GOVERNO DE PORTUGAL

MINISTÉRIO DA ECONOMIA

GPIAA

Gabinete de Prevenção e Investigação de Acidentes com Aeronaves

SATA INTERNATIONAL / CS-TGU

GPIAA SAFETY REPORT

Accident Occurrence Investigation

02/ACCID/2013

FINAL

Tail strike landing on runway 30

João Paulo II Airport

Ponta Delgada, Azores

2nd of March 2013, 21:10 UTC

Airbus 310-300

FINAL REPORT APPROVED BY GPIAA'S DIRECTOR (ÁLVARO NEVES), ON 29 DECEMBER 2014

RELEASED AND APPROVED IN ACCORDANCE WITH ARTICLE OF THE NATIONAL LAW 318/99 OF 11 OF AUGUST

Note: the photograph on the cover of this report was taken by Paulo Santos at Lajes Airport (taken from airliners.net website)

SAFETY ACCIDENT REPORT

SATA INTERNATIONAL
AIRBUS A310-300

CS-TGU

TAILSTRIKE LANDING

JOÃO PAULO II AIRPORT

PONTA DELGADA
AZORES

2nd of March 2013 at 21:10 UTC

FINAL ACCIDENT REPORT 02/ACCID/2013

Published by:	GPIAA – Gabinete de Prevenção e Investigação de Acidentes com Aeronaves Portugal Safety Accident Investigation Board
Postal address:	Praça Duque de Saldanha, 31 – 4º
Office:	1050-094 Lisboa Portugal
Phone Numbers:	+ 351 21 273 92 30 + 351 915 192 963 / +351 272 739 255 (24 hours) / 707 284 637 (707 AVI OES) (Accident and Incident notification)
Fax:	+ 351 21 273 92 60
Email:	investigacao@gpiaa.gov.pt
Internet:	www.gpiaa.gov.pt

Government of Portugal

Secretary of State Infrastructure, Transports and Communications

GPIAA 2014

This report is published in Portuguese and English. In the event of any discrepancy between these versions, the Portuguese text shall prevail.

GPIAA – PORTUGAL SAFETY INVESTIGATION BOARD

The Portugal Safety Investigation Board (GPIAA) is an independent State public body. The body is governed by a Director and is entirely separated from transport regulators, policy makers and service providers. The GPIAA function is to improve safety and public confidence in the aviation mode of transport through excellence by means of independent investigation of civil aviation accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

GPIAA is responsible for investigating accidents and other safety matters involving civil aviation operations in Portugal that fall within the country jurisdiction, as well as participating in overseas investigations involving Portuguese registered aircraft. Of primary concern is the safety of commercial air transport, with particular attention to fare-paying passenger operations.

GPIAA performs its functions in accordance with the provisions of the Aeronautical Safety Investigation rules in particular with its national Law 318/99, the E.U. Regulations 996/2010 and with ICAO Annex 13, as well as, where applicable, relevant international agreements.

PURPOSE OF SAFETY INVESTIGATIONS

The object of a safety investigation is to identify and reduce safety-related risk. GPIAA's investigations determine and communicate the safety factors related to the air transport safety matter being investigated. The terms GPIAA uses to refer to key safety and risk concepts are set out in the next section *Terminology Used in this Report*. It is not a function of GPIAA to apportion blame or determine liability. In addition, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times GPIAA endeavours to balance the use of material that could imply adverse comment by revealing *what and why* happened in a fair and unbiased manner.

DEVELOPING SAFETY ACTION

Central to GPIAA investigation of aviation safety matters is the early identification of safety issues in the aeronautical environment. GPIAA prefers to encourage the relevant organization(s) to initiate proactive safety action that addresses safety issues. Nevertheless, GPIAA may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organization. When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organizations, GPIAA has no power to enforce the implementation of its recommendations. It is a matter for the body to which a GPIAA recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue. When GPIAA issues a safety recommendation to a person, organization or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation. GPIAA can also issue safety advisory notices suggesting that an organization or an industry sector consider a safety issue and take action where it believes appropriate, or to raise general awareness of important safety information in the industry. There is no requirement for a formal response to an advisory notice, although GPIAA will publish any response it receives.

NOTES

The only aim of this technical report is to collect lessons which may help to prevent future accidents.

Safety investigation is a technical process aiming to accidents' prevention and comprises the gathering and analysis of evidences, in order to determine the causes and, when appropriate, to issue safety recommendations

In accordance with Annex 13 to the International Civil Aviation Organisation Convention (Chicago 1944), EU Regulation Nr. 996/2010 from the European Parliament and Council (20^{th} OCT 2010) and article 11 nº 3 of Decree-Law nº 318/99 (11^{th} AUG 1999), the sole purpose of this investigation is to prevent aviation accidents. It is not the purpose of any such investigation process and the associated investigation report to apportion blame or liability.

TABLE OF CONTENTS

ABBREVIATIONS

AC	Advisory Circular
ACARS	Airborne Communication Addressing and Reporting System
ACMS	Aircraft Condition Monitoring System
ALS	Approach Lighting System
Alt	Altitude
AMJ	Advisory Material Joint
ARFF	Aviation Rescue and Fire Fighting
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ARC	Aviation Rulemaking Committee
ATO	Aviation Training Organization (previously TRTO)
ATOW	Actual Take-off Weight
AZFW	Actual Zero Fuel Weight
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
CAAP	Civil Aviation Advisory Publication
CAR	Civil Aviation Regulation
CAS	Computed Air Speed
CAVOK	Ceiling and Visibility OK
CD	Compact Disc
CG	Centre of Gravity
CL	Climb Thrust
CONF	Configuration
CS	Certification Specifications
CVR	Cockpit Voice Recorder
DAR	Digital ACMS Recorder
DFDR	Digital Flight Data Recorder
DOI	Dry Operating Index
DOW	Dry Operating Weight
EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
ECAM	Electronic Centralised Aircraft Monitor
EAT	Expected Approach Time
ETA	Estimated Time of Arrival
EFB	Electronic Flight Bag

ABBREVIATIONS (continued)

EFIS	Electronic Flight Instrument System
EPR	Engine Pressure Ratio
FAA	Federal Aviation Administration (United States)
FADEC	Full Authority Digital Engine Control
FAST	Fatigue Avoidance Scheduling Tool
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FCU	Flight Control Unit
FDR	Flight Data Recorder
FLEX	Flexible (take-off)
FLTOW	Flex Limiting Take-off Weight
FLX/MCT	FLEX/Maximum Continuous Thrust
FMC	Flight Management Computer
FMGC	Flight Management and Guidance Computer
FMGS	Flight Management and Guidance System
FMS	Flight Management System
FOM	Flight Operations Manual
FRMS	Fatigue Risk Management System
ft	Feet
GPIAA	Air Accident Investigation Board (Portugal)
GW	Gross Weight
GWCG	Gross Weight Centre of Gravity
HF	High Frequency
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
INAC	Portugal Civil Aviation Authority
IRU	Inertial Reference Unit
JAA	Joint Aviation Authorities
JAR	Joint Airworthiness Regulations
JOEB	Joint Operation Evaluation Board
kg	Kilogram
kN	Kilonewton
kts	Knots
LAA	Laboratoire d’Anthropologie Appliquée

ABBREVIATIONS (continued)

LAW	Landing Weight
LPC	Licence Proficiency Check
m	Metres
M	Magnetic
MAC	Mean Aerodynamic Chord
MCDU	Multi-purpose Control and Display Unit
MFF	Mixed Fleet Flying
MSN	Manufacturer Serial Number
MTOW	Maximum Take-off Weight
NASA	National Aeronautics and Space Agency
NLR	Dutch National Aerospace Laboratory
NTSB	National Transportation Safety Board (United States)
OPC	Operator's Proficiency Check
OPT CONF	Optimum Configuration
PDC	Pre-departure Clearance
PF	Pilot Flying
PFD	Primary Flight Display
PIC	Pilot in Command
PM	Pilot Monitoring
POB	Persons on Board
QRH	Quick Reference Handbook
RNAV	Area Navigation
SAE	Society of Automotive Engineers
SFS	Senior Flight Steward
SID	Standard Instrument Departure
SOP	Standard Operating Procedures
TALCA	Take-off and Landing Performance Assessment
THS	Trimable Horizontal Stabiliser
TODC	Take-off Data Calculation
TO/GA	Take-off / Go-around
TOPMS	Take-off Performance Monitoring System
TOS	Take-Off Securing Function
TOW	Take-off Weight T
TRTO	Type Rating Training Organization (recently ATO)

ABBREVIATIONS (continued)

ULR	Ultra Long Range
UTC	Coordinated Universal Time
V1	Decision Speed
V2	Take-off Safety Speed
VHF	Very High Frequency
VLOF	Lift-off Speed
VMU	Minimum Unstick Speed
VR	Rotation Speed
ZFW	Zero Fuel Weight
ZFWCG	Zero Fuel Weight Centre of Gravity

GENERAL INFORMATION

Photo 1: CS-TGU, photo by Andrea Zaratin (planes spotters.net)

Identification number	02/ACCID/2013
Classification	Accident
Date, time[1] of occurrence	02/03/2013, 21:10 hours
Location of occurrence	João Paulo II Airport, Azores
Operator	SATA International
Registration	CS-TGU
Aircraft type	Airbus 310-300
Aircraft category	Twin engine passenger aircraft
Type of flight	Scheduled commercial carrier
Phase of operation	Landing
Damage to aircraft	Substantial tail structure damage
Flight crew	2 + 6
Passengers	17
Injuries	none
Other damage	none
Light and weather conditions	rainy night

The occurrence was initially classified by GPIAA's previous investigation team as an Incident; however, as the aircraft sustained substantial structural damage, the event was reclassified as an Accident. According to ICAO's Annex 13 and to actual incurred damage *the aircraft sustained substantial damage which adversely affected the structural strength, performance and flight characteristics and required major repair and replacement of the affected components*.

[1] All times in this report are UTC times unless otherwise specified

SUMMARY

On 2nd March 2013 an Airbus A310-304 airliner, registration CS-TGU, operated by SATA International, call-sign RZO129 and MSN 0571 was on a scheduled flight from Lisbon to Ponta Delgada in São Miguel Island in the Azores, Portugal. At the destination airport, at around 21:10 UTC, during the flare phase, the aircraft bounced and was taken to a high nose up angle which, in association with compressed main landing gear, caused the tail to contact the runway surface.

According to *VOLMET* information copied by the flight crew at 20:35 (± 35 minutes prior to the event) and subsequently at 21:00 the weather at Ponta Delgada airport was characterised by a scattered sky, light showers of rain, an air temperature of 14 with a dew point of 12ºC and an atmospheric pressure of 997hPa. The main change in the *VOLMET* data was regarding the wind observation as it had varied from 150º at 14 with gusts up to 27kts varying direction between 120º to 180º M to a later direction of 180ºM at 14kts. Despite the angular increase in the tailwind component and even if assigned runway 12, the flight crew elected to land on runway 30, equipped with ILS, considering the tail wind component (7kts) fell within acceptable limits.

INADEQUATE GROUND SPEED DUE TO TAIL WIND EFFECTS NOT DETECTED

It is commonly accepted that errors are possible when calculating take-off and /or approach & landing performance. As a result, flight crews are required to follow SOP that include the completion of various checks following that calculation. It was found that a number of human performance-related factors were combined during the night of this event that rendered the checks ineffective. These factors included interference and the effect of expectation when performing simple number comparisons.

In the investigation procedures GPIAA noted that this tail strike accident was not an isolated event and that there had been numerous incidents and accidents related to erroneous take-off performance and landing parameters prior to March 2013. GPIAA has been examining safety research studies to find out take-off & landing performance calculation and entry errors, which resulted in tail strikes (global perspective reviewing the factors involved in a number of incidents and accidents in the 10 years prior to 2013).

One of these safety studies was carried out by the *Laboratoire d'Anthropologie Appliquée* (on behalf of the *BEA- Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile)*, the French investigation authority. They found out that the manner in which performance calculation errors occurred varied and could be associated with any operator or aircraft type.

GPIAA found that, due to the large variation in take-off and landing weights and performance parameters experienced by any flight crew during normal operations, the take-off performance and /or the landing parameter values were themselves not sufficient to alert the crew to a gross error situation. This inability to make a 'reasonable' check of the performance parameters was also identified in the French study as applying to a much broader pilot group. With many pilots operating a range of transport aircraft in a mixed fleet flying environment, the range of parameters experienced is increasing and, without some guidance on how to manage the consequential loss of a 'reasonableness' check, this issue remains a significant problem for the worldwide fleet.

DEGRADED LANDING PERFORMANCE NOT DETECTED

The flight crew of CS-TGU had planned for a direct approach to runway 30 at PDL although due to the wind, the actual runway in use was 12. The use of the Auto Throttle for landing was done as per operator's SOP (*A/THR retard* mode active around 30 feet). The approach speed, calculated at the TOD (around 30 minutes prior to the ETA) assuming normal operations (within tail wind component limits of 10kts) induced the erroneous performance parameters being undetected throughout the final approach phase (ground speed and tail wind factor). As a result there was nothing to prevent the flight crew from attempting landing using those parameters. The use of the inadequate performance parameters meant that the ground speed was in excess for a safe landing involving a single touchdown. As a result and according to the local tail (and crossed) gusting wind conditions in association with a slightly high descent rate, the flare was done at a fast rate whilst the main landing gear (first right tyre then left) was compressed. The result was a firm landing with spoilers deploying followed by a natural aerodynamic pith up tendency whilst on the bouncing phase.

As the aircraft lost speed and most likely encountered varying decreasing wind intensity added to the pilot's inadvertent fast and accentuated input of pitch up command in the control column all contributed to a dissipation of most of its kinetic energy during the tail strike. The choice of *Auto Brakes to MEDIUM* also decreased substantially the landing distance avoiding the inherent risk of runway excursion and associated consequences.

In this case, the detection of the degraded performance would have required from the Pilot Monitoring both vigilance of the actual and the minimum ground speed during the approach. During any approach phase there are many different *call out* types that the PM is requested to do when observing some clearly defined exceedances. These *call out* are mandatory in all multi crew operation environment and are dictated by most aircraft manufacturers and operators. Of particular relevance to this event is the call out *Speed* (deviation of Vapp+10kts or Vapp-5kts): the speed indication displayed on the PFD consisting of KIAS and not ground speed. As a result, in this event, the excessive ground speed went undetected. The flight crew relied on their *empirical experience* flying with visual references for the landing at night (speed and pitch).

Because the reduced thrust during landing optimises the landing performance for the local runway circumstances and the aircraft's weight, the acceleration for the aircraft can vary with each landing. Due to the variations in runway conditions and weights experienced by flight crews in civil transport operations, that variation can be quite large, and not necessarily directly related to the aircraft's weight. Therefore, flight crews cannot reliably detect on time degraded performance until there is something more obvious happening such as when approaching the touch down zone of a runway. This late perception of the error inhibits most decisions to discontinue the approach at a safe altitude via a go-around procedure (also made more difficult due to time taken for any jet engine to suddenly deliver all power available, *spool up* time).

SAFETY ACTIONS

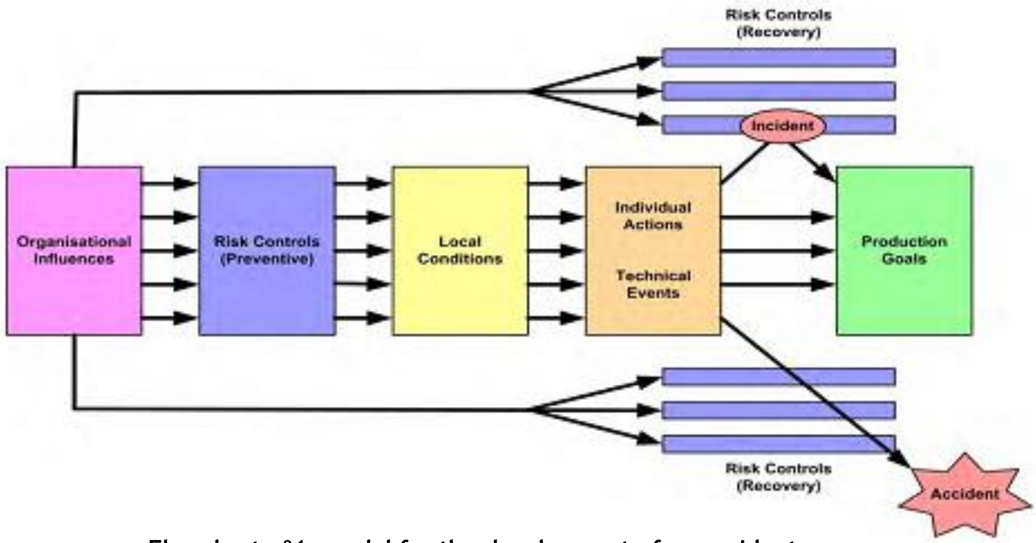
GPIAA has addressed safety recommendations to the Operator SATA International, the Airport management ANA – Aeroportos de Portugal, SA, NAV, I.P and a safety advisory notice to INAC (and the Flight Safety Foundation) in an effort to minimise the likelihood of future similar events.

INVESTIGATION METHODOLOGY

An organisation achieves its production goals through a combination of events and conditions. Different organisations have different production goals, for example, the production goal for a transport operator is the transport of passengers and cargo from one location to another in a safe, efficient manner. In most situations, the production goals will be achieved; however, in some situations various events and conditions combine to produce an occurrence event where the system 'goes off track'. If these events are not prevented by some form of control, an accident can result.

THE GPIAA SAFETY BOARD MODEL

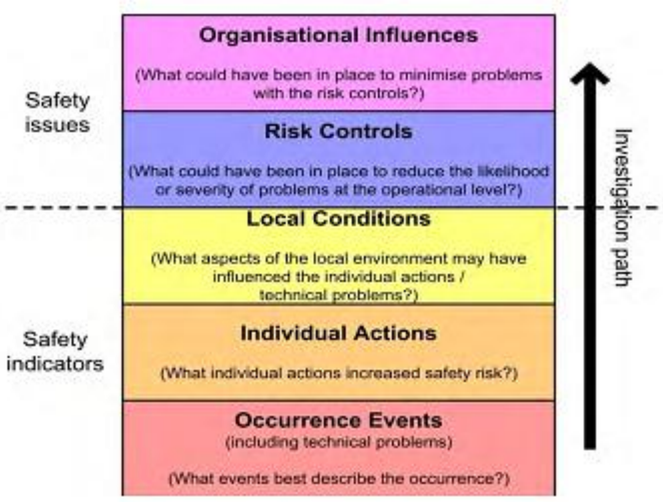
Portugal's Safety Public Body (GPIAA) follows the Reason Model[2] of accident causation. The model (Flowchart nº1) shows the development of incidents (where an unsafe condition developed, but the risk controls returned it to the production goal) and accidents (where the risk controls were ineffective in recovering an unsafe condition).



Flowchart nº1: model for the development of an accident

We know that the model does not attempt to describe all of the complexities involved in the development of an accident, but attempts to provide a general framework to help guide data collection and analysis activities during an investigation.

For analysis purposes, the model adopted by GPIAA for the development of an accident is represented as the GPIAA investigation analysis model (Flowchart nº2). The components of the model can be presented as a series of levels of potential safety factors.



Flowchart nº2: GPIAA investigation analysis model

---

[2] Reason, J. (1990). Human Error. Cambridge University Press, Cambridge, United Kingdom.

From the investigation viewpoint, the most useful way of using the model to identify potential safety factors is to start from the occurrence events and work up to the organisational influences (the investigation path).

The 5 levels of factors in the GPIAA investigation analysis model are defined as follows:

- **Occurrence events** are the key events that describe the occurrence or 'what happened'. Examples include technical failures, loss of aircraft control, breakdown of separation and overrunning the end of the runway, etc…

- **Individual actions** are observable behaviours performed by operational personnel. Such actions can describe how the occurrence events happened. It is widely acknowledged that people make errors every day and that flight crew are no exception. It is more productive to consider actions that increase risk (likelihood and/or level of consequences) as actions that should not occur in similar situations in the future, rather than failures of the individuals involved. Improvements in aviation safety will occur not by focusing solely on eliminating human error and violations, but by also ensuring there are adequate controls in place to ensure that when errors and violations do occur, they do not lead to an accident.

- **Local conditions** are those conditions that exist in the immediate context or environment in which the individual actions or occurrence events occur, and which can have an influence on these actions and events. Local conditions can increase the likelihood of individual actions that increase safety risk. Examples include the nature of the task and the physical environment.

- **Risk controls** are the measures put in place by an organisation to facilitate and assure the safe performance of operational personnel and equipment. The two main types of risk controls are preventive and recovery as follows:

  - ✓ Preventive risk controls are control measures implemented to minimise the likelihood and consequence of undesirable local conditions, individual actions and occurrence events. These controls facilitate and guide performance at the operational level to ensure that individual actions and technical events are conducted effectively, efficiently and safely. Such controls can include procedures, training, equipment design and fatigue risk management systems.

  - ✓ Recovery risk controls are control measures put in place to detect and correct, or otherwise minimise, the adverse effects of local conditions, individual actions and occurrence events. Such 'last line' controls include warning systems, emergency equipment and emergency procedures.

- **Organisational influences** are those conditions that establish, maintain or otherwise influence the effectiveness of an organisation's risk controls. There are two main types of organisational influences: internal organisational conditions and external influences. Those influences are defined as follows:
  - ✓ Internal organisational conditions are the safety management processes and other characteristics of an organisation which influence the effectiveness of its risk controls. Safety management processes include activities such as hazard identification, risk assessment, change management and monitoring of system performance.
  - ✓ External influences are the processes and characteristics of external organisations which influence the effectiveness of an organisation's risk controls and organisational conditions. These influences can include the regulatory standards and surveillance provided by regulatory agencies. It also includes a range of standards and other influences provided by organisations such as industry associations and international standards organisations.

Although some of these factors are associated with the actions of individuals or organisations, it is essential to note that the key objective of a safety investigation is to identify safety issues – that is, the safety factors that can be corrected to enhance the safety of future operations. In accordance with the International Civil Aviation Organization (ICAO) International Standards and Recommended Practices, Annex 13 to the Convention on International Civil Aviation, Aircraft Accident and Incident Investigation; and the European Regulation 996/2010, the objective of accident and incident investigation is to prevent the occurrence of future accidents and not to apportion blame or liability.

FINDINGS

The result of the investigation and analysis is the identification of a set of occurrence findings. Those findings are listed in the Findings section of the report and are defined and categorised as follows:

- **Safety factor**: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (for example, engine failure), individual actions (for example, errors and violations), local conditions, current risk controls and organisational influences.
- **Contributing safety** factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed

- **Other safety factor**: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.
- **Other key finding**: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.
- **Safety issue**: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

SAFETY ISSUE RISK LEVEL AND SAFETY ACTION

The GPIAA assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. GPIAA may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the GPIAA may sometimes issue a safety advisory notice.

The steps taken, or proposed to be taken, by a person, organisation or agency in response to a safety issue is classified as a safety action. The safety actions reported to the GPIAA at the time the report was published are presented in the Safety actions section of the report.

1. FACTUAL INFORMATION

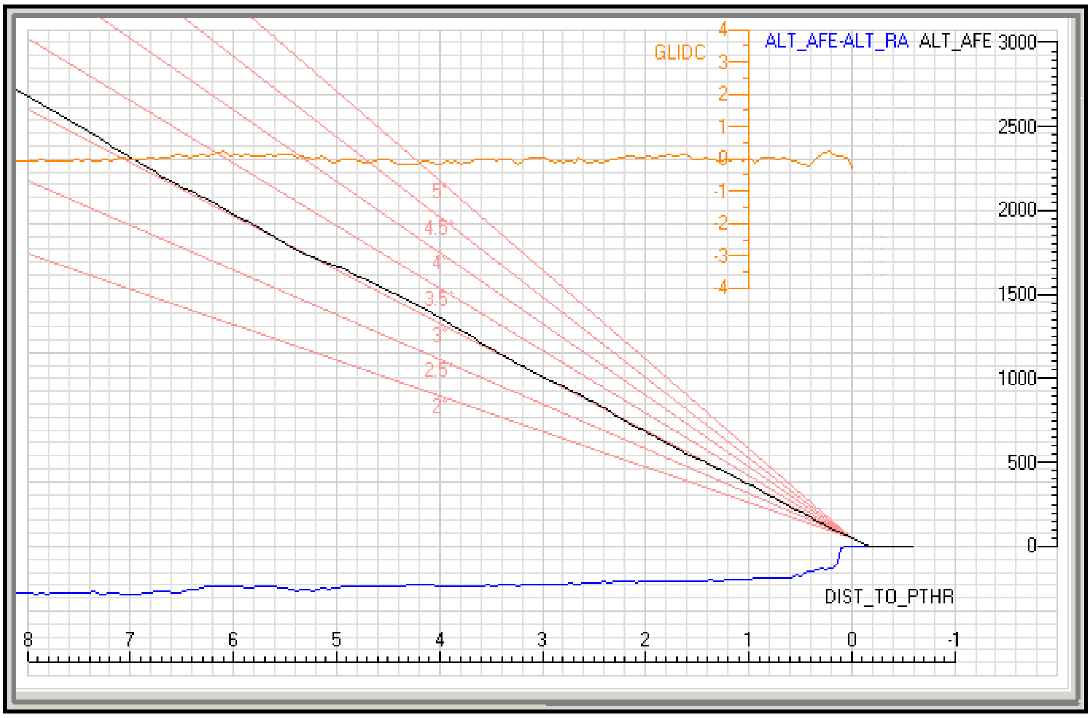
1.1. HISTORY OF THE FLIGHT

The aircraft departed Lisbon airport (LPPT) at 19:06 bound to Ponta Delgada airport (LPPD), in the Azorean island of S. Miguel. 125 people were on board (8 Crew + 117 Pax) with a cargo load of 4591kg and 16150kg of fuel, making an ATOM of 111247kg (for a MTOM of 157000kg). The centre of gravity for take-off was at 27.16, for a limit of 20.0 and 32.15, forward and afterward respectively.

The Copilot (CM2) was assigned as PF for the flight bound to Ponta Delgada whereas the Captain was to be the PF for the returning flight to Lisbon (see *Note* below). Before starting descent, the flight crew copied the VOLMET data (20:35) and kept flying in AP mode with FD engaged and making required selections on FCU.

After an eventless flight of approximately two hours, the aircraft was established on ILS, for landing on runway 30 at LPPD, with a Landing Mass of 103 tons and a Landing MAC of 29.56 for an 18.0 to 34.5 envelope.

Final approach was performed with both APs engaged in *LAND* mode and Auto Throttle engaged on selected *SPEED* mode, being the aircraft stabilized on glide and localizer, with an approach airspeed Vapp of 132Kts, for a Vref of 126kt (Graph nº1).



Graph nº1

By 286ft (Radio Altimeter) APs were disengaged. The aircraft was thereafter flown manually, assisted by the use of FDs and A/THR.

Below 20ft at a slightly high descent rate (2.25º) there was a short flare followed by a light bounce with spoilers extended. The ensuing aircraft´s natural aerodynamic tendency was an increase in the pitch attitude in conjunction with a pulling force exerted on the control column with a high pitch rate (3º/s) and increasing high pitch up attitude (up to 14.82º). This manoeuvre, most likely to avoid a hard nose wheel ground contact, made the tail strike the ground. By the time the main landing gear shock absorbers were fully compressed the aircraft's pitch angle had exceeded the ground/ tail clearance of 13.2º.

The aircraft was taxied to the apron and a maintenance preliminary check performed.

Note: The present investigation team was unable to determine if the flight crew operated according to SOP in the distribution of tasks as PF and PM as well as to establish who was the PF during the approach and landing events due to the missing relevant information from the CVR, communications with ATC and normally available equipment of the A310 (explained in more detail in sections 1.11.1 and 1.9).

1.2. INJURIES

There were no injuries reported (Table nº1).

INJURIES	CREW	PASSENGERS	OTHERS
Fatal	0	0	0
Serious	0	0	0
Minor/None	**0/8**	**0/117**	

Table nº1

1.3. AIRCRAFT DAMAGE

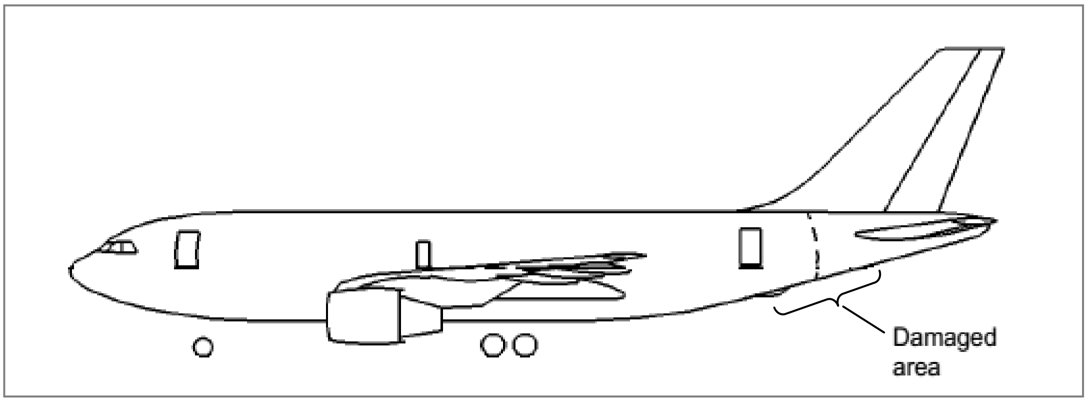
On the preliminary inspection and in accordance with Aircraft Maintenance Manual (AMM 05-51-11 & AMM 05-51-21) the aircraft revealed serious damage[3] to the underside of the rear fuselage (Picture nº1), where the lower skin panels were abraded by contact with the runway surface (Photos nº2, 3). In some areas, the skin was buckled through its full thickness and some vertical struts bent the attachment area in the airframe structure (Photo nº4).

The maintenance personnel reported the following damage:

- Buckled belly skin panel at Fr. 77, between Stgr 54/56 LH & RH and between Fr 75 and Fr 78, between Stgr 44/50 LH & RH;
- Pulled rivets between Stgr 50/47 LH & RH and Stgr 54/56 LH & RH, at Fr 77 and between Stgr 48/50 LH, at Fr 76;

[3] Based on the damage to the aircraft, GPIAA classified this event as an accident. Consistent with the ICAO definition outlined in Annex 13 to the Chicago Convention, an accident is defined in the National Law 318/99 as an investigable matter involving a aircraft where the vehicle is destroyed or seriously damaged, witch needed an important maintenance operation.

- Tail skid wear;
- Galey Drain Mast, forward of Fr 80/82, worn and buckled due to runway contact;
- Fuselage tail section Drain Mast, after of Fr 80/82, worn due to runway contact;
- Fr 77 diagonal struts sheared and vertical struts bent at the attachment area with Fr 77 crossbeam;
- Fr 77 crossbeam buckled at struts attachment area (bent afterwards);
- Fr 77 lower fitting buckled (bent forward with lower flange buckled) at Stgr 48/49 LH & RH;
- Fr 77 shear ties bent at the pulled fastener location referred above;
- Fr 76 shear ties, between Stgr 48/50 LH bent;
- Fr 77 web, at Stgr 42 LH & RH, buckled;
- Struts between Fr 77/78, inboard of Y1137, buckled.



Picture n.º1: Skin abrasion

Photo nº2: View of tail skid shoe and surrounding area damage

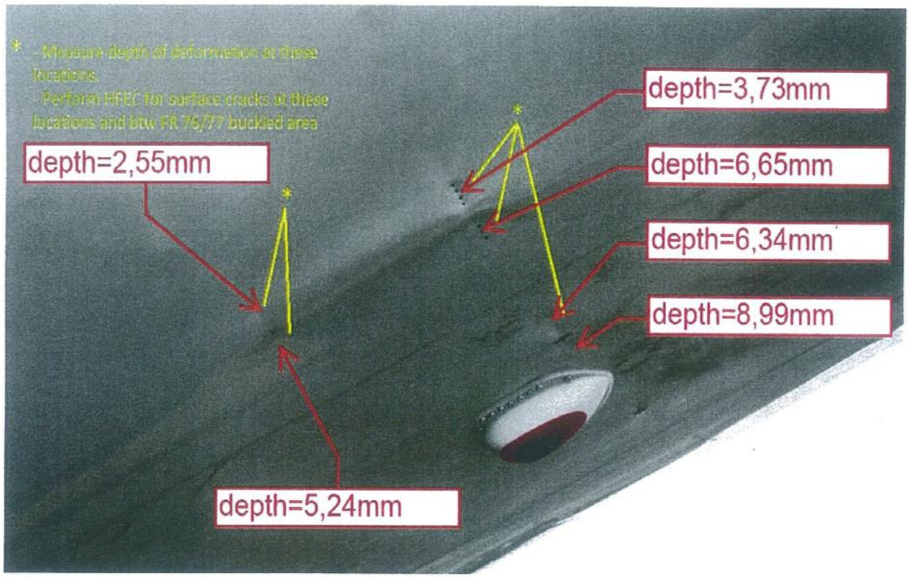


Figure 1

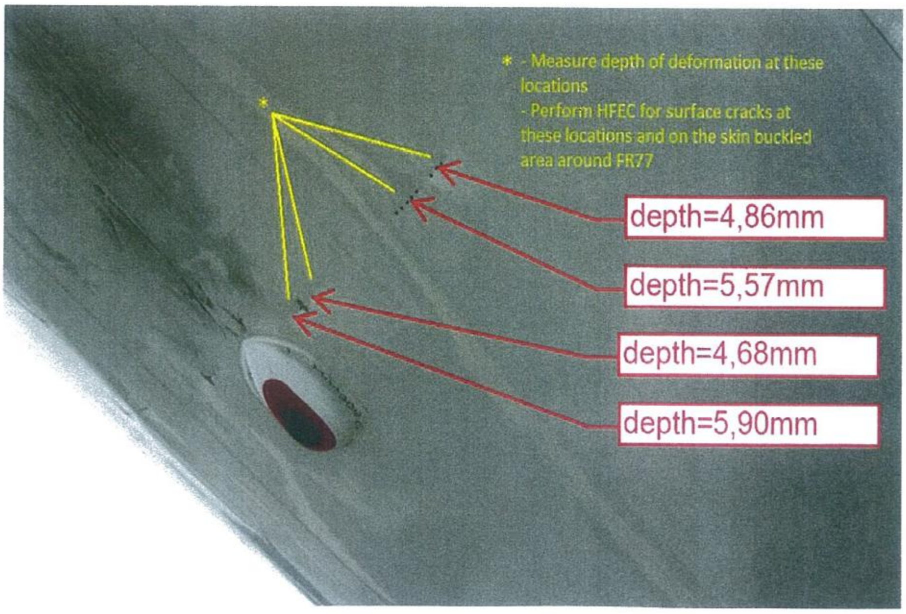


Figure 2

Photo nº3: Detailed analysis of tail skid shoe and surrounding area damage

Photo nº4: Tail internal structure damage

Numerous fuselage frames and stringers in the rear fuselage area were damaged by the abrasion and contact forces during the tail strike. The damaged frames were deformed and several were cracked. The diagonal struts sheared and the vertical struts bent at the attachment area with Fr77. Cross beam buckled at struts attachment area (bent in the Aft direction).

DFDR reading confirmed that a firm landing had occurred. According to maintenance personnel the aircraft had sustained damage beyond the structural repair manual, SRM and as a result was grounded for temporary repair at LPPD. The ferry flight to Lisbon for permanent repair took place on the 24/03/2013. The aircraft was released for flight on the 24/05/2013.

1.4. OTHER DAMAGE

There was no third party damage reported.

1.5. PERSONNEL INFORMATION

1.5.1. OPERATING FLIGHT CREW

The Flight Crew was composed by two pilots (Captain and FO) where their relevant qualifications and aeronautical experience are outlined (Table nº2):

Reference	Captain		F/O	
Personal: Sex:	Male		Female	
Age:	59		42	
Nationality:	Portuguese		Portuguese	
Flight License:	ATPL		ATPL	
Validity:	22-03-2013		16-12-2015	
Ratings:	A310-300/600		A310-300/600	
Last Medical Examination:	05-03-2012		16-11-2012	
Restrictions &/or limitations:	VDL		VDL	
Flight Experience (hours):	**Total**	**On Type**	**Total**	**On Type**
Total:	15 200	5 200	3 527	2 789
Last 90 days:	51:31	51:31	78:28	78:28
Last 4 weeks:	17:12	17:12	17:12	17:12
Last week:	02:25	02:25	02:25	02:25
Last day:	02:25	02:25	02:25	02:25
Flight Duty Time (hours):	**Actual**	**Maximum**	**Actual**	**Maximum**
Annual:	N/A	1 800	N/A	1 800
Last 90 days:	341:13*	480	192:39	480
Last 4 weeks:	138:37	190	48:24	190
Last week:	34:25	55	12:41	55
Last day:	03:25	12	03:25	12
* - Office duty included.				

Table nº 2

Both pilots had their licenses valid and passed the last simulator and line checks. The only limitation affecting the operation was that both pilots were requested to use corrective lenses and should carry a spare pair of spectacles.

Crew resource management

Due to the inability to collect voice data from the CVR, there is no recorded information to determine if crew resource management was in adherence to the company's SOP.

Flight crew alertness and fatigue

Fatigue can be defined as a state of impairment that can include physical and/or mental elements associated with lower alertness and reduced performance. Fatigue can impair individual capability to a level where a person cannot continue to perform tasks safely and/or efficiently.

As stated before, the inability to use recorded communications through the CVR during the last 30 minutes of the flight inhibits a reliable investigation in the determination of fatigue signs (such as silences, yawning, etc…) and also of the flight crew's alertness (interaction between crew members, interaction with ATC, aural warnings from the aircraft, etc…)

1.5.2. CABIN CREW

The cabin crew was composed by a female Purser and five other Cabin Attendants, four Stewardesses and one Steward. All cabin crew were current in respect of the operator's emergency procedures proficiency requirements.

1.6. AIRCRAFT INFORMATION

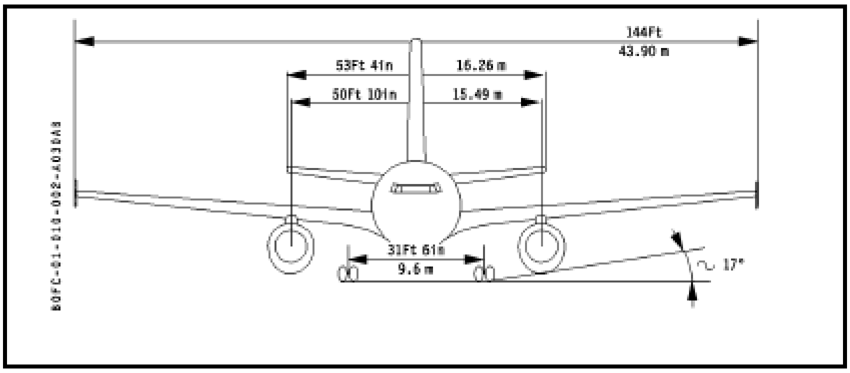
1.6.1. GENERAL

The aircraft is a low-wing, high-capacity transport category aircraft that was manufactured in France in 1991 with the construction number 571 (Picture nº2). The aircraft is equipped with two General Electric CF6 80C2-A2 high-bypass turbofan engines and was configured to seat 222 passengers in a two-class cabin. The aircraft was designed and certified to be operated by two pilots.

The aircraft, Portuguese registration CS-TGU, owned by G.I.E.Tutack and leased and operated by SATA International, with following references (Table nº3):

REFERENCE	AIRFRAME	# 1 ENGINES	# 2
Manufacturer:	Airbus	General Electric	
Model:	A310-304	CF6 80C2-A2	
Serial Nr.:	571	695505	695489
Flight Time:	60612H	52789H	50822H
Landings / Cycles:	20239	17646	16808

Table nº3

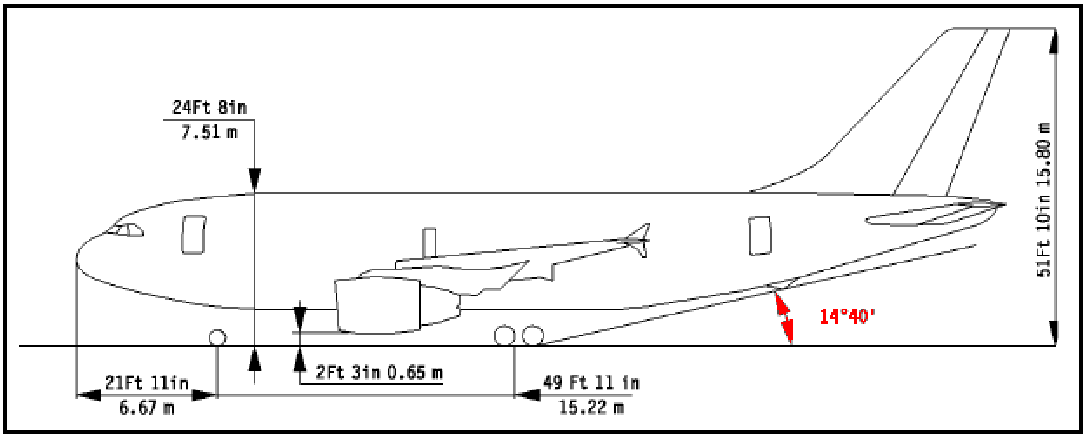


Picture n°2 (A310-300)

Its Airworthiness Certificate, issued by Portuguese Civil Aviation Authority (INAC) was valid until 19-04-2013 and last scheduled inspection had been performed on 01-03-2013 (1 day prior to the event).

1.6.2. AIRCRAFT GEOMETRY

Referring to the Aircraft Flight Crew Operating Manual (FCOM) issued by the manufacturer we find out that the geometry of A310-300, with main gear oleos[4] struts extended allows a 14º 40' clearance for the tail to contact the ground (Picture n°3) decreasing to a 13º with main landing gear shock absorbers fully compressed.



Picture n°3

1.6.3. TAIL STRIKE PROTECTION AND DETECTION

The aircraft had a tailskid shoe to protect the fuselage from damage in the event of a tail strike. Protection against a tail strike was provided by standard operating procedures, reference information and the aircraft's flight control system.

[4] A telescopic shock absorber in an aircraft's landing gear that is used to absorb the vertical energy during landing

Faced with tail strike occurrences Airbus issued FCOM Bulletin nº 08/1 providing additional background information and operational guidelines in order to avoid tail strikes. An extract of FCOM Bulletin Nº 08/01 is shown below (Picture nº4):

A310 / A300-600 FCOM BULLETIN

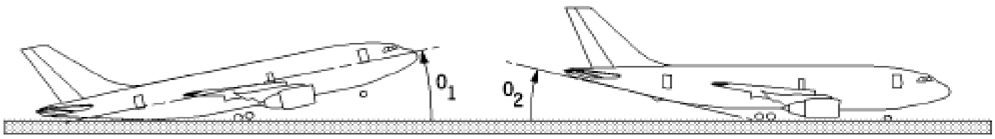
Nº 08/1
DATE : DEC 92
File in FCOM 2.20
Issued by AI/E-VO

SUBJECT Nº 26 : AVOIDING TAIL STRIKES

3.1 Aircraft geometry limits

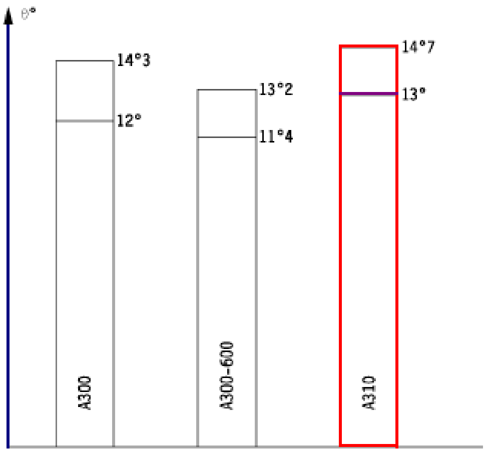
Two pitch attitudes are of primary importance:

- The geometry limit corresponding to main gear oleo fully extended (θ1);
- The geometry limit corresponding to main gear fully compressed (θ2).



MAIN GEAR FULLY OLEO EXTENDED

MAIN GEAR FULLY COMPRESSED



AIRBUS A/C GEOMETRY LIMIT

Touch-down attitude criteria

The following table provides the ground clearance in degrees at landing (all numbers are mean value).

Aircraft	θ max main gear oleo extended	θ APPR (Attitude at VREF (1)	θ Touch Down (Attitude at touch down VREF – 8 kt(2)	Margin (3)
A300	14°3	5°7	10°	4°3
A310	14°7	5°	9°3	5°4
A300-600	13°2 (3)	5°2	9°4	3°8

(1) Flight path in approach = – 3°

(2) Flight path at touch-down = – 1°. Vertical velocity = approximately 3 ft/second.

(3) Margin = θ max- θ touch-down.

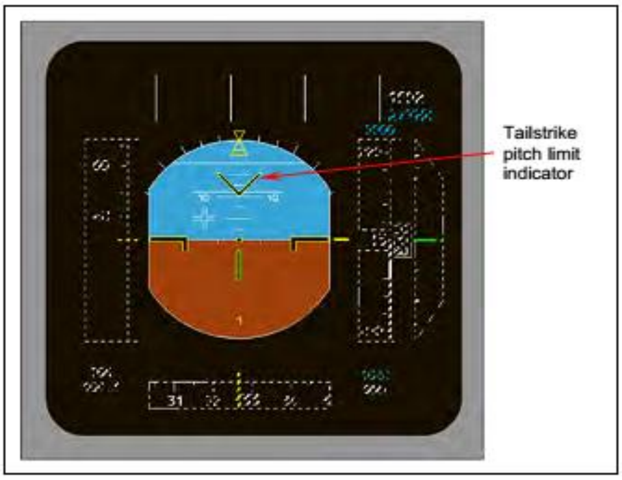
When the approach speed is increased by 5 kt, the margin increases by approximately 1°3 (attitude at touch-down decreased by 1°3).

We may conclude that tail strikes are mainly a function of landing attitude θ1. But rate of rotation and the indicated airspeed have also to be considered.

Picture nº4

Tail strike pitch limit indicator (not available on this aircraft)

Airbus has implemented a Tail strike pitch limit indicator (Picture nº5). It is displayed on the PFD during take-off and landing. The pitch limit indicator is in the form of a 'V' symbol the lower point of which represents the maximum pitch attitude attainable on the ground without striking the tail. During touchdown, the indicator progresses from the pitch limit value with the main landing oleos fully extended, to the pitch limit value with the main landing gear oleos compressed. The indication automatically disappears from the PFD 3 seconds after landing, when the risk of a tail strike is considered to be no longer present.

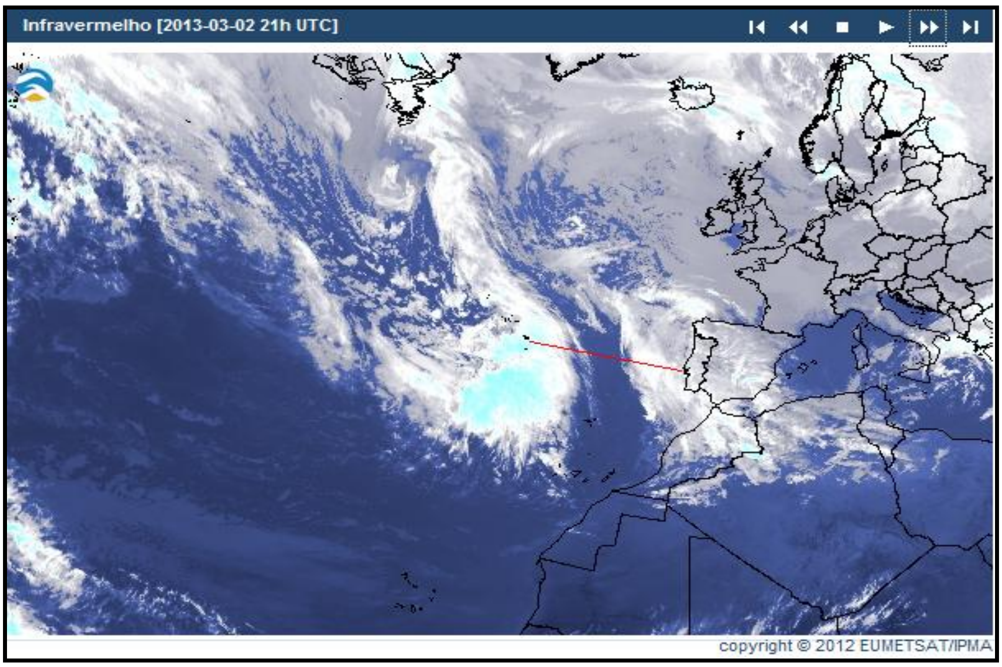


Picture nº5

Note: example shown for illustration only. Equipment is not available on this aircraft.

1.7. METEOROLOGY

The flight crew reported no significant weather enroute (Picture nº6).



Picture nº6

At destination, the sky was scattered with cloud layers at 1500ft and 3000ft bases, with light showers of rain and moderate to strong Southerly winds. Meteorological reports for Ponta Delgada airport, issued by Meteo Office and available to the crew via ACARS showed no significant variation during the flight period, as reproduced bellow:

METAR LPPD 021900Z 17013KT 9999 SCT020 15/12 Q0999
METAR LPPD 021930Z 17012KT 130V200 9999 SCT018 15/12 Q0998
METAR LPPD 022000Z 15012KT 9999 SCT018 15/13 Q0998
METAR LPPD 022030Z 15014KT 9999 -SHRA SCT016 14/12 Q0997
METAR LPPD 022100Z 17013KT 9999 -SHRA SCT015 SCT030 13/12 Q0997
METAR LPPD 022130Z 16015KT 130V190 9999 -RA FEW010 SCT020 BKN035 13/12 Q0995

The approach and landing were conducted in darkness with no moonlight. The captain reported landing with rain showers and that it was dark due to the lack of lighting in the surrounding area of runway 30.

1.8. NAVIGATION AIDS

All navigation aids were operating normally. The flight crew members were using visual references for the landing in accordance with standard operating procedures, independent of any ground-based navigation aids.

1.9. COMMUNICATIONS

Communications with ATC were primarily done through VHF radio with both Ponta Delgada approach and tower using separate VHF frequencies. The aircraft was also equipped with ACARS. The current investigation team was unable to determine the communications established between LPPD Approach and Tower and the flight crew as the recordings were not requested by the previous investigation team within due delay.

1.9.1. COMMUNICATION WITH PASSENGERS

The captain did not address nor ask cabin crew to address the passengers via the interphone system.

1.10. AIRPORT INFORMATION

Ponta Delgada Airport (LPPD) is classified as an International airport and is provided with all the equipment and services related to its category as specified on Portuguese AIP (Aeronautical Information Publication). There´s only one landing strip oriented on 120º / 300º magnetic with designated runways 12 and 30 respectively at a mean altitude of 260ft above sea level and a high slope terrain all around to the North, Northwest and Northeast recommending all takeoff and go-around manoeuvers on runway 30 to be executed to the left (Chart nº2 and Appendix C).

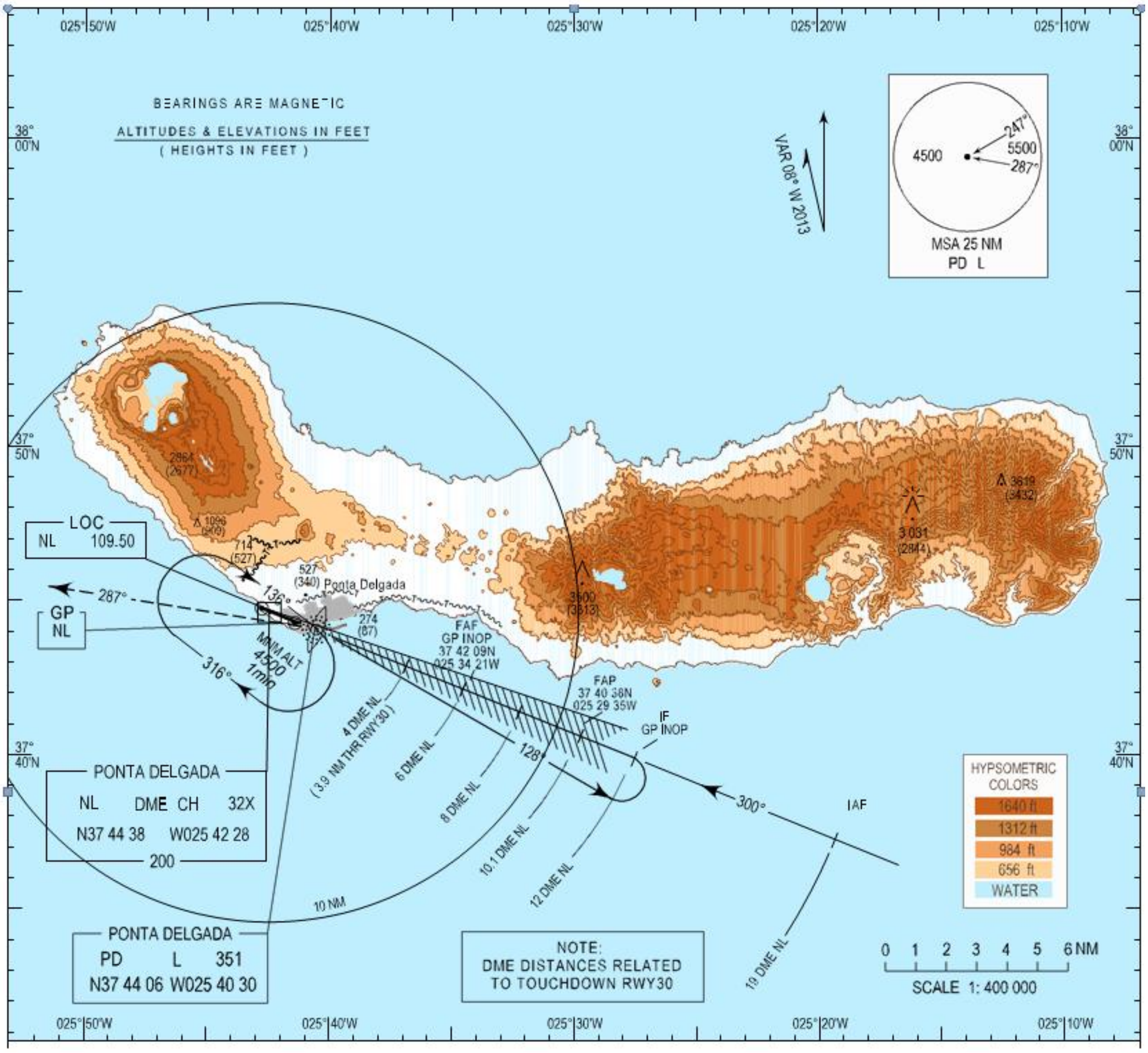


Chart nº2

As specified at the time in the Flight Procedures chapter 2.22 of the AIP: *Ground rises significantly to the Northwest of the strip, especially on the Runway 30 extended centerline sector. Pilots must take special caution on the visual Approach (right hand) circuit to RWY12 and on missed approach and take-off from RWY30.*

By June 2013 additional signaling terrain lighting was installed and the appropriate information published on the AIP (27-JUN-2013) in the Visual Approach Chart and under the Chapter 2.23 *Additional Information: a set of 8 aligned high intensity Type A and non-sequential flashing lights, spaced 60M, located 600M from THR 12 and 2200 left side of extended center line installed to identify natural obstacle (Coast) proximity during RWY12 approach operations (see Chart nº3)*

Chart nº3

This terrain configuration is prone to develop vertical currents and wind shear especially with strong Southerly or Easterly winds.

1.10.1. RUNWAY

Ponta Delgada airport has one runway oriented 120 and 300 º M: runway 12/30 (Photo nº5)

Photo nº5

Runway 30 with a landing distance available (LDA) of 2248m (7345ft) is served by an ILS with Localizer course 301ºM and a 3º Glide Slope. Additionally a 3º PAPI lighting system grants visual slope indication. There's a displaced threshold of 240m from beginning of surfaced area and a runway slope of +1.2 %.

Final approach path is over the sea until last 1300m, which is flown over Southwest outskirts of the city (Photo nº6).

Photo nº6

On short final, terrain altitude changes from 88ft to 165ft in a horizontal distance of less than 100m, which causes a sudden change on RA readings. This elevation change is the main reason for threshold displacement and restriction on automatic ILS approaches.

1.10.2. LIGHTING

The taxiway, runway edge and centerline lighting was in accordance with the applicable ICAO standard[5] (Chart nº4). The runway centerline lights are in accordance with the publication in the AIP. The runway centerline lights are white until 900 m from the end of the runway. From 900 m up to 300 m from the end of the runway, the lights alternate to red and white, and the final 300 m of the runway centerline lighting is red. The runway edge lights spacing 60 m in the last 600m are yellow with the runway end lights being red. Other than the apron areas immediately around the terminal facilities, the airport was not provided with general area lighting, nor was it required to be.

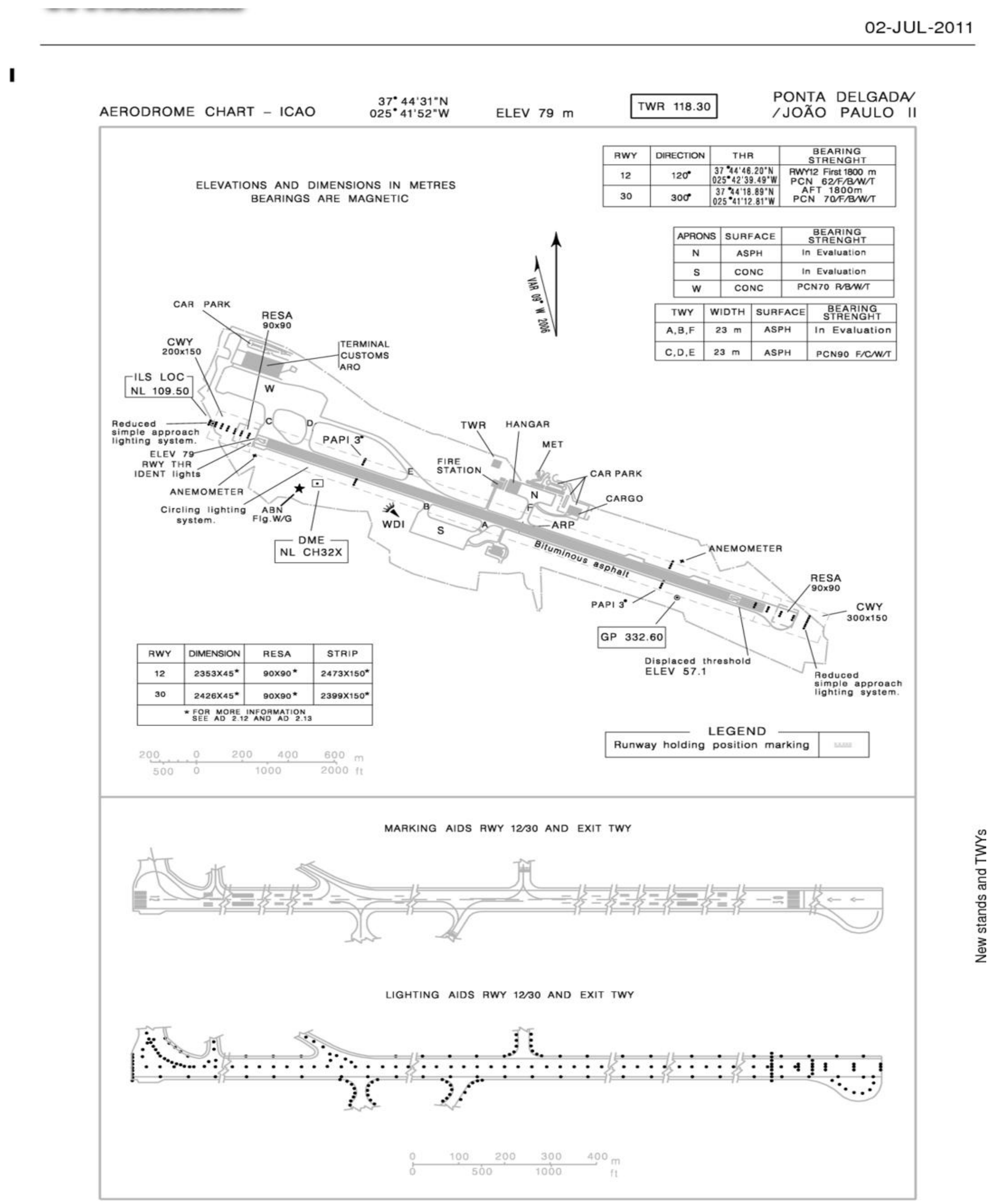


Chart nº4

[5] ICAO Annex 14, Aerodromes, Volume 1, Aerodrome and Operations, 6th edition.

1.11. FLIGHT RECORDERS

The aircraft was equipped with three flight recorders as follows, which were retrieved from the aircraft for download and analysis:

- Cockpit voice recorder (CVR)
- Flight data recorder (FDR)
- Digital ACMS[6] recorder (DAR).

The installation of a FDR and CVR was mandatory for this aircraft and the audio recorded on the CVR (30 minutes) and parameters recorded on the FDR were defined by regulation. The recorded flight and audio data was stored within the crash-protected memory modules of these two recorders.

The DAR was an optional recorder that was used for flight data and aircraft system monitoring as stipulated by the operator's requirements. The DAR parameters included most of the FDR parameters, with additional parameters as configured by the operator. The information recorded on the DAR was stored on a removable memory card that was not crash-protected. A graphical representation of relevant information of the landing obtained from the DAR is presented in section 1.11.2.

1.11.1. COCKPIT VOICE RECORDER (CVR)

The CVR a Fairchild model A 100 A, P/N 93-A 100-80 was left running after arrival and flight recordings were lost. Only post-flight crew and ground staff conversation was available which was not relevant for the investigation.

Whenever a cockpit voice recorder (CVR) is not secured after an occurrence, information relevant to an investigation is lost and the identification of safety deficiencies and the development of safety messages are impeded.

Guidance in the specific use of CVR following an incident or an accident are to be implemented as safety recommendation considering the pulling of the CVR/FDR's circuit breaker by the flight crew.

1.11.2. DIGITAL ACCESS RECORDER (DAR)

DAR was downloaded and decoded under Line Operation Monitoring System (LOMS) program. Subsequently the operator's safety department analyzed the data for flight deviations especially during the approach and landing phases.

During the landing phase seven events of different risk classifications were recorded, as per company set parameters (Picture nº7):

[6] Aircraft condition monitoring system.

Evt Num	Time	Description	Unit	Low	Med	High
1405	21:09:56	High rate of descent below 20ft AFE	ALT_AFE<=20ft, Slo	2.25 De	2.65 De	3 Deg
1819	21:09:59	Short flare	Time from 30ft to Tou	5	4	3
1033	21:09:59	Significant tail wind at landing	Average tail wind (fr	8 kts	11 kts	15 kts
1504	21:10:01	High acceleration at touch down	Max VTRG >=	1.5 g	1.6 g	1.75 g
1906	21:10:02	Bounced landing		Bounce	|IVVC| >	|IVVC| >
1111	21:10:02	High pitch rate at landing	Max PITCH_RATE>=	2 °/s	2.5 °/s	3 °/s
1108	21:10:03	Pitch high at touchdown	At touch down, max	9.7 °	10.7 °	11.7 °

Picture n°7

As mentioned before the critical phase was landing phase from 21:09:53 onwards. Immediately before, the aircraft was on landing configuration and stabilized on heading, speed and rate of descent, until reaching ≠80ft (RA) at 21:09:51. Flare started at 21:09:56/57, at <30ft and 132kt (CAS), with touchdown occurring at 21:10:00 (Table n°4).

Time (hh:mm:ss)	RALT1 (ft)	CAS (kt)	GS (kt)	AOA (°)	Pitch (°)	Heading (M°)	Roll (°)	IVVS (ft/m)	VRTG (g)
21:09:51	84	131.5	144	6.78629	2.82353	294.54	-1.408	-565.51	1.02201
21:09:52	68	132.25	-	6.36593	3.17647	294.18	-0.352	-628.12	1.07696
21:09:53	56	133	-	7.20665	4.23529	294.54	-1.056	-742.81	1.06780
21:09:54	44	132	143	8.25755	-	294.18	-	-738.84	1.05864
21:09:55	32	130.75	-	6.78629	3.88235	-	-	-730.35	1.08611
21:09:56	20	132.25	-	8.04737	4.94118	294.54	-3.872	-657.60	1.12274
21:09:57	12	131.75	142	7.83719	-	295.94	-2.112	-499.64	1.11359
21:09:58	4	130.75	-	7.62701	5.29412	297.35	2.112	-330.00	1.03117
21:09:59	2	127.50	141	7.41683	6.70588	298.76	3.168	-150.00	1.47987
21:10:00	**0**	125.25	140	**6.15575**	**5.64706**	**299.46**	**0.352**	**-060.00**	**0.98538**
21:10:01	**-2**	126.39	138	5.52521	-	-	1.056	-	**1.56229**
21:10:02	-4	124.39	136	9.09826	12.35294	299.11	0.352	-030.00	0.97623
21:10:03	-	122.39	134	**14.77311**	**14.82353**	298.76	-0.704	**0**	1.30589
21:10:04	-	120.39	131	14.14258	12	-	1.760	-030.00	1.07696
21:10:05	-	117.39	127	10.56952	7.41177	-	0.704	0	1.12274
21:10:06	-	113.39	120	3.00305	0	299.46	0	-	1.22347
21:10:07	-	106.39	113	-0.14964	4.94118	-	-	-	1.10443
21:10:08	-	99.39	110	5.73539	3.17647	-	-	-	1.38830
21:10:09	-	96.39	100	-4.14305	1.76471	300.17	-0.352	-	1.34252
21:10:10	-	86.39	96	2.16234	0.35294	300.52	-0.704	-	1.44324

Table n°4

There was a firm landing with bounce followed by an increase in pitch of 14.82° and respective AOA of 14.77°. This attitude being well above the aircraft's limit for compressed landing gear struts (13°) caused the tail to strike the runway tarmac on the second touchdown (21:10:03).

1.11.3. DIGITAL FLIGHT DATA RECORDER (DFDR)

DFDR Sundstrand P/N 980-4100-DXUN was removed and raw data sent to Airbus for decoding. Based on this Airbus issued the respective report where decoded data was presented and flight progress analysed with special emphasis to the landing phase. Having DFDR data as reference we will follow Airbus report findings (wind information on Diagram nº1 and DFDR extract in Graph nº2).

WIND INFORMATION

Between 500ft RA (GMT 21:09:36) and 200ft RA (GMT 21:09:53), wind information coming from IRU recorded on DFDR is as follows:

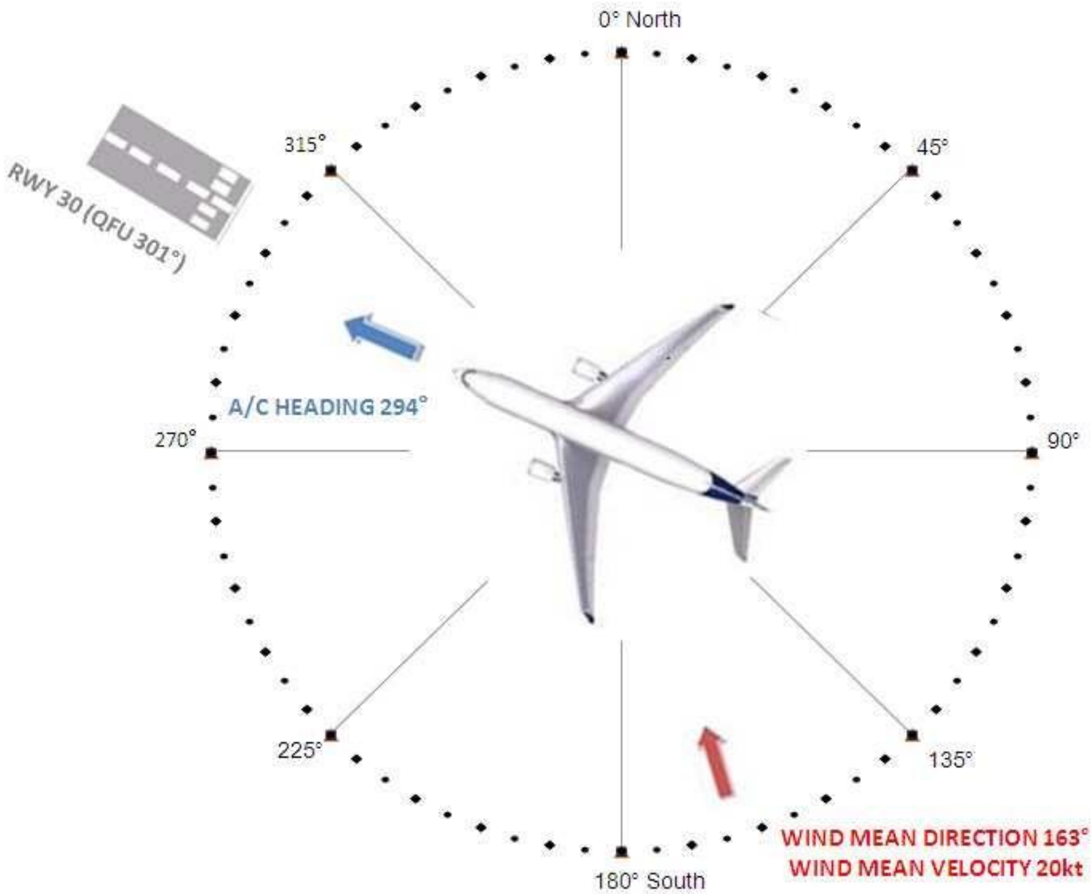
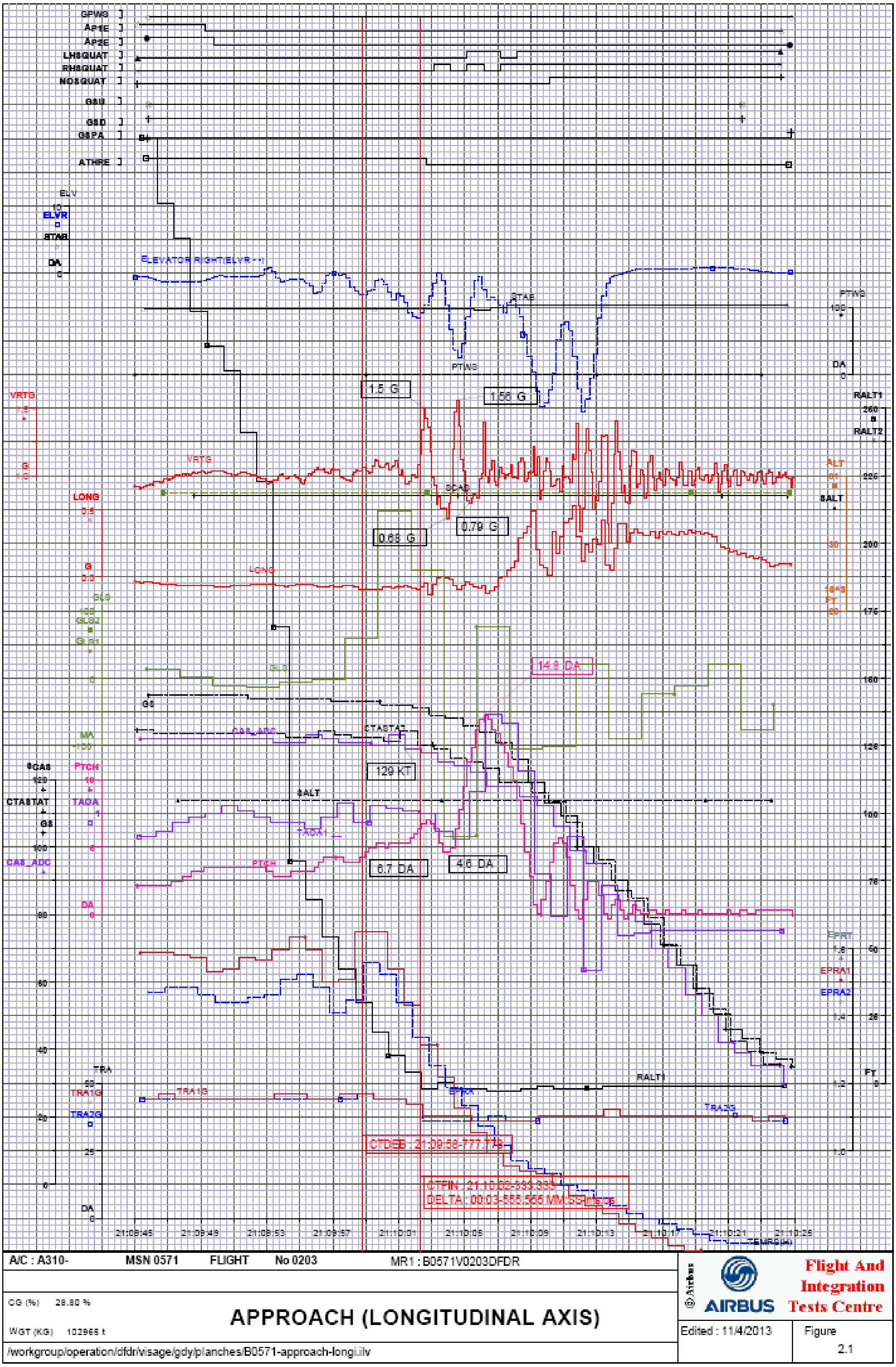


Diagram nº1

Analysis: Wind recorded by DFDR highlights a mean wind direction of 163° at 20kt (tailwind component: 13 kt, left crosswind component: 15kt) consistent with METAR data (170°/13kt).


A/C : A310-
MSN 0571
FLIGHT
No 0203
MR1 : B0571V0203DFDR
CG (%) 28.80 %
WGT (KG) 102965 t
APPROACH (LONGITUDINAL AXIS)
/workgroup/operation/dfdr/visage/gdy/planches/B0571-approach-longi.ilv
AIRBUS
Flight And Integration Tests Centre
Edited : 11/4/2013
Figure 2.1
1.5 G
1.56 G
0.68 G
0.79 G
14.8 DA
129 KT
6.7 DA
4.6 DA
CTDEB : 21:09:58-777.778
CTFIN : 21:10:02-333.333
DELTA : 00:03-555.555 MM:SS

Graph n°2

The approach phase showed no significant deviations from a normal profile. Airbus focused on the last seconds of the flight as there was the presence of a 14.6kts tail and 15kts left cross wind component, considering five significant moments.

A transcription of Airbus' report is presented below for the several phases of the landing event with no additional comments.

1.11.3.1. FLARE PHASE

► Between 30ft RA (GMT 21:09:58) and touchdown (GMT 21:10:02)

- Elevators upwards deflection increases to -3.3°, and then decreases briefly to -1.0° before increasing to -6.6°.
  - Aircraft pitch angle reaches about +5.3° and remains stable during ~2s, then increases to +6.7°.
  - Vertical load factor increases from +0.94g to +1.12g.
- CAS reaches 133kt then decreases to 129kt (=Vref+2kt) at touchdown.
- At 20ft RA, left aileron is recorded at +9.9° (downwards) and right aileron at +1.0° (upwards).
- From 10ft RA to touchdown, left aileron is recorded at -3.3° (upwards) and right aileron at +12.2° (downwards).
- Roll angle varies from -3.9° (left wing down) to + 3.2° (right wing down).
- Rudder deflection varies between -3.6° (rightwards) and +1.0° (leftwards).
- Heading increases from 294° to 298° (QFU 301°).
- No significant lateral load factor variations are recorded.
- A/THR "RETARD" mode engages around 30ft RA (GMT 21:09:59) -> throttles levers are set on "IDLE".

Analysis:
As control wheel and column are not recorded by this DFDR, flare was estimated to occur at around 30ft RA with regard to elevators deflections and VRTG increase. CAS slowly decreased from 133kt to 129kt (=Vref+2kt) at touchdown.
On lateral axis, roll angle moved from -3.9° (left wing down) to +3.2° (right wing down) just before touchdown. According to ailerons deflection, roll was commanded through control wheel (not recorded on DFDR).

1.11.3.2. 1ST TOUCHDOWN

► At GMT 21:10:02: first touchdown

- Aircraft touches down a first time on right then left main landing gear with:
  - +6.7° of pitch angle.
  - -8ft/s (+/-2ft/s) of recalculated aircraft vertical speed.
  - +1.50g of vertical load factor (delta 0.51g).
  - +3.2° of roll angle (right wing down).
  - 298° of heading (QFU 301°).
  - +2° of drift angle (aircraft nose towards the left of the track).
  - +0.05g (rightwards) of lateral load factor.
  - CAS 129kt.
- Right MLG is recorded compressed.
- A/THR disengages.

Analysis:
The sampling rate of "LHSQUAT/RHSQUAT" Booleans recorded at 1 point per second does not allow confirming the sequence of touchdown. Nevertheless according to VRTG peak at

+1.50g, first touchdown occurred at GMT 21:10:02. According to the roll angle recorded at touchdown (+3.2° right wing down), right MLG touched down first. Due to sampling rate, left MLG was not recorded compressed. However, with regards to ground spoilers' extension logic, left main landing gear touched down shortly after the right main landing gear leading to the ground spoilers' extension.

1.11.3.3. LIGHT BOUNCE

► Between GMT 21:10:03 and GMT 21:10:04: light bounce

- Ground spoilers are extending.
- Vertical load factor decreases to +0.68g.
- Elevators deflection increases to +0.1° (downwards) then decreases to -12.6° (upwards).
- Pitch angle decreases to +4.6° then quickly increases.
- Roll angle decreases to 0° then increases to +1.8° (right wing down).
- Right MLG is recorded uncompressed during 1 sample.

Analysis:
The significant elevators deflection recorded during the bounce highlights a commanded pitch up order. Associated with the ground spoilers' extension (nose-up natural effect), aircraft pitch angle increased accordingly.

1.11.3.4. 2nd TOUCHDOWN

► At GMT 21:10:05: second touchdown

- Aircraft touches down a second time on right then left main landing gear with:
  - -12.6° (upwards) of elevators deflection.
  - +6.3° of pitch angle quickly increasing.
  - +1.56g of vertical load factor.
  - +1.8° of roll angle (right wing down).
  - 299° of heading (QFU 301°).
  - +2.1° of drift angle (aircraft nose towards the left of the track).
  - +0.13g (rightwards) of lateral load factor.
  - CAS 124kt.
- Both main landing gears are recorded compressed.

Analysis:
The significant elevators deflection (-12.6°) reached during the second touchdown led to increase the aircraft pitch angle.
According to VRTG peak at +1.56g, second touchdown occurred at GMT 21:10:05.
According to roll angle recorded at touchdown (+1.8°), right MLG probably touched down first followed by left MLG.

1.11.3.5. TAIL STRIKE

► At GMT 21:10:06

- Elevators deflection decreases to -0.6° (upwards).
- Aircraft pitch angle reaches +14.8° (>13.2° clearance pitch up value with shock absorber fully compressed).
- Roll angle is -0.7° (left wing down).
- Right MLG is recorded uncompressed during 1 sample.
- Vertical load factor decreases to +0.79g then increases to +1.40g.

Analysis:
After a stabilized approach, aircraft firmly touched down then lightly bounced while a significant pitch-up order was commanded.

According to the "Ground clearance diagram" (FCOM 2.03.22 p.4 extract hereafter), the ground contact of tail skid probably occurred when pitch angle reached +14.8° (with shock absorber compressed and roll angle at -0.7°) and vertical load factor reached +1.40g.

1.12. WRECKAGE & IMPACT

The airport services inspected the runway of LPPD. No Foreign Object Debris was found. The event took place during a rainy night making the finding of evidence (marks on the runway) difficult.

1.13. MEDICAL OR PATHOLOGICAL

No medical or toxicological tests were conducted.

1.14. FIRE

There was no fire.

1.15. SURVIVAL ASPECTS

There was no need for a rescue operation.

1.16. TESTS & RESEARCH

Research was centered on DAR and DFDR study and analysis. Even if registered parameters were not the same and not all of them were received from the same source, the comparison revealed almost the same sequence of facts with a slight time difference. Hence the same conclusions were extracted from both sources.

The inadvertent use of erroneous take-off and landing data for performance calculations and subsequent takeoffs or landings has been the subject of two research studies, one by the Laboratoire d'Anthropologie Appliquée (LAA) and the other by the Australian Transport Safety Bureau (ATSB). Both studies highlighted the widespread, systemic nature of this issue, with the ATSB paper identifying 31 occurrences within a 20-year period. In addition, the studies offered considerable insight into the factors influencing the use of erroneous data for take-off and landing. These studies were used by GPIAA to conduct a more targeted comparison between similar and the accident flight events.

It is probable that the calculation of erroneous take-off and landing data is a larger problem than the research paper could determine, because in most cases the defences caught the error before an adverse outcome, such as a tail strike.

The research report found that the types of errors had multiple origins and involved a range of devices and systems. For example, crew actions could result in the wrong figure being used in a system, in data being entered incorrectly, data not being updated and data being excluded in a range of systems including performance documentation, laptop computers, FMS and aircraft communications addressing and reporting systems.

The occurrences reviewed indicated the systemic nature of the problem, and the fact that it manifests irrespective of location, aircraft type, operator, and flight crew. In some cases, the errors were by dispatchers situated away from the cockpit, thereby removing the error origin from the cockpit entirely.

The report highlighted the varied factors contributing to the use of erroneous take-off and landing performance parameters, including distraction and task experience, as well as some of the challenges in identifying these errors, such as ineffective procedures and the design of automated systems. It was found that robust defences are needed to help detect and prevent these errors.

1.17. ORGANIZATIONAL & MANAGEMENT - SATA INTERNATIONAL -

The operator is a passenger's transport airline and holds an Air Operator Certificate (AOC) issued by the Portuguese Civil Aviation Authority INAC. SATA International is certified for both scheduled and unscheduled flights and is also a certified Approved Training Organization ATO (previously TRTO) responsible for all flight crew training and qualification.

Flight Crew Qualification and Training programmes are accredited and certified by INAC and comply with Airbus' FCTM.

Both pilots followed company qualification and training courses and had passed their LPCs and OPCs. They had received training on bounce recovery and tail strike avoidance procedures as established on the Flight Simulator training program and manufacturer training recommendations. Flight operation briefing notes and other safety related publications were also issued.

All flight crew members have access and are familiarized with Airbus issued FCOMs, FCTMs, FCOM Bulletins and FOBNs where relevant information and recommended procedures regarding “Landing Flare”, “Bounce at Landing” and “Avoiding Tail Strike” are referred to. Company's SOPs covered all this information and are reflected in all phases of flight defined standard procedures.

1.18. ADDITIONAL INFORMATION

GPIAA did not travel to the place of the event.

1.19. SPECIAL INVESTIGATION TECHNIQUES

No special investigation techniques were used during this investigation process.

2. ANALYSIS

GENERAL INFORMATION: OPERATOR'S RISK CONTROLS

The operator has SOP and training in place for flight crew covering the approach and landing preparation. The operator's documentation, training, and SOP are summarised in this section to provide a background in the systems that were in place for the approach phase of flight and what was required from the flight crew. Particular emphasis is placed on the landing performance calculation.

OPERATIONAL DOCUMENTS PROVIDED TO THE FLIGHT CREW

The operator issued flight crew with copies of the relevant operational documentation for planning purposes. That documentation was provided in a paper format on a single compact hard cover manual which contained information on all of the operator's aircraft types (Airbus A310-300, A320) and included the following manuals:

- FOMs: the FOMs contained general company policies and procedures applicable to the entire fleet, in compliance with the current countries Civil Aviation Authority (INAC) Operations Specifications.
- FCOMs for the Airbus A310 aircraft. The FCOMs are operational documents within part of the Operations Manual. The FCOMs are divided into four volumes and contain information about the aircraft systems, performance, loading data, standard operating procedures, supplementary operational information and an FMGS guide. The aircraft's specific Quick Reference Handbook (QRH), which contains some specific procedures not displayed on the ECAM, is considered to be part of each aircraft type's FCOMs.
- Operations Manual, Part C, which contains specific instructions and information pertaining to navigation, communications, and aerodromes within the operator's area of operation.
- Operations Manual, Part D, which contains information about the operator's training and checking organisation.
- A310-300 Flight Crew Training Manual (FCTM), which is published as a supplement to the FCOMs. The FCTM is intended to provide pilots with practical information on how to operate the aircraft. The FCTM is intended to be read in conjunction with the applicable FCOM and, if there is any conflicting information, the FCOM is the overriding reference.

Aircraft manufacturers have more recently made available these and other relevant documents in a digital mode via portable computers, also known as EFB. This Electronic Flight Bag data is not available for this aircraft.

DESCENT PREPARATION

Landing data preparation

Standard operating procedures covering the calculation of landing performance including the use of the SOP are contemplated in the descent checklist and in the sections of the operator's A310-300 FCOM.

The FCTM, Supplementary Normal Operations, provides additional information about landing performance calculation and task sharing including flight crew duties and a flowchart of the landing performance calculation and data entry process.

Overview of the operator's landing performance calculation procedures

The procedures for calculating the landing performance parameters that were specified in the Cockpit Preparation subsection of the FCOM were presented in textual format, as shown in the copies of relevant sections provided in Appendix A. The investigation examined the procedures and compiled them into a process flowchart format to assist in the understanding of the information flow. The relevant tasks are presented in Appendix B with some explanation of the important aspects.

Although SOP are normally presented in operational documents in a sequential manner in the operating environment, many of them can often be carried out in parallel or in a different order depending on the flow of information present in the cockpit.

Last minute changes

During normal operations small changes in the aircraft's weight and balance known as *last minute changes*, may occur shortly before departure. These changes may be due to a variety of reasons such as late passenger arrivals. In order for the flight not to be unnecessarily delayed, the operator allows the flight crew to make minor alterations to the weight and balance information on the load sheet without the need to issue a new load sheet. The load sheet of the aircraft contemplated no *last minute change* departing from Lisbon airport.

To maintain control over the aircraft's weight, and to ensure that the center of gravity limits are not exceeded, the operator's restriction on *last minute changes* for the A310-300 is of 500 kg as per FOM Handling Operations.

Overview on distraction management

The Crew Resource Management Manual addresses the concept of "*distraction and its management*" stating some techniques to improve situational awareness. As stated crews should:

"Develop a plan and assign responsibilities for handling problems and distractions."

The FOM did contain a section on crew cooperation within the section of flight crew duties and responsibilities. That section noted amongst other things that all flight crew shall:

"Co-operate with all other personnel involved with the actual flight, such as the ground staff, in order to comply with the Company operating policy."

There were no items in the training syllabus that related to the flight crew's management of distraction.

Fatigue management

The EASA (and INAC CIA 05/2010) specify the approved flight and duty time limitations of flight crew also reproduced in the operator's FOM. At the beginning of the duty period relevant to the event none of the flight crew members had exceeded the 100 hours flight time in the 28-day period.

GENERAL INFORMATION ON HUMAN FACTORS

Human factor is the multi-disciplinary science that applies knowledge about the capabilities and limitations of human performance to all aspects of the design, operation and maintenance of products and systems. It considers the effects of physical, psychological and environmental factors on human performance in different task environments, including the role of human operators in complex systems. The following information is intended to provide a context for the actions of the flight crew, and factors affecting them, on the night of the accident.

Error formation

Human error has been defined as 'the failure of planned actions to achieve their desired ends – without the intervention of some unforeseeable event[7]. The following sections describe how human errors can be formed and what contributes to their progression through the systems intended to capture them.

Data entry and transposition errors

A common type of data entry error is known as a *slip*. A *slip* is an error in the execution of an action, for example, a slip of the tongue or 'finger trouble', such as hitting the wrong key when typing. Slips are externally observable actions that are not as the individual intended.

Slips are generally related to skill-based activities. That is, actions that have become so rehearsed and automatic that the individual does not need to closely monitor each stage of the action sequence in the way that they would if the task were less familiar or unknown. Due to this reduced monitoring, the individual will generally not realize that they have carried out an incorrect action until it is either too late to change, or there has already been an unforeseen consequence.

A transposition error occurs when an individual inadvertently swaps two adjacent numbers or letters while speaking or writing down a value or word. For example, writing down 132 instead of 123, or saying 'ACB' instead of 'ABC' during a conversation. In aviation, this may occur when reading back the aircraft call sign to ATC or when recording a numerical value, such as a fuel figure or an assigned heading, altitude or radio frequency.

Error detection

Various studies have shown that a significant number of errors made by individuals are detected only when it is too late for effective intervention and recovery. A study by Sarter and Alexander in 2000 examined error types and detection mechanisms and found that 'the majority of slips and lapses in the database [US Aviation Safety Reporting System] involved

[7] Reason, J. (1990). Human Error. Cambridge University Press, Cambridge, United Kingdom.

attentional problems' with slips most often relating to competing demands in high-tempo operations[8].

When it came to detecting errors, the same authors found that routine checks were the most frequently successful detection technique for errors of omission. Errors of omission, that is, a failure to do something that should have been done, relied on routine checks and therefore took longer to detect, and in some cases resulted in a violation[9] or other unintended outcome. However, slips were more likely to be detected based on routine or 'suspicious' checks, wherein crew suspected a problem and went looking for it, or on an observed outcome of the slip. The authors noted that, when they were detected, slips were more likely to be identified by the person who made them.

In a 2004 observational study of airline operations by Thomas, Petrilli and Dawson, that was designed to assess error detection and recovery, noted that 'less than half the errors committed by crews were actually detected[10]. In addition, it was found that 'error detection is more easily accomplished by the crewmember that was not responsible for the error'. While this appears to be the opposite of the findings by Sarter and Alexander, it should be noted that their study used self-reported data, and that the crew must therefore have been aware of the error in order to report it. That study found that slips were more likely to be noticed by the crewmember that made them, whereas this study discussed errors in general, which may not be comprised only of slips. The observational study also found that systemic defenses such as checklists detected only 0.8% of errors.

Another observational study by Thomas in 2004 examined threat and error management during different phases of flight[11]. The study found that the majority of errors occurred during pre-departure, takeoff, and descent-approach-landing. Those results were consistent with another finding of the study: that the majority of threats are found during the pre-departure and descent-approach-landing phases of flight.

Distraction and interruptions

Research in the area of distraction and interruptions in the cockpit has involved gathering data during observations of normal operations with researchers seated in aircraft cockpits and noting crew activities, actions, and interactions with external parties including ground staff, cabin crew, and ATC.

In a study by the US National Aeronautics and Space Administration (NASA) Ames Research Centre in 2001, researchers conducted in excess of 60 observation flights and commented on task activity, distraction, and interruptions in the cockpit[12]. The researchers noted that

[8] Sarter, N.B. & Alexander, H.M. (2000). Error types and related error detection mechanisms in the aviation domain: an analysis of aviation safety reporting system incident reports. The International Journal of Aviation Psychology 10(2), 189-206.

[9] Violations can be defined as deliberate – but not necessarily reprehensible – deviations from those practices deemed necessary to main the safe operation of a potentially hazardous system.Reason, J. (1990). Human Error. Cambridge University Press, Cambridge, United Kingdom.

[10] Thomas, M.J.W., Petrilli. R.M. & Dawson, D. (2004). An exploratory study of error detection processes during normal line operations. In Proceedings of the 26thconference of the European Association for Aviation Psychology. Lisbon, Portugal 2004.

[11] Thomas, M.J.W. (2004). Predictors of threat and error management: identification of core nontechnical skills and implications for training system design. The International Journal of Aviation Psychology 14(2) 207-231.

[12] Loukopoulos, L.D., Dismukes, R.K. & Barshi, I. (2001). Cockpit interruptions and distractions: A line observation study. In Proceedings of the 11thInternational Symposium on Aviation Psychology, Columbus, University, March 2001

the events that distracted and interrupted flight crew were *'numerous and varied'*. Related was the need for flight crew to make decisions regarding those interruptions, which may impact the scheduling and action of other tasks. The authors found that 'opportunities for errors increase dramatically as distractions continuously threaten to sidetrack even the most meticulous and experienced pilot'. Of particular interest to the accident flight was the finding that 'the flight deck [cockpit] is rarely ever sterile and devoid of distractions'.

Distractions and interruptions, and how flight crew manage them, have ramifications for the design of tasks and checklists. As part of the same broad NASA study, training and procedures were reviewed to assess the extent to which they correlated with what the researchers observed in flight. The researchers found that '*procedures and classroom training* ... give almost no indication of the substantial concurrent task demands we observed[13]' and that the 'procedures and training are misleading in three respects: they give the impression that the procedures are linear, that the pilots have full control of their execution, and that the procedures flow uninterruptedly'. With regard to training in this area, the authors noted that 'the haphazard arrival of paperwork on the line is poorly, if at all, captured in simulator training'.

It is known, that normally the simulator sessions are conducted without distraction or interruptions being introduced by the instructor.

Specific research into the disruptive effect of interruptions and the effect of those interruptions on task resumption has found that people may 'think they have completed the step, and upon resumption actually skip that step' and that 'in some workplace situations, the primary task is never actually resumed[14]' further study that was referenced in the Trafton and Monk article, found that 'high-priority, complex tasks...were negatively impacted the most by interruptions... [and] that it is quite difficult to return to these complex tasks[15]'.

The authors of the 2001 NASA study also discussed in a second study the implication of interruptions and distractions during monitoring tasks, including the cognitive demands in a monitoring role[16]. The authors highlighted the challenge of monitoring a system for an unexpected and untoward event, something '... at which humans are notoriously poor'.

Another study into concurrent and deferred tasks found that, despite numerous incidents and accidents being a function of excessive workload, there was often sufficient time for all essential tasks to be completed. They concluded that the issue '... seems to be how well pilots can manage attention to keep track of concurrent tasks without becoming preoccupied[17]'. This finding is of relevance to this event given that the operating crew com

[13] Loukopoulos, L.D., Dismukes, R.K. & Barshi, I. (2003). Concurrent task demands in the cockpit: challenges and vulnerabilities in routine flight operations. In Proceedings of the 12thInternational Symposium on Aviation Psychology, Columbus, OH, 14-17 April 2003

[14] Trafton, J.G. & Monk, C.A. (2008). Task Interruptions in Reviews of Human Factors and Ergonomics, volume 3, Human Factors and Ergonomics Society

[15] Czerwinski, M. P., Horvitz, E., & Wilhite, S. (2004). Cited in Trafton, J.G. & Monk, C.A. (2008). Task Interruptions in Reviews of Human Factors and Ergonomics, volume 3, Human Factors and Ergonomics Society.

[16] Loukopoulos, L.D., Dismukes, R.K. & Barshi, I. (2003). Concurrent task demands in the cockpit: challenges and vulnerabilities in routine flight operations. In Proceedings of the 12thInternational Symposium on Aviation Psychology, Columbus, OH, 14-17 April 2003.

[17] Dismukes, R.K., Loukopoulos, L.D. & Jobe, K.K. (2001). The challenges of managing concurrent and deferred tasks. In Proceedings of the 11thInternational Symposium on Aviation Psychology, Columbus, OH: The Ohio State University, March 2001

pleted the Descent procedures and performed the associated tasks, part of a normal operational sequence, about 30 minutes the ETA.

The use of checklists in aviation was reviewed in another study, which found that checklists were often not properly completed[18]. Numerous reasons were given for this, including the fact that the cockpit was extremely busy with various sources of information competing for attention.

Research conducted in 2001 focused on determining the effect of extraneous sound on flight crew performance[19]. The results of that research showed that '... memory for [the task] was severely disrupted when extraneous background speech was presented concurrently' and '... the presence of background speech disrupts performance on this task, despite participants trying to ignore it'.

Research on the impact of distraction and interruptions in the cockpit, specifically before departure, and before approach in the use of checklists is of particular relevance to any accident flight. Distraction and interruptions have been identified in previous data entry occurrences as an influence on either the error itself or non-detection of the error.

It is known that in the world of civil aviation the operating captains have admitted that when they first became a captain they were very '*strict and disciplined*' regarding distractions. For example they reaffirm that they had 'drifted' from that approach, especially at the operator's home base because the ground staff continued to interrupt the flight crew despite being instructed by the operator not to do so. Most captains considered that they were no longer as strict about managing ground crew interactions and others situations as they had been originally.

Prospective memory

Closely linked to distraction, interruption and task resumption is a topic of memory known as prospective memory. Prospective memory can be defined as the intention to perform an action in the future, coupled with a delay between recognizing the need for the action and the opportunity to perform it.[20] A distinguishing feature of prospective memory is the need for an individual to remember that they need to remember something. As highlighted in that study, 'the critical issue in prospective memory is the retrieval of intentions at the appropriate moment, which is quite vulnerable to failure'.

Prospective memory can create problems when used concurrently with habitual tasks, which ordinarily occur quite reliably both in aviation and everyday life. Problems can occur when the cues used by flight crew to perform habitual tasks are removed. For example, when items on a checklist are delayed or conducted out of sequence, thereby removing the habitual links between tasks that are usually conducted in a particular, unbroken sequence.

[18] Diez, M., Boehm-Davis, D.A. & Holt, R.W. (2002). Model-based predictions of interrupted checklists. In Proceedings of the Human Factors and Ergonomics Society 46thAnnual Meeting – 2002, 250-254.

[19] Banbury, S.P., Macken, W.J., Tremblay, S. & Jones, D.M. (2001). Auditory distraction and shorter memory: Phenomena and practical implications. Human Factors 43(1), 12-29.

[20] Dismukes, K. (2006). Concurrent task management and prospective memory: pilot error as a model for the vulnerability of experts. In Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting – 2006, 909-913.

This is particularly relevant when flight crews are interrupted and need to resume a task. They then rely on prospective memory and, in many cases, have no cues in the cockpit to indicate where they were at the time of the interruption. Studies have shown that people often fail to resume a task when interrupted if their attention is quickly diverted to a new task before they can resume the interrupted task.

Interaction with automation

Cockpit automation has been increasing since the 1980s and has influenced the way pilots interact with aircraft systems. Various studies into this interaction have been conducted in order to inform system design and to understand human limitations within this setting.[21][22]

Recent studies have focused on information searching and problem diagnosis within an automated cockpit. One such study found that automated systems were bringing 'cues from the outside environment into the cockpit and displaying them as highly reliable and accurate data thereby engineering out any uncertainty that would normally have existed.[23] However, the use of that data is affected by how flight crew identify what information is accurate and relevant, and how they interpret the information to make a decision. As noted by the authors of that study, 'Many pilot errors involve a failure to note or analyze important information in the electronic "story" that is not consistent with the rest of the picture'.

The study identified that 'pilots may be inclined to use the most salient information source – typically an automated indication' and that 'airline policies may promote dependence on automated displays and discourage taking the time to analyze them carefully or verify them by checking other data sources'. This highlights a potential problem in that flight crew may seek to only look at the automated source and rely on this to the exclusion of other data sources and, as such, may not detect discrepancies or inconsistent data. Previous studies identified a tendency for flight crew to 'see information they expected to see rather than what was there', which could be viewed as a form of expectancy that was based upon their experience of what the automation normally displayed.
In addition, a simulator study of flight crew found that 'even when scanning included the [instrument being monitored], pilots failed to understand the implications [of what they were seeing]'. That is, the pilots had a view that the results being presented by automation were accurate and often failed to understand that this may not always be the case.

Systems such as EFBs are examples of complex and coupled technology where the EFB calculation process is not readily apparent to the flight crew. To obtain performance parameters, the flight crew need only input the required data, such as ambient conditions, and then record the results.

[21] Lyall, B. & Funk, K. (1998). Flight deck automation issues. In M.W. Scerbo & M. Mouloua (Eds.) Proceedings of the Third Conference on Automation Technology and Human Performance held in Norfolk, VA, March 25-28, 1998. (pp. 288-292). Mahwah, NJ: Lawrence Erlbaum Associates.
[22] Christofferesen, K. & Woods, D.D. (2002). How to make automated systems team players. In Advances in Human Performance and Cognitive Engineering Research, Vol 2, p 1-12. Elsevier Science Ltd
[23] Mosier, K.L., Sethi, N., McCauley, S., Khoo, L. & Orasanu, J.M. (2007). What you don't know can hurt you: factors impacting diagnosis in the automated cockpit. Human Factors 49 (2), 300-310.

Checklist design and use

Checklists are used in airline operations to ensure that critical actions are performed as and when necessary during each phase of flight. Checklists are normally designed as 'challenge-response' items. That is, the pilot(s) set up the cockpit as necessary and then check that all actions have been completed correctly. To do this, one pilot calls the action or setting and the other confirms its completion. Given that checklists are used for every flight, pilots become very familiar with the required actions and responses

During observation flights looking at the use of checklists, one study found that 'often, the pilot would answer with the proper response immediately when he/she heard the challenge call from the [other] pilot, not verifying that the item called was set accordingly'. The study also found that the use of ambiguous terms in a checklist affected the use of the checklist by pilots. The continued use of 'checked' or 'set' instead of reading out what was being seen, for example 'airspeed set 125', will make it easier for pilots to respond to a checklist item without actually verifying what it is they are checking.

Potential error in take-off and landing performance calculation

The introduction of EFBs for take-off and landing performance calculations has replaced the manual process which required the use of paper-based charts and tables. This results in a reduction in the number of steps flight crew uses to determine the performance parameters, and hence the opportunities for error. However, the use of an EFB has not eliminated error potential; it has resulted in a range of error types primarily relating to data entry errors and in the misreading of the results. Those error types can include transcription errors, keystroke errors, and the selection/calculation of incorrect data.

Flight crew experience in the detection of erroneous take-off and landing performance parameters

Both crewmembers reported that certain errors were more likely than others, such as entering the block fuel incorrectly or entering incorrect ambient conditions and aircraft configuration into the FMS.

Both flight crew members reported that they believed that any data entry error in the FMS would be detected by the other crewmember during subsequent checks (such as before departure or before the approach stages). They also reported that their experience in detecting errors and the FMS' reliability during normal operations meant that they had a high level of trust in the calculation and checking processes.

Degraded landing performance not detected

Flight crew monitoring of approach and landing performance is based on a set of reference speeds and sink rates during the approach and does not include the monitoring of the aircraft's true air speed. Therefore, if the landing reference speeds are incorrect, or the acceleration insufficient, CAS /IAS, flight crew have no reliable indication of any problem. Accordingly, it is difficult for crew to identify that landing based on speed and descend rate performance is degraded. As for the night of the occurrence, it can be considered that the runway was wet (both relevant extracts from METARs at LPPD, at 2030Z and at 2100Z indicated light showers of rain -*SHRA*).

A runway is considered contaminated if more than 25% of its surface is covered with more than 3mm of water, slush or loose snow. This definition is an industry consensus inclusive the airbus manufacture that implicitly considers runways as wet if they are covered with loose or fluid contaminated less than 3mm in depth.

Contrary to the dry runway and wet runways cases, the air distance is defined as 7 seconds at approach speed. Speed bleed-off during the flare of the airborne phase is considered to be 7% of the approach speed. The resulting touchdown speed may be optimistically low for modern jet as an A310 and therefore produces a slightly conservative result. The braking means application sequence is as for the dry runway computation.

The deceleration during the ground roll takes into account the appropriate braking friction and can take credit for contaminant drag due to displacement and spray impingement. Hydroplaning is taken into account above the hydroplaning speed as applicable for the contaminant type. The wheel-to-runway friction coefficient is defined by a value for each contaminated type. One exception is ice where the retained value of 0.005 is extremely low. Such low values have never been observed in flight test or accidents, and would, if encountered (under freezing rain or melting ice), be unsafe for aircraft operations for controllability reasons.

Effect of speed increments and wind, and also credit for reverse thrust use, is provided for ALD contaminated in Airbus documentation.

Under EU-OPS regulation at time of dispatch the Landing Distance Available for contaminated runway at destination must be at least 115% of the ALD for contaminated runway and never less than the RLD for a wet runway.

AIRBUS

FLIGHT OPERATIONS INFORMATION LETTER

Summary of requirements for ALD computation

Runway condition	ALD computation		Regulatory basis
	Air Distance	Ground Roll	
DRY	Flight tests	Flight Tests	FAA/EASA
WET	Flight tests	FAA/EASA model with WET anti-skid efficiency from flight tests	FAA/EASA Rejected Take Off
CONTAMINATED	7 sec, with 7% speed decay	EASA CS25.1591	EASA

Runway condition	RLD computation	Regulatory basis	Reverse credit
DRY	1,67 x ALD DRY	FAA EASA	NO
WET	1,15 x RLD DRY = 1,92 x ALD DRY	FAA EASA	NO, but operational reverse thrust use is implied when available
CONTAMINATED	1,15 x ALD CONTAMINATED	EASA	AVAILABLE

It should be taken into account that for the early airbus aircraft, the A300 and A310, the case in investigation, contaminated runway data was provided on the basis of a JAR-OPS requirement in the operational documentation only, no AFM supplement exists. The published data is thus purely advisory. However the existing information was established on a very similar basis as for aircraft or which certified data under JAR 25.1591 exits.

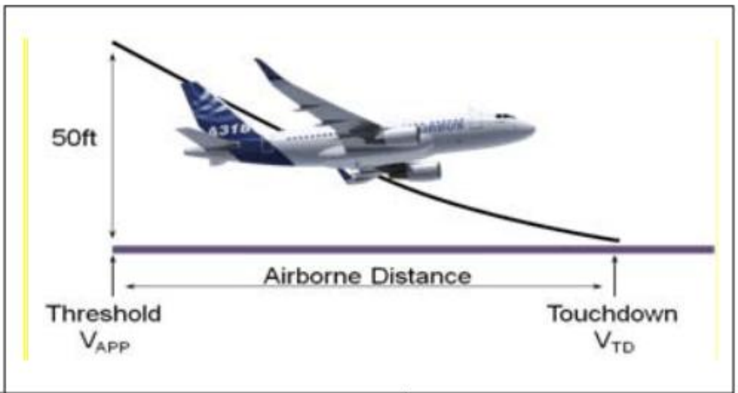
For all Airbus fly-by-wire aircraft, the methods used establish these factors include an adjustment for realistic air distance which is similar to the one defined in EASA AMC to CS 25.1591 (in other words a failure that would as the only consequence on the landing male a specific landing configuration mandatory, with otherwise unaffected landing performance, would already have a failure factor of more than 1.0 as a means to adjust for a realistic air distance).

Auto land

The automatic landing system assists the crew in making a safe landing when cloud ceiling is low or visibility is poor. The system relies on radio altimeter measurements to perform the flare. The flare control law is quite conservative in order to avoid hard landings on upward sloping runways or in case of wind gradients and downdrafts. As result, the airborne distance is significantly increased versus the manual flare assumed in the certified landing distances on a dry runway.

Auto land can be used in conjunction with automatic or manual braking. Automatic landing distances without auto brakes assume that maximum braking is applied at main gear touchdown. If at dispatch an automatic landing is planned at destination, maximum manual braking has to be assumed and the resulting distance increased by 15% to obtain the RLD associated with auto land. This distance must be checked to be at least equal to the RLD for manual landing technique.

This also results in the airborne distance computation being done according to the rules for contaminating runway, i.e. 7 seconds at approach speed. This is very close to the airborne distance defined in the TALPA ARC proposal for the operational landing distance (OLD) by Airbus, however the resulting touchdown speed, defined at 93% of the approach speed, while the OLD one is supposed to be 96% of VAPP.



Dry Runway (FAA/EASA)	1.23 x V_{S1g} ~	V_{APP}
Contaminated Runway (EASA)	1.23 x V_{S1g}	0.93 x V_{APP}
TALPA	Scheduled V_{APP} Minimum 1.23 x V_{S1g}	0.96 x V_{APP}

To achieve a TALPA computation on the ground phase with the correct initial speed, i.e. a $V/_{TD}$ OF 0.96 x V_{APP}, while using the EASA contaminated runway model programmed into the “OCTUPUS” software, the approach speed must thus be artificially increased to 1.23 x 0.96 / 0.93 approximately 1.27 V_{S1g}.

This however will increase air distance unduly and so the airborne distance must be manually computed from the equivalent groundspeed of the original VAPP backwards from the calculated Vapp:

$V_{APP} = 1.23 \times Vs1g = (1.23 / 1.27) \times V_{APP\ calc} \approx 0.9685 \times V_{APP\ calc}$

(Taking into account the effect of altitude, temperature and conservative 50% headwind and 150% tailwind) that is computed as a result by OCTUPUS, maintained for 7 seconds as per TALPA definition. The speed decay may be assumed to be linear during the flare. i.e. the airborne distance computation may be 7 seconds at an average value of 98% of V_{APP} .

Two items of information are required for flight crew to determine degraded landing performance:

- ✓ A measure of the aircraft's actual slowdown speed, in real time;
- ✓ A reference, or expected, level of aircraft slowdown in short final.

As previously discussed airspeed alone provides no indication of acceleration whereas the engine instruments provide an indication of engine thrust and other parameters. Flight crew has to derive engine- related problems from those parameters. A human's ability to determine acceleration / speed is neither an accurate nor reliable mean to assess landing performance. Furthermore, that accuracy and reliability is further degraded in dark environment.

Monitoring the TAS was not contemplated by the crew nor was it required to be. The landing performance philosophy was based on the aircraft accelerating or slowing down at a rate commensurate with the performance calculations.

What is new? – Landing distance without a failure

LANDING DISTANCE - DRY

The Reference Distance (REF DIST) considers : Sea Level (SL), ISA, no wind, no slope, no engine reverse thrust, manual landing, VAPP=VLS without APPR COR.

CONF FULL

Corrections on Landing Distance (m)		WEIGHT		SPD	ALT	WIND	TEMP	SLOPE	REV
Braking Mode	REF DIST (m) for 190T	Per 10T BELOW 190T	Per 10T ABOVE 190T	Per 5kt	Per 1000ft above SL	Per 5kt TW	Per 10°C ABOVE ISA	Per 1% Down Slope	Per Thrust Reverser Operative
Maximum MANUAL	1 310	- 40	+ 140	+ 70	+ 40	+ 120	+ 40	+ 20	- 10
AUTOBRAKE MED	1 670	- 50	+ 120	+ 100	+ 50	+ 150	+ 50	+ 20	0
AUTOBRAKE LOW	2 220	- 80	+ 160	+ 130	+ 80	+ 220	+ 70	+ 30	- 30

Overweight Ldg proc	+ 160 m
Autoland	+ 230 m

CONF 3

Corrections on Landing Distance (m)		WEIGHT		SPD	ALT	WIND	TEMP	SLOPE	REV
Braking Mode	REF DIST (m) for 190T	Per 10T BELOW 190T	Per 10T ABOVE 190T	Per 5kt	Per 1000ft above SL	Per 5kt TW	Per 10°C ABOVE ISA	Per 1% Down Slope	Per Thrust Reverser Operative
Maximum MANUAL	1 360	- 50	+ 160	+ 80	+ 40	+ 120	+ 40	+ 20	- 10
AUTOBRAKE MED	1 750	- 60	+ 120	+ 100	+ 60	+ 150	+ 50	+ 20	0
AUTOBRAKE LOW	2 350	- 90	+ 170	+ 140	+ 80	+ 220	+ 70	+ 40	- 30

Overweight Ldg proc	+ 200 m
Autoland	+ 220 m

Braking Action

Landing Configurations

Braking Modes
(Manual or Auto brake)

The REF DIST
(Provided at fixed landing weight)

Airbus source

RISK CONTROLS

Distraction management

Research on distraction and interruptions has identified their detrimental effect on the formation and detection of errors. The research has also highlighted that the majority of errors occurred before the departure and before the landing phases of a flight. Thus, it is important to manage distraction during these flight phases to minimize the potential for errors to be formed and not detected until they have effect.

By not including a component on the management of in-cockpit distractions in the operator's training program, the operator effectively left it to flight crews to develop their own distraction management practices based on their operational experiences and the environment in which they were operating.

The prevalence of distraction as a contributor or influence in error development is well documented in human factors research. The challenge for operators is to develop and implement training and standard operating procedures that enable flight crew to manage distractions during safety-critical tasks, especially before the departure and during the descent phases.

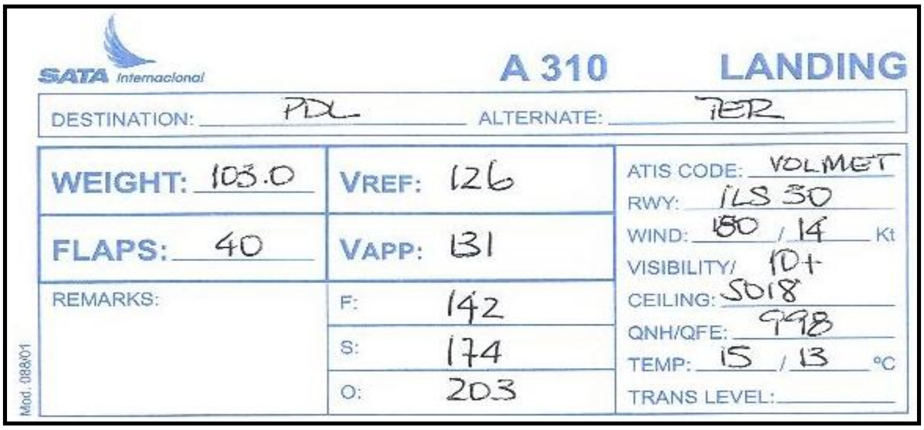
2.1. FLIGHT PREPARATION

The flight was prepared according to company's SOP, with all relevant information (meteorology, AIS, aircraft status and commercial load) contemplated in the briefing prior to departure.

Even if the weather was not critical at destination and in route, the captain elected to carry an extra-fuel of ≠3000kg, bringing the actual take-off mass well bellow the maximum allowed take-off mass of the aircraft.

2.2. FLIGHT PROGRESS

All flight was uneventful until landing at Ponta Delgada. Below is depicted the landing data card completed by the flight crew before the event.


SATA Internacional A 310 LANDING

DESTINATION: PDL ALTERNATE: TER

WEIGHT: 103.0	VREF: 126	ATIS CODE: VOLMET RWY: ILS 30
FLAPS: 40	VAPP: 131	WIND: 180 / 14 Kt VISIBILITY/ 10+
REMARKS:	F: 142 S: 174 O: 203	CEILING: S018 QNH/QFE: 998 TEMP: 15 / 13 °C TRANS LEVEL:

Mod. 088/01

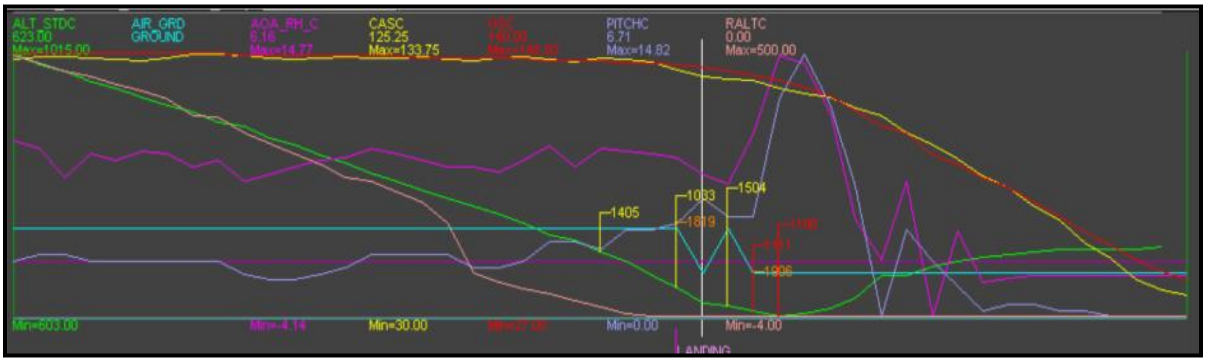
ATIS frequency is not available at LPPD, hence the VOLMET data copied by the flight crew.

Picture nº4

There was a direct approach from waypoint *NAVPO* to ILS Rwy 30 and *LOC & Glide* followed with both Flight Directors (FDs) and both Auto Pilots (APs) engaged in *LAND* mode and Auto-throttle (A/THR) engaged in *SPEED* mode. At approximately 260ft (RALT), ≠180ft above threshold, both APs were disconnected and the aircraft flown manually thereafter with the use of FDs and A/THR engaged.

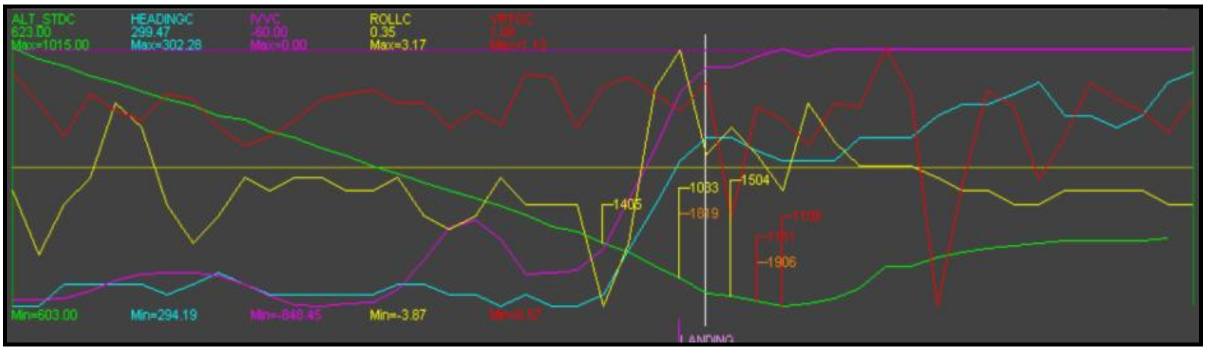
Analysing Graphs nº3 & 4 we may follow landing phase and observe that:

- ✓ Final app speed was stable at CAS 132kt (Vref+5) and a tailwind component of ≠13kt;



Graph nº3

- ✓ At flare starting, there was an increase on vertical acceleration, which caused a short flare and, aided by tailwind, a firm touchdown (1.48 VRTG), with both main landing gears touching down in sequence right than left and signalling spoilers to extend;
- ✓ As aircraft bounced there was an intention to keep the nose up by a "Pull" on the control column most likely to avoid a hard contact of the nose wheel;



Graph nº4

- ✓ Due to the aircraft bounce, strong tailwind and extension of spoilers there was a natural pitch-up tendency, the force exerted on the control column made the aircraft reach a pitch angle of 14.82º;

- ✓ When the aircraft touched down for the second time and main gear shock absorbers compressed pitch angle exceeded the aircraft's geometry limit for compressed absorbers, making the tail structure strike the ground, as confirmed by "Ground Clearance Diagram" (Diagram nº2), referred on Flight Crew Operating Manual (FCOM) 2.03.22.

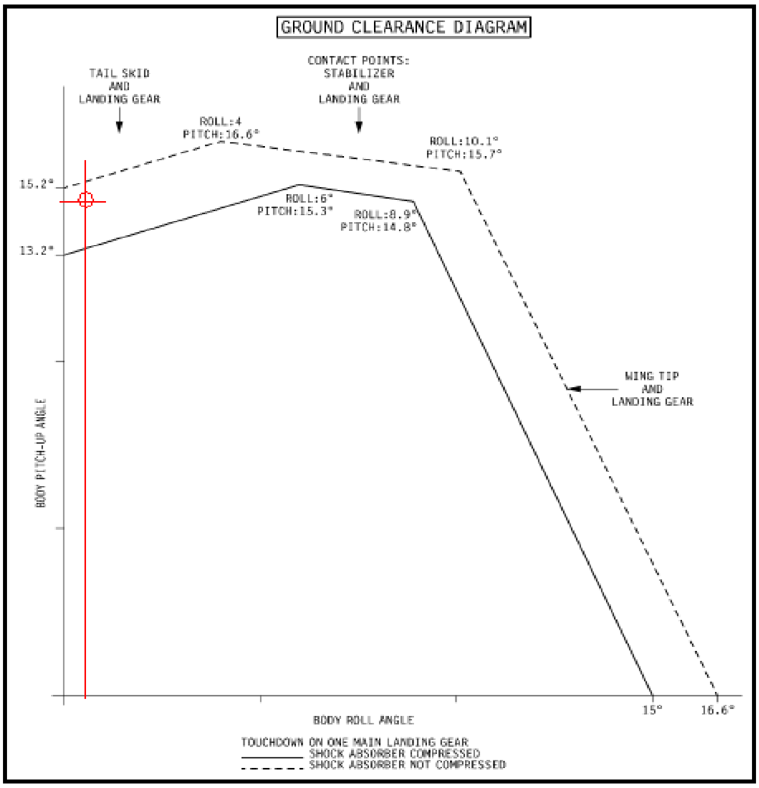


Diagram nº2

2.3. FLIGHT CREW MEMBER DUTIES

As per company procedures flight duties were assigned before departure. First Officer (CM2) was appointed as Pilot Flying (PF) for first sector (LPPT–LPPD) and the Captain (CM1) Pilot Monitoring (PM).

After take-off and aircraft clean, AP was selected and AP2 engaged. The entire route was flown on AP2 until established on final approach, with ILS selected, when both APs were engaged and an *Auto Approach* was performed until reaching 286' (ILS CAT I decision height of 241 feet for CAT C aircrafts). On a first interview held by the previous investigator both members of the flight crew stated that the Captain had assumed control of the aircraft just after the first bounce in an attempt to correct profile by holding the nose up in order to avoid a hard nose wheel contact. This version of the event was contradicted in a later interview held by the current investigation team as both pilots stated that Captain CM1 was the Pilot Flying (PF) from the moment of APs disconnection.

2.4. AIRBUS RECOMMENDED PROCEDURES

2.4.1. AVOIDING TAIL STRIKE

Airbus has addressed the avoidance of tail strikes in several publications. FCOM Bulletin nº 08/1, Subject nº 26 as shown on the extract below, presents some considerations on tail strikes, technical explanation and recommended flight crew procedures.

A310 / A300-600 FCOM BULLETIN

N° 08/1
DATE : DEC 92
File in FCOM 2.20
Issued by AI/E-VO

SUBJECT N° 26 : AVOIDING TAIL STRIKES

------------------- -------------------------------- -------------------

3.3. Tail strike at landing

All manufacturers : statistics, indicate that tail strike occurrence is greater at landing than take-off (2 to 1).
Deviation from normal landing technique, and the pitch up effect of landing at aft CG's seem the principal causes :

. ground reaction at aft CG
. deviation from normal landing technique

3.3.1. Ground reaction at aft CG

At pronounced aft CG, the ground reaction at touch-down has a pitch-up effect when the attitude exceeds a given value.

The aft CG maximum value and the corresponding maximum attitude, are presented below.

Above this max attitude, pitch-up will occur and will have to be manually counteracted.

Aircraft	CG	θ touch down (V_{REF-8})	max attitude	Margin
A310	36.5 %	8°.7	13°	4°.3
A300-600	37 %	9°	11°4	2°.4

Margin : Max attitude – θ touch-down
Margin must be 2° at least. Therefore, when this is inadequate, the landing speed has to be increased.

θ Touch-down : mean value of pitch attitude at touch-down assuming a deceleration of 8 kt during flare (V_{REF-8}), and a flight path of - 1° at touch-down (approximately 3 ft/second).

3.3.2. Deviation from normal landing technique

Deviation from normal landing technique remains the most common cause of tail strikes specifically :

. allowing the speed to decrease well below VAPP
. prolonged hold-of for a smooth landing
. flare started too high
. failure to fly the nose gear on to the runway after touch-down.

- **Allowing the speed to decrease well below VAPP on short finals**

  Generally when the aircraft decelerates well below VAPP, the pilot, to avoid an excessive sink rate, increases the pitch attitude.

  This may lessen the ground clearance to the critical value.

Wind gradient on finals may also lead to an inappropriate attitude during the flare. A windshear from headwind to tailwind leads to lower aerodynamic speed. In this event, the first reflex of the pilot is to increase the attitude, as he approaches the ground.

- **Holding the aircraft off the runway**

  This action is generally done in an attempt to touch-down very smoothly.
  Increasing attitude at a moment when the pilot needs to look well ahead to judge the aircraft position relative to the ground.

- **Flare too high**

  All pilots know how uncomfortable a flare can be if it is started too high. When in such a position, and if the engines are already reduced, the pilot can choose between an increased sink rate or an increased attitude (or both if the speed is too low).

3.3.2. Landing technique

The first important point in avoiding tail strikes is to reach the flare height with the appropriate speed and the correct path angle (– 3°) towards the touch-down point.

Autothrust and the Flight Path Vector (FPV) are very good assets in judging correctly to the flare height.

Flare technique

Start the flare at approximately 30 ft.

The thrust reduction is progressive from 35 ft. It has to be coordinated with the pitch rate, especially when crosswinds are encountered.

The attitude increment between the start of flare and touch-down is close to 4.5°, assuming an 8 kt speed decay and -1° flight path angle at touch-down (3ft/second).

Because of the downward visibility of all modern aircraft, it may now be more difficult to judge an abnormal pitch attitude than before. The PNF should monitored call out whenever the pitch attitude exceeds 10°.

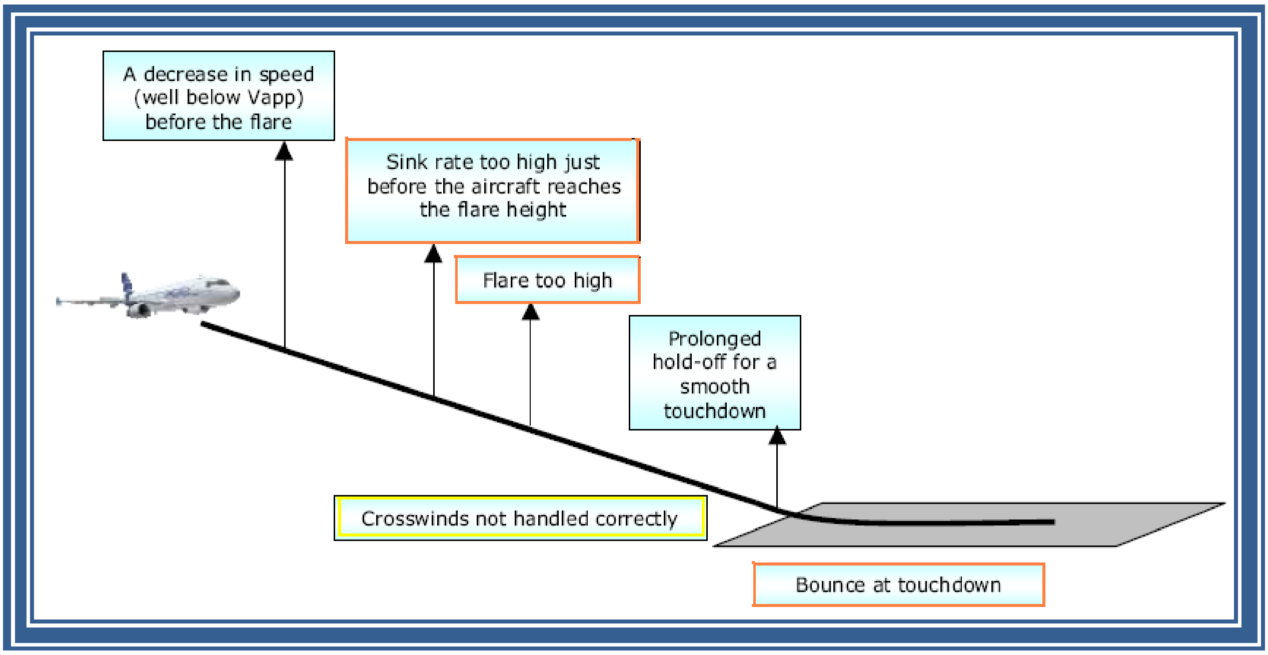
After the touch-down, fly the nose gear to the runway smoothly and maintain a pressure on the control wheel ; deflected elevators increase the load on the main gear, providing better braking.

When autobrake is set to medium, braking starts as soon as the ground spoilers deploy. It maycounteract any unexpected pitch-up effect.

2.4.2. PREVENTING TAIL STRIKE AT LANDING

In addition Flight Operations Briefing Notes Ref: FOBN FLT_OPS-LAND-SEQ08-REV1-SEP 2007 addressing landing techniques highlights the main common events during flare, factors that are likely to contribute to a tail strike and recommendations on the best procedures to prevent them from happening.

These are the factors that most influence and increase tail strike probabilities at landing (Picture n°5):



Picture n°5

From flight analysis it was noted that the following events with associated consequences, occurred:

- **Sink Rate Too High Just Prior to Reaching the Flare Height**

  If the sink rate is too high when the aircraft is close to the ground, the flight crew may attempt to avoid a firm touchdown by commanding a high pitch rate. This action will significally increase the pitch attitude. However, if the resulting lift increase is not sufficient to significantly reduce the sink rate, a firm touchdown may occur. In addition, the high pitch rate may be difficult to control after touchdown , particularly in the case of a bounce.

- **Flare Too High**

  A flare that is too high can result in a combination of decreased airspeed and a long float. Since both increase the aircraft's pitch attitude, the result is reduced tail clearance.

- **Bounce at Touchdown**

  In the case of a bounce at touchdown, the flight crew may decide to increase the pitch attitude, to ensure a smooth second touchdown. If the bounce results from a firm touchdown associated with a high pitch rate, it is important for the flight crew to control the pitch, so that it does not continue to increase.

Reverting to Prevention Strategy and Lines of Defence proposed on the same FOBN, crew adherence to the following procedures would have prevented the tail to strike the ground:

Approach

A stabilized approach (i.e. pitch, thrust, flight path, V_{APP}) is essential for achieving a successful landing.

Autothrust and the Flight Path Vector (FPV), if available, are effective flight crew aids.

For the approach phase, the flight crew should:

- Not chase the glide slope close to the ground: Progressively and carefully monitor the pitch attitude and sink rate
- Avoid high sink rate when close to the ground.

PNF callouts during the final approach are essential to alert the PF of any excessive deviation of flight parameters, and/or excessive pitch attitude at landing. Following a PNF flight parameter exceedance callout, the suitable PF response will be to:

- Acknowledge the PNF callout, for proper crew coordination purposes
- Take immediate corrective action to control the exceeded parameter back into the defined stabilized conditions
- Assess whether stabilized conditions will be recovered early enough prior to landing, otherwise initiate a go-around.

Flare

The flight crew should adapt the flare height to the aircraft inertia: It is imperative that the aircraft reaches the flare height at the appropriate airspeed and flight path angle.

The aircraft should be "in trim" at the start of the flare. For A300/A310/A300-600 aircraft, the flight crew should avoid the use of pitch trim during the flare, or after touchdown.

During the flare, the flight crew should concentrate on the pitch and roll attitude, using external visual cues.

Finally, the flight crew should set the pitch rate to zero prior touchdown.

Landing

The flight crew should avoid "holding off the aircraft" in an attempt to make an excessively smooth landing.

Immediately after main landing gear touchdown, the PF should release the back pressure on the sidestick (or control column, as applicable) and fly the nose wheel smoothly, but without delay, on to the runway.

The PNF should continue to monitor the attitude.

Bouncing at Touchdown

In case of a light bounce, the flight crew can apply the following typical recovery technique:

- Maintain a normal landing pitch attitude:
  - Do not increase pitch attitude, as this could cause a tailstrike
  - Do not allow the pitch attitude to increase, particularly following a firm touchdown with a high pitch rate.

  Note: Spoiler extension may induce a pitch-up effect.
- Continue the landing
- Keep thrust at idle
- Be aware of the increased landing distance.

In case of a more severe bounce, the flight crew should not attempt to land, because the remaining runway length might not be sufficient to stop the aircraft.

Operational recommendations

Although the present investigation team was unable to confirm if the wind conditions during the approach were within limits (as mentioned before CVR recorded post flight conversations and no communications with Ponta Delgada's ATC was available), the flight crew should always adopt a *defensive* attitude when facing marginal weather (wind) conditions. In this case, the pilots had been aware that the runway 12 was in use at LPPD throughout the entire flight (including its normal preparation at the briefing stage in Lisbon airport).

Below are listed some specific triggers for doing in flight performance reassessment.

- ➢ **Wet runways.** The dispatch landing distance on wet smooth runway might not offer satisfactory safety margins in hot and high conditions or for runways with descending slope for aircrafts with not very efficient reversers.
- ➢ **Contaminated runways.**
  - ✓ Under FAA regulations, dispatch in forecast contaminated conditions at arrival assumes wet runway, therefore an in-flight landing distance assessment always be required.
  - ✓ Under EASA regulation for contaminated runways, the dispatch landing distances may not offer satisfactory safety margins (e.g. in case of descending slope).
    - Deterioration of runway condition since dispatch.
    - Degrading / rapidly changing conditions should incite to determine the worst acceptable condition under which the landing can be continued, if information to that end is received late during the approach. .

- Landing planned with auto land and / or auto brake if at dispatch, manual landing and braking was assumed.
- Change of runway vs. assumption made at dispatch. If it is not known which runway was planned to be used at time of dispatch, assume that it was based on the longest runway and no wind. If the runway to be actually used has more unfavorable characteristics, a specific computation should be made.
- In-flight system failure impacting landing performance (change of configuration, increase of approach speed, loss of deceleration devices).
- Preparation of alternative runways if late changes are possible.

It is important to remember that the new definition of Operational landing Distance (OLD) is not deemed to include margins and assumes a stabilized approach in outside conditions consistent with the computation assumptions and, when computed for manual braking, prompt maximum brake application by the pilot.

Flight crews are well advised to use all available information to make a realistic assessment of the most likely runway conditions, and check how much these conditions may degrade before it becomes impossible to stop the aircraft within the declared distance. When doubts exist, requesting to change the runway for a more favorable one, or even a diversion, may be the better solution.

3. CONCLUSION

3.1. FINDINGS

From the evidence available, the following findings are made with respect to the tail strike on runway 30 at Ponta Delgada Airport, Azores on 2nd March 2013 involving an Airbus A310-300 with registration CS-TGU. It is reminded, once again, that these findings should not be read as apportioning blame or liability to any particular organisation or individual.

Although there are a number of factors identified directly relating to this accident, the accident needs to be taken in the context of the long history of similar landing performance events identified by this investigation. Even though the events leading to this accident may be particular to this case, the previous events highlight that there are a multitude of ways to arrive at the same situation, placing the aircraft and passengers in an unsafe situation. The preferred safety actions will be those that address the whole situation, not just those that address the specific factors identified in this accident. Based on what has been exposed previously, we may conclude that:

a) The aircraft was involved on a scheduled passengers transport flight;
b) The aircraft’s Airworthy Certificate was valid and all scheduled maintenance actions had been performed in accordance to maintenance programme and Aircraft Maintenance Manual;

c) The Aircraft's Technical Logbook had no registry of any limitation or restriction to the normal operation of the aircraft;

d) The aircraft was loaded within its operating limits;

e) The flight crew was certified, trained, and qualified for the flight in accordance with existing regulations. Both crew members had no restrictions or limitations in their operation;

f) There was no evidence that physiological factors affected the flight crew's performance;

g) CRM principles were not in evidence during the event;

h) The aircraft was serviceable and provided the appropriate warnings and cautions to the flight crew during the approach and landing phase;

i) Landing at Ponta Delgada was performed with a crosswind component of 15kt from the left and 13kt tailwind component;

j) Touchdown occurred with a high rate of descent followed by a short flare with high tail wind component making the aircraft bounce with spoilers extended;

k) After bouncing and before the aircraft touched down again high pitch rate was maintained up to 14.8º nose up angle;

l) On second touchdown the aircraft made a firm contact with the ground, landing gear shock absorbers were compressed and the tail structure contacted the runway surface;

m) Crew and passengers suffered no injuries;

n) The aircraft sustained substantial structural tail damage;

o) It was unlikely that the operating flight crew was affected by fatigue;

p) The captain's selection of (Auto brakes medium) during the approach / landing maneuver very likely limited the adverse consequences of a runway overrun.

3.2. CAUSES OF THE ACCIDENT

3.2.1. PRIMARY CAUSE

Inadequate recovery handling of a bounced firm landing (deviation from recommended flying pilot technique).

3.2.2. CONTRIBUTING FACTORS

The following were considered as contributing factors:

a) High sink rate prior to and during flare;

b) Aircraft firm landing followed by a light bounce;

c) Crew momentary unawareness of aircraft position (in the air) and intentional column pulling action, trying to smooth nose wheel contact with ground;

d) The presence of a tailwind component during the flare phase above recommended 10kts limits;

e) Aircraft's center of gravity at a slightly backward position but this factor is of marginal contribution only;

f) The decision to land on damp runway 30, with tailwind component marginal to the maximum permitted (10kts), instead of a *circling to land* to the actual runway (12) in use or the decision to discontinue the approach via a *go-around* procedure;

g) A bounce recovery at night (with less visual references) characterized by taking place very close to the ground (less than 20 feet) hence allowing for a very short reaction time from the PF and little control effectiveness of the aircraft (throttle retarded and normal configuration to land);

h) The existing take-off / landing certification standards, which were based on the attainment of the landing reference speeds, and flight crew training that was based on the monitoring of and response to those speeds, hindering crew to detect degraded landing speed and sink rate.

4. SAFETY RECOMMENDATIONS

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. GPIAA expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the GPIAA prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Note: *'Safety factors' are events or conditions that increase risk. If a safety factor refers to a characteristic of an organisation or a system that has the potential to affect future safety, it is called a 'safety issue'.*

4.1. SAFETY ACTIONS

<u>Note</u>: *pursuant to European Regulation n°996/2010 on accident investigations, a safety recommendation in no way constitutes a presumption of fault or responsibility in an accident or incident. The Portuguese Decree Law 318/99 Article nº27 and European Regulation n°996/2010 stipulate that the addressees of the safety recommendations inform GPIAA (the Portuguese civil aviation accident investigation body) of the actions they intend to take and, where no action is taken, the time necessary for its implementation.*

PRESERVING CVR DATA

No action to preserve the CVR recording after the accident was carried out by the aircraft operator therefore data of vital importance was missing for the accurate analysis of the event. European regulations (EU-OPS n°859/2008 and n°996/2010) require that all the necessary measures be taken to prevent the recordings of conversations being erased in the event of accidents or serious incidents. Numerous identical cases have been noted in the past.

<u>Consequently GPIAA recommends that</u>:

1. **The Portuguese National Institute of Civil Aviation, I. P. (INAC) issues a Circular of Aeronautical Information (CIA) defining the procedures to be adopted by the operators in order to ensure the rapid preservation of CVR (Cockpit Voice Recorder) and FDR (Flight Data Recorder) recordings after an accident or serious incident, in accordance with the obligations in EU-OPS n°859/2008 and European regulation n°996/2010 (article 13.3).(RS 01/2014)**

IMPLEMENTATION OF RNAV APPROACH

In order to avoid performing a right visual circle to land to runway 12 at night, the flight crew elected to land with tailwind component marginal to the manufacturer's and operator's limit of 10kts. This choice of runway was highly influenced by 3 main factors:

- Only runway 30 is equipped with instrument approaches, namely ILS/DME enabling automatic landing up to a decision height of 241 feet (or if glide slope equipment unserviceable up to a minimum height of 350 feet);
- The difficulty in maintaining the runway in sight throughout the whole circling procedure due to the relatively low altitude (850 feet for category C approach speed aircraft, as depicted in Appendix A) in conjunction with the positive slope of 1.2% on runway 30;

- The difficulty in identifying hence in assessing the distance of terrain obstacles (clearance from terrain) when turning from right base to final runway 12.

Consequently, GPIAA recommends that:

2. **NAV Portugal E.P.E implements a RNAV approach to runway 12 at LPPD airport (Ponta Delgada) covering the various operationally relevant entry sectors and subsequently, (RS 02/2014)**

3. **SATA International and other operators of Ponta Delgada's airport adequately certify, train and qualify their flight crew in RNAV approach flying and accordingly certify their aircrafts (RS 03/2014)**

EVALUATION OF EXISTING LIGHTING SYSTEM

Although additional signaling terrain lighting was installed and the appropriate information published on the AIP (27-JUN-2013), namely *a set of 8 aligned high intensity Type A and non-sequential flashing lights, spaced 60M, located 600M from THR 12 and 2200 left side of extended center line installed to identify natural obstacle (Coast) proximity during RWY12 approach operations)*, GPIAA recommends that:

4. **ANA - Aeroportos de Portugal (Ponta Delgada Management Airport) assesses the adequacy of existing lighting equipment in identifying natural obstacles within the airport vicinity and in particular in the approach segment of runway 12.(RS 04/2014)**

LISBON,15/12/2014

THE INVESTIGATION TEAM:

Agnès Cantinho Pereira

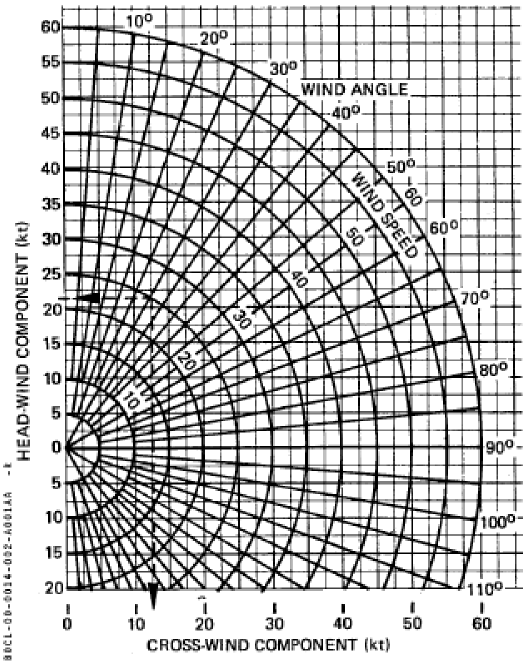
Carlos Lino

5. APPENDIX

Appendix A

A310	OPS DATA	REV 22 / SEQ 001	14.02

WIND COMPONENT



MAX CROSSWIND	REPORTED BRAKING ACTION	REPORTED FRICTION COEFFICIENT	EQUIVALENT RUNWAY CONDITION
37 kt*	GOOD	0.40 and above	1
30 kt	GOOD/MEDIUM	0.39 to 0.36	1
25 kt	MEDIUM	0.35 to 0.30	2/3
20 kt	MEDIUM/POOR	0.29 to 0.26	2/3
15 kt	POOR	0.25 and below	3/4
5 kt	UNRELIABLE	UNRELIABLE	4/5

* : This is the maximum computed crosswind capability on dry and wet runway (Max demonstrated : 28 kt) .

EQUIVALENT RUNWAY CONDITIONS :

1 : Dry, damp or wet runway (less than 3 mm water depth) without risk of hydroplaning.

2 : Runway covered with slush

3 : Runway covered with dry snow.

4 : Runway covered with standing water with risk of hydroplaning or wet snow.

5 : Runway covered with compacted snow or with standing water with high risk of hydroplaning or icy runway (allowed for landing only).

RZO ALL

Appendix B

LANDING OPERATING SPEEDS

Landing Weight **103**

VREF **126**

OPERATING SPEEDS (kt)					
WEIGHT (× 1000 kg)	F 1.25 Vs 15/0	S 1.25 Vs 0/0	0 (Green dot) (below 20 000 ft)	VREF + 10 1.3 Vs 20/20	VREF 1.3 Vs 30/40
90	134	168	190	128	118
95	138	172	195	131	121
100	141	177	200	135	125
105	145	181	205	138	128
110	148	185	210	141	131
115	151	190	215	144	134
120	154	193	220	147	137
125	158	198	225	150	140
130	161	201	230	152	142
135	164	205	235	154	144
140	167	209	240	157	147
145	170	213	245	160	150
150	172	216	250	163	153
155	175	220	255	166	156
160	178	223	260	168	158

. Green dot speed : add + 2 kt per 1 000 ft above 20 000 ft

VAPP - WIND CORRECTION

- VAPP can be computed based on VREF or VLS :
  - VAPP = VREF + VREF CORRECTION + WIND CORR.
  - VAPP = VLS + VLS INCREMENT + WIND CORR.
- VREF CORRECTION or VLS INCREMENT : REFER TO 15.03.
- WIND CORR = (1/3 tower average wind) or (gust increment, if higher)
- Apply WIND CORR only if there is no tail-wind component.
- If A/THR is used or if significant ice accretion is suspected :
  - if WIND CORR < 5 kt, take WIND CORR = 5 kt.
- Maximum WIND CORR = 15 kt.
- R If VREF CORRECTION ≤ 20 kt :
  - R maximum WIND CORR = 20 kt – VREF CORRECTION
- R If VREF CORRECTION > 20 kt :
  - do not apply any WIND CORR.

: If the forecasted tail wind at landing is greater than 10 knots, decelerated approach is not allowed, and the speed should be stabilized around VREF + 5 knots in final.

VAPP = VREF + 5 Knots

VAPP = 126 + 5 = 131

Appendix C

A310 FLIGHT CREW OPERATING MANUAL	STANDARD OPERATING PROCEDURES	2.03.30
	STANDARD CALLS	PAGE 8
		REV 30 SEQ 001

APPROACH AND LANDING
STABILIZED ILS APPROACH

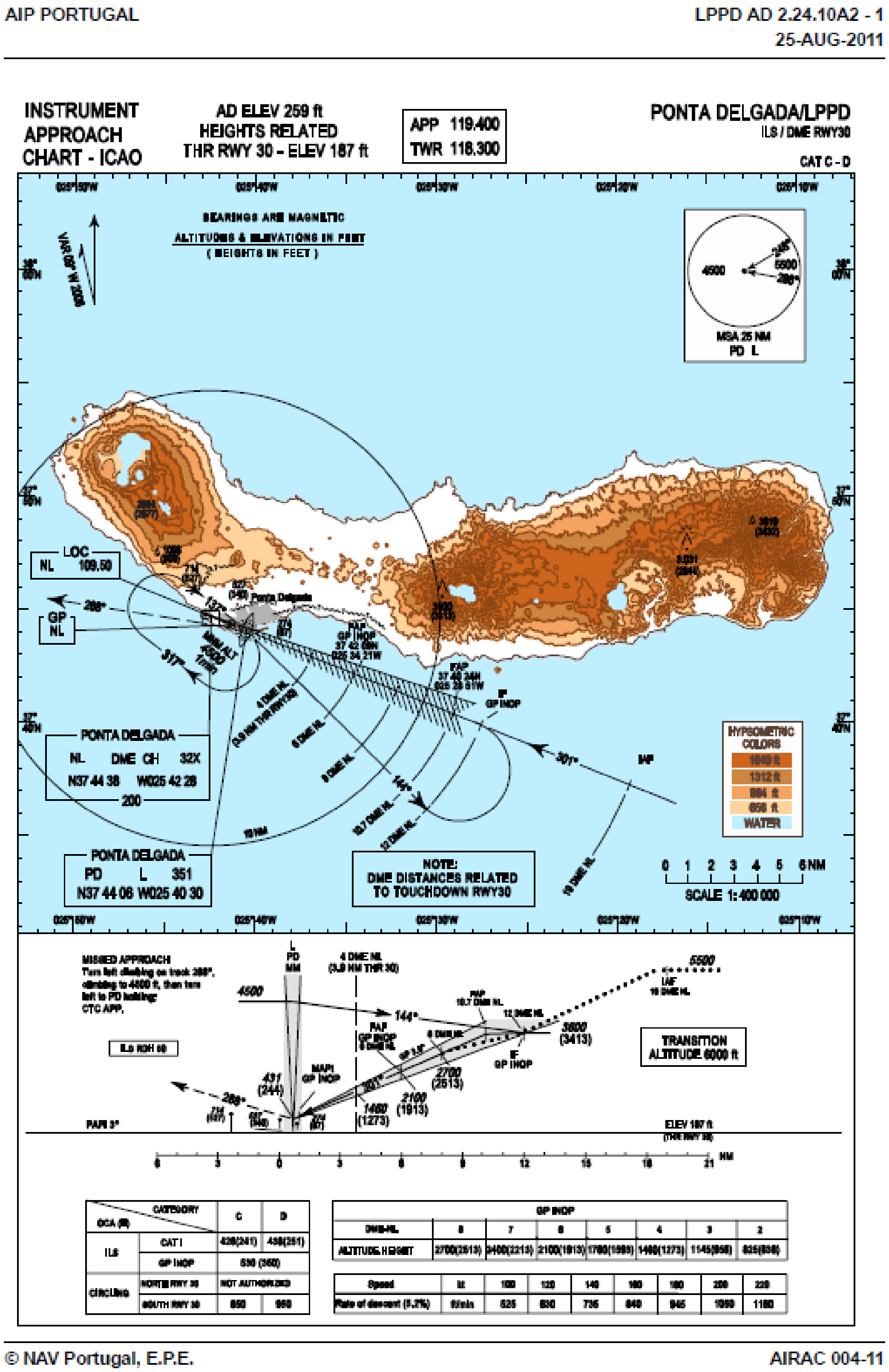
EVENT	PF	PNF
When cleared below transition level or as appropriate.	APPROACH CHECK LIST	APPROACH CHECK LIST COMPLETED
Initial Approach	SET GREEN DOT SPEED	GREEN DOT SPEED SET
Beginning of Radio Altimeter indication	CHECKED	RADIO ALTIMETER ALIVE
At Green Dot Speed (or below VFE)	SLATS EXTEND SET "S" SPEED	SPEED CHECKED SLATS EXTENDED
AT "S" SPEED (or below VFE)	FLAPS 20 SET "F" SPEED	SPEED CHECKED FLAPS 20
INTERCEPTION HEADING	ARM LAND	LAND ARMED
LOCALIZER CAPTURE	LOC* SET RWY HEADING	...° SET
2 DOTS (1 DOT) SINGLE ENGINE	GEAR DOWN	GS ALIVE GEAR IS DOWN
WHEN GEAR IS DOWN	FLAPS 40 SET VAPP	SPEED CHECKED FLAPS 40 VAPP SET
GS CAPTURE	GS* SET GO AROUND ALTITUDE	...^{FT} SET
FAF OR OM if applicable	PASSING (Fix name) OR OM...^{FT}/TIMING	CHECKED (TIMING)
When FLAPS 40	LANDING CHECK LIST	LANDING C/L COMPLETED
1000^{FT} AGL	CHECKED	ONE THOUSAND
700^{FT} AGL Each pilot checks the ILS selected course on his ND.		COURSE SET
400^{FT}	LAND GREEN	CHECKED
100^{FT} above MDA	CHECKED	ONE HUNDRED ABOVE
MDA visual reference	LANDING	MINIMUM
MDA no visual reference	GO-AROUND FLAPS	MINIMUM

APPROACH AND LANDING
STABILIZED ILS APPROACH

EVENT	PF	PNF
PNF monitors pin-programmed auto call out or announces if auto call out inoperative (as often as practical – CAT I and lower only)		ONE HUNDRED FIFTY
After touch down		SPOILERS REVERSE GREEN (See the note 1 below)
When autobrake armed		See note 2 below
At 80kts ground speed		EIGHTY

Note 1 : if reverse deployment is not as expected, call NO REVERSE ENGINE... or NO REVERSE, as appropriate.
Note 2 : if Autobrake is armed and NO flow BAR green light observed, call NO AUTOBRAKE

Appendix D



OCA (H) / CATEGORY		C	D
ILS	CAT I	428(241)	438(251)
	GP INOP	530 (343)	
CIRCLING	NORTH RWY 30	NOT AUTHORIZED	
	SOUTH RWY 30	850	960

GP INOP							
DME-NL	8	7	6	5	4	3	2
ALTITUDE HEIGHT	2700(2513)	2400(2213)	2100(1913)	1780(1593)	1460(1273)	1145(958)	825(638)

Speed	kt	100	120	140	160	180	200	220
Rate of descent (5.2%)	ft/min	525	630	735	840	945	1050	1160

New chart format