Guaraní International Airport

Aeronautical (Safety) Study of Airfield Items for the 747-8 Operations

24 January 2013

Table of Contents

INTRODUCTION

1 GENERAL

The Boeing 747-8 (passenger and freighter) is the latest derivative model of the 747 family of aircraft. The first 747-8F was delivered in October 2011, and Guaraní International Airport (SGES/AGT) has been identified as a destination and alternate airport by one of the purchasing all-cargo airlines. The 747-8 has a wingspan of 68.4m and outer main gear wheel span of 12.7m. The outer main gear wheel span is well within the International Civil Aviation Organization (ICAO) code letters D and E limit of 14m. However, the wingspan is more than 65m and, therefore, the aircraft is classified by ICAO as code letter F from the airport design perspective.

ICAO Annex 14, Chapter 1, Introductory Note states that “the specifications contained in this annex are not intended to limit or regulate the operation of an aircraft.” Where current airfield items do not meet ICAO code letter F specifications, any deviations from ICAO specifications should be supported by appropriate aeronautical (safety) studies and relevant risk analysis.

2 SUMMARY OF FINDINGS

Comparing the needs of the aircraft with the facilities at the airport has allowed the conclusion that SGES/AGT is fit for operations by the 747-8. The following contains detailed examinations of the airport’s runways, taxiways, aprons, aircraft parking, Obstacle Free Zone, NAVAIDs and other pertinent factors. Detail of the analyses can be found in the body of this report, highlights are as follows:

1. The 747-8 has successfully concluded certification flight tests. A part of the test program was the collection and analysis of lateral dispersion of the aircraft on the runway during take-off and landing to determine its capability to operate on a 45m wide runway. The Boeing Company has received approval to operate on a 45m wide runway from the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA). The 747-8 aircraft has similar landing gear geometry and performance characteristics as the 747-400 so the risk of lateral excursions on either take-off or landing is considered no different than that for the 747-400. Further, the combined width encompassed by the code letter E runway and the runway shoulder (60m) is sufficient to limit the risk of FOD ingestion and jet blast erosion protection based on the 747-8 engine span being the same as the 747-400 and the critical (56 km/h) take-off exhaust velocity contour width being contained within the 60m runway plus shoulder width. At SGES/AGT, the 45m runway width for Runway 05/23 meets the code letter E recommendation and is assessed as adequate for 747-8F operations. However, from the latest Google Earth Pro Imagery, Runway 05/23 does not have a paved shoulder located beyond the 45m runway width. As a substitute for the paved runway shoulder, the airport infrastructure provides a well maintained grass shoulder that should provide adequate protection. The 747-400 and other heritage 747 aircraft have successfully operated on 45m runways, without a paved shoulder, in various locations around the world and the 747-400F currently operates into SGES/AGT on a non-scheduled basis. To guard against possible FOD risk,

an inspection of Runway 05/23 should be undertaken after each 747-8F takeoff during the initial period of operations.

2. The primary taxiway system at SGES/AGT was assessed as adequate for 747-8F operations. The design/operational characteristics (landing gear configuration, cockpit visibility, steering/braking systems, etc.) of the 747-8 for taxiing are the same or similar to those for the 747-400. Dimensionally, the 747-8 landing gear design provides more than the required 4.5m wheel edge to pavement edge clearance to allow the operation on code letter E taxiway width of 23m. In addition to the 23m to 26.5m wide taxiway pavement at SGES/AGT, there are 10m to 10.5m wide shoulders on both edges that add to the safety margins expected during 747-8F operations. These shoulders provide a full width of taxiway and taxiway shoulder of 44m to 47.5m, which meet or exceed the 44m code letter E recommendation. The taxiway shoulder widths are therefore assessed as adequate for 747-8 operations based on the same engine span and the same critical (56 km/h) engine exhaust velocity contour width as those for the 747-400ER. It should be noted that the breakaway velocity contour of the 747-8 and the 747-400ER are smaller than that of the 747-400 due to the use of radial tires on the nose and main landing gears (tires which have lower coefficient of friction with the pavement).

   At SGES/AGT, there appears to be a grass area located beyond the paved taxiway shoulder for all assessed taxiways. A well maintained grass shoulder should provide additional protection from jet blast and engine ingestion risks. Grass taxiway shoulders (instead of paved shoulders) are used extensively in United Kingdom and to a lesser extent in Germany and the United States with satisfactory operations.

3. The SGES/AGT airfield geometry was also reviewed and factors such as runway-to-taxiway separation and apron taxiway/taxilane clearances were evaluated. (a) The Runway 05/23 centreline to the principal parallel taxiway centreline separation is approximately 195m and exceeds the code letter F recommendation of 190m and is therefore assessed as adequate for 747-8F operations. (b) Also, located along terminal taxiways/taxilanes, access taxiways, and apron parking taxilanes are several object separations that were evaluated for 747-8F manoeuvring. Along the principal parallel taxiway are 2 (two) object separations that are 49m (wingtip of the stored DC-8) and 52.5m (apron parking limit line). The 49m separation results in a wingtip clearance of 14.8m as the ICAO-Europe ANP recommended a 9m wingtip clearance for the 747-400 and the BACG agreement also recommends a 9m wingtip clearance for the 747-8. The 52.5m taxiway centreline-to-object separation exceeds the 50.5m code letter F recommendation. Both taxiway centreline-to-object separations are assessed as adequate for 747-8F operations.

4. One of the purchasing all-cargo airlines has designated Guaraní International Airport as a destination and alternate airport critical to its 747-8F route structure. The all-cargo airline operates both 747F and 747-8F aircraft and would like to interchange these aircraft into its schedule as day-to-day cargo demand require. Therefore, the all-cargo airline will require terminal ramp area for aircraft parking and aircraft servicing requirements.

The 747-400F operated by Atlas Air 747-400F currently utilizes the terminal ramp area for aircraft parking that is adjacent to the stored 747/DC-8. The 747-400F manoeuvres onto the apron area and will park after making a left hand turn of approximately 130º. The aircraft will then exit the ramp under power. To illustrate the 747-8F parking configuration, Chart VII located in Attachment A at the end of this aeronautical (safety) study shows the 747-8F operating under the same manoeuvring plan as the 747-400F. As such, this will leave the northwest parking stand available to support current code letter C A320 and lesser code letter regional jet aircraft operations. In this configuration, the tip of the 747-8F vertical stabilizer will not penetrate the 7:1 transition slope.

A possible terminal ramp configuration that could also accommodate 747-8F and provide multiple A320 and/or lesser code letter aircraft parking stands is to have the 747-8F power-in (and then push-back) to the parking stand adjacent the stored 747/DC-8. This configuration will provide 2 open code letter C parking stands (parking centreline offsets are approximately 66m). However, the tip of the parked 747-8F stabilizer will penetrate the 7:1 transition slope. This configuration is feasible only if an operational exemption or waiver can be obtained from the local airport authority or the governing civil aviation authority.

5. The impact that the 747-8 will have on visual and navigational aids was judged to be minimal since all of the airplane's operational characteristics (landing gear, cockpit height, engine placement, engine thrust) are similar to those for the 747-400, which currently operates at the airport.

Other observations are that since the 747-8 is equipped with digital autopilot/flight director and track hold guidance, it will be able to operate within the existing OFZ and other critical airspace areas.

3 PURPOSE

This report was prepared for the purpose of seeking exemptions from the Dirección Nacional de Aeronáutica Civil of the Republic of Paraguay (DINAC) in order to operate the 747-8, a code letter F aircraft, at Guaraní International Airport which is a code letter E airport. It contains;

- An assessment of the level of risk at Guaraní International Airport in handling of the 747-8 during normal operations given the current airport infrastructure.
- Proposed mitigation measures and associated operational procedures, if any, to provide and maintain an acceptable level of safety.

4 SCOPE OF CHANGE

Guaraní International Airport has been identified by one of the purchasing all-cargo airlines as a destination and alternate airport critical to its 747-8F route structure. They currently operate using 747Fs and are expecting to be able to interchange its 747-8F and 747Fs into the schedule as day-to-day cargo demand require.

5 ASSUMPTIONS, CONSTRAINTS, AND DEPENDENCIES

ASSUMPTIONS

This report is based on currently available guidance and recommendations from ICAO, the Airbus A380 Airport Compatibility Group (AACG), the Boeing 747-8 Airport Compatibility Group (BACG), and other documents available on New Larger Airplanes (NLAs). It is also based on the latest information available on the 747-8 configuration and performance characteristics.

This report may undergo several changes as the operator and the airline get more operational experience in handling the 747-8.

ICAO Annex 14, Volume 1, Fifth Edition, dated July 2009 (up to and including Amendment 10-A) was used where Annex 14 paragraph sources are quoted.

Information about SGES/AGT was obtained from several sources including;

- Aeronautical Information Publication (AIP) for Republic of Paraguay obtained from the Dirección Nacional de Aeronáutica Civil of the Republic of Paraguay (DINAC) dated 02 August 2012,
- Jeppesen Airway Manual Services dated 03 August 2012, and
- Images of the airport available through Google Earth Pro dated 07 April 2011, and other sources.

CONSTRAINTS

No data exists for the handling of the 747-8 at Guaraní International Airport as the aircraft is not yet in service at this airport.

Performance data of the 747-8 is available on The Boeing Company website at http://www.boeing.com/commercial/airports/747.htm .

Additional 747-8 data are enclosed as Attachment B.

Studies made for the 747-8 are limited and some of the taxiing deviation studies cited in this report are based on aircraft that are the closest to the 747-8 in terms of physical characteristics, primarily the 747-400.

DEPENDENCIES

The analysis, procedures, and policies discussed here are subject to National Civil Aviation Authority (DINAC) approval.

6 RESPONSIBILITIES

The responsibility for the acceptance and update of this report rests with Guaraní International Airport.

7 CONSULTATION AND COMMUNICATION

This aeronautical (safety) study was produced at the request of the purchasing all-cargo airline.

8 METHODOLOGY

The methodology used in this report to establish operational requirements and infrastructure needs follows the principles and guidelines described in ICAO Circular 305, “Operation of New Larger Aeroplanes at Existing Aerodromes”, June 2004. It has been applied specifically to the 747-8 aircraft operations at Guaraní International Airport.

A simple philosophy, a safety analysis in four steps, has been used for each infrastructure item that may be affected by the introduction of the 747-8. These elements include runways, taxiways, runway separations, taxiway separations and other items such as holdlines and runway visual aids. The following four steps are used in this analysis:

- Identify a baseline of relevant ICAO Standards and Recommended Practices (SARPS) and the rationale and justification for each
- Identify potential hazards and analyze these
- Conduct a risk assessment and identify possible mitigation measures
- Reach a conclusion

9 RISK ASSESSMENT

Depending on the nature of the risks, three methods for risk assessment can be identified:

- **Type A:**
  For certain hazards, risk assessment strongly depends on specific aircraft performance and handling qualities. The safety level is achieved by the suitability between aircraft performance and handling qualities on the one hand, and infrastructure characteristics on the other hand. Risk assessment should be based on the aircraft design and certification tests and simulation results taking into account the actual characteristics of the aircraft.

- **Type B:**
  For other hazards, the aircraft behaviour is not really linked with specific aircraft performance and handling qualities, and can be calculated from existing aircraft measurements. Risk assessment, then, should be based on statistics (e.g. deviations) for existing aircraft or on accident analyses, and the development of generic quantitative risk models that can be adapted.

- **Type C:**

  In this case, a “risk assessment study” is not needed. In such a case, a simple geometric argument is sufficient to calculate infrastructure requirements without waiting for certification results or collecting deviation statistics for existing aircraft.

10 ABBREVIATIONS:

AACG	Airbus A380 Airport Compatibility Group
ADM Pt2	Aerodrome Design Manual part 2
AOPG	Aerodrome Operational Planning Group
APAPI	Abbreviated Precision Approach Path Indicator
ARFF	Aircraft Rescue and Fire Fighting
BACG	Boeing 747-8 Airport Compatibility Group
FOD	Foreign Object Damage
ICAO	International Civil Aviation Organization
IIWG	International Infrastructure Working Group
JAR AWO	Joint Aviation Requirements All Weather Operations
JAR 25	Joint Aviation Requirements for Large Aeroplane
NLA	New Large Aircraft
OCA/H	Obstacle Clearance Altitude/Height
OCP	Obstacle Clearance Panel
OFZ	Obstacle Free Zone
OLS	Obstacle Limitation Surface
OPS	Operations
PAPI	Precision Approach Path Indicator
RESA	Runway End Safety Area
[RP] A14 P3.8.3	ICAO Recommended Practices Annex 14 Paragraph 3.8.3
RTO	Rejected Take-Off
RWY	Runway
SARPS	Standards and Recommended Practices
[Std]	ICAO Standard
TWY	Taxiway
Vmcg	Minimum control speed (ground)
WP	Working Paper

PART A: RUNWAYS

1 RUNWAY WIDTH

SYNOPSIS

<table>
<tr><td>ICAO BASELINE</td><td colspan="4">The width of a RWY should be not less than:
- 45m where the code letter is E,
- 60m where the code letter is F.
[RP] A14 P3.1.10

Strength of RWYs: A RWY should be capable of withstanding the traffic of aeroplanes the RWY is intended to serve. [RP] A14 P3.1.21

Planning to accommodate future aircraft developments. ADM Pt1 P6</td></tr>
<tr><td rowspan="5">HAZARD ANALYSIS</td><td colspan="2">Hazard Identification</td><td>Risk 1
Lateral runway excursion at take-off</td><td>Risk 2
Lateral runway excursion at landing</td></tr>
<tr><td colspan="2">Main causes and accident factors</td><td>- Human factors (crew, maintenance, balance, payload security)
- Powerplant (engine failure, ingestion)
- Surface conditions (aquaplaning, snow)
- Aircraft (control surfaces, hydraulic system, tires)</td><td>- Human factors (crew, maintenance)
- Aircraft (landing gear, control surfaces, hydraulic system, brakes, tyres)
- Powerplant (reverse)
- Surface conditions (aquaplaning, snow)
- Weather conditions (cross wind, visibility, inaccurate meteorological information)</td></tr>
<tr><td rowspan="2">Severity</td><td>Theoretical</td><td colspan="2" rowspan="2">Major to Catastrophic depending on the aircraft speed.</td></tr>
<tr><td>In-service</td></tr>
<tr><td colspan="4">Detailed hazard analysis within certification process</td></tr>
<tr><td rowspan="2">RISK ASSESSMENT</td><td colspan="2">Risk assessment category</td><td>A (aircraft performance)</td><td>A (aircraft performance)</td></tr>
<tr><td colspan="2">Main technical materials</td><td>- 747-8 operational approval on 45m wide RWY by the certifying authorities (FAA / EASA): critical failure conditions for veer-off at take off, V_{MCG} criteria, envelope of environmental conditions covered by aircraft certification, collection and analysis of aircraft lateral dispersion data during take-off.
- Numerous design changes from the 747-400 to improve lateral handling qualities during takeoff or rejected takeoff.
- Otherwise, design commonality with the 747-400.
- Flight deck features that improve situation awareness.
(see Attachments B, H and I)</td><td>- 747-8 operational approval on 45m wide RWY by certifying authorities (FAA / EASA): critical failure conditions for veer-off at landing, envelope of environmental conditions covered by aircraft certification, Autoland criteria, collection and analysis of aircraft lateral dispersion data during landing.
- Numerous design changes from the 747-400 to improve lateral handling qualities during landing.
- Otherwise, design commonality with the 747-400.
- Flight deck features that improve situation awareness
(see Attachments B, H and I)</td></tr>
<tr><td>CONCLUSIONS</td><td colspan="4">Prior to entry into revenue service (October 2011), The Boeing Company received approval for the 747-8 to operate on a 45m wide runway from the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) – see Attachment I.

RWY 05/23 at Guaraní International Airport has a 45m pavement width with full load bearing strength and meets the code letter E recommendation. The 45m pavement width for RWY 05/23 is assessed as adequate for 747-8F operations.</td></tr>
</table>

ICAO Baseline

Also see previous synopsis.

Next to Annex 14, the other location in current ICAO material where a 60m wide runway is justified for code letter F aircraft is the **ADM Part 1, Chapter 6** "planning to accommodate future aircraft developments". In this chapter, it is mentioned that the runway width for aircraft with large main gear wheel spans may be represented by the expression:

$$Wr = Tm + 2C$$

where
- Wr = Runway width
- Tm = Outer main gear wheel span
- C = Clearance between the outer main gear wheel and the runway edge

For the 747-8, the clearance between the outer main gear wheel and the runway edge, or C, is 16m. On a 45m wide runway and with the expected increased outer main gear wheel span of 20m for NLA, the formula results in a runway width of 52m. The ICAO manual concludes that "however, other factors, which are not included in this rationale, indicate that it might be advisable, for planning purposes, to consider a width of up to 60m (**ICAO ADM Part 1, para 6.3.4**)."

Hazard Analysis

1 Hazard Identification

The principal hazard linked to runway width is the potential for lateral runway excursions at take-off or landing.

2 Causal Analysis

The main causes of excursions and accident factors are listed as follows:

- For take-off:
  - Human factors (crew, maintenance, balance, payload security),
  - Aircraft (control surfaces, hydraulic system, tyres),
  - Powerplant (engine failure, ingestion),
  - Surface conditions (aquaplaning, snow).
- For landing:
  - Human factors (crew, maintenance, balance, payload security),
  - Aircraft (landing gear, control surfaces, hydraulic system, brakes, tyres),
  - Powerplant (reverse),
  - Surface conditions (aquaplaning, snow),
  - Weather conditions (cross wind, visibility, inaccurate meteorological information).

An analysis of 747 lateral runway excursion reports (**see Attachment B**) shows that accident mechanisms are not the same for take-off as they are for landing. Mechanical failures are, for instance, a frequent accident factor for take-off veer-off, while bad weather conditions are often reported for landing veer-off.

A review of 747 lateral runway excursions indicates that a significant factor in past 747 accidents/incidents was the influence of pilot procedures related to engine reverse or thrust lever applications that were associated with earlier 747 models prior to the 747-400. These problems have now largely been resolved through improved pilot procedure techniques and improvements in airplane design. The 747 Accident/Incident Analysis in **Attachment B** shows a dramatic decline in the rate of 747 veer-offs over the last 40 years of service history.

Safety analyses (Functional Hazard Assessment, System Safety Assessment, and Environmental Conditions Hazard Assessment) on landing and take-off operations will be made during the FAA operational approval process.

Lateral runway excursion is one of the risks explicitly taken into account by The Boeing Company in the aircraft design process (see 747-8 Performance Features and Safety Improvements in **Attachment B**). The historical 747 runway veer-off data was studied and taken into account in the FAA 45m wide runway operational approval process. In addition, critical takeoff failure case (30 ft (9.1m) maximum lateral deviation under Vmcg conditions) and autoland lateral dispersion tests are covered in the airplane certification process.

3 Consequences Analysis

Lateral runway excursion hazards could be classified as a major to catastrophic risk depending on the aircraft speed. Historical 747 accident/incident data from 1970 to 2005 indicate that there were no 747 fatal accidents due to runway veer-off alone. Of the total runway veer-offs, 15% resulted in serious injuries and/or substantial aircraft damage. The remaining 85% were of lesser severity of consequence.

RISK ASSESSMENT

1 The core study: the aircraft certification

The lateral runway excursion risk is clearly linked to specific aircraft characteristics (wheel span) and performance/handling qualities (approach attitude, aircraft manoeuvrability and stability, efficiency of control surfaces). Therefore, this type of risk comes under the “Type A” risk assessment category, mainly based on aircraft performance and handling qualities as well as "Type C" risk assessment based on maximum allowed lateral deviation (30 ft, 9.1m) during critical engine failure test at Vmcg[1].

The performance characteristics of the existing 747 models (747-100/-200/-300/-400) are well known. It is also evident from the historical 747 accident/incident statistics that design and pilot procedural improvements have contributed significantly to the declining frequency of the 747 runway veer-offs over the last 35 service years. The following comparison with the 747-400 shows continuing improvements that are expected from the 747-8.

[1] V_{mcg} is the lowest speed during takeoff run at which the airplane will laterally deviate no more than 30 ft (9.1m) from the runway centreline using only aerodynamic surfaces for control and no nose wheel steering. This is one of the airplane certification tests to ensure that the airplane remains on the runway when simulating the critical engine failure case.

- **747-8 final approach speed**

  The 747-8 final approach speeds are 153 knots for the passenger model and 159 knots for the freighter model. In comparison, the 747-400ER approach speed is 158 knots for both passenger and freighter models.

- **747-8 flight handling quality**

  The design objective is to achieve 747-8 manoeuvrability similar or better than that of the 747-400. This was achieved by numerous design changes from the 747-400 to improved lateral handling qualities.

  For take-off or rejected take-off, these changes include double hinged lower rudder and spudders (spoiler – rudder) to improve directional control; 60° ground spoilers to improve braking and rejected take-off performance (these are 45° on the 747-400); drooped ailerons to improve take-off and landing performance; and revised rudder mechanism to eliminate exposure to single failure rudder hardovers.

  To improve lateral handling qualities during landing, changes include increased outboard aileron deflection to -30° (-25° on 747-400) to improve aileron effectiveness; use of spoilers for lateral control to improve roll response rate and control; fly-by-wire aileron and spoilers to allow tuning of roll control; double hinged lower rudder and spudders for improved directional control; and 60° ground spoilers to improve braking and landing field length (45° on 747-400). The spudder refers to the deployment of spoilers during large rudder deflections that provide increased yaw authority on the ground.

- **747-8 landing incidence/attitude and cockpit visibility**

  The landing incidence, aircraft attitude and cockpit visibility of the 747-8 are expected to be similar to those of the 747-400.

- **747-8 Autoland**

  The 747-400 Autoland certification test results show that landings were made well within the prescribed touchdown box inside the 45m width. The 747-8 met the same autoland accuracy test requirement.

- **747-8 flight deck features to improve situation awareness**

  New flight deck features that improve situation awareness include vertical situation display to improve vertical awareness and better path prediction relative to the ground; integrated approach navigation; Global navigation satellite Landing System (GLS) with less signal interference than ILS; Navigation Performance Scales (NPS) for more accurate flight path information; tire pressure monitoring system (standard on the 747-8 but option on the 747-400) and brake monitoring system.

- **747-8 Critical engine failure test at Vmcg**

  Maximum lateral deviation of 30 ft (9.1m) is allowed under the critical engine failure case certification test. This test was successfully completed during the certification test flights. With an outer main gear wheel span of 12.7m, a runway width of 45m would allow the maximum 9.1m deviation plus provide an additional deviation margin of 7m before the outer main gear tire is at the edge of a 45m runway.

- **747-8 main gear design commonality with 747-400**

  The outer main gear wheel span of the 747-8 (12.7m) is well within the code letter E upper limit (13.99m) and almost equal to the 747-400 (12.6m). The clearance between the outer main gear wheel and the runway edge for the 747-8 is essentially equal to the 747-400 and larger than for the code letter E outer main gear wheel span upper limit. The data in the following table show the comparison between the 747-400 and the 747-8 and relates these to the ICAO code letter E requirements.

Table 1: 747-400 and 747-8 Characteristics Relative to ICAO Standards

	Tm	WR	C
	Outer Main Gear Wheel Span	Runway Width	Clearance between the outer main gear wheel and the runway edge
747-400	12.6m	45m	16.20m
747-8	12.7m	45m	16.15m
code letter E *main gear wheel span upper limit*	13.99m	45m	15.50m

The “core” risk assessment, which is a “Type A” category (aircraft performance), will be made during the aircraft certification process (safety analysis, flight test, simulations, etc).

Operational capability to operate safely on a 45m wide runway is one of the core objectives of the geometric and performance design of the 747-8. This capability was successfully demonstrated during the flight test period.

To ensure visibility by the Airport Authorities, the relevant Aviation Authorities, the International Organizations and the Airline world that the 747-8 will be able to land and take-off on 45m wide runways without additional limitations, The Boeing Company had:

- base the 747-8 nominal performance on a 45m runway width;
- base the safety analyses on a 45m runway width;
- mention the 45m runway width as nominal for 747-8 operations within the Flight Manual, to which the Type Certificate Data Sheet (TCDS) refers;
- Report this nominal 45m runway width within the Flight Crew Operations Manual (FCOM).

The FAA and EASA have completed their evaluation and have concluded that the 747-8 can safely operate on runways as narrow as 45m wide by pilots of average skill and knowledge and appropriate statement to this effect has been added to the 747-8 Aircraft Flight Manual.

CONCLUSIONS

Based on the data available, a 45m wide runway is sufficient to accommodate the operations of the 747-8. A minimum central 45m of pavement of full load bearing strength should be provided on the runway. At SEGS/AGT, Runway 05/23 is 45m wide and is therefore assessed as adequate for 747-8F operations.

2 RUNWAY SHOULDER WIDTH

SYNOPSIS

<table>
<tr><td>ICAO BASELINE</td><td colspan="5">The RWY shoulders should extend symmetrically on each side of the RWY so that overall width of RWY and its shoulders is not less than 60m where the code letter is E and 75m where the code letter is F. [RP] A14 P3.2.3

Strength of RWY shoulders:
- A RWY shoulder should be prepared or constructed so as to be capable, in the event of an aeroplane running off the RWY, of supporting the aeroplane without inducing structural damage to the aeroplane and of supporting ground vehicles which may operate on the shoulder. [RP] A14 P3.2.5
- A RWY shoulder should be prepared or constructed so as to minimise any hazard to an aeroplane running off the RWY ADM Pt1 P5.2.3
- In some cases, the bearing strength of the natural ground may be sufficient, without special preparation, to meet the requirements for shoulders. ADM Pt1 P5.2.4
- When designing shoulders, prevention of the ingestion of stones or other objects by turbine engines should be an important consideration. ADM Pt1 P5.2.5
- In case of special preparations, visual contrast between RWY and RWY shoulders may be needed ADM Pt1 P5.2.6</td></tr>
<tr><td rowspan="4">HAZARD ANALYSIS</td><td colspan="2">Hazard Identification</td><td>Risk 1
Shoulder erosion and engine ingestion (snow and ice ingestion included) at landing or take-off</td><td>Risk 2
Difficulties for Aircraft Rescue and Fire Fighting (ARFF) services to intervene on a damaged aircraft on the runway</td><td>Risk 3
Aircraft damage after incursion on runway shoulder</td></tr>
<tr><td colspan="2">Main causes and accident factors</td><td>- Powerplant (engine position, engine power)
- Shoulder width and cohesion
- Runway centreline deviation factors (see runway veer-off risk)
- Location and height of snow banks</td><td>- Aircraft wingspan and engine position
- Shoulder width and bearing capability</td><td rowspan="5">No 747-8 specific issue</td></tr>
<tr><td rowspan="2">Severity</td><td>Theoretical</td><td rowspan="2">Potentially major</td><td rowspan="2">Major to catastrophic</td></tr>
<tr><td>In-service</td></tr>
<tr><td rowspan="2">RISK ASSESSMENT</td><td colspan="2">Risk assessment category</td><td>C (geometric argument)</td><td>C (geometric argument)</td></tr>
<tr><td colspan="2">Main technical materials</td><td>- 747-8 engine position
- 747-8 jet blast velocity at take-off thrust
- Information about lateral deviation from runway centreline
(see Attachment B)</td><td>- 747-8 wingspan and engine position
(see Attachment B)</td></tr>
</table>

CONCLUSIONS	
CONCLUSIONS	**From the latest Google Earth Pro Imagery, RWY 05/23 does not have a paved shoulder located beyond the 45m runway width. As a substitute for the paved runway shoulder, the airport infrastructure provides a well maintained grass shoulder that should provide adequate protection.** **The 747-8 outer engine span is approximately 42m, which is the same as the 747-400. The 747-400 and other heritage 747 aircraft have operated successfully on 45m runways, without a paved shoulder, in various locations around the world. Currently, the freighter variant (747-400F) of the 747-400 family operates into Guaraní International Airport. Therefore, the 45m pavement width for RWY 05/23 with the well maintained grass shoulder is assessed as adequate for 747-8F operations.** **The purchasing all-cargo airline intends to use Guaraní International Airport as a destination and alternate airport. To guard against possible FOD risk, an inspection of RWY 05/23 should be undertaken after each 747-8F takeoff during the initial period of operations.** Depending on local conditions, decisions on the composition and thickness of runway shoulders should be made by each national authority and/or airport operator.

ICAO BASELINE

See previous synopsis.

HAZARD ANALYSIS

1 Hazard Identification

Runway shoulders have three main functions:

- To provide jet blast protection and to prevent engine ingestion
- To support occasionally ground vehicles traffic (ARFF vehicles in particular)
- To support occasional aircraft incursions without inducing structural damage to the aeroplane

Therefore, the hazards linked to runway shoulder characteristics (width, cohesion, bearing capability) are:

1. Shoulder erosion and engine FOD ingestion: it seems logical to deal also with snow and ice ingestion risk at the same time, even if the latter is not really linked with runway shoulder characteristics.
2. Difficulties for ARFF services to access a damaged aircraft on the runway
3. Aircraft damage after incursion onto the runway shoulder

Hazards 1 and 2 could be effectively related to NLA characteristics (engine position, engine thrust, and wingspan). Concerning hazard 3:

- The shoulder width should not be regarded as a specific NLA issue: 7.5m wide runway shoulders shall be provided to allow pilots to steer the aircraft back onto the runway in the event of a minor lateral excursion, whatever the aircraft code letter.
- The shoulder composition and thickness may vary according to aircraft types to ensure an occasional bearing capability is sufficient to accommodate all of them. Therefore, the composition of 7.5m wide shoulders may be a NLA issue, but aircraft other than the NLA may have stronger impact on runway shoulders, depending on aircraft weight per wheel and tire pressure. For example, the A340-600, a code letter E aircraft, has a higher single wheel load and higher tire pressure than the 747-8. Therefore, focus may be placed on

geometric issues rather than pavement strength aspect. Decisions on shoulder composition and thickness will be made by each national authority and/or airport operator.

For this reason, only jet blast protection, engine ingestion and ARFF vehicle traffic issues are considered here.

2 Causal Analysis

The main causes and accident factors identified for FOD are:

- Powerplant characteristics (engine position, engine power, etc)
- Shoulder width and cohesion
- Runway centreline deviation factors (see runway veer-off risk)

In addition to this, in case of snowfalls, the location and height of snow banks can induce an ice ingestion risk and should be considered.

With regard to ARFF vehicle traffic issue, the specific NLA issues are:

- Aircraft wingspan and engine position
- Shoulder width and bearing capability

3 Consequences Analysis

Certification requirements define FOD risks on wheel tyres and engines as potentially major risks. Delay on ARFF operations could be classified as major to catastrophic.

RISK ASSESSMENT

Shoulder erosion, engine ingestion and ARFF vehicle traffic hazards are all geometric issues and come under the “Type C” risk assessment category (geometric argument). A geometric argument combined with 747-8 jet blast characteristics is therefore relevant to calculate infrastructure requirements.

1 Jet Blast Issue

Information about outer engine position and jet blast velocity contour at take-off **(see Attachment B)** is needed to calculate the required width for jet blast protection. The lateral deviation of an aircraft from runway centreline must be taken into account.

The margin between the 747-8 outer engine axis, when the aircraft is on the runway centreline, and the edge of a 60m ICAO code letter E runway (runway + shoulder), is 9.0m which is the same as for other 747 models.

The 56 km/h exhaust wake velocity contour at take-off thrust is used as a reference for the evaluation of jet blast protection in the runway environment. The 56 km/h velocity contour width is estimated at slightly over 60m for the 747-8. It should be noted that this estimated width is based on computer simulation and that they are steady-state data assuming a stationary aircraft and takeoff thrust is allowed to run until the velocity contour enlarges to a stabilized maximum size. In actual operations when the aircraft reaches a maximum thrust during takeoff roll, the aircraft is in motion and the contours would be narrower compared to the steady-state data and the 56 km/h velocity contour will be within the code letter E 60m shoulder width.

This geometric argument combined with jet blast drawings **(see Attachment B)** leads to a conclusion that a 60m wide runway plus shoulder will avoid erosion for 747-8 operations with an acceptable level of safety.

Concerning engine ingestion risk at low speed, additional elements on ingestion force in front of the 747-8 outer engines at take-off thrust are, in theory, necessary before reaching a conclusion. However, the engine inlet air velocity for the 747-8 is estimated to be similar to that of the 747-400 since the higher thrust of the 747-8 is offset by the larger inlet area. Furthermore, considering the geometric comparison with current large aircraft operations on current runways, there is:

- An equal margin between outer engine axis and the edge of the shoulder (in comparison with the 747-400) and,
- An equal distance from the outer engine to the ground (in comparison with the 747-400),

Based on this information, it is reasonable to conclude that a 60m total width (runway + shoulders) is adequate to mitigate engine ingestion risk.

Table 2: Comparison of the Engine Placement Between the 747-400 and 747-8

	Distance between aircraft fuselage axis and (outer) engine axis	(Outer) engine nacelle minimum height above ground
747-400	21.03m	1.32m
747-8	21.03m	1.52m

Although the margin between the ground surface and the engine cowl for the 747-8 is essentially the same as for the 747-400, the thrust centreline axis of the 747-8 outboard engine is 0.66m higher than for the 747-400. This has the effect of reducing the ground contact area of the velocity contours.

2 ARFF Vehicle Intervention

The comparison with current large aircraft on current runways **(see attachment B)** allows the conclusion that an overall runway plus shoulder width of 60m (ICAO code letter E runway) for occasional ARFF vehicle traffic permits firemen intervention on the 747-8 at least as easily as for the other 747 models (same margin between outer engine axis and edge of runway shoulder).

Note: depending on fire location, wind direction and wreckage site, firemen may have to intervene outside paved areas, whatever the aircraft size.

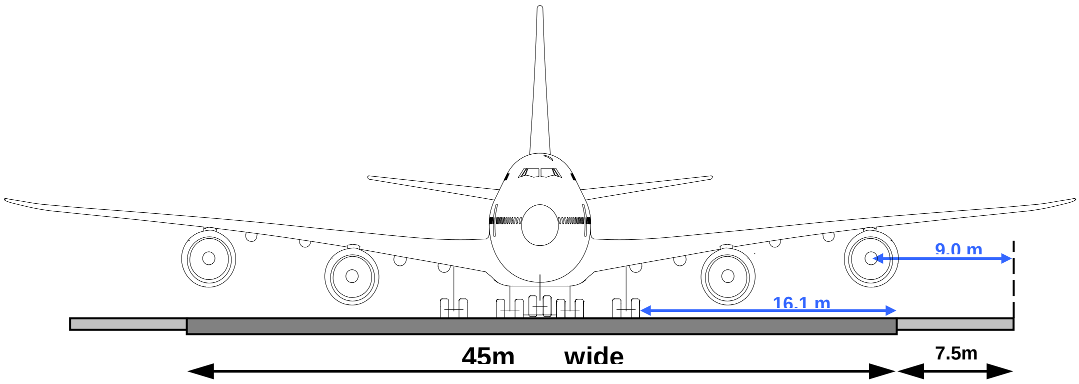
CONCLUSIONS

A 60m total width (runway + shoulders) should be provided in compliance with Annex 14 code letter E (2x7.5m wide shoulders on 45m wide runways) for 747-8 operations. From the latest Google Earth Pro Imagery for Guaraní International Airport, Runway 05/23 does not have a paved shoulder located beyond the 45m runway width. As a substitute for the paved runway shoulder, the airport infrastructure provides a well maintained grass area shoulder that should provide adequate protection.

The 747-400, with the same outer engine span and similar thrust as the 747-8, have successfully operated on 45m runways, without a paved shoulder, in various locations around the world. Currently, the freighter variant of the 747-400 family operates into Guaraní International Airport.

The purchasing all-cargo airline intends to use Guaraní International Airport as a destination and alternate airport. To guard against possible FOD risk, an inspection of Runway 05/23 should be undertaken after each 747-8F takeoff during the initial period of operations.

Exhibit 1: 747-8 Dimensions relevant to Runway and Shoulder Width



PART B: TAXIWAYS

1 TAXIWAY WIDTH

SYNOPSIS

<table>
<tr><td>ICAO BASELINE</td><td colspan="4">Unless otherwise indicated, the requirements are applicable to all types of TWYs. A14 P3.9

Minimum clearance between the outer main wheel and TWY edge: 4.5m for both code letters E and F. [RP] A14 P3.9.3

For curved TWYs, ensure that when the cockpit is over centerline, the outer main gear wheel maintains 4.5m clearance from TWY edge [RP] A14 P3.9.6

The width of a straight portion of TWY is recommended to be 23m where code letter is E and 25m where code letter is F. [RP] A14 P3.9.5</td></tr>
<tr><td rowspan="4">HAZARD ANALYSIS</td><td colspan="2">Hazard Identification</td><td colspan="2">Risk 1
Lateral taxiway excursion in straight section</td></tr>
<tr><td colspan="2">Main causes and accident factors</td><td colspan="2">- Mechanical failure affecting steering capability (hydraulic system)
- Surface conditions (aquaplaning, loss of control on ice-covered surface,…)
- Loss of visual taxiway guidance system (markings and lights covered by snow,…)
- Pilot precision and attention (directional control)</td></tr>
<tr><td rowspan="2">Severity</td><td>Theoretical</td><td colspan="2">Potentially major</td></tr>
<tr><td>In-service</td><td colspan="2">Minor</td></tr>
<tr><td rowspan="2">RISK ASSESSMENT</td><td colspan="2">Risk assessment category</td><td>B (generic risk model)</td><td>C (geometric argument)</td></tr>
<tr><td colspan="2">Main technical materials</td><td>Taxiway deviation statistics analysis (existing and on-going studies)
(see Attachment C)</td><td>747-8 geometric characteristics (wheel span within code letter E limits, nearly same as 747-400)
(see Attachment B)</td></tr>
<tr><td>CONCLUSIONS</td><td colspan="4">From the latest Google Earth Pro Imagery, the following TWY pavement widths at SGES/AGT meet or exceed the code letter E (23m) and code letter F (25m) recommendations and are therefore assessed as adequate for 747-8F operations:

- 23m pavement width for the principal parallel TWY,
- 26.5m pavement width for intersection TWYs A and B.

Maintain a wheel to edge minimum clearance of 4.5m on straight and curved taxiway sections</td></tr>
</table>

ICAO BASELINE

See previous synopsis

HAZARD ANALYSIS

1 Hazard Identification

The hazard is a lateral taxiway excursion in either straight or curved section.

2 Causal Analysis

The causes of such an event can be classified as:

- Mechanical failure (hydraulic system failure)
- Surface conditions (aquaplaning, loss of control on ice-covered surface)
- Loss of visual taxiway guidance system (markings and lights covered by snow)
- Pilot precision and attention (directional control, orientation error)

3 Consequences Analyses

Consequences are, in theory, potentially major. In practice, according to the 747 accidents and incidents involving lateral taxiway excursion events compiled from various sources by Boeing **(see Attachment B)**, only minor injuries in some cases were reported.

RISK ASSESSMENT

Of the four causes listed above (Hazard Analysis, Section 2 "Causal Analysis"), the first three have a low dependency on the type of aircraft (i.e. the aircraft are equally likely to go off of the taxiway, regardless of the main landing gear track width).

The fourth one is a 747-8 issue, in that it is heavily related to the margin between the main gear outer wheels and the taxiway edge. It is a case of a Type B (generic risk model) as well as a Type C risk assessment category (geometric argument).

All functioning aircraft respond reliably to pilot directional inputs when taxiing at normal speeds: The 747-8's behaviour can be deduced from its similarity to the current 747 models in operation. The 747-8 steering system and landing gear design, including the body gear steering system, are the same as those for the previous 747 models and have been designed to retain the same touch and feel characteristics.

Various taxiway deviation studies on straight sections show that larger aircraft do not deviate from the centreline during normal taxiing any more than a smaller aircraft. Most of the taxiway deviation studies involved collecting code letters D and E aircraft deviation data and primarily the 747. Therefore, the data is directly applicable to the 747-8. The 4.5m wheel to edge clearance proves to be adequate for safe and expeditious taxiing and in some cases is considered to be conservative. (Based on the FAA/Boeing taxi deviation studies at New York JFK and Anchorage International Airports, the estimated risk of the 747-8 veering 5.15m to the edge of a 23m wide taxiway is 1.29×10^{-7}).

The geometric argument shows that for the 747-8 the wheel to edge clearance on a code letter E taxiway (23m wide) is equal to the one for the 747-400 and even larger (5.15m) than the minimum required (4.5m) by ICAO for code letter E.

Table 3: Comparison of 747-400 and 747-8 Main Gear Configuration and the ICAO Code E Standard

	Outer Main Gear Wheel Span	Taxiway Width	Clearance between the outer main gear wheel and the taxiway edge
747-400	12.6m	23m	5.2m
747-8	12.7m	23m	5.15m
Code Letter E *main gear wheel span upper limit*	13.99m	23m	4.5m

In addition to this, another geometric argument (Type C) that is dependent on pilot visibility from the cockpit can be developed; the cockpit and pilot eye position of the 747-8 is equal to the 747-400 **(see Attachment B)**.

Special attention may be given to taxiway curves. However, the 747-8F has similar demand in terms of taxiway fillet requirements and U-Turn capability as the 747-400, which currently operates into Guaraní International Airport. Judgmental oversteer procedures are required at the runway-to-taxiway and taxiway-to-taxiway turns for 747-8F manoeuvring in order to maintain the ICAO design requirement of 4.5m clearance between the outer tire edge and the edge of the full-strength pavement (See Chart V in Attachment A at the end of this aeronautical (safety) study for manoeuvring between Runway 05/23, intersection Taxiway A and intersection Taxiway B, and to the principal parallel taxiway).

CONCLUSIONS

- Minimum taxiway width of 23m should be provided for the 747-8.
- Wheel to edge minimum clearance of 4.5m on straight and curved taxiway sections shall be maintained. The 747-8 will have more than 4.5m clearance on the straight portion of a 23m wide taxiway.

From the latest Google Earth Pro Imagery, the principal parallel taxiway is 23m wide and intersection Taxiway A and intersection Taxiway B are 26.5m wide and meet or exceed the code letter E (23m) and code letter F (25m) recommendations. These taxiway widths are therefore assessed as adequate for 747-8F operations.

2 TAXIWAY SHOULDER WIDTH

SYNOPSIS

<table>
<tr><td>ICAO BASELINE</td><td colspan="4">Overall width of TWY + shoulders on straight portion:
- 44m where code letter is E and
- 60m where code letter is F [RP] A14 P3.10.1

The taxiway shoulder surface should be so prepared as to resist erosion and ingestion of surface material by aeroplane engines [RP] A14 P3.9.2

Shoulder is intended to protect an aircraft operating on the TWY and to reduce the risk of damage to an aircraft running off the TWY. ADM Pt2 p1.6.1 and ADM Pt2 p1.6.2 + table 1-1</td></tr>
<tr><td rowspan="4">HAZARD ANALYSIS</td><td colspan="2">Hazard Identification</td><td>Risk 1
Shoulder erosion and engine ingestion during taxiing</td><td>Risk 2
Aircraft damage after incursion on taxiway shoulder</td></tr>
<tr><td colspan="2">Main causes and accident factors</td><td>- Powerplant (engine position, engine power)
- Taxiway shoulder width and cohesion
- Taxiway centreline deviation factors (see taxiway veer-off risk)</td><td rowspan="6">No 747-8 specific issue</td></tr>
<tr><td rowspan="2">Severity</td><td>Theoretical</td><td rowspan="2">Minor except if undetected and followed by engine failure at take-off (potentially major)</td></tr>
<tr><td>In-service</td></tr>
<tr><td rowspan="2">RISK ASSESSMENT</td><td colspan="2">Risk assessment category</td><td>C (geometric argument)</td></tr>
<tr><td colspan="2">Main technical materials</td><td>- 747-8 engine position
- 747-8 jet blast velocity at idle (most of taxi time is spend at idle thrust)
- 747-8 jet blast velocity contour at break-away and the transient (temporary) nature of the breakaway thrust application
- Information about lateral deviation from taxiway centreline
(see Attachment B & C)</td></tr>
</table>

CONCLUSIONS	**As determined using the latest available Google Earth Pro Imagery for Guaraní International Airport, the following taxiway plus paved shoulder widths meet or exceed the code letter E (44m) recommendation:** - **44m taxiway + paved shoulder width for the principal parallel TWY,** - **46.5m taxiway + paved shoulder width for intersection TWY B,** - **47.5m taxiway + paved shoulder width for intersection TWY A.** **In addition, the above referenced taxiways appear to have a well maintained grass area located beyond the paved taxiway + shoulder width. A well maintained grass shoulder should provide additional protection from erosion and engine ingestion risks.** **The benchmark for evaluation of jet blast protection in the taxiway environment is the 56 km/h exhaust wake velocity contour at breakaway thrust. The exhaust wake velocity contour width is approximately 48m for the 747-8, which is similar to the 747-400ER, but less than the 747-400. The exhaust wake should be contained within the taxiway plus paved shoulder (and the grass shoulder) widths for all assessed taxiways.** **It is noted that the breakaway thrust is momentary since the pilot will reduce power once the aircraft gains forward momentum, well before the exhaust velocity contour has reached the steady state condition. The contour width and length shown in the BACG attachment B is based on steady state conditions and therefore, more conservative.** **Therefore, the principal parallel TWY and intersection TWY A and intersection TWY B with the paved shoulder, are assessed as adequate for 747-8F operations at Guaraní International Airport.**

ICAO BASELINE

See previous synopsis

HAZARD ANALYSIS

1 Hazard Identification

The main purposes of the provision of taxiway shoulders are twofold:

- To prevent jet engines that overhang the edge of a taxiway from ingesting stones or other objects that might damage the engine and
- To prevent erosion of the area adjacent to the taxiway.

In addition, the risk of damage to an aircraft running off the taxiway should be, in theory, taken into account for taxiway shoulder design. Concerning this hazard:

- The shoulder width should not be regarded as an issue for any specific airplane. Taxiway shoulders should be, in theory, designed to allow pilots to steer the aircraft back onto taxiway in case of minor lateral excursion, whatever the aircraft code letter is.
- The shoulder composition and thickness may be a specific airplane issue, but aircraft other than the 747-8 may have stronger impact on taxiway shoulders. For example, the A340-600, a code letter E airplane, has a higher single wheel load and a higher tire pressure than the 747-8 and can cause a more severe shoulder pavement rutting damage.

Thus, the 747-8 risk assessment focuses on geometric issues. Decisions on taxiway shoulder composition and thickness will be made by each national authority and/or airport operator.

Additionally, the current low frequency and low severity of taxiway veer-off cases do not justify any further evaluation of this risk.

These are the reasons why only shoulder erosion and engine ingestion are considered here.

2 Causal Analysis

The main causes and accident factors for shoulder erosion and engine ingestion are:

- Powerplant characteristics (engine position, engine power)
- Taxiway shoulder width and cohesion
- Taxiway centreline deviation factors (see taxiway veer-off risk)

3 Consequences Analysis

The erosion and ingestion hazard when taxiing could be classified as a minor risk except when it is undetected by crew and followed by engine failure at take-off (potentially major).

RISK ASSESSMENT

A geometric argument is relevant to establishing the infrastructure requirements relative to jet blast and engine ingestion issues. Shoulder erosion and engine ingestion issues come under the “Type C” risk assessment category (geometric argument).

Comparisons of the engine position and breakaway thrust jetblast velocity contours between the 747-400 (basic), 747-400ER, and the 747-8 show that the 747-8 is compatible with airports operated by the 747-400 (code letter E) in terms of taxiway shoulder width as described below. .

The margin between the 747-8’s outer engine axes, when the aircraft is on the taxiway centreline, and the edge of a 44m wide jet blast protection (taxiway + shoulders) is 0.97m; the same margin as for the 747-400.

The width of the 747-8 breakaway exhaust velocity contour at 56 km/h is estimated at 48m which is similar to that of the 747-400ER, but less than the 747-400. It should be noted that breakaway thrust is momentary since the pilot will reduce power as soon as the aircraft starts rolling, well before the exhaust velocity contour has reached the stabilized steady-state size as shown **(see Attachment B)**. The following table compares the physical dimensions relative to the exhaust velocity of the 747-400ER with those for the 747-8.

Table 4: Comparison of 747-400 and 747-8 Engine Positions

	Distance between aircraft fuselage axis and engine axis	Margin between outer engine axis and shoulder edge	(Outer) engine nacelle height above ground
747-400	21.03m	0.97m	1.32m
747-8	21.03m	0.97m	1.52m

A comparison of the outer engine height above ground shows that the 747-8 nacelle clears the ground by 0.20m more than the 747-400, and the thrust centreline axis of the 747-8 outer engine is 0.56m higher than that of the 747-400, which helps reduce the contour size at ground level.

In this report, exhaust velocity contour comparisons are made with the 747 model which is closest to the 747-8 in terms of weight, thrust, etc. This model is the 747-400ER. It should be pointed out that starting with the 747-400ER model, radial tires were used which require lower thrust to break away from a stationary position because of lower coefficient of friction associated with radial tires compared to the bias-ply tires. This results in smaller (and narrower) breakaway thrust velocity contours for the 747-400ER and 747-8 compared to the basic 747-400 model. Therefore, the freighter variant of the 747-400 family currently operates into SGES/AGT (large majority of the 747-400 models in service are the basic 747-400, not the 747-400ER), the jet blast effect of the 747-8 on taxiway shoulders will be less critical than the 747-400.

As for the ingestion risk, the engine inlet air velocity for the 747-8 is estimated to be similar to that for the 747-400 since the higher thrust required for the 747-8 will be offset by the larger inlet area.

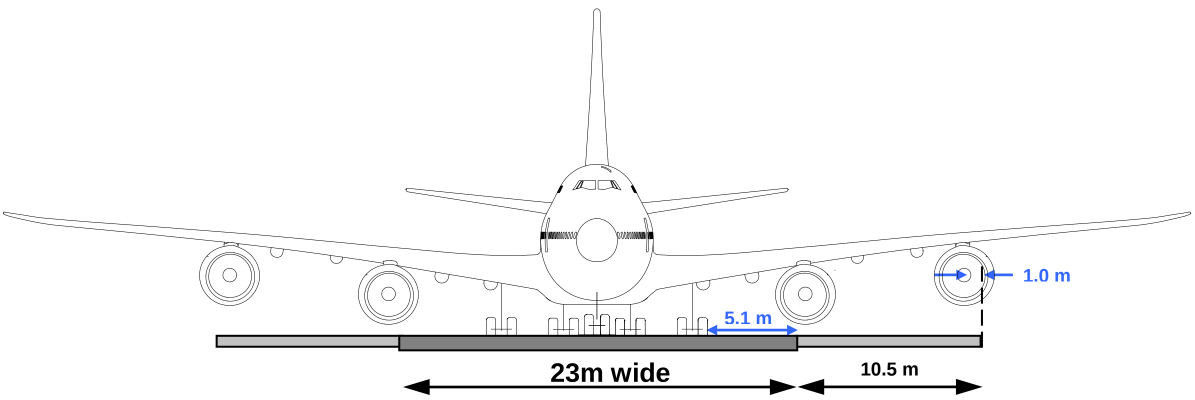
The above geometric argument combined with jet blast contours at breakaway thrust allows the conclusion that a 44m wide taxiway jet blast protection will avoid shoulder erosion and engine ingestion risks for 747-8 taxiing with a level of safety equal to the current 747.

CONCLUSIONS

Based on dimensional data from the latest Google Earth Pro Imagery, the assessed paved taxiway plus paved shoulder widths for the principal parallel taxiway and for intersection Taxiway A and intersection Taxiway B meet or exceed the code letter E (44m) recommendation and are assessed as adequate for 747-8F operations.

In addition, from the latest Google Earth Pro Imagery, there appears to be a well maintained grass area located beyond the paved taxiway shoulders which provides additional protection from FOD ingestion and jet blast.

Exhibit 2: 747-8 Dimensions Relevant to Taxiway and Shoulder Width



PART C: RUNWAY SEPARATIONS

SYNOPSIS

<table>
<tr>
<td>ICAO BASELINE</td>
<td colspan="5">Runway to Parallel Taxiway Separation:
190m for instrument RWY or 115m for non-instrument RWY (may be reduced subject to aeronautical study). [RP] A14 P3.9.8 + table 3-1 columns 5&9

Obstacle Free Zone (OFZ)
OFZ half width = 60m where code letter is E and 77.5m where code letter is F; inner transitional surface slope is 1:3. [Std] A14 P4.1.11 & 4.1.12 + 4.1.17 to 24, Table 4-1
Note e) to table 4-1: Where the code letter is F (Column (3) of Table 1-1), the width is increased to 155m. For information on code letter F aeroplanes equipped with digital avionics and track hold guidance that provide steering commands to maintain an established track during the go-around manoeuvre, see Circular 301 "New Larger Aeroplanes- Infringement of the Obstacle Free Zone: Operational Measures and Aeronautical Study".

Runway Holding Positions
Take-off RWY, non-instrument & non-precision approach minimum holding position distances - no change compared with code letter E (75m).
Precision approaches all CATs: Minimum holding position distances increased to 107.5 m for code letter F (90m for code letter E). [RP] A14 table 3-2 footnote 'c'
Aircraft at precision approach holds - not to interfere with the operation of NAVAIDS. [Std] A14 P3.12.6</td>
</tr>
<tr>
<td rowspan="4">HAZARD ANALYSIS</td>
<td colspan="2">Hazard Identification</td>
<td>Risk 1
Collision between an aircraft in flight and an object (fixed or mobile) on the airport</td>
<td>Risk 2
Collision between an aircraft veering off the runway and an object (fixed or mobile) on the airport</td>
<td>Risk 3
Perturbation of ILS signal caused by taxiing or stopped aircraft</td>
</tr>
<tr>
<td colspan="2">Main causes and accident factors</td>
<td>- Human factors (crew, Air Traffic Services)
- Weather conditions (visibility)
- Aircraft: mechanical failure (engine, hydraulic system, flight instruments, control surfaces,…), wingspan
- Airport layout and facilities: location of holding points and parallel taxiway, radar system
- Obstacle density (taxiing aircraft included), marking, lighting and publication</td>
<td>- Runway veer-off causes and accident factors (see runway veer-off risk)
- Lateral veer-off distance
- Aircraft size
- Airport layout: location of holding points and parallel taxiway
- Obstacle density (taxiing aircraft included)</td>
<td>- Aircraft position / NAVAIDS
- Aircraft characteristics (height, shape, component)
- Obstacle density</td>
</tr>
<tr>
<td rowspan="2">Severity</td>
<td>Theoretical</td>
<td>Catastrophic</td>
<td rowspan="2">Potentially catastrophic</td>
<td rowspan="2">Potentially major</td>
</tr>
<tr>
<td>In-service</td>
<td>No known cases reported in-service</td>
</tr>
</table>

RISK ASSESSMENT	Risk assessment category	A (aircraft performance) & B (generic risk model) & C (geometric argument)	B (generic risk model)	Generic risk assessment not feasible
RISK ASSESSMENT	Main technical materials	- ICAO Circular 301 states that when digital autopilot or flight director with track hold guidance is used for the approach, a code letter F airplane can be contained within the code letter E OFZ. - The 747-8 has digital autopilot/flight director and track hold guidance. - FAA regulations. **(see Attachment C)**	- Declining trend of 747 runway veer-off frequency over the years - Code letter E design separation degraded by only 1.7m increase in half-wingspan (182.5m→184.2m) - Separation based on OFZ requires only (60+[3x19.6]) = 118.8m - Separation based on taxiing 747-8 clear of precision RWY graded strip requires (105+34.2) = 139.2m **(see Attachment B)**	- Recent studies and ICAO work indicates that vertical tail size is critical, not wing span, and that the size of the sensitive and critical areas and the operational impact of infringement of CSAs should be reassessed. Hence the need for specific runway studies. - However, the vertical tail size of 747-8 is the same as 747-400 which would imply an identical impact for 747-8 and 747-400. **(see Attachment C)**
CONCLUSIONS	**The RWY 05/23 centreline to the principal parallel TWY centreline separation is not noted in the Guaraní International Airport AIP or in the Jeppesen Airway Manual Services charts. From measurements obtained from the latest available Google Earth Pro Imagery, this separation is approximately 195m and exceeds the code letter F recommendation of 190m. This separation is therefore assessed as adequate for 747-8F operations.** **The OFZ dimension for RWY 05/23 is also not noted in the latest Guaraní International Airport AIP. The OFZ width of 120m that is applicable for existing aircraft in ICAO Code Number 4 is also applicable for the 747-8F.** **As determined from the latest Google Earth Pro Imagery, the runway holding position for RWY 05/23 is approximately 91m from the runway centreline for intersection TWY A and intersection TWY B. These separations meets the code numbers 3 or 4 recommendations for a precision approach and is therefore assessed as adequate for 747-8F operations since the 747-8F meets the aircraft dimensions noted in Annex 14, Table 3-2, footnote b, Note 1 which allows holdlines at 90m.**			

ICAO Baseline

See previous synopsis

Hazard Analysis

1 Hazard Identification

The hazards linked to runway separation requirements are:

- Collision risk between an aircraft in flight and an object (fixed or mobile) on the airport
- Collision risk between an aircraft which runs off the runway and an object (fixed or mobile) on the airport
- Perturbation of the ILS signal by a taxiing or stopped aircraft

2 Causal Analysis

The main causes and accident factors could be defined as follows:

- Collision between an aircraft in flight and an object (fixed or mobile) on the airport
  - Human factors (crew, Air Traffic Services)
  - Weather conditions (visibility)
  - Aircraft: mechanical failure (engine, hydraulic system, flight instruments, control surfaces,…), wingspan
  - Airport layout and facilities: location of holding points and parallel taxiway, radar system
  - Obstacle density (taxiing aircraft included), markings, lighting and reliability of published information
- Collision between an aircraft veering off the runway and an object (fixed or mobile) on the airport
  - Runway veer-off causes and accident factors (see runway veer-off risk)
  - Lateral veer-off distance
  - Aircraft size
  - Airport layout; location of holding points and parallel taxiway
  - Obstacle density (taxiing aircraft included)
- Perturbation of ILS signal by a taxiing or stopped aircraft
  - Aircraft position / NAVAIDS
  - Aircraft characteristics (height, shape, component,…)
  - Obstacle density

The huge variety and the complexity of accident factors for collision risk must also be emphasized.

3 Consequences analysis

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

RISK ASSESSMENT

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

Based on aircraft performance (Types A & B), risk assessment focus on the ability of the aircraft to follow the runway centreline when performing a balked landing.

The object of the balked landing simulation study is to determine whether the improvements in avionics and aircraft performance over the last 20 to 30 years have led to a quantifiable decrease in the expected aircraft deviations from the desired track when landing or executing a balked landing. This decrease, if it exists, might be used to justify reducing code letter F requirements for certain type of airspace, particularly the OFZ, for these state of the art aircraft.

The ICAO OCP was in charge of this study for NLA operations **(see Attachment C)** which resulted in the release of ICAO Circular 301 "New Larger Aeroplanes-*Infringement of the Obstacle Free Zone: Operational Measures and Aeronautical Study*".

This ICAO circular states that, when digital autopilot or flight director and flight track hold guidance are used for the approach, a code letter F aircraft can be contained within the 120m OFZ width.

As the 747-8 is equipped with these avionics (digital autopilot/flight director and track hold guidance), a 120m OFZ width is applicable.

Based on a 120m OFZ width, the runway-to-taxiway separation required to keep the taxiing 747-8 from penetrating the OFZ inner transition surface is calculated to be 118.8m: [½(120m OFZ) + 3(19.6m tail height) = 118.8m].

Since a 120m OFZ is applicable for the 747-8, the runway holding position that is 90m from the runway centreline for precision approach is considered adequate for the 747-8: [½ (120m OFZ) + 3(10m aircraft nose height) = 90m].

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

Lateral runway excursions database analysis from the Airbus A380 Airport Compatibility Group (AACG) comes out with the following outputs:

- Veer-off distances[2] do not increase in proportion to aircraft size. This means that this collision risk comes under a “Type B” (generic risk model) risk assessment category (i.e. extrapolation of the current accident database to future aircraft is relevant).
- Taxiing deviation effect of an aircraft on the principal parallel taxiway is relatively of little consequence.
- Lateral runway excursion risk (frequency and veer-off distances) is not lower for non-instrument approach and take-off than for instrument approach. That means that, in theory, to provide a uniform level of safety, requirements to mitigate collision risk in case of aircraft veer-off should be as strict for non-instrument and take-off runways as for instrument runways.

Concerning instrument runways, according to accident database analyses and the experience of current operations in today’s airports **(see Attachment C)**, ICAO SARP relative to code letter F runway-taxiway distance seems conservative in terms of collision risk after an aircraft veer-off.

[2] The veer-off distance is defined here as the maximum lateral deviation distance reported during a veer-off between the aircraft centre of gravity and the runway centreline.

Considering the regulations for and history of operations at U.S. airports with lesser RWY/TWY separation - 400 ft (122m) for Group V (code letter E equivalent) for instrument runways, it can be concluded that RWY/TWY separations significantly less than recommended in Annex 14 Table 4-1 are considered safe with respect to collision between an aircraft veering off the runway and an object (fixed or mobile) on the airport.

The FAA has issued Airport Obstructions Standards Committee (AOSC) Decision Document #4, dated 21 March 2005, amending Groups V and VI RWY/TWY separations to 400 ft (122m) and 500 ft (152m) respectively for CAT I and 500 ft (152m) and 550 ft (168m) respectively for CAT II / III.

In March 2010, the FAA issued Engineering Brief 81 directing U.S. airports that Group V runway-to-parallel taxiway separations are adequate and applicable for 747-8 operations.

It may therefore be concluded that for the 747-8 RWY/TWY separations for CAT II/III operations equal to those of code letter E aircraft can safely be applied.

ICAO guidance on the graded portion of the runway strip specifies 105m between the runway centreline to the edge of the graded strip. (**ADM Part 1, Figure 5-3**) This is for a precision approach runway where the code number is 3 or 4. This dimension is based on the historical veer-off data and makes no distinction between the size (code letter) of aircraft. Based on this graded strip guideline, the runway-to-taxiway separation would be 167m, where the wingtip of the 747-8 (with its outer main gear tires at the edge of the graded strip) comes in contact with the wingtip of the 747-8 on the parallel taxiway centreline.

3 Perturbation of ILS signal by a taxiing or stopped aircraft

A generic risk assessment on this topic seems not feasible. ILS signal distortion risk should be assessed in a case-by-case basis taking into account local conditions like airport layout and traffic density.

These case-by-case studies could take advantage of several generic studies dealing with A380 effects on ILS safety area:

- A preliminary study from Park Air Systems (AACG, Appendix 4 Part M) calculates for Nomarc ILS the difference between A380 and 747 Sensitive Areas. The output indicates that the Sensitive Area for a CAT III approach is approximately 30-40% wider for an A380 than for a 747. However, it must be noticed that the A380 was modelled with a metal vertical tail (like the 747) instead of the carbon fibre.
- According to ILS specialists, the carbon fibre that is used for A380 vertical tail could lead to a decrease in ILS signal perturbation versus metal.
- A study by ADP to assess the impact of carbon fibre versus metal on ILS signal perturbations by making real tests at CDG with A310 fitted with two kinds of tail material (carbon fibre and metal).
- A recent study (2006) by a workgroup of ILS experts in Europe indicates that vertical tail size is critical, not the wingspan even with the provision of winglets.

The vertical tail of the 747-8 and 747-400 is metal but the vertical tail size of the 747-8 is equal to that of the 747-400 and it is expected that no additional issues/problems with the perturbation of the ILS signal will occur. However, as no airport is the same with respect to layout and traffic density, specific runway studies to evaluate ILS interference risks may be needed.

CONCLUSIONS

The Runway 05/23 centreline to the principal parallel taxiway centreline separation is not noted in the airport AIP or in the Jeppesen Airway Manual Services charts. Measurement obtained from Google Earth Imagery, this separation is approximately 195m and exceeds the code letter F recommendation of 190m. This separation is therefore assessed as adequate for 747-8F operations.

The OFZ dimension for Runway 05/23 is also not noted in the latest Guaraní International Airport AIP. The OFZ width of 120m that is applicable for existing aircraft in ICAO Code Number 4 is also applicable for the 747-8F.

As determined from the latest Google Earth Pro Imagery, the runway holding positions for Runway 05/23 is approximately 91m from the runway centreline for intersection Taxiway A and intersection Taxiway B. These separations meet the code numbers 3 or 4 recommendations for a precision approach and are therefore assessed as adequate for 747-8F operations since the 747-8F meets the aircraft dimensions noted in Annex 14, Table 3-2, footnote b, Note 1 which allows holdlines at 90m.

PART D: TAXIWAY SEPARATIONS

SYNOPSIS

ICAO BASELINE	Parallel Taxiway Separation Code letter F taxiway centreline to taxiway centreline separation = 97.5m. Possibility to operate with lower separation distances based on an aeronautical study. **[RP} A14 P3.9.8 + table 3-1 col. 10.** No specific safety buffers for curved portion. **A14 P.3.9.8 Note 3** Taxiway / Apron Taxiway to object Separation Code letter F taxiway centreline to object separation = 57.5m. Possibility to operate with lower separation distances based on an aeronautical study. **[RP] A14 P3.9.8 + table 3-1 col. 11** Aircraft Stand Taxilane to Object Separation (including service road and height limited object) Taxilane centreline to object separation = 50.5m. Possibility to operate with lower separation distances based on an aeronautical study. **[RP] A14 P3.9.8 + table 3-1 col. 12** The distance shown (above) may need to be increased if jet exhaust is likely to be hazardous **[RP] A14 P3.9.8 note 4** Clearance at the gate Minimum distance between aircraft and obstacle = 7.5m but special circumstances on nose-in stands may permit reduction between the terminal (including fixed passenger bridge) and the aircraft nose and over any portion of the stand provided with azimuth guidance by a visual guidance system **[RP] A14 P3.13.6** The Taxiway strip should provide an area clear of objects which may endanger aircraft **[RP] A14 3.11.3**		
HAZARD ANALYSIS	Hazard Identification		Risk 1 Collision between two aircraft or between an aircraft and an object (fixed or mobile)
	Main causes and accident factors		Human factors (crew, marshaller, taxi routing error) Weather conditions
	Severity	Theoretical	Potentially major
		In-service	
RISK ASSESSMENT	Risk assessment category		B (generic risk model)
	Main technical materials		- Taxiway deviation statistics analysis (existing and ongoing analyses) - Air Navigation Plan – ICAO European Region – Reduced Separation Distances for NLA operations - 747-8 cockpit visibility **(see Attachment B, C & D)**
CONCLUSIONS	**- <u>General</u>:** **(a) One of the purchasing all-cargo airlines has designated Guaraní International Airport as a destination and alternate airport critical to its 747-8F route structure. The all-cargo airline operates both 747F and 747-8F aircraft and would like to interchange these aircraft into its schedule as day-to-day cargo demand require. Therefore, the all-cargo airline will require terminal ramp area for aircraft parking and possible aircraft servicing and refuelling requirements.** **(b) From the latest available published schedule from the OAG, Guaraní International Airport has 21 weekly frequencies consisting of code letter C A320 and lesser code letter regional jet aircraft operations. The 747-400F currently operates into Guaraní International Airport on a non-scheduled basis.** **(c) The terminal apron is configured with 5 parking stands (power-in/tow-out); but the 3 mid-apron parking stands are usable for commercial aircraft operations (the 2 end parking stands are used for General Aviation aircraft and for 747/DC-8 storage). The 747-400F currently uses the ramp area adjacent to the stored 747/DC-8 for cargo loading/unloading operations. The 747-8F should also utilize this area as this will provide concurrent open parking stand for scheduled A320 and other lesser code letter aircraft operations.**		

CONCLUSIONS (CONTINUED)	
CONCLUSIONS (CONTINUED)	**- <u>Taxiway / Apron Taxiway to Object Separation</u>:** **(a) Principal parallel TWY centreline to the tip of the stored DC-8 (located at the southwest edge of the airport terminal ramp) is 49m. This results in a wingtip clearance of 14.8m and is assessed as adequate for 747-8F operations. The ICAO-Europe ANP recommended a 9m wingtip clearance for the 747-400. The BACG agreement also recommends a 9m wingtip clearance for the 747-8.** **(b) Principal parallel TWY centreline to terminal apron parking limit line separation is 52.5m. This results in a wingtip clearance of 18.3m and is assessed as adequate for 747-8F operations. The ICAO-Europe ANP recommended a 9m wingtip clearance for the 747-400. The BACG agreement also recommends a 9m wingtip clearance for the 747-8.** **- <u>Parking</u>:** **(a) As the principal parallel TWY does not extend to the ends of RWY 05/23, to access the terminal ramp area, the arriving 747-8F must turn around on the turn pad provided at either runway end, back taxi on the runway to either intersecting TWY A or intersecting TWY B, and then connect to the principal parallel TWY.** **(b) The 747-400F operated by Atlas Air currently utilizes the terminal ramp area for aircraft parking that is adjacent to the stored 747/DC-8. The 747-400F will manoeuvre onto the apron area and will park after making a left hand turn of approximately 130º. The 747-400F will then exit the ramp under power. Chart VI located in Attachment A shows the 747-8F operating under the same manoeuvring plan as the 747-400F. As such, this will leave the northwest parking stand available to support current code letter C A320 and lesser code letter regional jet operations. In this configuration, the tip of the 747-8F stabilizer will not penetrate the 7:1 transition slope (See Chart IV in Attachment A)** **(c) A possible terminal ramp configuration that could also accommodate the 747-8F and provide multiple A320 and/or lesser code letter aircraft parking stands is to have the 747-8F power-in (and then push-back) to the parking stand adjacent the stored 747/DC-8. This configuration will provide 2 available code letter C parking stands (parking centreline offsets are approximately 66m). However, the tip of the parked 747-8F will penetrate the 7:1 transition slope. This configuration is feasible only if an operational exemption or waiver can be obtained from the local airport authority or the governing civil aviation authority.** **- <u>Runway End Turn Pads</u>:** **(a) As mentioned previously, the principal parallel TWY does not extend to the ends of RWY 05/23. Arriving and departing aircraft must turn around on the turn pad provided at each runway end and then back taxi on the runway. The 747-8F U-Turn minimum width requirement is 52m which does not include any allowance for wheel edge clearance to the edge of the pavement. For code letter E and code letter F aircraft, from ICAO Annex 14 – Runway Turn Pads, Section 3.3.6, the clearance distance between any wheel of the aircraft landing gear and the edge of the turn pad shall be 4.5m (6m clearance under severe weather conditions which may lower the surface friction characteristics). The turn pad at the end of RWY 05 and the end of RWY 23 are both 84m wide and are therefore assessed as adequate for 747-8F operations (See Chart VII in Attachment A).**

ICAO BASELINE

See previous synopsis.

HAZARD ANALYSIS

1 Hazard Identification

The separation distances during taxiing are intended to limit the risk of collision between two aircraft (taxiway/taxiway separation) and between an aircraft and an object (taxiway/object, taxilane/object separations, and clearance at the gate).

2 Causal Analysis

The accident/incident database **(see Attachment B)** includes only two accident reports relative to collision on taxiing. Therefore, the causes and accident factors identified for taxiway separation issue are mainly supported by experience and not by accident database analysis. The causes of such an event could be classified as:

- Mechanical failure (hydraulic system failure)
- Surface conditions (aquaplaning, loss of control on ice-covered surface)
- Loss of visual taxiway guidance system (markings and lights covered by snow)
- Pilot precision and attention (directional control, orientation error)

3 Consequences Analysis

Consequences of a collision between two aircraft or between an aircraft and a fixed object while taxiing are potentially major.

RISK ASSESSMENT

The collision hazard during taxiing does not depend on specific aircraft performances but on human factors. The expected 747-8 behaviour could therefore be inferred from existing aircraft behaviour data.

As existing measurements on straight taxiway sections tend to show that the bigger the aircraft, the smaller the taxiway deviation **(see Attachment C, D and E)**, the extrapolation of available data on taxiway deviation for the 747-8 seems quite conservative. This statement means that the taxiway separation distances issue comes under a “Type B” risk assessment category (generic risk model). Accordingly, the following argument has been developed:

- Use taxiway deviation statistics to assess the collision risk between two aircraft or between an aircraft and an object. Several taxiway deviation studies **(see Attachment C)** have been completed and are available. These were conducted at Amsterdam (AMS), London (LHR), New York (JFK), Anchorage (ANC), Paris (CDG), Frankfurt (FRA), San Francisco (SFO), and Sydney (SYD). The results of these studies at different airports show similarities in the characteristics of lateral deviation distribution. The Boeing Company was directly involved with the taxiway deviation studies at Amsterdam (AMS), Anchorage (ANC), New York (JFK), and San Francisco (SFO).
- Consider the experience at some major airports where lower separation distances specified in the ICAO Air Navigation Plan of European Region for 747-400 operations were applied. **(see Attachment D & E)** ICAO European ANP defines specific measures for applying these reduced wingtip margins on existing infrastructures for generic NLA operations based on 747-400 experience (e.g. centreline lighting or equivalent guidance (i.e. marshaller) for night, winter and low visibility operations, objects marking and lighting, good surface friction conditions, publication in AIP, etc). ICAO-Europe developed AOP Document 7754 that recommended a minimum taxiing wingtip clearance of 11m between parallel taxiways, 9m wingtip clearance between taxiway and object, and 7.5m wingtip clearance between aircraft stand taxilane and object. There has been no reported incident or accident that resulted from the adoption of these operational criteria at European airports. From taxiway

deviation studies, the results indicate that the probability of deviating the amount of wingtip clearance distances mentioned above to be extremely remote.

- Consider the recommendations of the AACG for A380 operations that proposed reduced tip-tip and tip-object margins based on extensive analysis of various studies and experiences. **(see Attachment C).** The AACG recommended taxiing clearances for the A380 that are the same as those in ICAO-Europe AOP Document 7754: 11m between parallel taxiways; 9m between taxiway and object; and 7.5m between aircraft stand taxilane and object.
- Consider the recommendations of the BACG for 747-8 operations that proposed reduced tip-tip and tip-object margins based on extensive analysis of various studies and experiences. **(see Attachment C).** The BACG recommended taxiing clearances for the 747-8 that are same as those in ICAO Europe AOP Document 7754: 11m between parallel taxiways; 9m between taxiway and object; and 7.5m between aircraft stand taxilane and object.

As collision risk when taxiing is a “Type B” hazard (generic risk model), the reduced taxiing wingtip clearances used at some major airports for the 747-400 with no adverse effect on the safety can be extrapolated for 747-8 operations, with the same specific measures as for the 747-400 aircraft.

CONCLUSIONS

The taxiway separation distances shown in Table 3-1, Taxiway Minimum Separation Distance, of ICAO Annex 14 are recommendations for design of the airfield. In explaining this table, it is stated in paragraph 3.9.8 of Annex 14 that “it may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.” It should be noted that “lower separations” are meant to imply “lower wingtip clearances” from design specifications. In this context, many member states have conducted taxi deviation studies to determine how much a large aircraft deviates from the taxiway centreline in actual operations. Many of these studies are available directly from the websites shown in **Attachment C** or through industry organizations or Boeing. Results from various taxiway deviation studies yield a similar statistical pattern of deviation distribution among the airports studied and, therefore, the results are thought to be applicable for other code letter E airports. It can be said that statistical studies validate the reduction in taxiing wingtip clearances recommended in ICAO Air Navigation Plan – European Region for 747-400 (AOP Doc 7754). The recommended clearance figures are noted in the Conclusion section of the Synopsis. It should also be pointed out that there has been no accident/incident directly resulting from implementation of AOP Doc 7754 at European airports. Since then, the taxiing clearance recommendations made in AOP Doc 7754 has been adopted by Airbus A380 Airport Compatibility Group (AACG) and Boeing 747-8 Airport Compatibility Group (BACG).

Since the 747-8F will be operated by one of the purchasing all-cargo airlines at SGES/AGT, the taxi paths leading to the candidate terminal apron parking stand were examined. As documented previously in the Synopsis section of Part D:

Taxiway and Apron Taxilane Separations – Conclusions – Page 36, along the various terminal taxiways/taxilanes, intersection taxiways, and apron parking taxilanes are several object separations that were evaluated for 747-8F manoeuvring. Along the principal parallel taxiway are 2 centreline-to-object separations that are 49m (wingtip of the stored DC-8) and 52.5m (apron parking limit line). Both centreline-to-object separations are assessed as adequate for 747-8F operations. The 49m separation results in a wingtip clearance of 14.8m that exceeds the ICAO-Europe ANP recommended a 9m wingtip clearance for the 747-400 and the BACG agreement which also recommends a 9m wingtip clearance for the 747-8. The 52.5m centreline-to-object separation exceeds the code letter F recommendation of 50.5m.

Aircraft Parking Analysis

The 747-400F operated by Atlas Air currently utilizes the terminal ramp area for aircraft parking that is adjacent to the stored 747/DC-8. The 747-400F will manoeuvre onto the apron area and will park after making a left hand turn of approximately 130º. The aircraft will then exit the ramp under power. To illustrate the 747-8F parking configuration, Chart VII located in Attachment A shows the 747-8F operating under the same manoeuvring plan as the 747-400F. As such, this will leave the northwest parking stand available to support current code letter C A320 and lesser code letter regional jet aircraft operations. In this configuration, the tip of the 747-8F stabilizer will not penetrate the 7:1 transition slope.

A possible terminal ramp configuration that could also accommodate the 747-8F and provide multiple A320 and/or lesser code letter aircraft parking stands is to have the 747-8F power-in (and then push-back) to the parking stand adjacent the stored 747/DC-8. This configuration will provide 2 available code letter C parking stands (parking centreline offsets are approximately 66m). However, the tip of the parked 747-8F stabilizer will penetrate the 7:1 transition slope. This configuration is feasible only if an operational exemption or waiver can be obtained from the local airport authority or the governing civil aviation authority.

Runway 05/23 Turn Pads

The principal parallel taxiway does not extend to the ends of Runway 05/23. Arriving and departing aircraft must turn around on the turn pad provided at each runway end and then back taxi on the runway. The 747-8F U-Turn minimum width requirement is 52m which does not include any allowance for wheel edge to pavement edge clearance. For code letter E and code letter F aircraft, from ICAO Annex 14 – Runway Turn Pads, Section 3.3.6, the clearance distance between any wheel of the aircraft landing gear and the edge of the turn pad shall be 4.5m (6m clearance under severe weather conditions which may lower the surface friction characteristics). The turn pad at the end of Runway 05 and Runway 23 are both 84m wide and are therefore assessed as adequate for 747-8F operations

PART E: OTHER ITEMS

1 RUNWAY VISUAL AIDS

SYNOPSIS

<table>
<tr><td>ICAO BASELINE</td><td colspan="5">Elevated edge Lights
- Elevated RWY lights shall be frangible and clear of propellers & engine pods. [Std] A14 P5.3.1.7
- Surface (inset) lights shall withstand being run over by aircraft. [Std] A14 P5.3.1.8
- Elevated RWY lights shall be placed along the edge of the area declared for the use as RWY or outside by less than 3m. [Std] A14 P5.3.9.4

Signals shall be frangible and clear of propellers & engine pods. [Std] A14 P5.4.1.3

Precision Approach Path Indicator (PAPI)
- Where a PAPI or APAPI is installed on a RWY without an Instrument Landing System (ILS) or Microwave Landing System (MLS) they shall be sited to ensure guidance for the most demanding aircraft regularly using the RWY. Where a PAPI or APAPI is installed on a RWY with ILS or MLS, it should be sited to provide guidance for those aircraft regularly using the RWY. A14 Chap 5 Figure 5-15 P a) & b), & A14 Chap 5 Table 5-2 footnote a.
- The location of PAPI units depends on eye-to-wheel height of the group of aircraft that use the system regularly and by using the most demanding aircraft of the group. A14 Chap 5 Table 5-2 note a. Wheel clearances may be reduced subject to aeronautical study but not less than the values indicated in Table 5-2 column 3. A14 Chap 5 Table 5-2 note c.</td></tr>
<tr><td rowspan="4">HAZARD ANALYSIS</td><td colspan="2">Hazard Identification</td><td>Risk 1
Elevated edge lights damaged by jet blast</td><td>Risk 2
PAPI guidance not adapted for an aircraft in approach</td><td>Risk 3
Aircraft damage caused by elevated lights after a veer-off</td></tr>
<tr><td colspan="2">Main causes and accident factors</td><td>- Powerplant (engine position, engine power)
- Elevated edge lights strength
- Aircraft (rotation angle at take-off)
- Runway centreline deviation factors (see runway veer-off risk)</td><td rowspan="5">No 747-8 specific issue</td><td rowspan="5">No 747-8 specific issue</td></tr>
<tr><td rowspan="2">Severity</td><td>Theoretical</td><td rowspan="2">Potentially major if undetected before take-off and followed by engine ingestion and tire bursting risks</td></tr>
<tr><td>In-service</td></tr>
<tr><td rowspan="2">RISK ASSESSMENT</td><td colspan="2">Risk assessment category</td><td>C (geometric argument)</td></tr>
<tr><td colspan="2">Main technical materials</td><td>- 747-8 engine position
- 747-8 jet blast contours
(see Attachment B)</td></tr>
<tr><td>CONCLUSIONS</td><td colspan="5">For RWY edge lighting position, ICAO SARPs to be followed (placed along the edge of the area declared for use as RWY or outside by less than 3m).

Inset RWY edge lights may be considered. However, elevated runway edge lights have not been a problem in revenue service to date.

PAPI: No specific 747-8 requirement; ICAO compliant.</td></tr>
</table>

ICAO BASELINE

See previous synopsis

HAZARD ANALYSIS

1 Hazard Identification

Three potential hazards linked to runway visual aids characteristics could be identified as:

1. Elevated edge lights damaged by aircraft jet blast
2. PAPI guidance not adapted for an aircraft in approach
3. Aircraft damage caused by elevated lights after an aircraft veer-off

Hazards 1 and 2 could effectively be related to NLA characteristics (engine position, engine thrust, eye-to-wheel height, landing attitude). However, hazard 3 is not a specific NLA issue. The frangibility characteristic of elevated edge lights is a mitigating measure potentially useful for all kinds of aircraft (and probably more for the smallest aircraft since the bigger the gear wheel, the more the frangibility) in case of runway veer-off.

PAPI guidance issues are linked to aircraft characteristics but, considering 747-8 eye-to wheel height in approach configuration **(see Attachment B)**, Annex 14 requirements should be sufficient to determine PAPI guidance for 747-8. This is not a specific 747-8 item.

In addition to these three hazards, it could be relevant to study the risk of centreline lights damage caused by aircraft rolling on surface lights. In this case, the 747-8 is not the most critical aircraft in term of weight/wheel. Hence, only the jet blast effect on runway edge lights has been considered here for the 747-8.

2 Causal analysis

Main causes and accident factors for elevated runway edge lights damage risk are:

- Powerplant characteristics (engine position, engine power)
- Elevated edge lights strength
- Aircraft rotation angle at take-off
- Runway centreline deviation factors (see runway veer-off risk)

3 Consequences analysis

Edge lights damages can potentially have major consequences if undetected before take-off and followed by engine ingestion and tire bursting.

RISK ASSESSMENT

1 Runway Edge Lights Damage

Jet blast hazards are typical geometric issues and come under “Type C” risk assessment category (geometric argument).

The 747-8 jet blast contours are available on The Boeing Company website at http://www.boeing.com/commercial/airports/747.htm and can be compared to other existing aircraft jet blast contours. The outboard engine positions on the 747-8 are the same distance laterally from the lights as with the 747-400. The takeoff thrust of the 747-8F engine is 66,500 lbs, and only marginally higher compared to 63,300 lbs for the 747-400ER.

The French DGAC (CAA) has conducted studies to determine the effect of jet blast from the A380 on runway edge lights **(see Attachment C, Item 29)**. The studies were made before the A380 was introduced into service and includes three phases – a theoretical study, real test using A340-600, and a simulated test. It was concluded that it is highly probable that the jet blast from the A380 will have no specific impact on the runway edge elevated light fixtures when operating on 45m wide runways in typical in-service conditions. The 747-8 is less critical than the A380 from the two key considerations – engine thrust level and the location of the engine relative to the location of the runway edge lights.

There has been no report of damage to the elevated runway edge lights during revenue service to date.

CONCLUSIONS

- For runway edge lighting position, ICAO SARPs are to be followed (placement along the edge of the area declared for the use as runway or outside by less than 3m).
- Inset runway edge lights may be considered. However, a marginal increase in the takeoff thrust compared to the 747-400ER has not caused damage to the elevated runway edge lights during revenue service to date. The French DGAC tests also lead to a conclusion that existing elevated edge lights should not be damaged by the 747-8 jet blast.
- PAPI: No specific 747-8 requirement; ICAO compliant.

2 RUNWAY END SAFETY AREA WIDTH

SYNOPSIS

ICAO BASELINE	The width of a RESA shall be at least twice that of the associated runway. 120m for an associated runway code letter F RWY; 90m for an associated runway code letter E RWY. **[Std] A14 P3.5.4** The width of a RESA should, wherever practicable, be equal to that of the graded portion of the associated runway strip. 150m for code numbers 3 and 4. **[RP] A14 P3.5.5** The RESA is intended to provide protection beyond the runway strip to minimize damage when aircraft undershoot or overshoot/overrun the RWY during landing or take-off. **ADM Pt1 P5.4.1**			
HAZARD ANALYSIS	Hazard identification		Risk 1 Runway overrun excursion at take-off	Risk 2 Runway undershoot or runway overrun excursion at landing
	Main causes and accident factors		- Human factors (crew, maintenance, balance, payload security) - Powerplant (engine failure, ingestion) - Surface conditions (aquaplaning, snow) - Aircraft (control surfaces, hydraulic system, tyres)	- Human factors (crew, maintenance) - Aircraft (landing gear, control surfaces, hydraulic system, brakes, tyres) - Powerplant (reverse) - Surface conditions (aquaplaning, snow) - Weather conditions (tail wind, visibility, inaccurate meteorological information)
	Severity	Theoretical	Major to Catastrophic depending on the aircraft speed.	
		In-service		
RISK ASSESSMENT	Risk assessment category		A (aircraft performance)	A (aircraft performance)
	Main technical materials		- FAA / EASA have approval to operate the 747-8 on 45m wide RWY: critical failure conditions at take off, V_{MCG} criteria, envelope of environmental conditions covered by aircraft certification. - Numerous design changes from the 747-400 to improve handling qualities during takeoff or rejected takeoff. - Otherwise design commonalities with the 747-400. - Flight deck features that improve situation awareness. **(see Attachments B, H and I)**	- FAA / EASA have issued approval to operate the 747-8 on 45m wide RWY: critical failure conditions at landing, envelope of environmental conditions covered by aircraft certification, Autoland criteria. - Numerous design changes from the 747-400 to improve lateral handling qualities during landing. - Otherwise design commonalities with the 747-400. - Flight deck features that improve situation awareness **(see Attachments B, H and I)**
CONCLUSIONS	**A minimum 90m RESA width should be provided which is based on the 45m code letter E associated runway width, or twice the actual associated runway width. However, a RESA width equal to the width of the graded portion (150m) of the associated runway strip is strongly recommended, wherever practicable. RESA data is not provided in the latest airport AIP, but from Google Earth Pro Imagery, there appears to be RESA of recommended size on all runway ends.** **From ICAO Annex 14, Section 3.5.2 – Runway End Safety Areas, a runway end safety area shall extend from the end of a runway strip to a distance of at least 90m. However, the required RESA length is independent of code letter, and therefore, it is not discussed in this study.**			

ICAO BASELINE

See previous synopsis

HAZARD ANALYSIS

1 Hazard Identification

The principal hazards linked to Runway End Safety Area are runway-undershoot at landing and runway-overrun at take-off or landing.

2 Causal Analysis

There are many factors that may cause a runway undershoot or overrun. Most of them are not related to the size of the aircraft. The main causes and accident factors are listed as follows:

- For take-off:
  - Human factors (crew, maintenance, balance, payload security)
  - Aircraft (control surfaces, hydraulic system, tyres)
  - Powerplant (engine failure, ingestion)
  - Surface conditions (aquaplaning, snow)
- For landing:
  - Human factors (crew, maintenance, balance, payload security)
  - Aircraft (landing gear, control surfaces, hydraulic system, brakes, tyres)
  - Powerplant (reverse)
  - Surface conditions (aquaplaning, snow)
  - Weather conditions (tail wind, visibility, inaccurate meteorological information)

3 Consequences Analysis

The runway undershoot and runway overrun hazard can be classified as a major to catastrophic risk depending on the aircraft speed.

Safety analyses (Functional Hazard Assessment, System Safety Assessment, Environmental Conditions Hazard Assessment,…) on landing and take-off operations will be made during the operational approval process.

Runway undershoot and overrun are risks explicitly taken into account by Boeing in the aircraft design process (see 747-8 Performance Features and Safety Improvements in **Attachment B**).

RISK ASSESSMENT

This type of risk comes under “Type A” risk assessment category, mainly based on aircraft performance and handling qualities.

The design and pilot procedural improvements are focused on safe operations on code letter E runways. The FAA and EASA have now issued an approval to operate the 747-8 on 45m wide runways.

Numerous design changes were made from the 747-400 to improve handling qualities during take-off and landing. There are also design commonalities with the 747-400, like main gear geometry and also final approach speed. These changes and commonalities are described in Part A: Runways, Risk Assessment section of this document.

It may be expected that, due to these handling improvements as well as commonalities, the behaviour of the 747-8 in case of runway undershoot or overrun, will be similar to that for the 747-400.

Since the 747-8 is approved by the FAA and EASA to operate on 45m wide runways, it is concluded that the RESA width of 90m, twice the required width of the runway, is adequate.

CONCLUSIONS

- The RESA width shall apply to actual "associated" runway width.
- A minimum RESA width of 90m, based on 45m code letter E associated runway width, or twice that of the actual associated runway width, is adequate for the 747-8
- A minimum recommended RESA width is equal to the width of the graded portion (150m) of the associated runway strip, wherever practicable.

The RESA data for both ends of Runway 05/23 at SGES/AGT are not provided in the latest airport AIP. A minimum 90m RESA width should be provided which is based on the 45m code letter E associated runway width, or twice the actual associated runway width. However, a RESA width equal to the width of the graded portion (150m) of the associated runway strip is strongly recommended, independent on the size of (large) aircraft using that runway. The latest airport Google Earth Pro Imagery appears to show the RESA of recommended size at both runway ends.

From ICAO Annex 14, Section 3.5.2 – Runway End Safety Areas, a runway end safety area shall extend from the end of a runway strip to a distance of at least 90m. A 90m length is applicable for runways with a code numbers 3 and 4, and instrumented runways with code numbers 1 and 2. Since the RESA lengths are not provided in the latest Guaraní International Airport AIP and because the required RESA length is independent of code letter and will not be influenced by the code letter F status of the 747-8F, the RESA length is not discussed in this aeronautical (safety) study.

Attachment A

Guaraní International Airport Drawings

Chart I: Guaraní International Airport (SGES/AGT) Layout

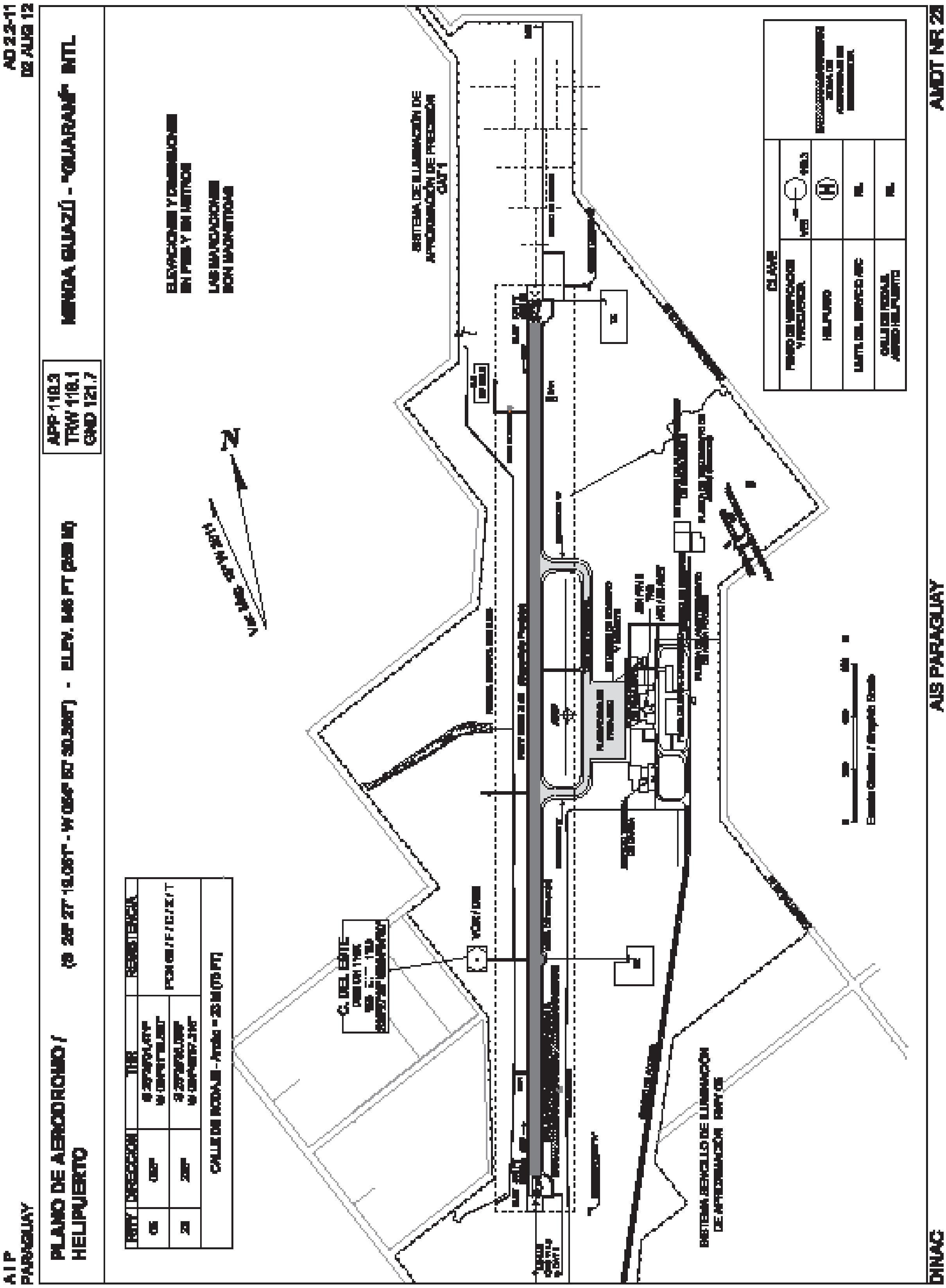


Chart II – Guaraní International Airport (SGES/AGT) Cross Section

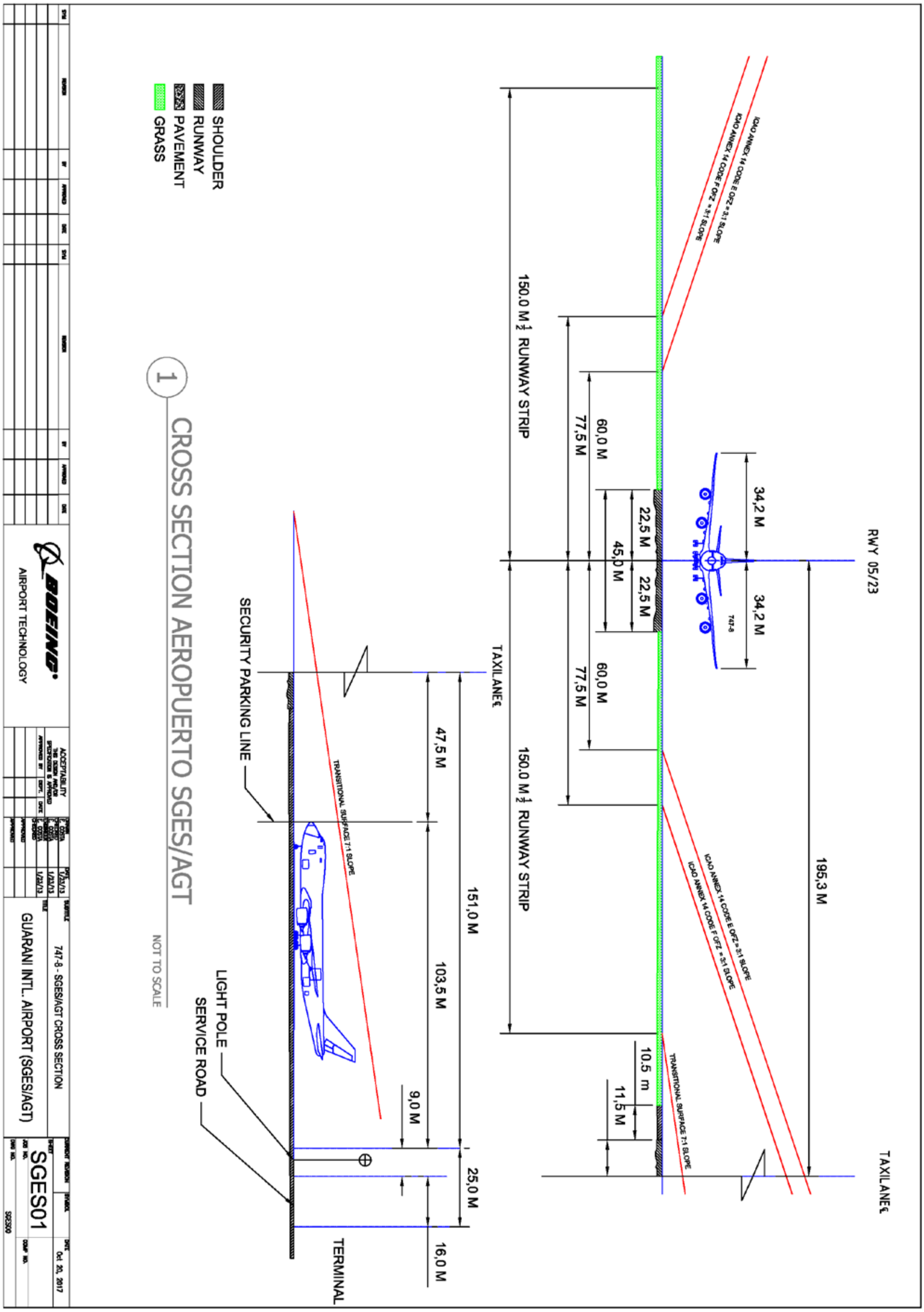


Chart III: Comparison of 747-8F and 747-400F Characteristics

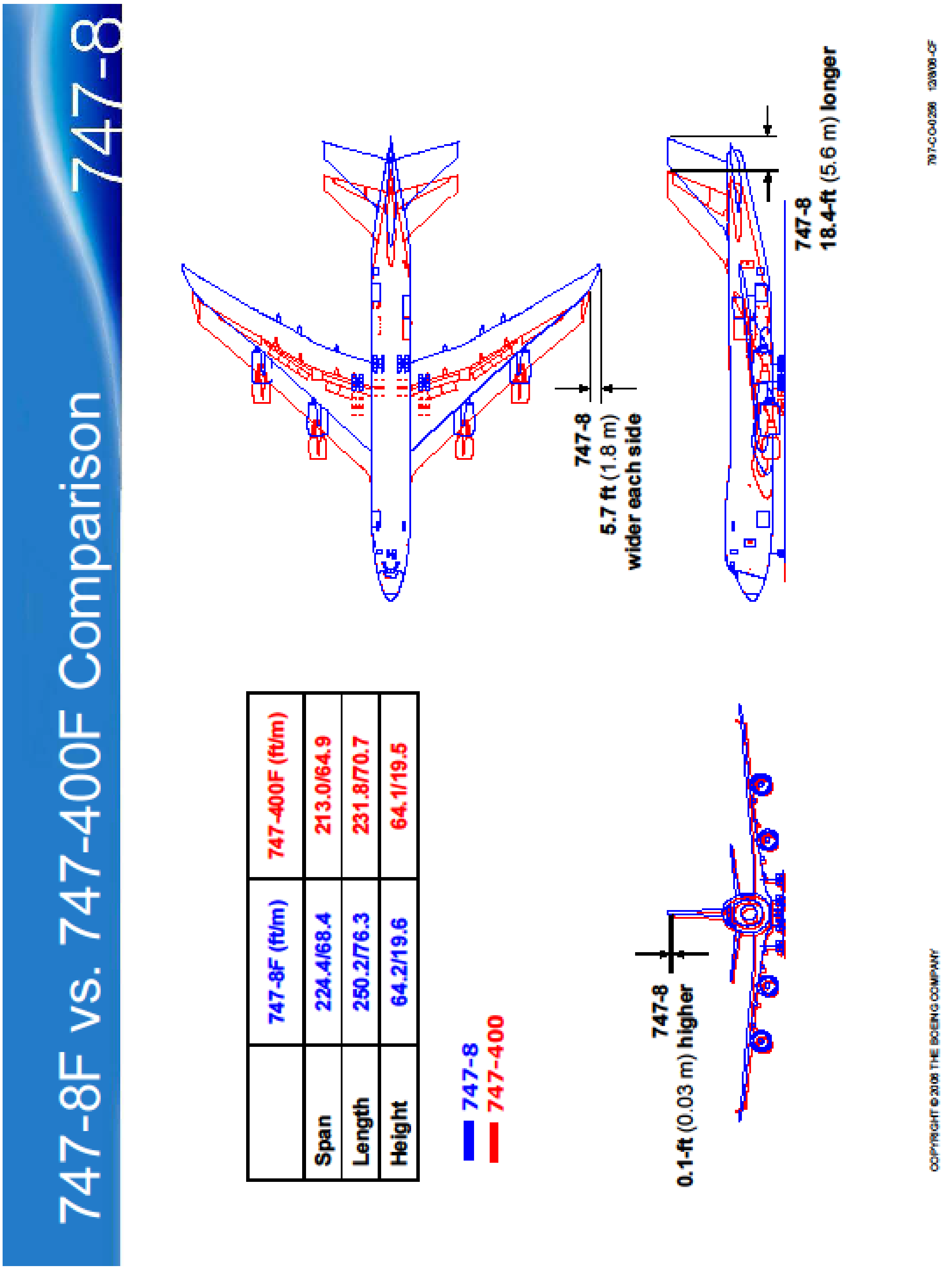


Chart IV: ICAO Annex 14 – Transition Slope Definition

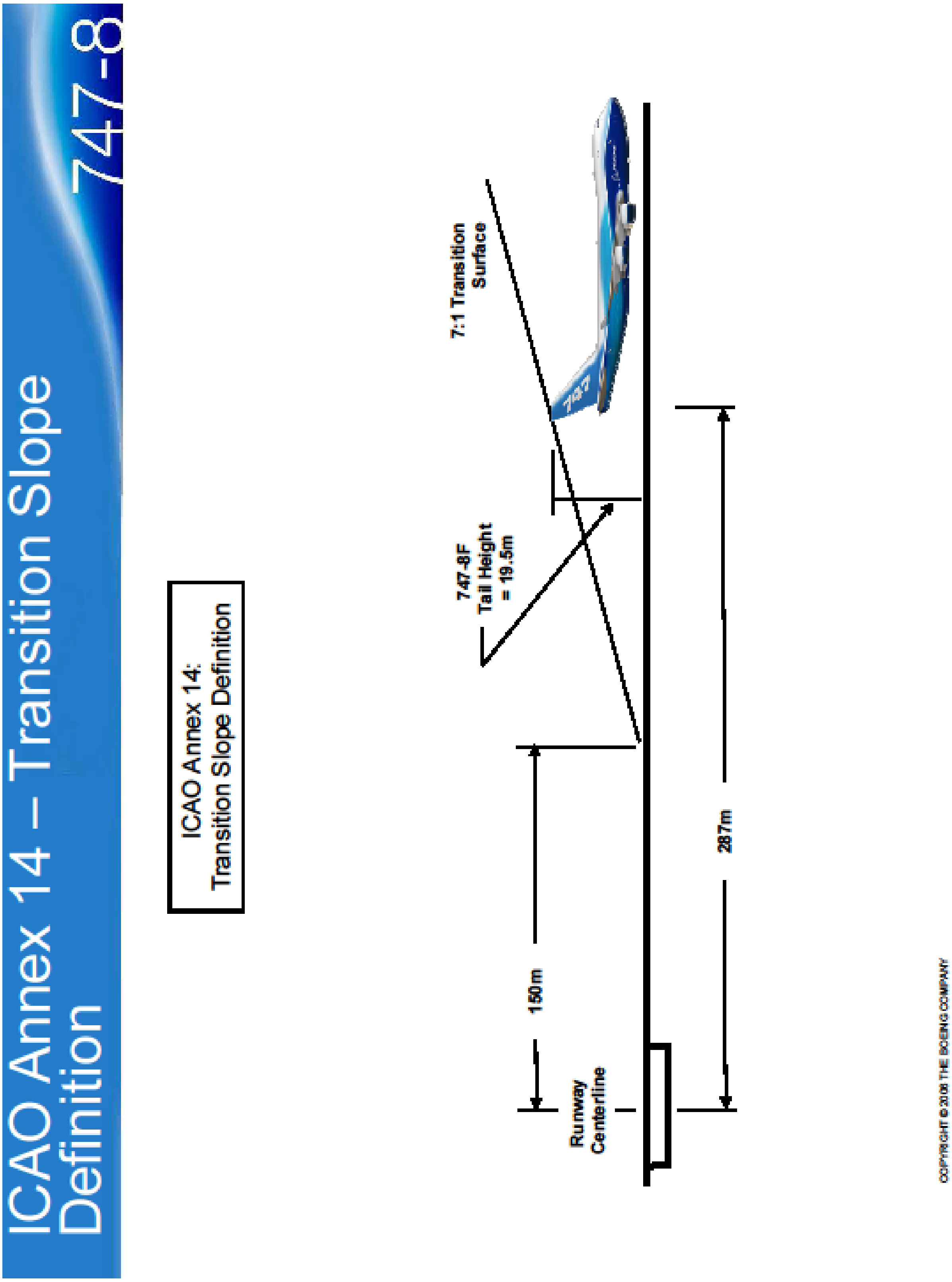


Chart V: 747-8F Manoeuvring – Runway/Taxiway and Taxiway/Taxiway

Chart VI: Proposed 747-8F Parking – Guaraní International Airport (SGES/AGT)

Chart VII: 747-8F U-Turn Analysis – RWY 05 and RWY 23 Turn Pads