.3 (47)

Assumes symmetric thrust and no braking.
Note that the U-turn width has little relation to the code letter.

Table A-5. Engine data

Engine data	*Code F*				*Code E*		
	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 (centre line to centre line)	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".
* B747-Advanced is a proposed aircraft (not yet in service), and therefore the specifications are subject to change.
** Freighter version values are provided where appropriate.

Note.— Jet blast velocity contours are available in Section 6 of the "Airplane Characteristics for Airport Planning" document on the website of the respective manufacturer (Appendix B).

Table A-6. Maximum passenger- and fuel-carrying capacity

Layout and capacities	*Code F*				*Code E*		
	A380-800	*B747- Advanced**	*C5*	*An 124*	*A340-600*	*B747-400ER*	*B777-300ER*
Three-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 in service), and therefore the specifications are subject to change.
** Freighter version values are provided where appropriate.
*** B747-400ER is standard with a one body fuel tank; an optional second body fuel tank will increase the fuel volume by 12 151 litres.
# Data shown are approximate.

Note.— Emergency exit locations are available in Section 7 of the "Airplane Characteristics for Airport Planning" document on the website of the respective manufacturer (Appendix B).

Table A-7. Landing incidence/attitude and final approach speed at MLW and forward centre of gravity

Attitude approach data	*Code F*				*Code E*		
	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".
* B747-Advanced is a proposed aircraft (not yet in service), and therefore the specifications are subject to change.

Note.— B747-Advanced, B777-300ER and A380-800 data are estimated values.

2. TECHNOLOGY EVOLUTION

Possible NLA design features that may impact aerodrome elements

Over past decades, there has been steady progress in aviation technology, enhancing the accuracy and reliability of aircraft operations. This technology, along with improvements in airport infrastructures and the improved operational procedures of airports and aircraft have contributed to overall aviation safety. A review carried out by one member State showed a decline in the fatal accident rate from 3.5 fatal accidents per million flights for first generation modern aeroplanes (e.g. B707) to 1.6 for second generation aeroplanes (e.g. DC-10, A300) and to 0.5 for 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 possible integration into 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 a 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 ground contact by all gear prior to full spoiler deployment. This may ensure that anti-skid operations 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. Experience with the A340-600/B777-300 has shown that pilot skills can be enhanced through the use of cameras (correct visual cues acquired), when conducting runway U-turns and when using oversteering turning techniques on taxiway turns.

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 metre from the taxiway centre line. This can prevent inadvertent deviation such as in poor visibility.

OFZ/runway width and other operations/airworthiness aspects

— *Track guidance.* For go-arounds and especially in the 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 much more accurate guidance and prevent 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.

Appendix B

BIBLIOGRAPHY

1. LIST OF REFERENCES AND AERONAUTICAL STUDIES ASSOCIATED WITH THE OPERATION OF NLAs

Subject to the caution and guidance given elsewhere in this circular, the following references may assist authorities in developing their own aeronautical studies. The 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. Paragraph 3 contains an example of how to classify risks and severity levels.

1. Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*.

2. *Aerodrome Design Manual* (Doc 9157), Part 1 — *Runways*.

3. *Aerodrome Design Manual* (Doc 9157), 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 Company Information and Support 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)[8] of the A380 Aerodrome Compatibility Group, December 2002, CAA-France, CAA-UK, CAA-Netherlands, CAA-Germany, ACI, IATA.

10. Obstacle Free Zone, FAA Balked Landing Study, United States, FAA, 2003. 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.

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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.

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.

2. AEROPLANE CHARACTERISTICS DATABASES

Boeing website: www.boeing.com/airports

Airbus website: www.airbus.com/customer/technical.asp#

3. EXAMPLE OF CLASSIFICATION OF RISKS

Careful consideration should be given by the relevant authorities to the definition of the safety objectives for each level 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).

Effect on aircraft and occupants	Normal	Nuisance	• Slight reduction in safety margins • Slight increase in crew workload • Inconvenience to occupants	• Significant reduction in safety margins • Significant increase in crew workload • Passenger injuries	• 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	• Multiple fatalities • Loss of the aeroplane

Numeric probability	10	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}

FAR	<--------------- PROBABLE --------------->			<----------- IMPROBABLE ----------->		EXTREMELY IMPROBABLE
JAR-25	<----- FREQUENT------>		REASONABLY PROBABLE	REMOTE	EXTREMELY REMOTE	
Classification of severity level	<------------------- MINOR ------------------->			MAJOR	HAZARDOUS	CATASTROPHIC

Appendix C

OBSTACLE FREE ZONE — OVERVIEW OF A BALKED LANDING SIMULATION STUDY OF NLAs

1. INTRODUCTION

1.1 A two-year study was conducted by the United States Federal Aviation Administration (FAA) to investigate the balked landing scenario for new larger aeroplanes (NLAs) 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 NLAs 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 from that study. It should be noted that the study assumes 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 specified in the *Manual of Criteria for the Qualification of Flight Simulators* (Doc 9625).)

2.2 The study followed the outline for an aeronautical study prescribed in section 1.2.32 of the *Aerodrome Design Manual* (Doc 9157), Part 2, for assessing 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 wingspan 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 the 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 the NASA Ames B747-400 flight simulator data.

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

4.1 An analysis was made of the wind data and instrument landing systems at forty existing aerodromes worldwide that were considered likely to host NLAs 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 An 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 centred on the extended runway centre line. These contours were based on the location of the centre of gravity of the aircraft and were, at times, oval in shape. The iso-probability contour at the threshold is shown in Figure C-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).

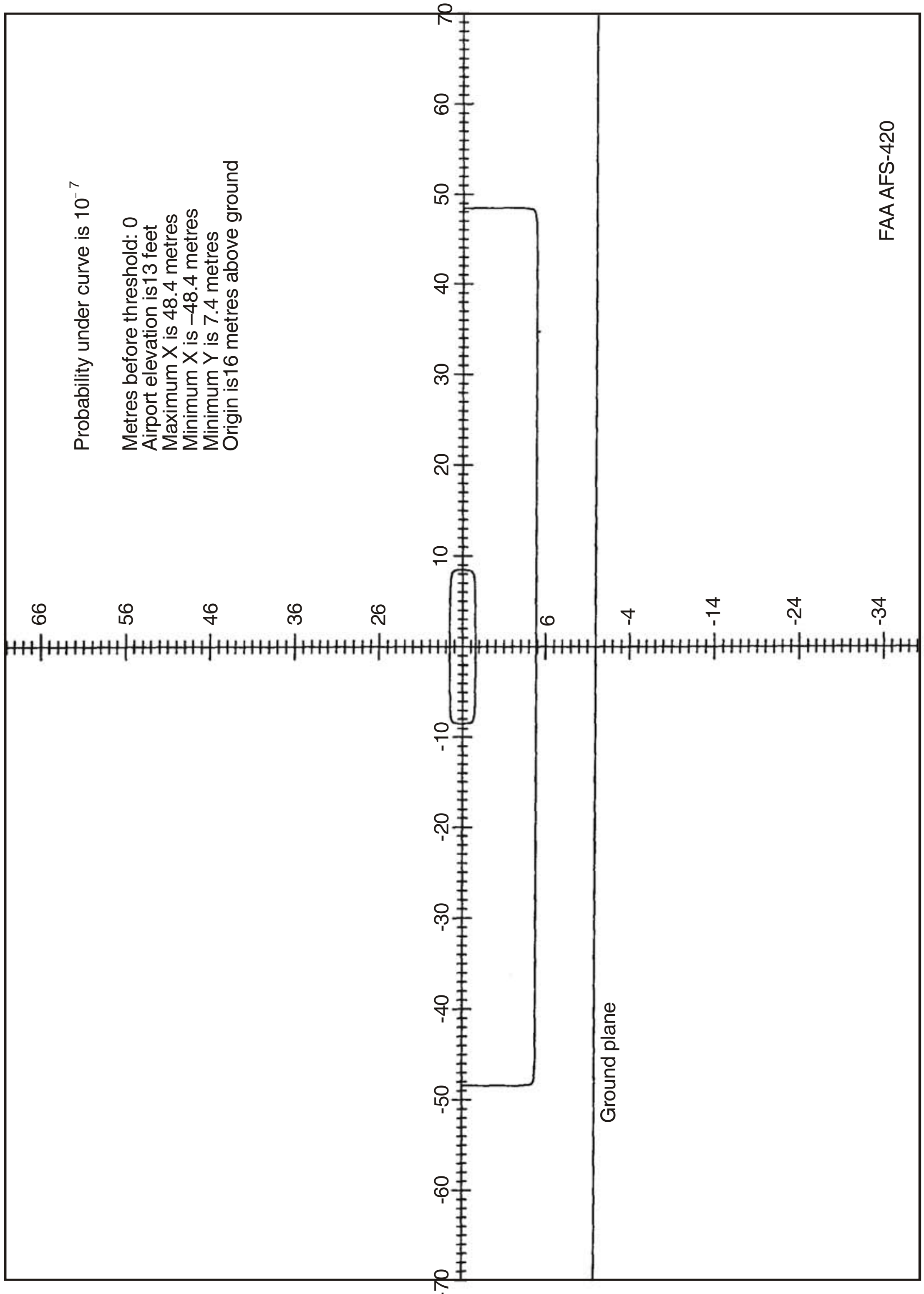

Figure C-1. The iso-probability contour at runway threshold

4.3 The lower curve in Figure C-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 centre of gravity 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 the runway centre line, for a probability of 1×10^{-7} that one would expect to find an aircraft wing tip.

5. FINDINGS

The simulation studies, for autoland approaches, found that the maximum distance from the 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 the operation of NLAs using autoland, see the *Manual of All-Weather Operations* (Doc 9365), section 5.2.13. These findings are part of an aeronautical study conducted by the United States. A follow-on study involving the use of the aircraft flight director will be included in Circular 301 — *New Larger Aeroplanes — Infringement of the Obstacle Free Zone: Operational Measures and Aeronautical Study*. 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.

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