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MINISTÉRIO DAS OBRAS PÚBLICAS, TRANSPORTES E COMUNICAÇÕES
GPIAA

GABINETE DE PREVENÇÃO E INVESTIGAÇÃO DE ACIDENTES COM AERONAVES

FINAL ACCIDENT REPORT

Airbus A320

SATA INTERNACIONAL

CS-TKO

João Paulo II Airport
Ponta Delgada Is. / AZORES
PORTUGAL

4 DE AGOSTO DE 2009

GPIAA

Homologo nos termos do n.º3 do art.º 26º do D.L. 318/99, de 11/08

28 / 12 / 2010

O Director

Fernando Ferreira dos Reis

REPORT Nr 33/ACCID/2009

NOTES

> This report presents the Investigation Team technical findings regarding the circumstances and probable causes which led to the accident.
>
> According to Annex 13 to the International Civil Aviation Organization Convention (Chicago 1944), to the Council Directive nr. 94/56/EC (21st November 1994) and to nr. 3, 11th article of Decree-Law 318/99 (11th August), it is not the object of this report to determine blame or liability but solely to identify causes and deficiencies capable of undermining flight safety and to gather information for preventing further occurrences of similar circumstances.

1. The Investigation:

   The accident was notified on-line by aircraft's captain and later was confirmed by SATA Maintenance and Engineering Department, at 17:00 hours on 2010, 17th August.

   GPIAA's Director appointed Safety Investigator Artur Pereira as Investigator-in-charge to find out the circumstances leading to the accident, accordingly to Annex 13, CE Directive 94/56/CE, of 21st November and Decree-Law 318/99, art. 11 § 3, of 11th August.

   Regarding to international legislation, *BEA – Bureau d'Enquêtes et Analyses*, as State of Design and Manufacturer, appointed Investigator Erell Ravel as accredited representative.

   The Investigator-in-charge (IIC) requested the setting up of an investigation team, having been then appointed Mr. António Alves, who was qualified as ex-Airbus aircraft pilot.

   Due to aircraft expected immobilization time and associated costs, the event was classified as an ACCID.

2. According to Annex 13, the relevant identities of the engineers-in-charge as well as the technicians referred on Technical Adaptation and Maintenance Release Form were preserved (pages 29 and 30).
3. All times in this report are UTC. Local time for Lisbon was UTC+1 and Ponta Delgada used UTC.

4. The original report of this incident has been issued in Portuguese language which is the official version and takes precedence as report of reference. This English translation was published for international readers' information purpose.

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SYNOPSIS

On August, the 4th, 2009, SATA International aircraft Airbus A-320/214, registration CS-TKO, was engaged on flight RZO129, from Lisbon (LPPT) to Ponta Delgada (LPPD) – Azores (Portugal), with scheduled departure at 18:10 hours and arrival at 20:25 hours.

With seven crew (2 pilots and 5 cabin crew) and 166 passengers on board, the aircraft took-off from Lisbon at 18:40 hours and by 20:30 hours, the pilot started the approach for landing, supported by the ILS for runway 30 at João Paulo II International Airport at Ponta Delgada.

Pic 1 – Photographed by João Melim - *in Jetphotos.net* (http://www.jetphotos.net/viewphoto.php?id=6590940)

After an ILS approach the aircraft touched down hard at 20:45 hours, bounced to 12ft height above the runway and it touched again the ground, in a severe hard landing situation.

At the ramp, crew and ground support engineer performed a visual inspection to the aircraft, focusing their attention on landing gear status, but nothing abnormal was detected and the aircraft flew back to Lisbon.

The Data Management Unit (DMU) printed a Load Report presenting aircraft excessive landing values but no one was able to decode them.

No report was written on Technical Log book. The aircraft continued its programmed flights until it entered an "A" check, two days after. Based on the DMU Load Report recorded at the event time, the Maintenance carried out an inspection foreseen on AMM 05-51-11, finding some damage on LH and RH wing shroud box lower panels.

Aircraft manufacturer was consulted and a thorough dedicated Inspection was performed.

1. FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

SATA International aircraft Airbus A-320/214, registration CS-TKO, was scheduled to operate flights RZO 124 (PDL/LIS), RZO 129 (LIS/PDL) and RZO 128 (PDL/LIS) with the same flight crew, starting at 15:05 hours and ending by 23:30 hours, on August 4th, 2009.

First leg was uneventful and operated on schedule, with F/O as Pilot Flying (PF) and Captain as Pilot Not Flying (PNF)[1]. For second leg they changed functions, becoming the Captain PF.

Flight RZ 129 took off from Lisbon International Airport at 18:40 hours to Ponta Delgada - Azores, with 7 crewmembers (2 pilots + 5 cabin crew) and 166 passengers on board and making a total Take-off Mass of 69 365kg.

The descent to LPPD started at 20:12 hours and the aircraft reached IAF position – NAVPO – at 20:30 hours. Slightly before, the PF engaged both Auto Pilots and performed a RWY30 ILS straight in approach.

Passing 875ft (RA) both AP were disconnected and approach continued manually, with FD engaged in LOC & G/S mode and A/THR engaged in SPEED mode.

The approach was performed with the aircraft in normal configuration for landing. For a Landing Mass of 63 900kg approach speed was 141kts, which has been selected and followed during the approach. The maximum landing mass for CS-TKO is 64 500kg.

At 20:35 hours, the aircraft made a hard touch down, bounced to a height of 12ft AGL and came back to the ground in a severe hard landing condition.

At the apron, the Captain reported hard landing to ground support engineer. Both have analysed DMU Load Report (pic. *2*), encoded data. However, they were not able to reach a coherent interpretation.

The Load Report stated two figures [max. 4.85g, for a limit of 2.60g, being the reason of a VRTA (vertical acceleration)], which are directly linked to double landing impacts. Unfortunately, they were unable to clarify the data and so they suspected it might be inconsistent information.

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1 Between pilot's briefing it was settled who will fly the plane (PF) and the PNF will perform assistance tasks such as air/ground communications, gathering meteorological information (enroute, destination and alternate), checklists reading, however being his/her most important task the monitoring and crosscheck PF flight.

The event has occurred at night, the Engineering Department was closed and they could not get the necessary help to clarify the Load Report message.

Both pilots and ground support engineer performed a visual inspection, looking for any damage to landing gear or associated parts and they haven't detected any irregularity. The event was not even reported on the Technical Log book.

The aircraft flew back to LIS without further problems. At Lisbon, the flight crew reported again, and verbally, to the ground engineer asking his assistance to decode de DMU message, also here without success.

There was no decoding capability at that time in the night. Then, ground personnel decided to wait for the next shift delivering the message to the coming staff.

Meanwhile, time elapsed was too long and CS-TKO should be prepared for the next scheduled flight. Consequently, the aircraft left the airport without the message being decoded.

```
              A320 LOAD REPORT <15>
   A/C ID DATE  UTC    FROM TO   FLT
CC CS-TKO AUG04 203508 LPPT LPPD 0129
   PH CNT   CODE BLEED STATUS       APU
C1 07 00101 4500 56 0010 0 0100 56 X
   TAT  ALT   CAS MN  GW   CG  DMU/SW
CE 0250 -0007 132 206 6377 335 C31000
   ESN    EHRS  AP FLAP SLAT
EC 699350 00507 06 3400 2700
EE 699352 00507 06 3400 2700
LIMIT EXCEEDANCE AND SPOILER EXT SUMMARY
   MAX  LIM  COUNTS
E1 0485 0260 000 000 000 000 000
   REASON: VRTA
   VALUES AT 1 SEC BEFORE LAND/EVENT
   RALT RALR PTCH PTCR ROLL ROLR YAW
S1 0012 -129 0042 0032 -015 0012 -006
   VALUES AT LAND/EVENT
S2 -001 -074 0070 -003 0004 0012 -005
   MAX/MIN 1 SEC TO 3 SEC INTERVAL
   VRTA LONA LATA
S3 0213 0030 0016
S4 0090 0005 -002
   VALUES AT 1 SEC BEFORE BOUNCED
   RALT RALR PTCH PTCR ROLL ROLR YAW
T1 0012 -035 0042 -013 -009 0009 -004
    VALUES AT BOUNCED
T2 0000 -203 0058 -005 -001 -018 -013
  MAX/MIN 1 SEC TO 3 SEC INTERVAL
   VRTA LONA LATA
T3 0486 0031 0007
T4 0009 -019 -007
```

Pic 2 – Load Report

In the following flights no irregularity was detected. During between flights, at the time when turn-around checks, neither pilots nor ground assistance engineers were able to find any inaccuracy. No reports of any hard landing suspicion were written on the aircraft Technical Log book.

The aircraft performed six more sectors after the event before entering an "A" type inspection.

1.2 INJURIES

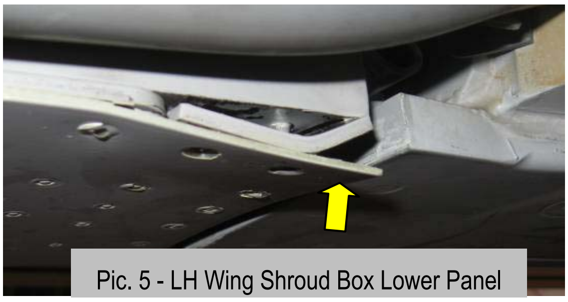
INJURIES	CREW	PASSENGERS	OTHER
FATAIL	—	—	—
SERIOUS	—	—	—
LIGHT	—	—	—
NONE	7 (2+5)	166	

1.3 Aircraft Damage

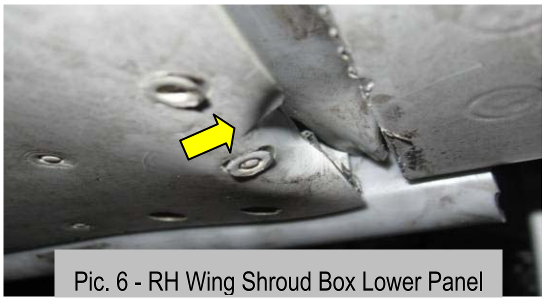
Wing Shroud Box Lower Panels, on both sides, showed some damage (pic. 3, 4, 5 and 6). Some rivets on these panels popped out.

Pic. 3 – LH main gear.

Pic.4 – RH main gear.



Pic. 5 - LH Wing Shroud Box Lower Panel



Pic. 6 - RH Wing Shroud Box Lower Panel

It was found compression marks on the main gear tires (pic. 7) due to the impact on the RWY.

The nose gear touchdown was softly and so there was no evidence of damage.

During special detailed inspection progress some other information was collected, as expressed on 1.16 – Tests and Research.

Pic. 7 – Evidences of tire compression due to vertical acceleration during hard landing experienced.

1.4 OTHER DAMAGE

There was no third part damage reported.

1.5 PERSONNEL INFORMATION

1.5.1 Flight Crew

Flight crew was composed by two pilots, with following references:

Reference	***Captain***	***Co-pilot***
Identification		
Sex	Male	Male
age	44 years old	49 years old
Nationality	Portuguese	Portuguese
Flight License		
Designation/Nr	ATPL(A) / N/A	ATPL(A) / N/A
Issued by/in	INAC / N/A	INAC / N/A
Validity	20-02-2010	30-11-2009
Flight Experience		
Total	4 592.00 hours	4 550:00 hours
On type	1 206:10 hours	2 200:00 hours
On position	233:00 hours	2 200:00 hours
Last 28 days	56: 55 hours	57:15 hours
Last 7 days	16:50 hours	14:40 hours
Last 24 hours	6:15 hours	6:15 hours
Landings on last 24 hours	3	3
Aeronautical Medical Examination		
Last Medical Examination	30-05-2009	21-01-2009
Restrictions e/or limitations	VNL	VNL

Flight crew performed a 10:00 hours duty time, as mentioned in the service report.

Both pilots carried out refreshment training on ground, and were checked on flight simulator and on line flight still.

1.5.2 Ground Assistance Engineers

Company ground engineers were duly qualified for the job (servicing) holding Airbus A320 certification.

1.6 AIRCRAFT INFORMATION

1.6.1 General

CS-TKO aircraft was a recent member of A320 family and joined the company fleet in May 2009. It had the references shown in table below and it was equipped with 165 passenger's seats, in two classes.

REFERENCE	AIRFRAME	ENGINES		
		# 1	# 2	
Manufacturer	Airbus Industries SA	CFM International		
Model	A320-214	CFM56-5B4/3		
Serial nr.	3891	699350	699352	
Year of construction	2009	N/A	N/A	
Time Since New (TSN):	533:58 hours	538:03 hours	537.48 hours	
Time Since Overhaul (TSO):	N/A	N/A	N/A	
Landings/Cycles:	237	246	245	
Last Inspection A1:	533:58 hours	538:03 hours	537:48 hours	
MTOM	77 000 Kg			
Max. POB	(2+5) + 165			
Licenses/Certificates	**Nr**	**Issued by**	**Date**	**Validity**
Certificate of Registration	2898/1	INAC	29/05/09	-
Airworthiness Certificate	PT-0103/09		29/05/09	29/05/10
Radio License	1453/1		29/05/09	29/05/11
Insurance Certificate				30/11/2009

There were no restrictions or limitations registered in Technical Log or Hold Item List.

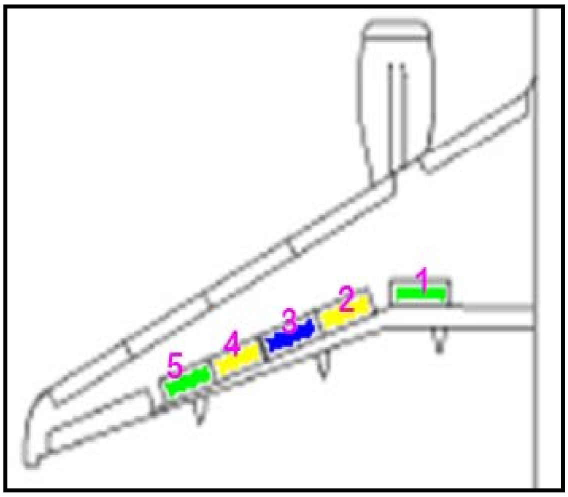
1.6.2 Spoiler System Design and Operation

1.6.2.1 *Description*

Airbus 320 aircrafts are equipped with 5 spoilers on each wing (pic. 8), electrically controlled and hydraulically actuated.

For more reliability, spoilers are controlled by three different Spoiler Elevator Computers (SEC), and actuated by different hydraulic systems.

All of them act as ground spoilers; spoilers 2 to 4 are also used, in flight, as speed brakes.



Pic. 8 – Spoilers location.

Spoilers 2 to 5 assist ailerons on lateral aircraft control.

When a ground spoiler surface fails on one wing, si-milar surface on the other wing is inhibited. This will avoid an aircraft asymmetry control.

A318/A319/A320/A321 SATA International FLIGHT CREW OPERATING MANUAL	FLIGHT CONTROLS	1.27.10	P 12
	DESCRIPTION	SEQ 001	REV 37

GROUND SPOILER CONTROL

Spoilers 1 to 5 act as ground spoilers.
When a ground spoiler surface on one wing fails, the symmetric one on the other wing is inhibited.

Arming
The pilot arms the ground spoilers by pulling the speedbrake control lever up into the armed position.

Full extension
The ground spoilers automatically extend during rejected takeoff, at a speed greater than 72 knots, or at landing when both main landing gears have touched down, when :
R - Ground spoilers are armed and all thrust levers are at or near idle, or
- Reverse is selected on at least one engine (other thrust lever at or near idle), if ground
R spoilers were not armed.

Note : - In autoland, the ground spoilers fully extend at half speed one second after both main landing gear touch down.
R *- The spoiler roll function is inhibited when spoilers are used for the ground spoiler*
R *function.*

Partial extension
The ground spoilers partially extend (10°) when reverse is selected on at least one engine (other engine at idle), and one main landing gear strut is compressed. This partial extension, by decreasing the lift, eases the compression of the second main landing gear strut, and consequently leads to full ground spoiler extension.

Retraction
The ground spoilers retract :
- After landing, or after a rejected takeoff, when the ground spoilers are disarmed.

Note : If ground spoilers are not armed, they extend at the reverse selection and retract when idle is selected.

- During a touch and go, when at least one thrust lever is advanced above 20°.

Note : After an aircraft bounce, the ground spoilers remain extended with the thrust levers at idle.

Pic. 9 - FCOM 1.27.10 – "Flight Controls - Description"

1.6.2.2 *Ground Spoilers Control*

When speedbrake control lever is pulled up into the armed position, ground spoilers are armed, allowing them to deploy automatically.

Depending on circumstances, spoilers will deploy fully or partially, according the following philosophy:

a. ***Rejected Takeoff Phase*** – With spoilers armed, if speed exceeds 72kt, ground spoilers will automatically extend fully as soon as both thrust levers are positioned to *IDLE*. If spoilers are not armed but speed is above 72kt, ground spoilers will automatically extend fully as soon as reverse is selected at least in one engine (being the other thrust lever not above *IDLE*).

b. ***Landing Phase*** – If spoilers are armed and both thrust levers are at *IDLE*, ground spoilers will automatically extend fully as soon as both landing gears touch down. If spoilers are not armed and both landing gears have touched down, ground spoilers will automatically extend fully as soon as reverse is selected at least on one engine (being the other thrust lever at *IDLE*).

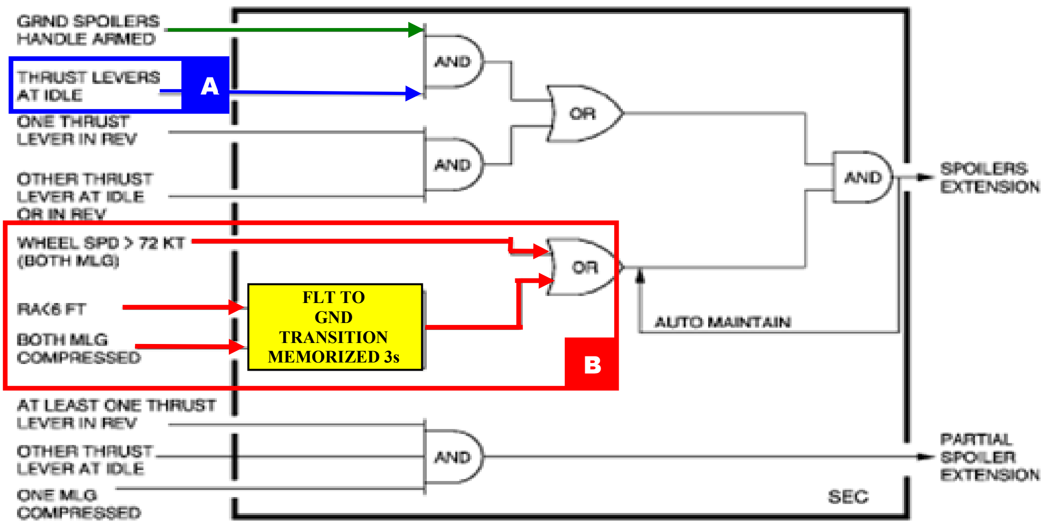
c. ***Partial Extension*** – In order to ease the sitting down of the aircraft on landing, a partial ground spoilers deployment (10 degrees) is achieved when only one main landing gear strut is compressed, spoilers are armed and reverse is selected on one engine (with the other thrust lever set at *IDLE*). This decreases lift and eases the compression of second main gear strut, leading to full ground spoiler's extension.

1.6.2.3 Ground Spoilers Extension Control Logic

All those functions may be summarized on System Logic diagram:

A318/A319/A320/A321 SATA International FLIGHT CREW OPERATING MANUAL	FLIGHT CONTROLS	1.27.10	P 13
	DESCRIPTION	SEQ 001	REV 42

The landing gear touchdown condition is triggered for both main landing gear, either when their wheel speed is greater than 72 knots, or when their landing gear struts are, confirmed to be compressed by the radio altitude (RA < 6 feet).
The thrust levers are considered to be at idle when they are :
· Below 4°, when the RA is above 10 feet,
· Below 15°, when the RA is below 10 feet.



A — **Thrust Levers Idle Condition** – *Thrust levers are considered to be at idle when they are:*
- Below 4º - when the RA is above 10ft;
- Below 15º - when the RA is below 10ft;

B — **Landing Gear Touchdown Condition** – *The landing gear touchdown condition is triggered for both main landing gear, either when their wheel speed is greater than 72kt or when their landing gear struts are confirmed to be compressed by the radio altitude (RA <6ft)*

Pic. 10 – FCOM 1.27.10 – "Flight Controls - Description"

To summarize, Ground Spoilers do extend when two conditions are fulfilled:

1. Ground spoilers armed.

   "Ground spoilers armed" means:

   a. Ground Spoilers handle armed and both THR levers at *IDLE*

      or

   b. At least one reverse selected, the other THR Levers not being above *IDLE*.

and

2. Aircraft on ground.

   "Aircraft on ground" means:

   a. Wheels turning at a speed higher than 72kt

      or

   b. both gears compressed and Radio Altitude lower than 6ft

      NOTE: (This flight to ground transition is latched 3s).

1.7 METEOROLOGICAL INFORMATION

Meteorological information (METAR) received on board the aircraft at 20:12:23 showed:

► LPPD 042000Z – 01009kt 330VAR040 9999 FEW 016 21/15 Q 1020;

► LPPD 042030Z – 02008kt 350VAR050 9999 FEW 016 21/15 Q 1020.

There was no report on significant wind changes or windshear during landing phase, but DFDR registered light wind variations during touchdown, even showing a 5kt tail wind component[2].

1.8 Navigation Aids

All navigation aids, serving the approach, were operating normally at arrival time.

1.9 Communications

All communications with the aircraft were normal, clear and obvious.

[2] The wind direction and speed information comes from the ADIRS. For weak wind speeds the wind direction is not accurate. ADIRS wind information outputs have a precision of 010 degrees or 10kt for a wind speed greater than 50kt. Therefore, for weaker winds, this information should be used just as an indication.

1.10 AERODROME INFORMATION

1.10.1 General

Name, localization and ICAO code: João Paulo II - Ponta Delgada/Azores – LPPD

Coordinates: 37 44 31N 025 41 52W (on RWY 12/30 and Taxiway "F" intersection)

Pic 11 – João Paulo II airport satellite picture (*NASA – Google Earth*)

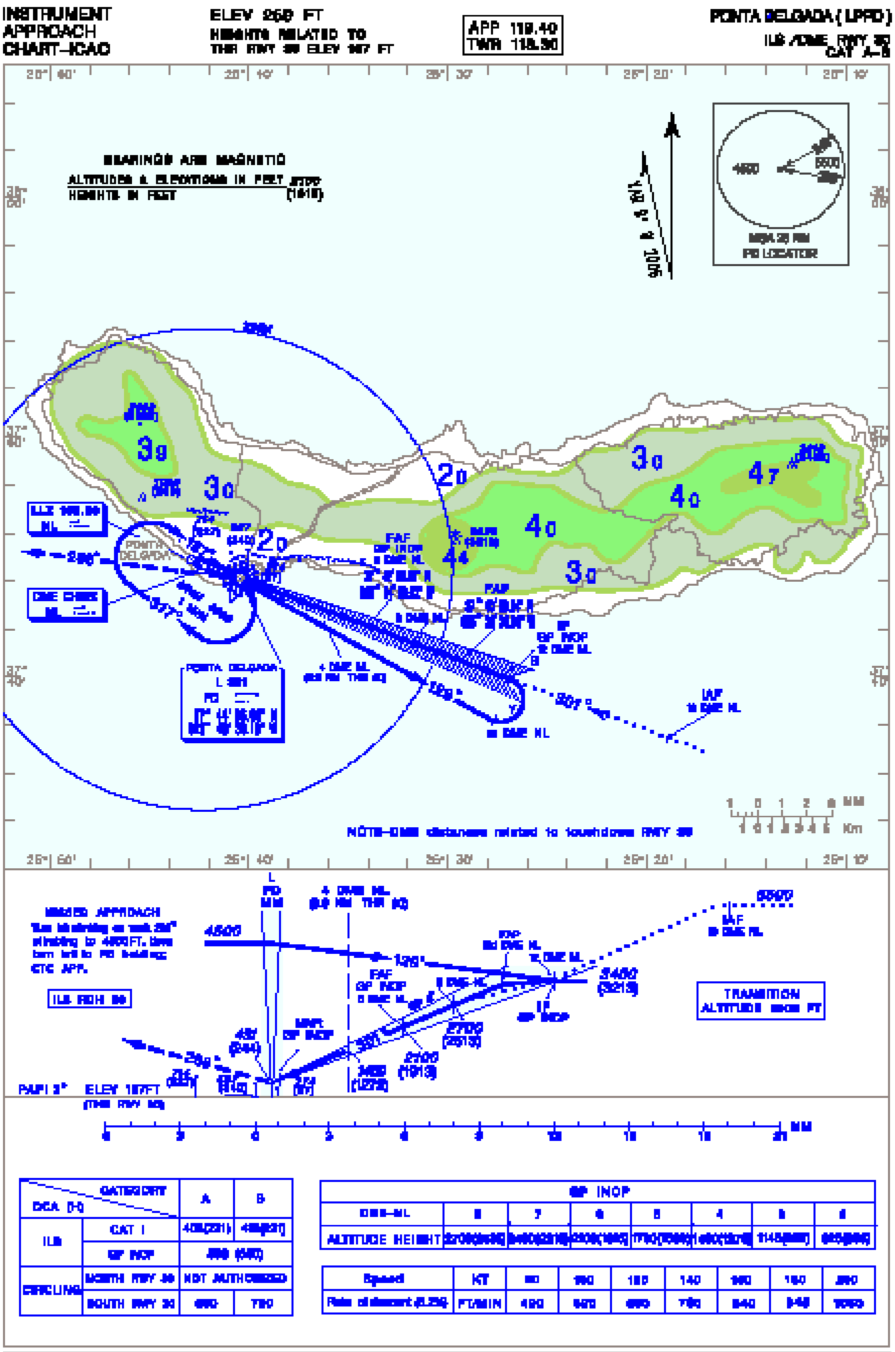
RWY 30 physical characteristics:

- Surface and dimensions (length x width): asphalt; 2 426m x 45m
- QFU – 301
- Slope: 1%
- Elevations – airport: 79m; THR – 57m (displaced 240m); TDZ – 62 m.
- Declared distances: TORA: 2426m; TODA: 2626m; ASDA: 2426m; LDA: 2279m
- Approaching lights – VASIS type: PAPI on both sides with 4 barrettes (each with 3 lights), 3 degrees, coincident to the ILS glide slope. MEHT – 21m.

1.10.2 RWY 30 ILS/DME Approach

Runway 30 is equipped with an ILS system CAT I supported on a DME, which reads “zero” at touchdown point. As the approach is performed over water, there’s no outer marker and DME becomes essential for the approach.

Initial Approach Fix (IAF) is located 19NM (DME) from touchdown, allowing for a direct entry to ILS from arrival procedure via NAVPO position. For other arrivals a 12NM (DME) Initial Fix (IF) should be considered, following a teardrop reversion procedure.



Pic.12 – LPPD RWY 30 ILS DME approach chart

1.11 FLIGHT RECORDERS

The Flight Data Recording System, which records the mandatory parameters, consists of the following components:

- Linear Accelerometer (LA) – A three-axis accelerometer measures the acceleration of the aircraft along each of the three axes;

- Flight Data Interface and Management Unit (FDIMU) – collects and processes parameters from SDACs, DMCs, FWCs, FCDCs, BSCU, DFDR event pushbutton, GND CTL pushbutton and Clock;

- Digital Flight Data Recorder (DFDR) – stores the last 25 hours of these data on a fireproof and shockproof device;

- Quick Access Recorder (QAR) – An optional recorder that stores the same data as the DFDR but is more accessible for the maintenance crew.

1.11.1 Cockpit Voice Recorder (CVR)

The aircraft was equipped with a Honeywell Solid State Cockpit Voice Recorder, PN 980-6022-001, capable of 120 minutes of audio, digital, and timing information recording memory, with Underwater Locator Beacon (ULB) attached.

CVR recording support is an endless tape system, overlapping previous recordings, exhibiting only the two last flight hours. After the event, the aircraft flew six sectors more. Thus, this flight data recorder was not retrieved for investigation due to its unrelated contents registry.

1.11.2 Flight Data Recorder (FDR)

CS-TKO DFDR was a *Honeywell Solid State Flight Data Recorder,* PN: 980-4700-042.

1.11.3 Quick Access Recorder (QAR)

The QAR on board the CS-TKO was a *Dassault Electronic Quick Access Recorder,* PN: 1374-200-002.

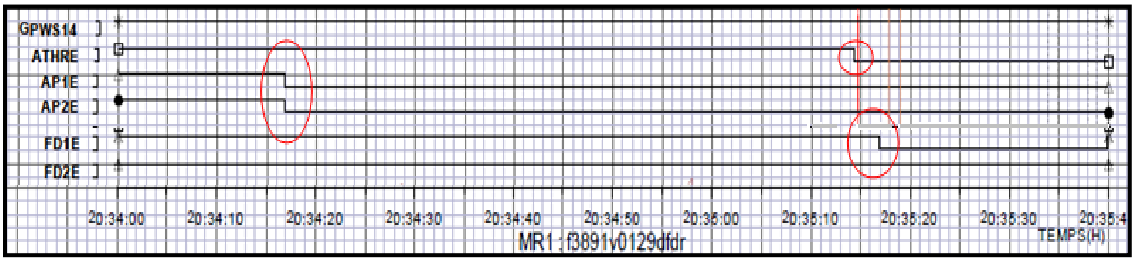
1.11.4 Approach and landing profile

Both recorders were retrieved for data decode and analyses, in order to rebuild the event, as follows:

I. Approach:

The Ponta Delgada International Airport RWY 30 instrument approach was performed according to the suitable ILS category, with A/THR in SPD Managed Mode, Autopilots 1 & 2 engaged and Flight Directors 1 and 2 (FD1, FD2) engaged in G/S and LOC mode.

- At 20:34:17 hours:
  - AP 1 & 2 were disconnected at 875ft, and PF manually performed the approach to runway 30;
  - A/THR was engaged in SPD Managed Mode;
  - FD1 & FD2 were engaged in G/S e LOC modes.

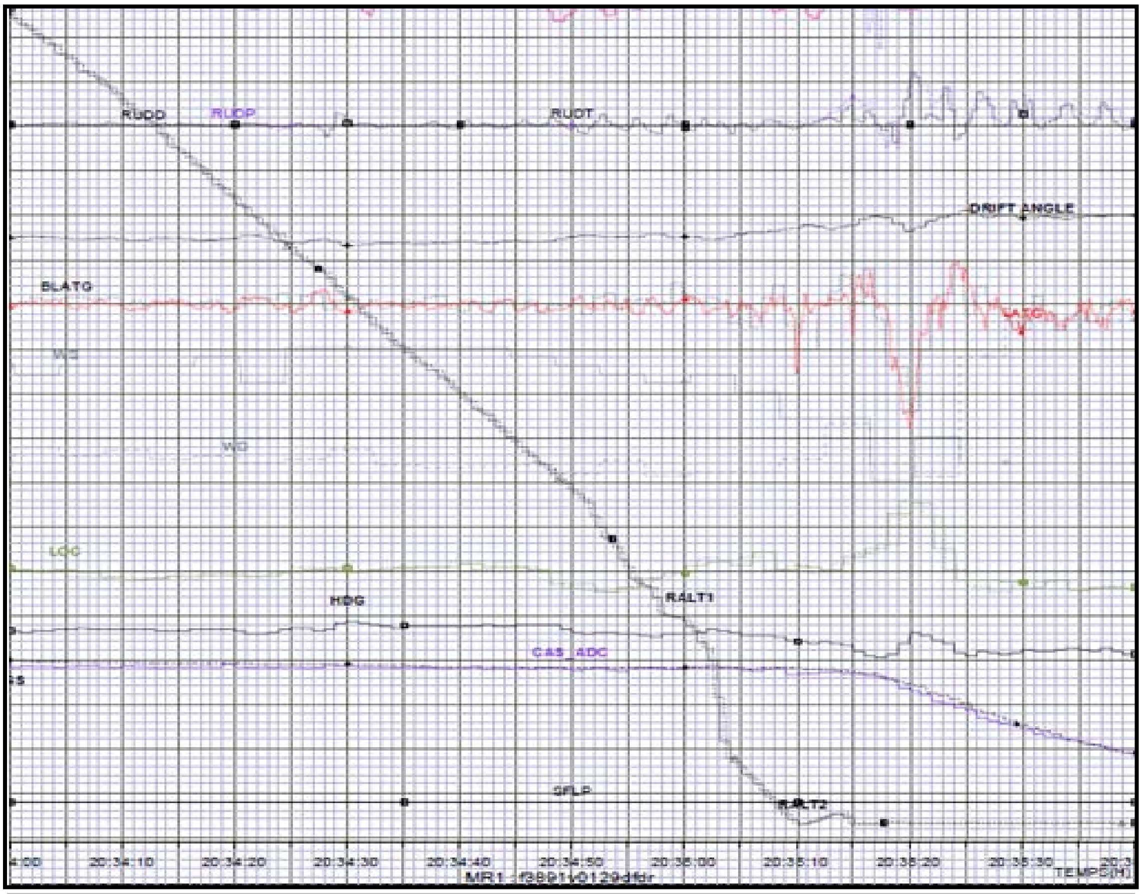


Pic. 13 – A/THR, AP 1& 2, FD 1& 2. Red circles show each one disengage moment.

At this time the aircraft configuration was as follows:

- The actual Landing Mass was 63 900 kg;
- CG was 30,4%;
- Os SLATS/FLAPS were in CONF FULL configuration (27°/35°), THR Levers were in “CLB” notch and Ground Spoilers were armed;
- Side-stick inputs on both longitudinal and lateral axis, as well as accelerations recorded on aircraft three axis do not show any turbulence conditions;
- There was no Glide deviation recording.
- Also no significant LOC deviation was recorded

- o V_{app} was 141kt (which was selected on pilot's panel).



Pic 14 – No Glide Slope or Localizer deviation; speed maintained 141kt until touchdown.

❖ **20:34:50 hours (450ft RA) to 20:35:07-25 hours (35ft RA):**

The following information was recorded:

- <u>20:34:50 hours to 20:35:02 hours</u>:
  - o Approach was performed initially around +2.5 degrees pitch on longitudinal axis and then +2 degrees pitch;
  - o Nose-down input leaded to attitude reduction to +1.41degree pitch;
  - o Vertical acceleration was stable at around 1g;
  - o Rate of descent fluctuate between 710ft//min and 850ft/min;
- <u>At 20:35:02 hours</u>:

  When passing 220ft RA down to 90ft RA, a sudden height drop was registered. Nevertheless, the rate of descent remained stable on 800ft/min (this sudden height fall was due to the terrain orography profile which rises abruptly just before RWY 30 threshold).

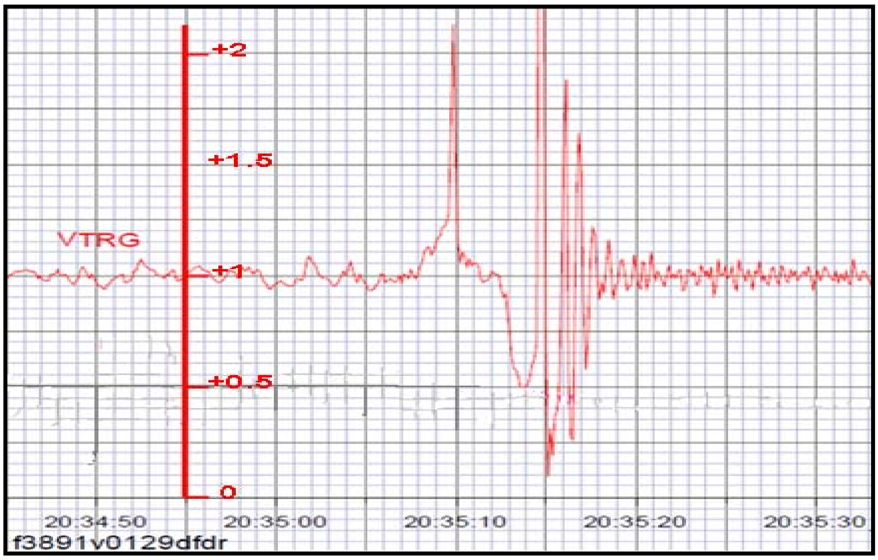
❖ **From 20:35:07-25 hours (35 ft RA) to 20:35:10 hours:**

- Flare was initiated at 35ft RA, with a 12.5 degrees order on PF side-stick and pitch angle increased from 1.41 degrees to 7.03 degrees up and rate of descent decreased to 752ft/min. Speed decreased from 139.8kt to 134kt;
- Vertical acceleration increased towards1.27g.
- THR levers were not retarded before touchdown.

❖ **From 20:35:09 hours to 20:35:14 hours**

II. <u>First Touchdown</u>

- <u>At 25:35:09 hours</u>:
  - Aircraft touches down on both MLG simultaneously with a Ground Speed of 141kt, a vertical speed of 12.5 ft/sec. (752ft/min), with an attitude of 7.03 degrees nose up;
  - Vertical acceleration was +2.13g;



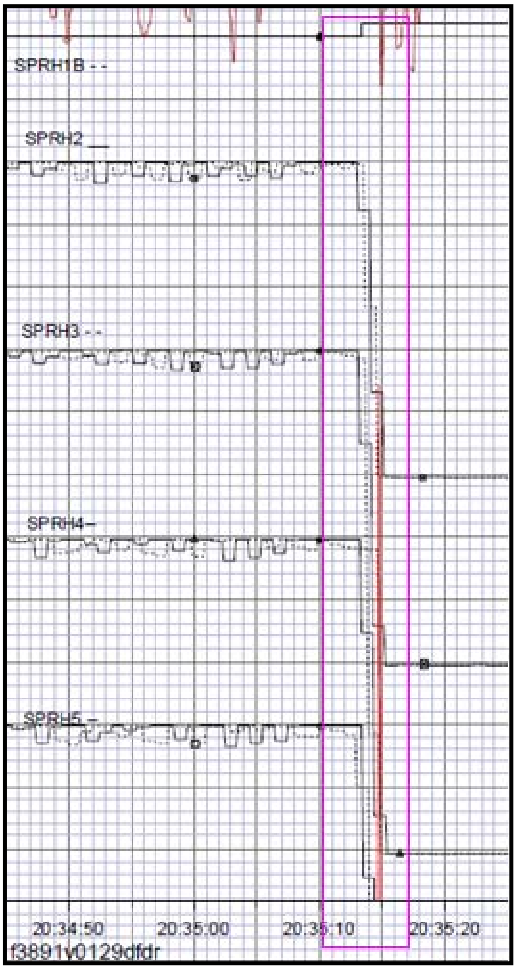
Pic 15 – Gráfico da aceleração vertical do CS-TKO

  - THR levers were on CLB detent and A/THR was still selected.
  - There was no Ground Spoilers extension.

III. <u>Bounce</u>

- <u>At 20:35:11 hours</u>:
  - The aircraft bounced on the runway. PF reacted, commanded nose-up order and pitch remained at +7 degrees;

- <u>At 20:35:12 hours</u>:
  - During the bounce, PF ordered some alternate pitch up/pitch down inputs that changed the attitude to 3.7 degrees up;
  - Being A/THR active and speed decreasing, automatism reacted suitability and power was increased on both engines;
- <u>At 20:35:13 hours</u>:
  - Aircraft bounced up to 12ft RA;
  - PF ordered full nose-up input and pitch started to increase again.
- <u>At 20:35:13,5 hours</u>:
  - THR levers were set to *IDLE* notch and this action leaded to the A/THR disconnection (pic. 13) and a power decreasing;
  - Simultaneously, Ground Spoilers were extended, causing drag leading to a vertical speed acceleration increment of the aircraft towards the ground (pic16).
- <u>At 20:35:14 hours</u>:
  - Action applied on the rudder pedal was maintained during the whole bounce which lasted for about 5 seconds.



Pic. 16 – Spoilers extension graphic

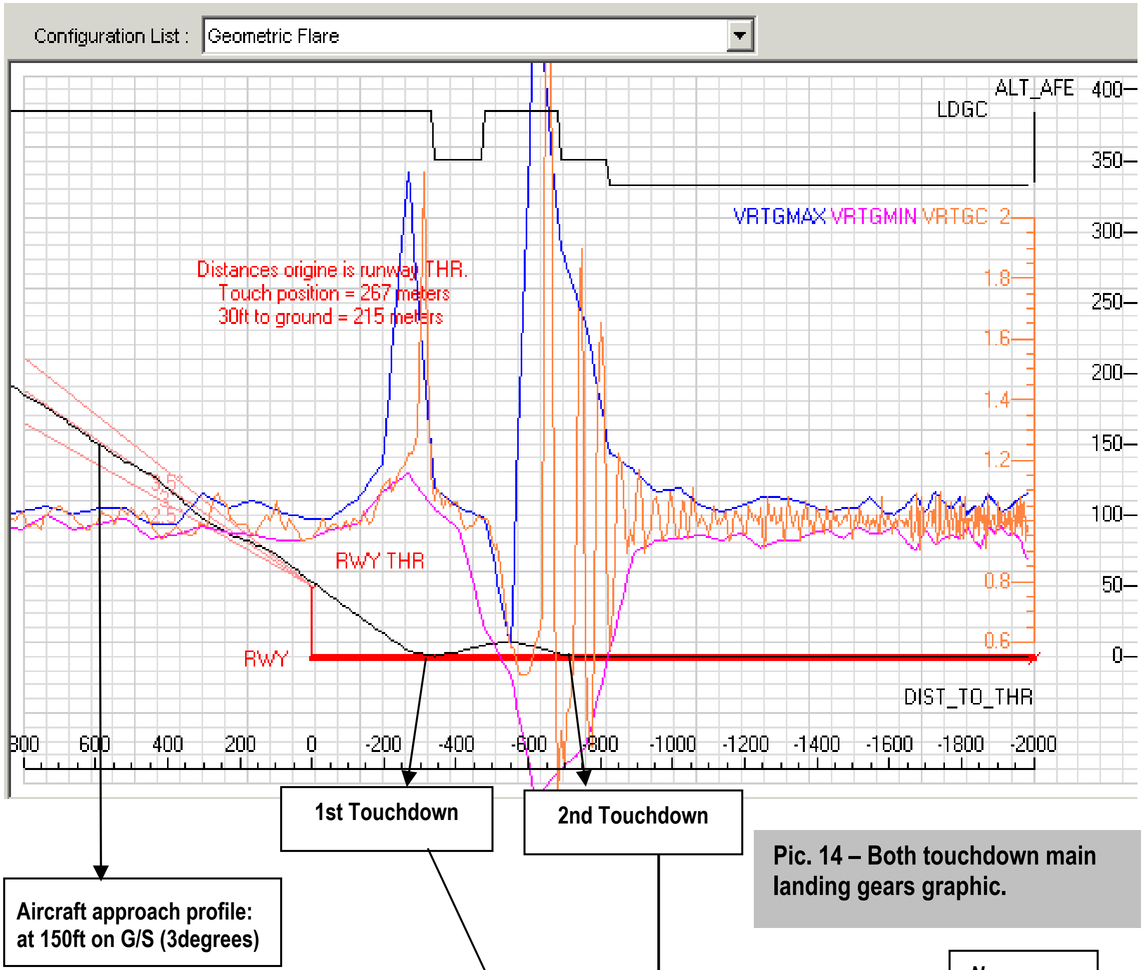
❖ **From 20:35:14 hours to 20:35:17 hours**

IV. <u>Second Touchdown</u>

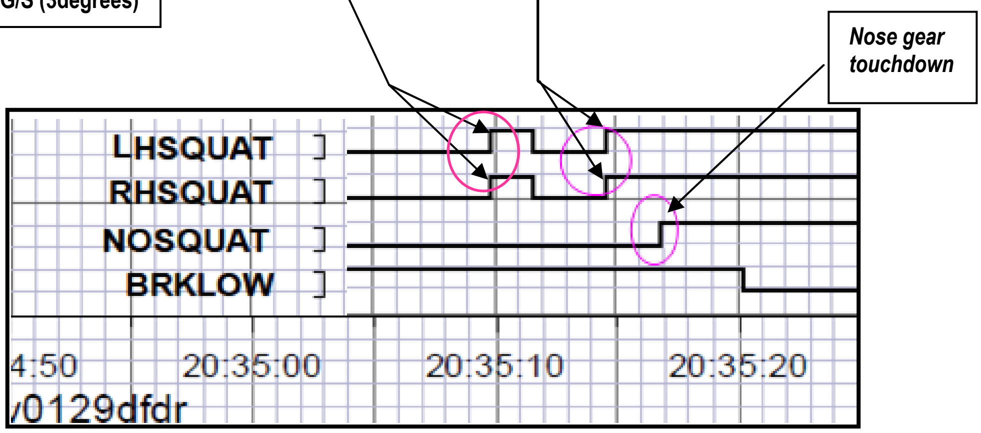
- <u>At 20:35:14,5 hours</u>:
  - Aircraft touched down again on both landing main gear almost at the same time. Ground speed was 138kt;
  - Vertical acceleration reached a pick at +4.86g[3] (pic.17).

[3] In AMM 05-51-11, *Hard Landing* is defined any time the vertical acceleration is more than 2.6g

- <u>At 20:35:16,5 hours</u>:
  - PF ordered nose-down and the pitch, until then at 4.5 degrees nose-up, start decreasing;
  - Both THR levers were transiently moved out from *IDLE* notch.



Pic. 14 – Both touchdown main landing gears graphic.



Pic. 15 – Main and nose gears' sensors graphic.

❖ **From 20:35:17 hours to 20:35:22 hours**

V. Nose landing gear touchdown and deceleration

- At 20:35:17 hours:

  Nose gear touch down softly, (vertical acceleration was 1.6g), 2,5 seconds after main landing gear touchdown;

- At 20:35:18,5 hours:

  Full reversers were deployed (THR levers at -20 degrees) and brakes applied.

1.12 IMPACT AND WRECKAGE INFORMATION

Not applicable.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

Not applicable.

1.14 FIRE

There was no fire.

1.15 SURVIVAL ASPECTS

Everybody was sit, with safety belts fasten, the impact forces were absorbed by gear struts and there were no claims from aircraft occupants.

There was no need of any airport emergency and rescue means intervention, due to the accident characteristics.

1.16 TESTS AND RESEARCH

1.16.1 Aircraft dedicated inspection

Aircraft entered the hangar on the 6th for an “A” type maintenance inspection, as per maintenance schedule.

Noting the load message, a special check was carried out, according to AMM-05-51-11 - “*Hard/overweight landing inspection*”, during which some LH and RH wing shroud box lower panels were found damaged and some tire marks showed that they suffered a great contraction (Ref. 1.3 – Aircraft Damage, page 10).

Manufacturer was contacted and a special inspection programme was approved, covering all the aircraft structure, from nose to tail and wing tip to wing tip, engines and APU included. Nose gear leg suffered no great stress and it was considered unnecessary to be removed.

Findings of such programme were reported by the operator as per table below:

CS-TKO Inspection Status

1. **General Inspections (AMM 05-51-11 Inspection for Severe Hard Landing)**
   - Small damage in LH & RH Wing Shroud Boxes Lower Panel - damage repaired.
   - No further damage found.
2. **Fuselage - Sections 18 and 19.1**
   - NIL Findings.
3. **Fuselage - Sections 15, 16/17, 19, Keel Beam and rudder**
   - Small mark found on AFT cargo door lock fitting/fitting blended-out.
   - Small gap found in a fitting in the aft cargo compartment/applied sealant to fill the gap.
   - Some cracked sealant found in the aft cargo compartment/restored sealant.
   - No further damage found.
4. **Fuselage - Section 21**
   - Found just one hi-lock broken - hi-lock replaced.
   - No further damage found.
5. **Belly Fairings**
   - NIL Findings.
6. **Fuselage - Sections 11/12 and 13/14**
   - NIL Findings.
7. **Cockpit**
   - NIL Findings.
8. **Pylons and engine mounts**
   - Sealant in pylon-to-wing #1 aft attachment fitting found damaged - sealant to be restored.
   - Small crack found in a pylon #1 inboard panel - panel will be replaced.
   - No further damage found.
9. **Thrust reversers and Nacelles**
   - NIL Findings.
10. **Wing structure**
    - Lack of sealant at aft edge of reinforcing plate - RH wing bottom skin - seal repaired.
    - Some fasteners found with head dishing - fasteners to be replaced.
    - Some fasteners found with cracked paint around head - paint to be restored.
    - Slight ovality in MLG rib lugs with no further findings - lugs reworked.
    - Small damage in LH & RH Wing Shroud Boxes Lower Panel - damage repaired.
    - No further damage found.
11. **Trimmable Horizontal Stabiliser (THS)**
    - Paint peeled off over a rivet head and over a sealant area in THS - will be repainted.
    - Slight waviness in panel 4 of the upper skin THS - waviness Ok according with Airbus.
    - Hinge arm #6 with small lack of material - hinge smoothly blended-out and reprotected.
    - No further damage found.
12. **Engines**
    - NIL Findings.
13. **APU**
    - NIL Findings.

Pic. 18 – Maintenance findings and related corrective actions

Due its complexity and specialized tooling requirements, main landing gear inspection was not carried out at station and it was decided to replace both main landing gear legs by new ones and send the others to the manufacturer (Goodrich) for further tests.

Airbus	**Technical Adaptation** Statement of Approved Data	1. Date: 26-Nov-2009 2. TA Ref.: TA-SEOT1-2009-383802-1
3. Subject : SEVERE HARD LANDING		4. Y/Ref.: 074.19-51-2009
5. Aircraft type or P/N: A320	6. MSN or S/N: 3891	7. FC: 231 FH: 523

8. Operator request:

A320-214 MSN 3891 suffered a severe hard landing on August 4th, 2009.
The maximum vertical acceleration recorded is 4,86g according to the loads report.
The full inspection program requested by Airbus has been carried out and all findings have been corrected in accordance with Airbus requirements.

RZO therefore request Airbus agreement to return MSN 3891 to service.

9. Airbus response:

The appropriate inspections, as detailed in SEOT1-2009-383802-Inspections-issue 02, have been performed. All corrective actions have been implemented, including replacement of LH and RH main landing gears and their structural components, and the 4 MLG wheels and tyres.

The aircraft has been shown to be airworthy following this event and can return back to service

10. Minor TA : [X] Major TA : [ ]

11 Definitive TA: [X] Temporary TA: [ ] Limitation: (if temporary) FC FH Days/Months/Years or date

12. Issuing Organization: SEOT1	13. Customer Services Engineer: CHRISTIAN LAHARY

Declaration - The technical information described above is approved under the authority of EASA approved Design Organization Number EASA.21J.031 and as per EASA rules Part 21 Subpart M & D.

Designated Airworthiness Engineer Signature:

14. Name: [illegible]	15. Signature: APPROVED UNDER EASA DESIGN ORGANISATION APPROVAL [redacted] Date :

This approved data is based on the information and data provided by the requester to Airbus.
Airbus disclaims any and all responsibility for incorrect or inaccurate information provided by the requester.

Statement of Approved Data
FM0900351 A5009 issue C

Page 1 / 1

Pic. 19 – *Technical Adaptation*

Once the works were finished and all ground tests granted aircraft airworthy, a test flight was performed, uneventfully, at 30th November.

Maintenance issued a Maintenance Release Form and released the aircraft for service:

TAP PORTUGAL

Sheet *(Folha)* 1 of *(de)* 1

MAINTENANCE RELEASE *(Declaração de Aptidão para o Voo)*

☐ Check here in case of test flight *(Assinalar aqui em caso de voo de ensaio)*

AIRCRAFT *(Aeronave)*

MANUFACTURER *(Fabricante)* AIRBUS	MODEL *(Modelo)* A320-214
SERIAL NO. *(Nº. de Série)* 3891	NATIONALITY & REGISTRATION MARKS *(Nacionalidade e Matrícula)* PORTUGUESA CS-TKO
FLIGHT HOURS SINCE NEW *(Total de Horas de voo)* 534:33	CYCLES SINCE NEW *(Total de Ciclos)* 238

CUSTOMER/OPERATOR *(Cliente/Operador)*

NAME *(Nome)* SATA INTERNATIONAL	ADDRESS *(Morada)* PONTA DELGADA - AÇORES

THE AIRCRAFT ABOVE IDENTIFIED WAS INSPECTED AND REPAIRED OR MODIFIED, EXCEPT AS OTHERWISE SPECIFIED, IN ACCORDANCE WITH PART 145 AND, IN RESPECT TO THE WORK PERFORMED, IS CONSIDERED READY FOR RELEASE TO SERVICE. *(A aeronave acima identificada foi inspeccionada e reparada ou modificada, excepto se de outra forma especificado, de acordo com a PARTE 145 e, relativamente aos trabalhos realizados, é considerada aprovada para serviço)*
DESCRIPTION OF WORK PERFORMED *(Descrição do trabalho efectuado)*:

A1.1 Check; AD; EO´s; RE´s; RTR´s and NR´s + V/T04 ; AIRBUS TA -SEOT1-2009-383802-1 (EOs; RTR´s and NR´s).
PERTINENT DETAILS OF THE REPAIR ARE ON FILE AT THIS MAINTENANCE ORGANIZATION UNDER EVENT No. (O processo documental com os detalhes dos trabalhos efectuados encontra-se arquivado nesta Organização de Manutenção, sob o nº do evento): AV 77008 and AV 77818.

FOR SPECIAL REMARKS, SEE 2 ATTACHED SHEETS, BY THE ORIGINAL CERTIFICATE *(As condições especiais em que é emitida esta declaração estão indicadas nas folhas anexas ao certificado original)*

DATE *(Data)*: segunda-feira, 30 de Novembro de 2009

SIGNATURE AND PRINTED NAME OF AUTHORISED PERSON BY QUALITY ASSURANCE DEPARTMENT:
(Assinatura e nome legível de uma pessoa autorizada pela Direcção da Qualidade):

Sig *(Ass)*: [redacted] Name *(Nome)*: [redacted]

TAP PORTUGAL PART - 145 APPROVAL CERTIFICATE NO. PT.145.001

TAP MAV 650

Maintenance & Engineering
Quality Assurance Department
P. O. Box 50194
1704-801 LISBOA - Portugal

Tel. No. 351 21 8416204
Fax No. 351 21 8415775
SITA Code LISMVTP
Telex 12231 TAP LIS P

TAP MOD ME 110 REV. 6, 11 AGO 2009

Pic. 20 - *Maintenance Release Form*

1.16.2 Other similar in-service events

There have been several cases of hard landings with a common root (ground spoiler's deployment in flight after bouncing), involving Airbus aircrafts, not only on A320 family but also on A330 and A340 models.

1.17 Organizational and Management

1.17.1 Flight Operations

Operator carries its operations according its AOC, issued by Portuguese Civil Aviation Authority, and Flight Operations Department is organized as per Company Flight Operations Manual, approved by the Authority and following EASA requirements and other national and international regulations.

1.17.2 Flight Crew Training

Crew type rating qualification and training is achieved in house, by company certified TRTO, following course structure recommended by the manufacturer and approved by the Authority. Simulator training is performed by company instructors using certified third part simulators.

1.17.3 Maintenance Organization

Operator's aircraft Line Maintenance is performed by company Line Maintenance Department, in Lisbon, and by EASA part 145 certified contracted Companies, all other places. All programmed inspections and heavy maintenance works are performed by TAP Maintenance & Engineering Department, or other certified AMRO. All maintenance control and supervision is the responsibility of SATA International Maintenance & Engineering Department, following the Maintenance Management Exposition, approved by the Authority and covering all EASA requirements.

1.18 ADDITIONAL INFORMATION

1.18.1 AMM – Aircraft Maintenance Manual

The A-320 Aircraft Maintenance Manual (AMM), chapter 05-51-11-200-004 – Inspection After Hard Landing, defines (1) **Hard landing** when the aircraft, below its Maximum Landing Weight (MLW), touches down with a vertical acceleration equal to or more than 2.6 g and less than 2.86 g at aircraft Centre of Gravity (CG) or when its vertical speed (V/S) is equal to or more than 10 ft/s (600 ft/min) and less than 14 ft/s (840 ft/min). (2) ***Severe hard landing*** when the aircraft, under its Maximum Landing Weight (MLW), touches down with a vertical acceleration (VertG) equal to or more than 2.86 g at aircraft Centre of Gravity or, a vertical speed (Vs) equal to or more than 14 ft/s.

Yet, this manual states that the responsibility of issuing a report, whenever a hard landing is suspected of having occurred, lies on flight crew. However, it is a Maintenance team duty *to confirm the impact parameters values to know the category of the landing based on the DMU Load Report or the FDRS read out. In the case the impact parameters are* *impossible to confirm with DMU or DFDR, the Severe Hard/Overweight Landing procedures must be followed* (pic.21).

A320

AIRCRAFT MAINTENANCE MANUAL

REFERENCE DESIGNATION

3. <u>Job Set-up</u>

Subtask 05-51-11-210-090

A. Hard/Overweight Landing Inspection Requirements

R **ON A/C 001-005, 008-050, 101-101, 104-111, 113-113, 401-406, 409-409,
R 414-420, 422-499, 501-506, 552-559,

R (Ref. Fig. 617/TASK 05-51-11-991-015, 618/TASK 05-51-11-991-016)

**ON A/C 001-050, 101-101, 104-111, 113-113, 401-406, 409-409, 414-420,
422-499, 501-506, 552-559,

(1) Definitions
There are several categories of hard/overweight landing:

(a) Hard landing
A hard landing is a landing with an aircraft weight less than the Maximum Landing Weight (MLW) and:
- a vertical acceleration (VertG) equal to or more than 2.6 g and less than 2.86 g at aircraft Center of Gravity (CG) or,
- a vertical speed (Vs) equal to or more than 10 ft/s and less than 14 ft/s.

(b) Severe hard landing
A severe hard landing is a landing with an aircraft weight less than the Maximum Landing Weight (MLW) and:
- a vertical acceleration (VertG) equal to or more than 2.86 g at aircraft Center of Gravity (CG) or,
- a vertical speed (Vs) equal to or more than 14 ft/s.

(2) Hard/overweight landing confirmation

(a) It is the responsibility of the flight crew to make a report if they think there was a hard/overweight landing.

(b) After a crew report of a hard/overweight landing, you must confirm the impact parameters to know the category of the landing.
To know this, refer to:
- the DMU load report 15 (Ref. TASK 31-37-00-200-001) or,
- the FDRS read out.

(c) When you know the category of the landing, you must do the inspections for that category.

<u>NOTE</u> : If you cannot confirm the impact parameter values with the DMU or the FDRS, you must do the inspection with the steps for a severe hard/overweight landing.

R EFF : 001-050, 101-101, 104-111, 113-113,
401-406, 409-409, 414-420, 422-499, 501-506,
552-559,
XF

05-51-11 Page 678
Nov 01/08

Printed in France

Pic. 21

1.18.2 Operational Procedures

1.18.2.1 Flight Operations

I. General

Company operation policy was to follow manufacturer recommended procedures, as step down on FCOM and highlighted on Standard Operating Procedures (SOP), Chap. 3.03.00, as they represent the best way to proceed, from a technical and operational standpoint.

II. Standard landing procedures

FCOM states that, for a standard landing operation, with the *"aircraft stabilized at approach time, flare must be performed at 30 feet approximately"* and that *"thrust levers must be at IDLE".*

Still, it reminds the pilots for the following:

a. ***"In manual landing conditions, the "RETARD" callout is triggered at 20 feet Radio Altimeter (RA), in order to remind the pilot to retard the thrust levers"*** **(IDLE position);**

b. Through a Note, in the same reminder intention, it is establishes ***"If one or both thrust levers remain above the IDLE detent, ground spoilers extension is inhibited"***

A318/319/320/321 FLIGHT CREW OPERATING MANUAL	STANDARD OPERATING PROCEDURES	3.03.22	P 4
	LANDING	SEQ 100	REV 42

LANDING

The cockpit cut-off angle is 20 degrees.

- **In stabilized approach conditions, the flare height is approximately 30 feet :**

  – **FLARE . . . . PERFORM**

  – **ATTITUDE . . . . MONITOR**
  The PNF should monitor the attitude, and call out :
  – "PITCH, PITCH", if the pitch angle reaches 7.5 degrees.
  – "BANK, BANK", if the bank angle reaches 7 degrees.

  – **THRUST levers . . . . IDLE**
  R If autothrust is engaged, it automatically disconnects when the pilot sets both thrust
  R levers to the IDLE detent.
  In manual landing conditions, the "RETARD" callout is triggered at 20 feet Radio Altitude (RA), in order to remind the pilot to retard the thrust levers.

  R *Note : If one or both thrust levers remain above the IDLE detent, ground spoilers*
  R *extension is inhibited.*

Pic. 22 - FCOM 3.03.22 – "Standard Operating Procedures - Landing"

III. Supplementary techniques

The same Manual (FCOM), Chapter 3.04.27 - Supplementary Techniques - Flight Controls -, paragraph ***"Bounce at Landing",*** we underlined the significant part:

"(…) In case of a high bounce, initiate a go-around, initially maintaining the pitch attitude. Retract the flaps one step, and than the landing gear, once the aircraft is properly established on the go-around segment. In all cases, do not attempt to soften the (potential) second touchdown by increasing the pitch attitude".

A318/A319/A320/A321 SATA International FLIGHT CREW OPERATING MANUAL	SUPPLEMENTARY TECHNIQUES	3.04.27	P 5
	FLIGHT CONTROLS	SEQ 001	REV 43

When time permits, the pilot should check the ECAM's FLT CTL page, and refine the rudder trim to give neutral lateral control, and also trim the rudder toward the spoilers that are up or toward the aileron that is farthest up to bring the lateral controls back to neutral.

<u>ENGINE-OUT LANDING</u>

The engine-out landing is basically a conventional landing. The pilot should trim to maintain the slip indication centered. It is yellow, as long as N1 is less than 80%. Between 100 and 50 feet, the pilot can reset rudder trim to make the landing run easier, and to recover full rudder travel in both directions.

<u>BOUNCE AT LANDING</u>

R In case of a light bounce, maintain the current pitch attitude and complete the landing, while maintaining the thrust at idle. <u>In case of a high bounce, initiate a go-around, initially maintaining the pitch attitude. Retract the flaps one step, and then the landing gear, once the aircraft is properly established on the go-around segment. In all cases, do not attempt to soften the (potential) second touchdown by increasing the pitch attitude</u>.

<u>TRAINING TOUCH-AND-GO</u>

With the nosewheel on ground, pitch trim automatically resets to zero. The pilot should select CONF 2 and add thrust. He must always move the thrust levers to TOGA to bring up the speed reference system (SRS), and then reduce to a lower thrust (not less than CL), if he chooses. Takeoff may be a little out of trim, which may affect the rotation slightly, but once the aircraft is off the ground, the control law holds the "out of trim", then retrims at 50 feet.

Pic. 23 - FCOM – "Supplementary Techniques – Flight Controls (*Bounce* at landing)"

Note: FCOM2 and FCTM, at the time, didn't disclose suitable information in order to distinguish *"high bounce"* from *"low bounce".*[4]

4 These definitions were only available in FBON SQ 309 – "Landing Techniques Bounce Recovery" which is not supplied to the pilots as tutorial material. It is only available on SATA network for consultation.

IV. Use of automatics

It's Airbus policy to make use of automatics as much as possible.

As per FCOM 3.04.70 P 2, the pilot selected to use ATHR during the approach, in order to be ready for any profile correction and more accurate speed control (pic.24).

A318/A319/A320/A321	SUPPLEMENTARY TECHNIQUES	3.04.70 P 2	
SATA International – Serviço e Transportes Aéreos, S.A. FLIGHT CREW OPERATING MANUAL	POWER PLANT	SEQ 100	REV 42

Use of autothrust in approach

The pilot should use autothrust for approaches. On final approach, it usually gives more accurate speed control, although in turbulent conditions the actual airspeed may vary from the target speed, by as much as five knots. Although the changeover between auto and manual thrust is easy to make with a little practice, the pilot should, when using autothrust for the final approach, keep it engaged until he/she retards the thrust levers to idle for touchdown. If the pilot is going to make the landing using manual thrust, he/she should disconnect the A/THR by the time he/she has reached 1000 feet on the final approach.
If he/she makes a shallow flare, with A/THR engaged, it will increase thrust to maintain the approach speed until he/she pulls the thrust levers back to idle. Therefore he/she should avoid making a shallow flare, or should retard the thrust levers as soon as it is no longer necessary to carry thrust, and if necessary before he/she receives the "retard" reminder.
When using autothrust, the pilot can always change thrust by moving the thrust levers above the CL detent. The thrust then increases to what corresponds to the thrust lever position. However, autothrust stays armed, and immediately takes effect when the thrust levers are returned to the CL detent. Therefore, the pilot should normally put the thrust levers back to CL, as soon as the aircraft has made the change for which he increased thrust. This feature gives the pilot a means of advancing phase on the autothrust in very difficult environmental conditions. But, it should only be needed in exceptional circumstances.

Note : *When below 100 feet, moving thrust levers above the CL detent, will result in A/THR disconnection.*

Although use of the autothrust is recommended for the entire approach, this does not absolve the pilot from his responsibility to monitor its performance, and to disconnect it if it fails to maintain speed at the selected value. Such monitoring should include checking on whether or not the managed speed, calculated by the FMGC, is reasonable.
For more information concerning aircraft handling during final approach, refer to the FCOM Bulletin "Aircraft handling in final approach".

Pic. 24 - FCOM – "Supplementary Techniques – Use of autothrust in approach)"

V. FCTM – Flight Crew Training Manual

In Flight Crew Training Manual (FCTM NO-160, edition 08 JUL 08), page 2/12, Airbus recalls: ***"At 20 ft, the "RETARD" auto-call reminds the pilot to retard thrust levers. It is a reminder rather than an order. The pilot will retard the thrust levers when best adapted e. g. if high and fast on the final path the pilot will retard earlier […]"*** (pic. 25):

AIRBUS A318/A319/A320/A321 FLIGHT CREW TRAINING MANUAL	NORMAL OPERATIONS LANDING

[…]

FLARE

Ident.: NO-160-00005576.0001001 / 26 MAR 08
Applicable to: ALL

PITCH CONTROL

When reaching 50 ft, auto-trim ceases and the pitch law is modified to flare law. Indeed, the normal pitch law, which provides trajectory stability, is not the best adapted to the flare manoeuvre. The system memorizes the attitude at 50 ft, and that attitude becomes the initial reference for pitch attitude control. As the aircraft descends through 30 ft, the system begins to reduce the pitch attitude at a predetermined rate of 2 ° down in 8 s. Consequently, as the speed reduces, the pilot will have to move the stick rearwards to maintain a constant path. The flare technique is thus very conventional.
From stabilized conditions, the flare height is about 30 ft. This height varies with different parameters, such as weight, rate of descent, wind variations...
Avoid under flaring.

- The rate of descent must be controlled prior to the initiation of the flare (rate not increasing)
- Start the flare with positive backpressure on the sidestick and holding as necessary
- Avoid forward stick movement once Flare initiated (releasing back-pressure is acceptable)

At 20 ft, the "RETARD" auto call-out reminds the pilot to retard thrust levers. It is a reminder rather than an order. The pilot will retard the thrust levers when best adapted e.g. if high and fast on the final path the pilot will retard earlier. In order to assess the rate of descent in the flare, and the aircraft position relative to the ground, look well ahead of the aircraft. The typical pitch increment in the flare is approximately 4 °, which leads to -1 ° flight path angle associated with a 10 kt speed decay in the manoeuvre. A prolonged float will increase both the landing distance and the risk of tail strike.

RZO A318/A319/A320/A321 FLEET FCTM — NO-160. P 2/12 — 08 JUL 08

Pic. 25 – FCTM – "Normal Operations – Landing (Flare)"

On subsequent revision (24 JUN 09) Airbus introduced some more considerations on pitch and thrust control during flare *(original states yellow highlighted)* namely the alert

"…the pilot must ensure that all thrust levers are at IDLE detent at the latest at the touchdown, to ensure ground spoilers extension at touchdown" (pic. 26).

SATA International

A318/A319/A320/A321
FLIGHT CREW TRAINING MANUAL

NORMAL OPERATIONS
LANDING

This technique will ensure that performance margins are not compromised and provide adequate main gear clearance.

FLARE

Applicable to: ALL

PITCH CONTROL

When reaching 50 ft, auto-trim ceases and the pitch law is modified to flare law. Indeed, the normal pitch law, which provides trajectory stability, is not the best adapted to the flare manoeuvre. The system memorizes the attitude at 50 ft, and the attitude becomes the initial reference for pitch attitude at a predetermined rate of 2° down in 8 s. consequently, as the speed reduces, the pilot will have to move the stick rearwards to maintain a constant path. The flare technique is thus very

Prior to flare, avoid destabilization of the approach and steepening the slope at low heights in attempts to target a shorter touchdown. If a normal touchdown point cannot be achieved or if destabilization occurs just prior to flare, a go-around (or rejected landing) should be performed. The PNF monitors the rate of descent and should call "*SINK RATE*" if the vertical speed is excessive prior to the flare.

From stabilized conditions, the flare height is about 30 ft.

This height varies due to the range of typical operational conditions that can directly influence the rate of descent.

Compared to typical sea level flare heights for flat and adequate runway lengths, pilot need to be aware of factors that will require an earlier flare, in particular:

- High airport elevation.
  Increased altitude will result in higher ground speeds during approach with associated increase in descent rates to maintain the approach slope.
- Steeper approach slope (compared to nominal 3 °).
- Tailwind.
  Increased tailwind will result in higher ground speed during approach with associated increase in descent rates to maintain the approach slope.
- Increasing runway slope.
  Increasing runway slope and/or rising terrain in front of the runway will affect the radio altitude callouts down to over flying the threshold used by the flight crew to assess the height for the start of flare possibly causing flare inputs to be late. The visual misperception of being high is also likely.

Note that the cumulative effect of any of the above factors combined for one approach will require even more anticipation to perform an earlier flare.

RZO A318/A319/A320/A321 FLEET — NO-160. P 2/12
FCTM — 24 JUN 09

SATA International

A318/A319/A320/A321
FLIGHT CREW TRAINING MANUAL

NORMAL OPERATIONS
LANDING

If the flare is initiated too late then the pitch changes will not have sufficient time to allow the necessary change to aircraft trajectory. Late, weak or released flare inputs increase the risk of a hard landing.

Avoid under flaring.

- The rate of descent must be controlled prior to the initiation of the flare (rate not increasing)
- Start the flare with positive (or "prompt") backpressure on the sidestick and holding as necessary
- Avoid forward stick movement once Flare initiated (releasing back-pressure is acceptable)

At 20 ft, the "RETARD" auto-call reminds the pilot to retard thrust levers. It is a reminder rather than an order. When best adapted, the pilot will rapidly retard all thrust levers; depending on the conditions, the pilot will retard earlier or later. However, the pilot must ensure that all thrust levers are at IDLE detent at the latest at the touchdown, to ensure ground spoilers extension at touchdown. In order to asses the rate of descent in the flare, and the aircraft position relative to the ground look well ahead of the aircraft. The typical pitch increment in the flare is approximately 4°, which leads to -1° flight path angle associated with a 10 kts speed decay in the manoeuvre. Do not allow the aircraft to float or do not attempt to extend the flare by increasing pitch attitude in an attempt to achieve a perfectly smooth touchdown. A prolonged float will increase the landing distance and the risk of

LATERAL AND DIRECTIONAL CONTROL

FINAL APPROACH

In crosswind conditions, a crabbed-approach wings-level should be flown with the aircraft (cockpit) positioned on the extended runway centerline until the flare.

FLARE

The objectives of the lateral and directional control of the aircraft during the flare are:

- To land on the centerline
- And, to minimize the lateral loads on the main landing gear.

The recommended de-crab technique is to use:

- The rudder to align the aircraft with the runway heading during the flare; and
- The roll control, if needed, to maintain the aircraft on the runway centerline. Any tendency to drift downwind should be counteracted by an appropriate lateral (roll) input on the sidestick.

In the case of a strong cross wind, the aircraft may be landed with a residual drift (up to about 5 °) to prevent an excessive bank.

Consequently, combination of the partial de-crab and wing down techniques may be required. Depending on cross wind value, this may result in touching down with some bank angle into the wind (hence with the upwind landing gear first).

RZO A318/A319/A320/A321 FLEET — NO-160. P 3/12
FCTM — 24 JUN 09

Pic. 26 – FCTM – "Normal Operations – Landing" Ed. 24 JUN 09

The FCTM is not an Operating Manual (*strictus sensus*) and it is mainly used for training purposes. SATA, as the majority of operators, have two distinct training periods (spring/autumn). So, the entire fleet was not ware of this change (occurred less than two months before the event) and the previous version recommendations were being adhered to.

At pages 11 e 12, § *"BOUNCING AT TOUCHDOWN*", the FCTM refers that, *"**in case of bouncing at touchdown, the pilot may be tempted to increase the pitch attitude to ensure a smooth second touch down"*** and also that he/she should, ***"in case of high bounce, maintain the pitch attitude and initiate a go-around. Do not try to avoid a second touch-down during the go-around. Should it happen, it would be soft enough to prevent damage to the aircraft if pitch attitude is maintained. […] A landing should not be attempted immediately after high bounce, as thrust may be required to soften the second touch down and the remaining runway length may be insufficient to stop the aircraft[5]".***

AIRBUS A318/A319/A320/A321 FLIGHT CREW TRAINING MANUAL	NORMAL OPERATIONS LANDING

- Bouncing at touch down
  In case of bouncing at touch down, the pilot may be tempted to increase the pitch attitude to ensure a smooth second touch down. If the bounce results from a firm touch down, associated with high pitch rate, it is important to control the pitch so that it does not further increase beyond the critical angle.

APPROACH AND LANDING TECHNIQUES

A stabilized approach is essential for achieving successful landings. It is imperative that the flare height be reached at the appropriate airspeed and flight path angle. The A/THR and FPV are effective aids to the pilot.
VAPP should be determined with the wind corrections (provided in FCOM/QRH) by using the FMGS functions. As a reminder, when the aircraft is close to the ground, the wind intensity tends to decrease and the wind direction to turn (direction in degrees decreasing in the northern latitudes). Both effects may reduce the head wind component close to the ground and the wind correction to VAPP is there to compensate for this effect.
When the aircraft is close to the ground, high sink rate should be avoided, even in an attempt to maintain a close tracking of the glideslope. Priority should be given to the attitude and sink rate. If a normal touchdown distance is not possible, a go-around should be performed.
If the aircraft has reached the flare height at VAPP, with a stabilized flight path angle, the normal SOP landing technique will lead to the right touchdown attitude and airspeed.
During the flare, the pilot should not concentrate on the airspeed, but only on the attitude with external cues.
Specific PNF call outs have been reinforced for excessive pitch attitude at landing.
After touch down, the pilot must "fly" the nosewheel smoothly, but without delay, on to the runway, and must be ready to counteract any residual pitch up effect of the ground spoilers. However, the main part of the spoiler pitch up effect is compensated by the flight control law itself.

BOUNCING AT TOUCH DOWN

In case of light bounce, maintain the pitch attitude and complete the landing, while keeping the thrust at idle. Do not allow the pitch attitude to increase, particularly following a firm touch down with a high pitch rate.
In case of high bounce, maintain the pitch attitude and initiate a go-around. Do not try to avoid a second touch down during the go-around. Should it happen, it would be soft enough to prevent damage to the aircraft, if pitch attitude is maintained.
Only when safely established in the go-around, retract flaps one step and the landing gear. A landing should not be attempted immediately after high bounce, as thrust may be required to soften the second touch down and the remaining runway length may be insufficient to stop the aircraft.

Pic. 27 – FCTM – "Normal Operations – Bouncing"

[5] FCTM – 2008, July revised edition.

These and some other reminding notices are present in several FOBN. They draw pilots' attention for the importance of a stabilized approach, a normal and on time flare performance and the need of retarding the thrust levers to *IDLE* position at the touch-down.

In all occasions the need to put thrust levers at IDLE at or before touch-down is referred, the reason presented is *"ground spoilers deployment at touchdown"* but under no circumstances a reference is made to the possibility of ground spoilers deployment in the air if, after a bounce, thrust levers are retarded to IDLE within the 3s interval of FLT to GRD transition memorized concept.

1.18.2.2 Airbus procedures

In consequence of hard landing recurrence observed with all its aircrafts, Airbus have published several articles on its "Flight Operations Briefing Notes" official publication, drawing pilot's attention for the importance of following recommended procedures for landing, stated in FCOM and FCTM, highlighting the need to retard the thrust levers to *IDLE* position before touchdown, in order to allow ground spoilers deployment when main landing gear struts are compressed at touchdown. Special emphasis is made to FOBN FLT_OPS_LAND – SEQ09 *("Landing Techniques: Bounce Recovery - Rejected Landing").*

However, bounces kept on, followed by hard landings at the second touchdown, being the thrust levers above *IDLE* at the landing moment. The "*flight to ground transition memorized 3s*" feature, along with wheel spin up condition, allowed the Ground Spoilers deployment, while the aircraft was still flying. Therefore, when thrust levers were retarded to *IDLE*, leading to a lift drop and adding vertical speed acceleration downwards to the aircraft.

To minimize this outcome, Airbus conceived a modification to be introduced on A330 and A340 fleets Ground Spoilers Logic but not set up to the A320 family at the time of CS-TKO event. So, Airbus decided to anticipate an A320's SEC modification.

So, together with Thales Aviation S. A., some adaptations were developed to be incorporated in the Spoiler Elevator Computer (SEC), as per SB Nr A320-27-1198, dated July 01, 2010.

The purpose of the new SEC software standard is:

- To improve reliability of A320 ground spoilers in case of landing with speed brake and/or thrust levers in an inadequate position;

- To improve the conditions of the phased lift dumping (PLD) function activation to reduce hard landing occurrence after a bounce;
- To improve reverse authorization logics to be more robust to radio altimeter behaviour.

On the whole, this modification, validated under the identification *"SEC 120"*[6], will allow the Ground Spoilers' partial deployment[7], triggering a 10° spoilers extension as soon as the ground condition is detected, even if throttles are not at the right position at landing when retard is not performed.

1.18.2.3 Operator procedures

Before the accident, the DCA/SE (Operator Airworthiness and Engineering Services Department) had implemented an effective Maintenance Procedure (PM16). Thus, ground engineers should take the suitable actions in case an A320 Hard/Overweight Landing was reported by pilots. Wisely, it should be noted that the PM16 does not replace the AMM 05-51-11-200-004 procedures. Here, they could find a summary describing of what a severe hard landing is, and what appropriate actions should be applied. Nevertheless, there was no reference in how to interpret the DMU Load Report readings.

After the CS-TKO event, that Department decided to improve the PM document and, taking the event Load Report strip as an example, a workshop has been provided to all Company ground assistance engineers in order to prepare them conveniently for further events of same kind.

Further GPIAA's Preliminary Report, SATA's pilots attended *Balked and Bounced Landing Recover* training refreshment, as well.

1.19 INVESTIGATION TECHNIQUES

No special investigation techniques were used for this investigation. All evidence was collected from official documentation and dedicated inspection progress reports.

[6] This modification was introduced by the SB nr. 27-1198 and 27-1201 publication and will be considered as a standard implementation to all A320 models with MSN 4472 and subsequent serial numbers.

[7] Partial extension function, also called Partial Lift Dumping (PLD). If new PLD logic was already implemented on CS-TKO, the bounce height would be reduced and the VRTA at the second touchdown would be about +1,7g.

2. ANALYSIS

2.1 HUMAN FACTORS

2.1.1 Pilots Undertaking

The simulator flight training and checking were conducted according to the recommended manufacturer's FCTM and SOP; the pilots' evaluation was registered in their individual records. The very last training was based on the FCTM version of 08th July, 2008 due to have been done prior the new version publication of 24th June, 2009.

Both pilots were qualified for the flight and fulfilled the flight duty time, flight resting and legal work time requirements and those determined by the operator.

While the technical preparation of the pilots do not assume the interpretation of the data supplied by DMU Load Report, it is their responsibility (ref. pic. 21, p.31) to report suspicious hard landing and they must do so in writing into the Technical Log Book and still warn verbally ground engineer on duty from the configuration of the aircraft landing for immediate action before the next flight.

However, the pilots just did it verbally, both to the LDP and LIS ground engineers.

2.1.2 Ground assistance engineers undertaking

It is Ground Engineers' responsibility to quantify a touchdown, to classify it as hard/severe hard landing, to perform the suitable inspection, accordingly to AMM 05-51-11, based on pilots' information and to record the taken actions in reply to pilots' explanation, in the Technical Log Book, before the next aircraft flight.

The AMM is quite clear and especially detailed about the tasks to be accomplished every time a hard/severe hard landing is reported: one of them is to read the Load Report to establish the type of the landing and apply the appropriate inspections, accordingly to the manufacturer requirements. PDL and LIS ground assistance engineers examined the Load Report strip and, in spite of being there the needed data to classify as a severe hard the CS-TKO landing, they were unable to understand them probably due to different values shown.

Pic. 28

So, only a normal visual check was carried out to the main landing gear after the event, by pilots and GE together, and no damage was found on both sides of the Shroud Boxes Panels.

The late detection of this occurrence could, eventually, compromise the safety of the aircraft operation and its occupant's, by additional irregularities aggravation in similar landings. Till the dedicated inspection "A" type, the aircraft performed six more sectors and the same number of landings.

2.2 WEATHER CONDITIONS

The pilots have received METAR weather information concerning to 20:00 and 20:30 hours which did not show significant changes in wind velocity (direction and speed). Specifically during the landing there were no changes in wind velocity or the presence of windshear, in spite of the slight DFDR variations have been pointed at the time of touchdown.

The weather at the time of landing was within the capabilities of the aircraft and the responsibilities of the technical crew.

Thus, the weather factor was not considered contributing factor to this accident.

2.3 AIRCRAFT

The aircraft was new (built in the year of the event), was properly certificated and maintained and was equipped and dispatched in accordance with applicable regulations and industry practices.

In the Technical Handbook it was not found any pre-existing powerplant, system, or structural failure.

All aircraft systems were operating and feasible in accordance with the operation standards and provisions established by the manufacturer in the Maintenance Manuals.

The history of the aircraft did not reveal any condition incompatible with the proper operation of the aircraft for the flight.

The loading operation was routine and the aircraft operated within the limits of mass and CG.

Before that fact, it was established that the cargo and its load factors were not contributing factor for this event.

2.4 EVENT ANALYSIS

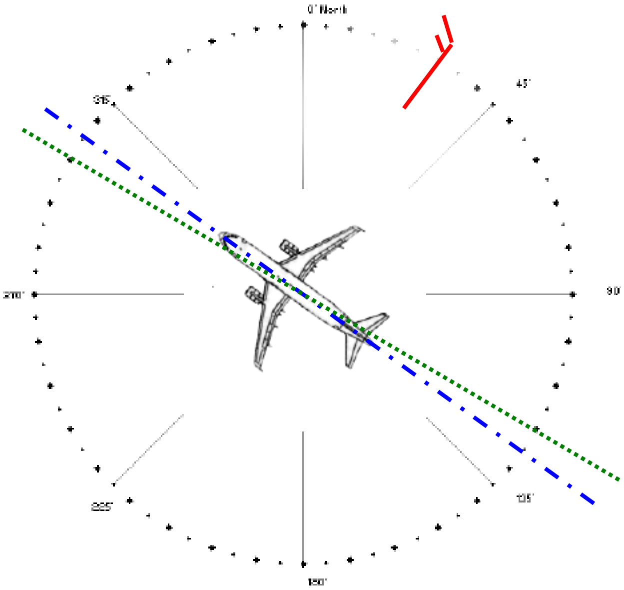
2.4.1 Approach and landing profile

The DFDR data analysis allowed remaking the approach and landing profile:

CS-TKO initiated a Rwy 30 ILS approach to Ponta Delgada Airport. Passing 875ft, PF disengaged the autopilot and manually flew the aircraft to the runway, but kept ATHR engaged for a smoother power management and speed control. The approach was performed according to SOP.

During all the approach the aircraft was under the influence of a right moderate wind speed, as it was forecasted in PDL METAR (20:30 hours).

On final, the aircraft experienced right wind of 13kt speed, from 030 degrees (in **red** in the picture). Aircraft heading was 306 degrees (in **blue** in the same diagram); the rwy 30 QFU (301 degrees) is represented in **green**:



Pic. 29– Diagram: CS-TKO heading (in blue), wind vector (in red) and RWY 30 QFU (in green).

Just before the flare, nose-down inputs were applied leading to a low aircraft attitude (1.41degrees).

Flare was initiated at 35ft RA, with a rate of descent of 800ft/min and an indicated air speed of 139.8kt.

PF increased the pitch up from 1.41degrees to 7.03 degrees, the speed decreased to 134kt and vertical acceleration increased to 1.27g.

During flare, the throttle levers were not retarded to *IDLE* position before touchdown.

First touchdown happened simultaneously on both main landing gear wheels, in 7.03 degrees nose up attitude, with a 752ft/min rate of descent, a ground speed of 141kt and a vertical acceleration of +2.13g.

Thrust levers remained set at CLB which caused the inhibition of Ground Spoilers deployment.

The aircraft bounced to a 12ft height RA. With autothrottle active and due to speed reduction, automatics ordered engine power to increase, to achieve the selected speed, increasing aircraft energy.

During the five seconds bounce time (the plane flew about 360 metres) the THR levers were brought to *IDLE* position, causing the ATHR disarming. Being within the 3s MLG compressed memorized period and with MLG wheels rolling above 72kt, the SEC commanded for fully extension of ground spoilers.

Spoilers' deployment caused a lift reduction and the aircraft touched the ground for the second time, in a severe hard landing condition, registering +4.86g of vertical acceleration.

Nose gear touched gently the ground, reverses were full applied and differential brake and rudder inputs were used to maintain the aircraft centred in runway axis.

2.4.2 Use of Automatics

It's Airbus policy to make use of automatics as much as possible. During the approach the pilot should keep the autothrust engaged until he/she retards the thrust levers to *IDLE* for touchdown; this action should be initiated by the pilot as soon as it is no longer necessary to carry thrust and, if necessary, before he/she receives the "retard" reminder (FCOM 3.04.70 P2 - Pic. 24, page 34 in this report).

Against the recommended procedure, thrust levers were kept at CLB setting, even after touchdown, with ATHR remaining active and ground spoilers' deployment inhibit.

2.4.3 Landing techniques (Flare, Hard Landing and High Bounce procedures)

In a normal landing operation, being the aircraft stabilized in the approach phase, Airbus recommends in the FCOM – Flight Crew Operations Manual and in the FCTM – Flight Crew Training Manual, the following procedures:

1. *The rate of descent must be controlled prior to the initiation of the flare -* (FCTM, Normal Operations – Landing – ref.ª pic. 26, page 35 in this report).

   PF complied with SOP during approach, disconnecting the Auto Pilot before reaching high rise terrain on final approach, which could react in excess to some expected turbulence and erroneous height information, but he kept ATHR engaged for a smoother power management and speed control.

2. *Flare must be initiated at 30ft but, depending on several parameters, such as mass, rate of descent, wind variations, etc. this height must be anticipated to avoid a late flare.*

   Flare was initiated at 35ft (RA), slightly before the recommended height of 30ft (RA), probably to reduce the rate of descent (752 ft/min.) but this action was insufficient to reduce vertical speed and a hard landing was performed at first touchdown.

3. *At pilot's decision, but never after touchdown, THR levers must be retarded to IDLE position, keeping in mind that:*

   a. *In standard landing conditions, at 20 ft (RA), the "RETARD" auto-call out will remind the pilot that he/she must retard the thrust levers to IDLE position in order to assure the Ground Spoilers deployment at touchdown. This call-out is a reminder rather than an order; (RZO A318/A319/A320/ A321 FLEET NO-160 P1/2 e 2/2 FCTM 08 JUL 08,* - refer to pic. 25, page 35 of this report).

   b. *If one or both throttle levers are above IDLE position, the Ground Spoilers deployment will be inhibit.*

   At 20ft RA thrust levers were still above *IDLE* position. Touchdown occurred at a vertical speed of 752ft/mn and a vertical acceleration of +2.13g, forcing the aircraft to bounce up to 12ft AGL.

4. *In case of high bounce, a go-around must be initiated […] a landing should not be attempted immediately after high bounce [...] as the remaining runway length may be insufficient to stop the aircraft.* (*RZO ALL FCOM 3.04.27 P5.* Refer to pic. 26, page 35 of this report).

Against the recommended procedure the pilot decided to accomplish the landing, tried to control the aircraft and to correct the profile for a new touchdown on the runway ahead.

The pilot was not aware of spoilers' extension and retarded the THR levers to *IDLE* position while he was varying pitch attitude to soften the second touchdown. As soon as he reduced thrust to *IDLE*, Ground Spoilers deployed, the lift dropped, the vertical speed increased and the aircraft was brought against the runway in an harder than first touchdown condition, registering a vertical acceleration of 4.86g.

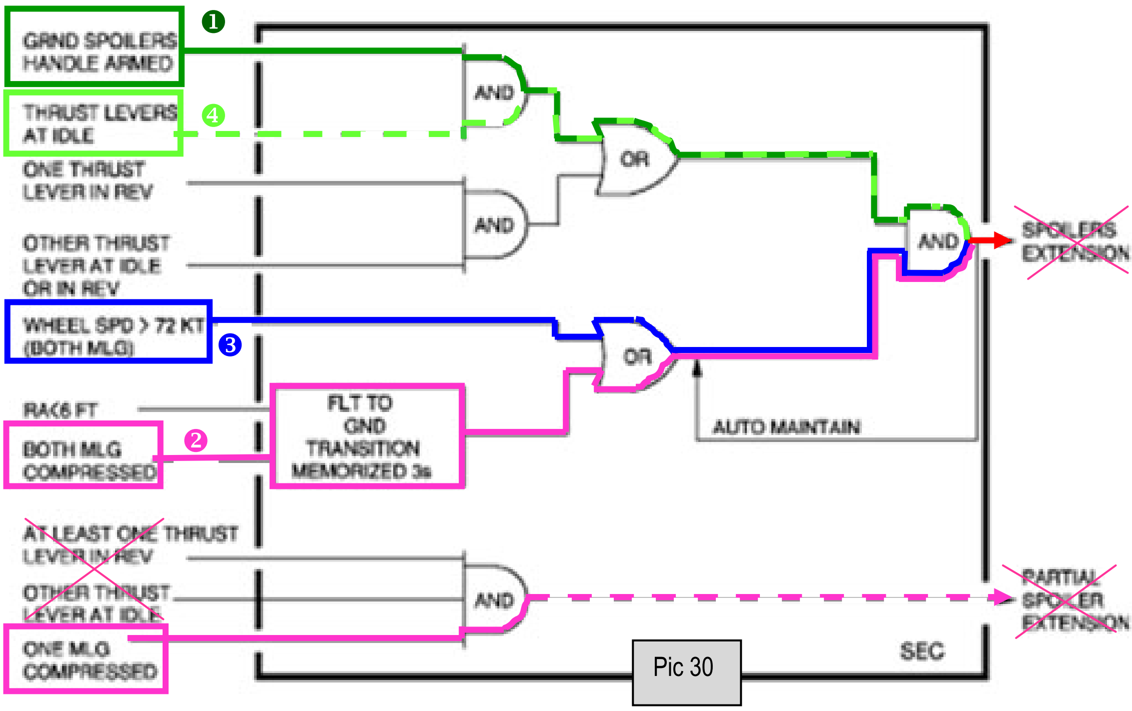
2.5 SPOILERS SYSTEM OPERATION

2.5.1 No spoilers deployment at touchdown

When aircraft came for landing, speed brake handle was selected to “ARMED” position, granting condition ❶ for SEC actuation.

At touchdown, both main landing gear struts were compressed, giving condition ❷, immediately followed by wheel spin up (condition ❸), which reinforced condition ❷.

Ground spoilers were not deployed because thrust levers were set at “CLB” and condition ❹ was not fulfilled, thus condition ❶ was not enough to close the circuit and spoilers’ extension was disabled (pic. 30).



Pic 30

There was no partial deployment, even with main landing gear compressed, because thrust levers were not in required position.

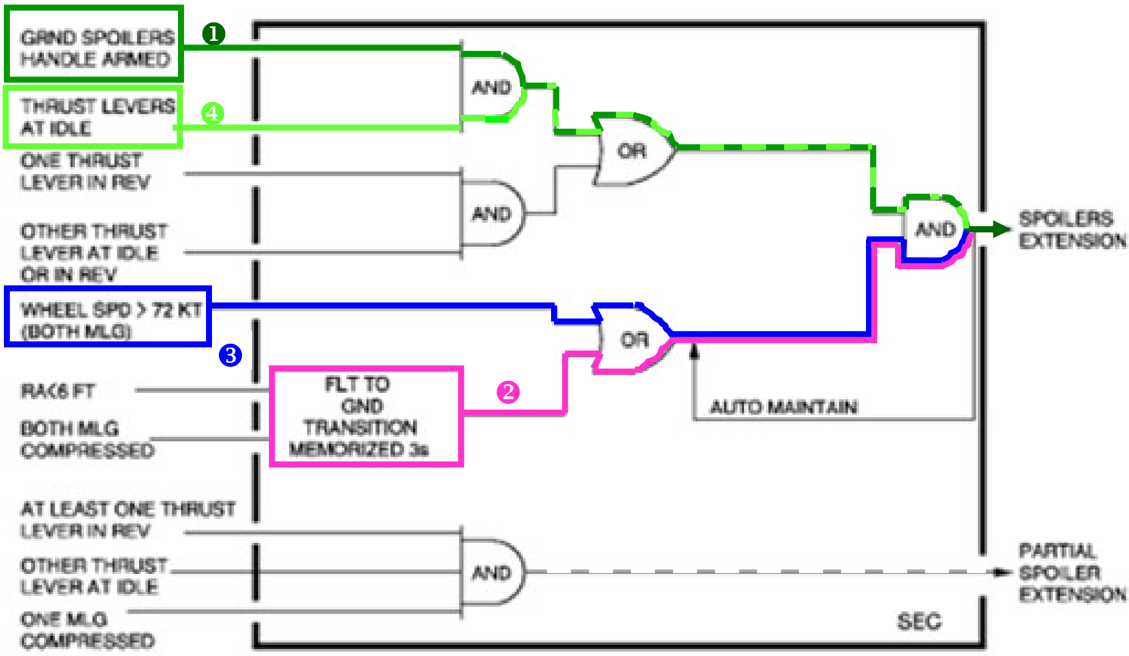
2.5.2 Automatic spoilers deployment in flight

Due to speed reduction after bouncing, being ATHR active (selection in CLIMB), engine power was increased to recover speed loss. The pilot, wishing to bring the aircraft back for landing, responded selecting thrust levers to IDLE position.

Such selection, not only disarmed ATHR but, being inside the 3s MLG compressed memorized period and with MLG wheels rolling above the speed of 72kt, caused the SEC to command fully extension of ground spoilers.

With the aircraft 12ft high above the runway, spoilers' deployment caused a lift reduction that forced the aircraft against the ground with a 4.86g vertical acceleration.

In fact, consulting FCOM 1.27.10 (pic. 31), necessary conditions for ground spoilers' deployment are possible not only on the ground but in the air during a bounce, if the crew has not retarded the thrust levers for touchdown and retards the thrust levers during the bounce.



Pic. 31

- The aircraft came for landing with spoilers "ARMED", fulfilling condition ❶;
- When it touched down both main landing gear struts were compressed and condition ❷ remained active for 3s; Both main wheels started rotating and its speed attained >72kt, giving condition ❸ as a backup for condition ❷;
- When the pilot reduced thrust levers to "IDLE", condition ❹, associated with condition ❶, provided the necessary signal for the system to command ground spoilers' extension in the air.

2.6 AIRBUS PROCEDURES

2.6.1 Procedure in force before the event

Ground spoilers are used to reduce the lift produced by the wing and transfer the weight of the aircraft to the landing gear in order to provide a more efficient braking action (fig. 32). Its deployment may be obtained automatically or manually.

Pic. 32

For their automatic extension some conditions have to be met, being them:

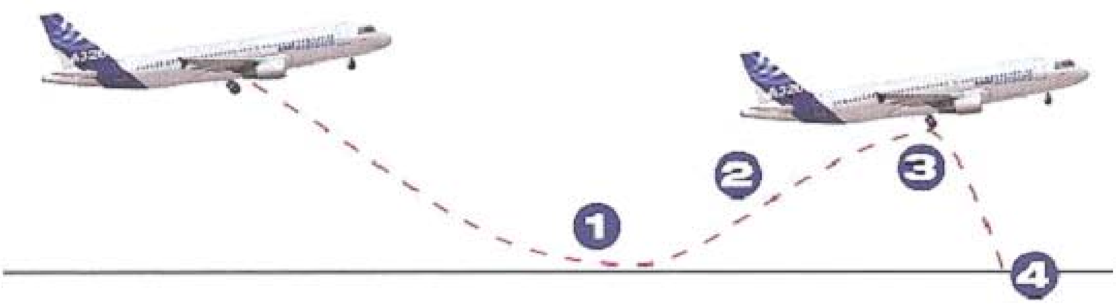
- The “arming” of the system;
- The aircraft being on the ground;
- Thrust levers’ selection.

Those conditions were obtained according to the logic principles illustrated in pictures 30 and 31 above.

The SEC received signals from all those sources and delivered commands for spoiler actuators.

The absence or the untimely extension of ground spoilers had been a factor on several events, relating to increased landing distances or hard landings, especially derived from inappropriate thrust levers selection and no arming of ground spoilers.

In this case an untimely extension of ground spoilers, due inappropriate thrust levers selection, caused the ground spoilers deployment, with the aircraft in the air, with consequent hard landing (*Pic. 33 – retrieved from Airbus Safety Magazine, issue 9 / Feb 2010*).



❶ No engine throttle reduction (retard) during the flare ⇨ No ground spoiler extension.
❷ Bounce induced by a too high energy level and by the lack of lift destruction.
❸ Engine throttle reduction performed during the bounce → Ground spoiler extension if the retard is performed within 3 seconds following the first touchdown.
❹ Severe hard landing, due to sudden loss of lift, leads to a fall from a height of about 5ft to 15ft. It has been established that most of the hard landings occurring after a bounce are severe.

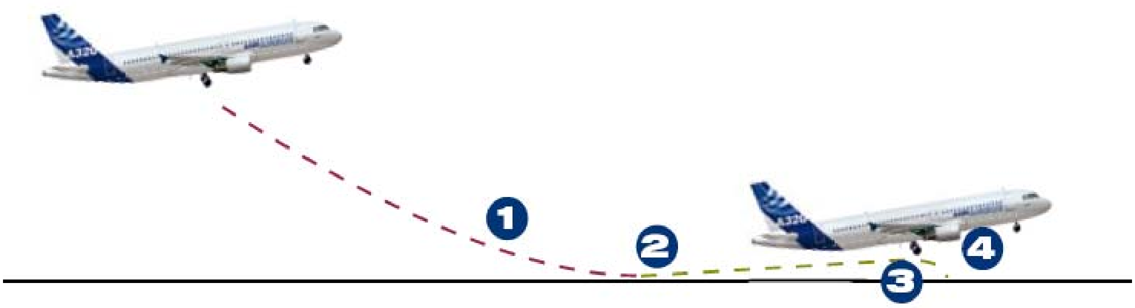
Pic. 33

2.6.2 Procedure development (SB Nr A320-27-1198)

Following this and other similar events to A320 family, recorded before, leaded Airbus to think about the need to change the Ground Spoilers Extension Logic, as it was already done with A330 and A340 families' models.

With the "Ground Spoilers Extension Logic" philosophy rearrangement, implemented under SEC 120, bounce height will be reduced and vertical acceleration limited, thus preventing severe hard landing occurrence.

So, Airbus expects to overcome eventual runway overrun events – with the Ground Spoilers automatic deployment even if speed brake lever is not retracted and thrust levers are above *IDLE* position – and to reduce the bounces' frequency and amplitude in hard landings situations – with the Ground Spoilers Partial Lift Dumping (PLD) at the touchdown, even if both levers are on A/THR position. (Pic. 34, retrieved from *Airbus Safety Magazine*, ed. Feb., 9th 2010):



1. No engine throttle reduction (retard) during the flare ⇨ No ground spoiler extension.
2. With the SEC 120 modification, the ground spoilers will extend partially at touchdown, as long as both engines levers are at or below the Climb notch (ATHR). Lift is decreased and the bounce is reduced or cancelled.
3. As soon as the thrust lever conditions are fulfilled (for instance engine throttle reduction to Idle), the ground spoilers extend fully (if achieved within 3 seconds of the initial touchdown).
4. As the height of the bounce is significantly reduced, the vertical speed at the second touchdown is largely reduced as well.

Pic. 34

If new PLD logic was already implemented on CS-TKO, the bounce height on this event would have been significantly reduced and the impact at the second touchdown would have been considerably lighter (about +1,7g instead of the experienced +4.86g, as stated by Airbus).

2.7 OPERATOR PROCEDURES

2.7.1 Procedure prior the event

The Operator conceived a Maintenance Procedure (PM16) which, not being a document to replace the AMM 05-51-11-200-004, it provided guiding lines to ground engineers to identify what is a hard or a severe hard landing and the suitable procedures to be taken, but the document made no reference ~~to~~ how to understand the DMU Load Report readings.

Both PDL and LIS Ground Engineers didn't comply with PM16 or AMM 05-51-11 requirements. As they were unable to understand the Load Report, they concluded that the displayed data might be erroneous. The visual check to which the LH and RH Wing Shroud Box Lower Panels damage were unnoticed leaded to devalue the situation.

2.7.2 Procedure after the event

After detecting the irregularities at the Type "A" Inspection, and facing the ground engineer's difficulties in reading the Load Report, the Operator took the immediate decision to organize a workshop to provide ground engineers the capability to read a Load Report data. At the close time of this report, all ground engineers had already accomplished the training.

3. CONCLUSIONS

3.1 FINDINGS

1. Both pilots were properly certificated and qualified in accordance with applicable regulations and company requirements and possessed valid and current medical certificates;
2. They had received the suitable training program and observed the duty times, rest periods and flight limitations recommended by national regulations;
3. Both crew members had ample and similar total flight hours (almost 4 600:00 hours);
4. PF, recently promoted to Captain, had 1 206:10 hours experience on CS-TKO type aircrafts;
5. Co-Pilot was the PNF and had 2 200:00 hours flown on A320 family aircrafts;
6. Captain reported hard landing to the ground assistance engineer, accordingly to his duties, but he didn't write down the event in the Technical Log Book for future maintenance action and subsequent flights' crew acknowledgement;
7. The airplane, manufactured in the same year of the occurrence, had a total of 533:58 hours at the event time, was properly certified by INAC to perform commercial air transport flights, held valid documentation and was maintained in accordance with Airbus requirements;
8. There was no evidence of any pre-existing powerplant system, structural failure or other limitations or restrictions to the flight operation;
9. CS-TKO was equipped and dispatched correctly (Weight and Balance), in accordance with applicable regulations and industry practices and its MLM was within operation limits at the landing time. So, the airplane's cargo and its loading were not factors in the accident.
10. The Airbus landing techniques recommendations were not followed as stated in FCOM and FCTM;
11. In consequence, the aircraft performed a hard landing, bounced to 12ft AGL height for five seconds and flew 360 metres until come back to the runway;
12. The second touchdown was performed with a vertical acceleration of 4.86g which is typified as severe hard landing;

13. The excessive vertical forces experienced on landing exceeded those that the aircraft was designed to withstand and resulted in some visible damage in "LH and RH Wing Shroud Box Lower Panels" and other small irregularities considered of minor importance as reported in the *CS-TKO Inspection Status* (refer to pic. 18, page 27 of this report);
14. The aircraft ground assistance engineers were properly certificated and qualified, but they didn't implement the AMM 05-51-11-200-004 actions stated by the manufacturer and were not able to read correctly the Load Report data;
15. The Operator provided a proactive program to all ground engineers in order to identify hard/severe hard and overweight landings and give additional oversight and training about Load Report data readings.
16. Pilots also attended *Balked and Bounced Landing Recover* simulator training refreshment;
17. The atmospheric conditions encountered during the approach and landing were within the performance capabilities of the airplane and crew skill; there was no evidence of windshear at the touchdown. So, the weather condition was not a factor in this event.

3.2 ACCIDENT PROBABLE CAUSE

The GPIAA Investigation Team determine that the probable cause of this accident was a hard landing, of significant vertical acceleration (4.86g), due to aircraft loss of lift caused by Ground Spoilers extension in flight, during a bounce of great amplitude (12ft AGL).

Contributing factors to this accident were:

- The flare inputs were not adequate to reduce the A/C vertical speed before touchdown, thus leading to the first hard landing;
- The thrust levers were not retarded before touchdown;
- During the 12ft high bounce the crew decided to continue landing and did not initiate a go around.

4. SAFETY RECOMENDATIONS

Considering that:

a. Airbus, as already done on A330 and A340 aircraft, conceived a Ground Spoilers Logic modification to be introduced on A320 family to minimize bouncing consequences, the Investigation Team has no recommendations to suggest while the manufacturer SB Nr A320-27-1198 is effective;

b. Operator carried on a workshop to all its ground engineers providing refreshment to face future hard landing situations requiring specific inspections to the aircraft and to qualify them to identify and read the MDU Load Report and also pilots attended *Balked and Bounced Landing Recover* simulator training refreshment, the Investigation Team has no other recommendations to suggest.

Lisbon, 27th December 2010.

The Investigator-in-charge

Artur A. Pereira

The Safety Investigator

António Alves

ACRONYMS

(A)	Airplane
ACCID	Accident
ADIRS	Air Data Inertial Reference System
AD	Airworthiness Directive
AFT	Afterward
AGL	Above Ground Level
AMM	Aircraft Maintenance Manual
AMRO	Aircraft Maintenance, Repair and Overhaul
AOA	Angle Of Attack
AOC	Air Operating Certificate
AP	Auto Pilot
APU	Auxiliary Power Unit
Art.	Article
ASDA	*Accelerate-Stop Distance Available*
A/THR	*Auto Throttle*
ATPL	*Airline Transport Pilot's Licence*
BEA	*Bureau d'Enquêtes et Analyses* (French Air Accident Investigation Branch)
BSCU	*Braking/Steering Control Unit*
CAT	*Category*
CG	*Centre of Gravity*
CLB	*Climb*
CNT	*Control*
CONF	*Configuration*
CVR	*Cockpit Voice Recorder*
DCA/SE	*Departamento de Continuidade e Aeronavegabilidade/Serviço de Engenharia* (SATA's Maintenance and Engineering Department)
DFDR	Digital Flight Data Recorder
DMC	Display Management Computer
DME	Distance Measuring Equipment
DMU	Data Management Unit
EASA	European Aviation Safety Agency
EO	Engineering Order
EXT	Extension
FCDC	Flight Control Data Concentrator
FCOM	Flight Crew Operation Manual
FCTM	Flight Crew Training Manual

FD	Flight Director
FDIMU	Flight Data Interface and Management Unit
FDRS	Flight Data Recorder System
Feb	February
FLT	Flight
FMGS	Flight Management and Guidance System
FOBN	Flight Operations Briefing Notes
FPV	Flight Path Vector
Ft	Feet
FWC	Flight Warning Computer
FWD	Forward
g	Acceleration unit
GND	Ground
GPIAA	*Gabinete de Prevenção e Investigação de Acidentes com Aeronaves* (Portuguese Air Accident Investigation Branch)
G/S	Glide Slope
ICAO	International Civil Aviation Organization
IAF	Initial Approach Fix
IF	Initial Fix
ILS	Instrument Landing System
INAC	*Instituto Nacional de Aviação Civil* (Portuguese Civil Aviation Authority)
Kg	Kilogram
Kt	Knot(s)
LA	Linear Accelerometer
LAD	Landing
LAND	Landing
LAT	Lateral Acceleration
LDA	Landing Distance Available
LH	Left Hand
LIM	Limit
LIS	IATA Code for Lisbon
LOC	Localizer
LOMS	Line Operations Monitoring System
LONA	Longitudinal Acceleration
LPPD	ICAO code for Ponta Delgada
LPPT	ICAO code for Lisbon airport
LTD	Limited

m	Metros
Max	Maximum
MG	Main Gear
METAR	Meteorological Aerodrome Report
MLG	Main Landing Gear
MEHT	Minimum Eye Height over Threshold
Min	Minute
MLM	MAXIMUM Landing Mass
MME	Maintenance Management Exposition
MSN	Manufacturer Serial Number
MTOM	Maximum Take-Off Mass
N	North
N/A	Not Available
NIL	Nothing, zero
NM	Nautical Miles
Nr	Number
OPS	Operations
P	Page
PAPI	Precision Approach Path Indicator
Pic	Picture
PN	Part Number
PDL	IATA code for Ponta Delgada
PF	Pilot Flying
PLD	Partial Lift Dumping
PM	*Procedimento de Manutenção* (Maintenance Procedure)
PNF	Pilot Not Flying
POB	People On Board
Q	QNH
QAR	Quick Access Recorder
QFU	Aviation Q-code for Magnetic Heading of a Runway
QNH	Altitude above mean sea level based on local station pressure
RA	Radio Altimeter
Ref.	Reference
RH	Right Hand
RWY	Runway
RZO	ICAO code for SATA
s	Seconds

SA	*Société Anonyme* (Anonymous Society)
SATA	*Sociedade Açoriana de Transportes Aéreos* (Azores Air Company)
SB	Service Bulletin
SDAC	System Data Acquisition Concentrator
SEC	Spoiler Elevator Computer
SEQ	Sequence
SOP	Standard Operating Procedures
SPD	Speed
TDZ	Touch Down Zone
THR (1)	THReshold
THR (2)	THRottle
TLG	Technical Log Book
TODA	Take-Off Distance Available
TORA	Take Off Run Available
TRTO	Type Rating Training Organization
TSN	Time Since New
TSO	Time Since Overhaul
UTC	Universal Time Coordinated
V	Variable
V_{app}	Final Approach Speed
VAR	Variable
VASIS	Visual Approach Slope Indicator System
VNL	Visual Near Lenses
VRTA	Vertical Acceleration
VRTG	Vertical Acceleration
VS	Vertical Speed
W	West
Z	Zulu (same as UTC)