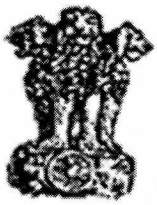

Report of Hard Landing incident to M/s Jet Airways, B-777-300 aircraft VT-JEQ at Hong Kong during the operation of flight 9W-78(Delhi-Hong Kong) of 27th April 2017

O/o Director Air Safety(NR),
Safdarjung Airport,
New Delhi-03

Foreword

This document has been prepared based upon the evidences collected during the investigation, opinion obtained from the experts etc. The investigation has been carried out in accordance with Annex. 13 to the Convention on International Civil Aviation and under the Rule 13(1) of Aircraft (Investigation of Accidents and Incidents) Rules 2012. The investigation is conducted not to apportion blame or to assess individual or collective responsibility. The sole objective is to draw lessons from this incident which may help to prevent such future accidents or incidents.

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Appendix "A": Analysis report of M/s Boeing

Appendix "B": Glossary of abbreviations used in this report

Final Investigation Report of Hard Landing incident to M/s Jet Airways,B-777-300 aircraft VT-JEQ at Hong Kong during the operation of flight 9W-78(Delhi-Hong Kong) of 27th April 2017

1. Type	:	B-777-300ER
Nationality	:	INDIAN
Registration	:	VT-JEQ
2) Owner	:	Bishopsgate Aircraft 2008 Designated Activity Company (DAC), Ireland
3) Operator	:	M/s Jet Airways
4) Pilot-in-Command	:	ATPL Holder
Extent of injure	:	Nil
5) Date & Time of Incident	:	28.04.2017, 05:55 IST
6) Place of Incident	:	Hong Kong International Airport
Co-ordinates of Incident Site	:	22^0 18' 32" N, 113^0 54' 53" E
7) Last Point of Departure	:	Delhi
8) Point of Intended Landing	:	Hong Kong International Airport
9) No. of Passenger on board	:	163
10) Type of Operation	:	Scheduled Flight
11) Phase of Operation	:	Landing
12) Type of Incident	:	Abnormal Runway contact of the aircraft

(All timings in the report are in IST unless otherwise specified)

SYNOPSIS

M/s jet Airways B777-300 aircraft VT-JEQ was scheduled to operate Flight 9W-78 (Delhi-Hong Kong) on 27.04.2017. On this flight 10th (final) Pilot in Command Release check was planned for an ATPL holder trainee pilot who occupied the left seat in the cockpit. A Designated Examiner was assigned to carryout this 10th (final) route check for PIC upgrade who occupied the right seat in the cockpit. During landing at R/W 07L at Hong Kong the aircraft was involved in hard landing incident.

The incident of Hard landing was detected during the routine Flight monitoring programme of the Airline. On 3.05.2017, hard landing inspection was carried out and no damage was observed to the aircraft.

DGCA instituted an Inquiry under Rule 13(1) of the Aircraft (Investigation of Accident and Incident) Rule 2012.

The Incident occurred due to frequent change in pitch input during the landing phase of flight & touchdown with inadequate flare.

1. FACTUAL INFORMATION

1.1 History of the Flight

M/s jet Airways B777-300 aircraft VT-JEQ was scheduled to operate Flight 9W-78 (Delhi-Hong Kong) on 27.04.2017. On this flight 10th (final) Pilot in Command Release check was planned for an ATPL holder trainee pilot who occupied the left seat in the cockpit. A Designated Examiner was assigned to carryout this 10th (final) route check for PIC upgrade who occupied the right seat in the cockpit. The trainee was positioned in Delhi from Mumbai the same day. He travelled as ACM from Mumbai to Delhi and started for the airport at Mumbai by 5 a.m. After reaching Delhi he was provided hotel accommodation.

As per the flight plan filed, the aircraft was to take the route "VIDP LAPOT ALI R460 LKN A201 LSO A599 POU R473 SIERA SIER7A VHHH" with alternate as RCTP(Taiwan Taoyuan International Airport).

The aircraft took off from IGI Airport at 1:37 Hrs IST (20:07 UTC) on 28.04.2017. There were 163 passengers and 14 crew members on board. The flight was uneventful.

The aircraft started descent into Hong Kong at 05:16 Hrs IST (23:46:50 UTC). It made an ILS Approach for Rwy 07L. It was established on ILS(LOC & GS) by 2000ft (Baro Altitiude). There was no significant deviation observed from the DFDR data after the aircraft was established on ILS (LOC & GS).
The airplane descending from 1000 feet radio altitude configured for a flaps 30 landing with the speedbrakes armed while on approach to Runway 07L. The autopilot was engaged in glideslope (G/S) and localizer (LOC) modes and the autothrottle engaged speed (SPD) mode at 05:53:47 Hrs IST (00:23:47UTC). The autopilot was disengaged at 5:54:03 Hrs IST (00:24:03 UTS) at 843ft RA while the autothrottle remained engaged until after touchdown,
The reference landing speed (VREF) was recorded at 140 knots and during the approach the computed airspeed was maintained at approximately 145 knots (VREF+5). The descent rate was maintained at an average of 800 feet/minute during the approach.

The wind direction was variable but was primarily from an average of 50 degrees and the wind speed was approximately 8 knots. The airplane primarily experienced a left quartering head wind during the approach at an average magnitude of 8 knots with some variation in the direction as touchdown neared. Due to the crosswind, the airplane was in a 1 to 2 degree left crab angle (opposite of drift angle) until touchdown. Flare was initiated at time 5:55:03 Hrs IST (00:25:03 UTC) with a pull of the column at a radio altitude of 36 feet. The pitch attitude increased from 0.7 degrees nose-up to 3.25 degrees nose-up during the flare. As the pitch attitude increased, the descent rate was arrested at 700 feet/minute and began to decrease until touchdown. There was no intervention from the DE as he felt that it would aggrevate the situation.Touchdown occurred at 05:55:06 Hrs IST(00:25:06 UTC) and vertical load as per DFDR at time of landing was 3.23 g. After landing shudder was felt by the crew.

The Analysis carried out by M/s Boeing indicates that soon after touchdown, 3 successive increasing peaks were observed in the vertical acceleration, with values of 0.65, 0.82, and 2.23 g's (normal load factor of 1.65, 1.82, and 3.23 g's, respectively). The maximum peak in vertical acceleration occurred 0.7 seconds after the estimated touchdown time. The airplane touched down at a gross weight of approximately 219891kgs (below the maximum landing weight [MLW] of 251290 kgs) with a left bank angle of about 1.3 degrees.The computed airspeed at touchdown was 143 knots (VREF+3). After touchdown, the crew input right rudder pedal to de-crab the airplane. The lateral acceleration reached 0.38 g's to the right as the speedbrakes extended and the weight of the airplane settled onto the main gear. The remainder of the landing rollout continued without incident.

The crew in their assessment did not feel that the hard landing was made and accordingly did not make any entry to this effect in the pilot defect report. The DE in the assessment form inter alia wrote that PIC R/C No 10 was unsatisfactory due to

(a) Flare inadequate
(b) Touch down short of course point.

The incident was detected duing the routine Flight Data Monitoring and Analysis programme of M/s jet Airways. Then on 03/05/2017 phase IA and IB of hard landing inspection was carried out on the aircraft. No deficiency was detected during the inspection.

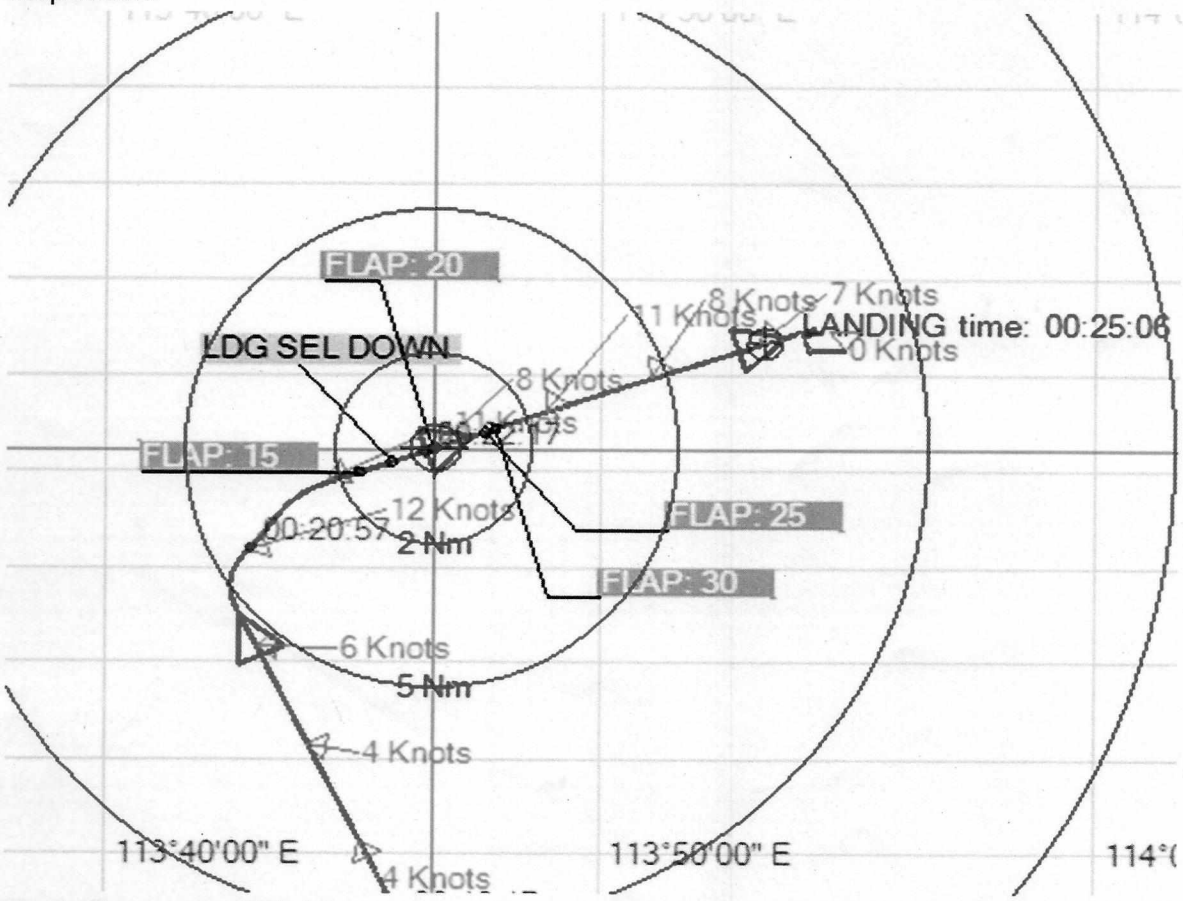


Fig.1*: **Progress of Fight***

1.2 Injuries to Persons:

Injuries	Crew	Passengers	Others
Fatal	Nil	Nil	Nil
Serious	Nil	Nil	Nil
Minor/None	Nil	Nil	

1.3 Damage to Aircraft

Nil

1.4 Other Damage

Nil

1.5 Personnel information

1.5.1 Pilot Flying (trainee Pilot)

He joined M/s Jet Airways on 02.12.2002. He underwent initial type training on B777 aircraft with Eithad airways and commenced flying as PIC on B777 aircraft with Etihad airways from 11th March 2015. Consequent to his return to M/s Jet Airways, on 14.03.2016 M/s Jet Airways submitted application to DGCA for the P-1 endorsement on his Indian License. During the scrutiny by the DGCA, it was observed that he was not meeting the Indian requirments for the P-1 endrosement and accordingly M/s Jet Airways was directed to resubmit the application for the pliots who were having more than 100 hrs as PIC on B777(in Eithad Airways) after successful completion of 10 Route Checks, as per Schedule II, Section M, para 6 of the Aircraft Rule 1937 for P-1 endrosement.

During the incident flight he was undergoing command upgrade with M/s Jet Airways. In this respect he had undergone the required training. He had undergone 6 SLF and 9 satisfactory PIC upgrade route checks prior to the incident flight. The six SLF were on sectors (Mumbai-Amesterdam, Amesterdam-Mumbai, Mumbai-London, London-Mumbai, Mumbai-London, London-Mumbai). Details of ten route checks is as follows:

Date	Route Sector	Assessment	Remarks
03.03.2017	Delhi - London	Satisfactory	PIC Route Check (By Night) Satisfactory
04.03.2017	London - Delhi	Satisfactory	PIC Route Check No. 2 (BY Day) Satisfactory
13.03.2017	Delhi - London	Satisfactory	PIC Route Check No. 3 By Day
14.03.2017	London -Delhi	Satisfactory	PIC Route Check No. 4 By Day

05.04.2017	Mumbai - London	Satisfactory	PIC No. 5 (4th By Day)
07.04.2017	London - Mumbai	Satisfactory	PIC R/C No. 6 (2nd By Night)
13.04.2017	Mumbai - Dubai	Satisfactory	PIC R/C No. 7 (3rd By Night)
13.04.2017	Dubai - Mumbai	Satisfactory	PIC R/C No. 8 (4th By Night)
21.04.2017	Dubai -Mumbai	Satisfactory	PIC R/C No. 9 (By Night)
28.04.2017	Delhi – Hong Kong	Unsatisfactory	PIC R/C No 10 was unsatisfactory due: •Incorrect MCP altitude set for departure •Flap retraction commanded at 1200ft AGL prior to acceleration •Briefing- departure incorrect, MLW figure by 20T. • Briefing-arrival did not brief for windshear, GA, stall •FMC- not able to setup route 2, E O E P at VHHH •Flare inadequate •T/D short of course point

1.5.1.1 **License Details**:

License type	: ATPL
Seat occupied in Cockpit	: Left
ATPL Valid up to	: 10-Jul-2020
Date of Initial Issue	: 11-Jul-2007
Date of Birth	: 05-Oct-1973
Medical Valid up to	: 06-Nov-2017
FRTOL	: 22-Jul-2018
Date of last IR Check	: 29-Dec-2016
Date of last Route Check	: 21-Apr-2017
PPC	: 29-Dec-2016

1.5.1.2 **Aircraft Ratings**:

As PIC	: B-737-700/800/900
Date of Endorsement on Boeing Series	: 24-Oct-2007
Other Aircraft endorsed	: B777 – 16-Aug-2017

1.5.1.3 **Flying Experience:**

Total flying hours on B737NG	: 9427:17 hours
As Captain on B737NG	: 5697:24 hours
As First officer on B737NG	: 3729:53 hours
Flying hours in last 12 months	: 353:43 hours
Flying hours in last 30 days	: 26:10 hours
Flying hours in last 7 DAYS	: 07:32 hours
Flying during last 24 hrs.	: 04:44 hours

- On the day of incident flight, he was positioned to Delhi on flight 9W301 as ACM. Flight departed Mumbai at 07:00 hrs. He started from his residence at around 05:00 hrs. After arriving at Delhi he reached hotel at around 10:20 hrs. He reported at airport at 23:00 hrs. (Approx.) for operation of flight 9W78.
- He flew as PIC with Eithad airways B777 aircraft to Hongkong on 31.07.2016 and from Hong Kong to Delhi on 2.08.2016

1.5.2 **Designated Examiner:**

He obtained the approval of the Designated Examiner from DGCA on 21.03.2017. He underwent initial endorsement training on Boeing 777 aircraft at Jet airways training academy as per DGCA approved type training course. He was cleared to fly as Pilot in Command on B777 aircraft on 28-Nov-2012. He was approved as examiner on B-777 type of aircraft on 20.12.2013.The approval of Examiner was granted to him in terms of requirements of CAR Section 7, Series 'I", Part-I Issue- I, dated 27th may 1998, Rev 4 dated 12.03.2009. As he has been an examiner on B737 type of aircraft he was approved as Examiner on B777 aircraft.

From 15th Dec 2012 till 28th April 2017, he has operated 13 flights to Hong Kong. He last operated flight to Hongkong on 23.03.2014

1.5.2.1 **License Details**:

License type	:	ATPL
Seat Occupied in Cockpit	:	Right Seat
Valid up to	:	28/10/2020
Date of Initial Issue	:	04/10/1996
Date of Birth	:	24/01/1963
Medical Valid up to	:	12/07/2017
FRTOL No, valid till	:	30/04/2017
Date of last IR Check	:	16/02/2017
Date of last Route Check	:	30/12/2016

1.5.2.2 **Aircraft Ratings**:

As PIC	:	B-737-700/800/900,B-777
Date of Endorsement on Boeing 777	:	B-777 on 23-Nov-2012
Last technical Refresher	:	06-June-2016

1.5.2.3 **Flying Experience**

Total flying Experience	:	14421:05 Hrs
Total on B777	:	1049:20 Hrs
Flying hours in last 12 months	:	148:15 Hrs
Flying hours in last 30 days	:	28:54 Hrs
Flying hours in last 7 days	:	04:44 Hrs
Flying during last 24 hrs.	:	04:44 Hrs

1.5.2.4 **Training and Check from Right Hand Side on B777 aircraft as per CAR Section 8 Series F Part II**

RHS training on B777 FFS	:	16.02. 2017
RHS check on B777 FFS	:	17.02. 2017

1.6 Aircraft Information

1.6.1

Manufacturer	Boeing Commercial Airplane Group, USA
Type	Boeing 777-35RER
Aircraft Serial No.	35161
Year of Manufacturer	2008
Certificate of Airworthiness	No. 6538 issued on 05/06/2013; Valid till 28/01/18
Airworthiness Review Certificate	JEQ/6538/ARC2ND/2016/137 Issued on 26.05.2017 valid till 04/06/18
Category	Normal
Sub Division	Passenger / Mail / Goods
Certificate of Registration	Cert No. 4429/2 Valid till 30/01/2020 Category "A"

Owner	Bishops-Gate Aircraft 2008 DAC Custom House Plaza, Block 6, International Financial Services Centre, Dublin 1, Ireland
Operator	Jet Airways(India) LTD
Minimum Crew Required	Two
Maximum All Up Weight Authorised	3,37,926.00 Kgs
Last Major Inspection	C1 Check done on : 25.04.17, FH 41832/FC 5487
Air frame Hrs. Since New	41854 : 26 Hours as on 27.04.2017

1.6.2 **Scrutiny of Records**

The incident of hard landing was not recorded In the TechLog/Voyage report at the end of flight on 28.04.2017. On 02.05.2017 a mail was sent by the flight safety department of M/s Jet Airways to the engineering department informing that VT-JEQ/27.04.2017/9W078/ DEL-HKG had a touchdown vertical 'g" of 3.23 and advising inspection of the aircraft. Work order No. 2671985 dated 03.05.2017 was raised and closed for the hard landing inspection. Hard landing inspection was carried out as per AMM 05-51-01 and nose landing gear and fwd fuselage inspection was carried out as per AMM 05-51-36 found satisfactory . Phase 1A and 1B of hard landing inspection c/o with nil findings hence phase II inspection not required.

1.6.3 **Weight and Balance**

- There were total of "163" passengers, "12" cabin crew and "2 " pilots.
- Take Off fuel 47939 Kgs,
- Take off Weight (Max) 337926 Kgs
- Take off Weight(Actual) 252013 Kgs
- MACTOW 27.84 %
- Landing Weight (MAX) 251290 Kgs
- Landing Weight (ACTUAL) 219891Kgs

1.6.4 **Hard Landing Inspection**

Section 05-51-01 of the AMM defines the maintenance practices for hard landings, overweight hard landings, or high drag or high side load conditions. The inspection is divided into two phases (Phase I and Phase II), and Phase I is divided into two phases (Phase IA and Phase IB). Phase IA is a visual

inspection, Phase IB contains inspections that require special tools or access to the airplane, and Phase II is a detailed structural inspection. AMM Section 05-51-01 defines the conditions upon which each phase should be completed, and those conditions are outlined below.

- 05-51-01 Hard Landing or High Drag/Side Load Landing
- Section 05-51-01, Chapter (1)(C) states that a high drag or high side load condition occurs if one or more of the following conditions are met:

(a) The flight crew reported a high drag load or high side load event
(b) The airplane ran off the prepared surface
(c) The airplane landed short of the prepared surface
(d) The airplane made a landing and two or more tires were blown
(e) One or more of the landing gear hit an obstacle or were hit by an obstacle.

- Hard Landing
- Section 05-51-01, Chapter (1)(D) states that a hard landing occurs if one of the following conditions is met:

(a) The landing is reported by the flight crew as "hard".
(b) It was a landing where the nose gear contacted the runway before the main gears.

1.6.5 **Analysis by M/s Boeing**

- Section 05-51-01, Chapter (1)(F) outlines the inspection logic, which is also presented in flowchart format (AMM Figure 201). If the flight crew reported a hard landing, the Phase IA and Phase IB inspections would have been required prior to the next flight. If flight data had been available, then it is advised to check the vertical load factor and roll angle against the 777 CG Load Factor AMM threshold. If the data indicate a vertical load factor below the threshold, and no damage is found during the Phase IA inspection, the Phase IB inspection may be waived. The graphic below shows the AMM vertical load factor threshold, with the maximum vertical load factor and roll angle at touchdown for the event landing overlaid on the graphic (red dot symbol). **The magnitude of the vertical load factor was off the scale of the graphic.** For this comparison, the 8+ sps curve must be used along with the appropriate touchdown weight (yellow highlight).

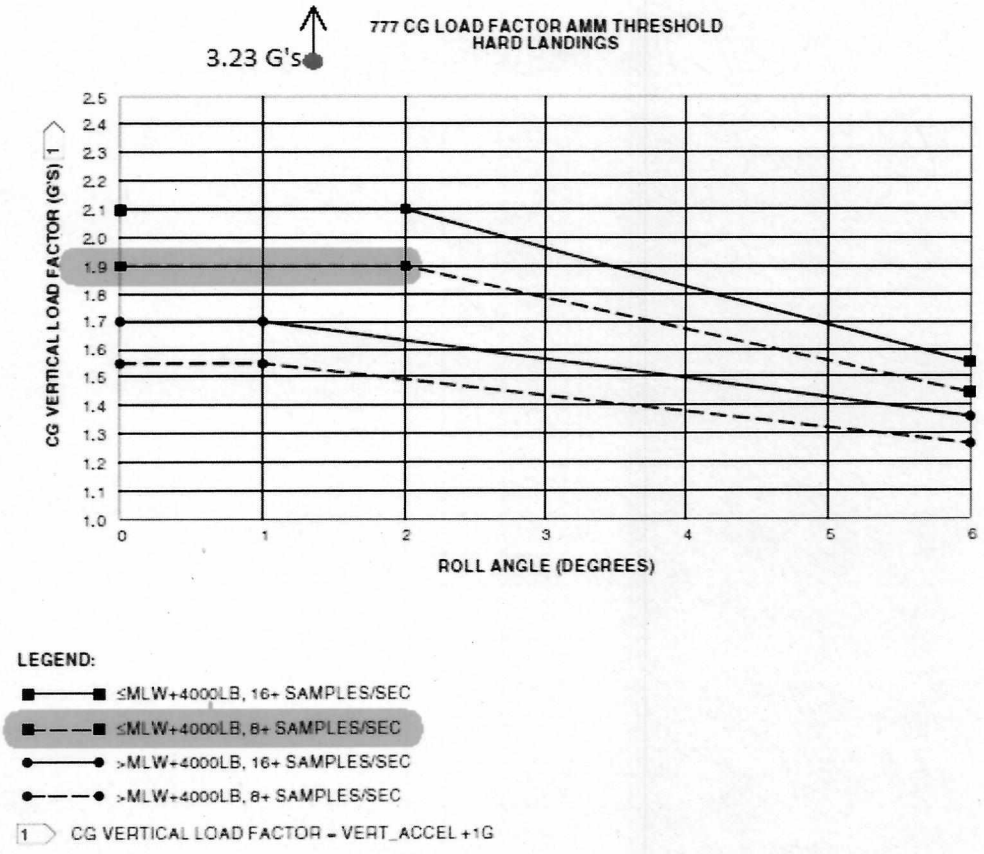


Fig.2 *C.G Load factor Chart*

- **Based on the graphic above, the magnitude of vertical load factor translated to the CG was above the threshold for hard landings, indicating that the Phase IB inspection could not have been waived, regardless of the findings of the Phase IA inspection**. Note that a Phase IA inspection is not required unless the flight crew reported a hard landing. The inspections would be at the airline's discretion.
- **Conclusion**
- If the subject landing had been reported as "hard" by the flight crew, Phase IA and IB inspections would have been required prior to the next flight. If flight data had been available, an evaluation could have been performed to determine if the Phase IB inspection could be waived. Analysis of this landing indicates that the vertical acceleration experienced was **above the AMM threshold, indicating that the Phase IB inspection could not have been waived, regardless of the findings of the Phase IA inspection,** if the pilot had called the landing hard. If using data alone, without the pilot's call, the inspections are at the airline's discretion. At touchdown, the closure rate of the main landing gear with the runway was 8.1 feet/second
- (assuming a zero runway slope) which is below the design limit of the gear. Boeing maintains that the flight crew's judgment is the most reliable criterion to use for determining if a hard landing has occurred. Data alone are insufficient to make this determination.

1.6.6 Aircraft Warning System for the Crew:

Warning systems consist of:

- engine indication and crew alerting system (EICAS)
- airspeed alerts
- tail strike detection system
- takeoff and landing configuration warning system
- MCP selected altitude alerts
- crew alertness monitor
- traffic alert and collision avoidance system (TCAS)
- windshear alerts
- ground proximity warning system (GPWS)

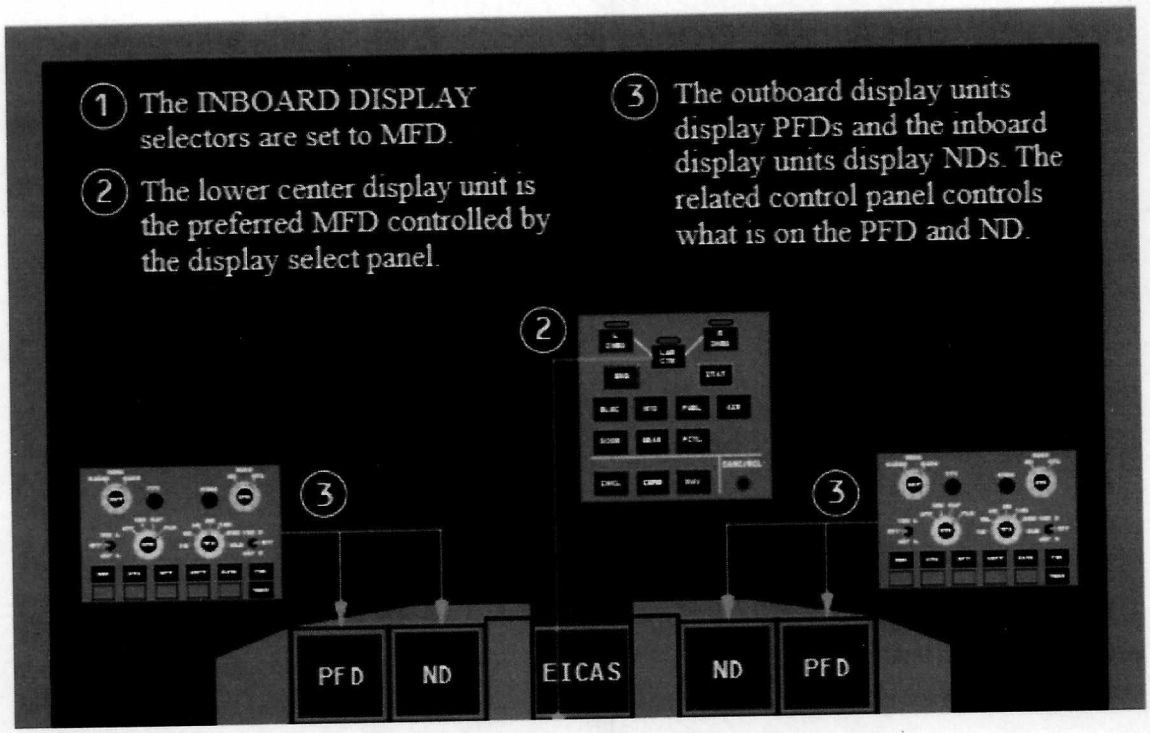


Fig.3: ***Normal Cockpit Display***

Engine Indication and crew Alerting System

EICAS consolidates engine and airplane system indications and is the primary means of displaying system indications and alerts to the flight crew. The most important indications are displayed on EICAS which is normally displayed on the upper center display.

Vertical load factor at time of landing is not displayed on the EICAS.

Maintenace Access Terminal:

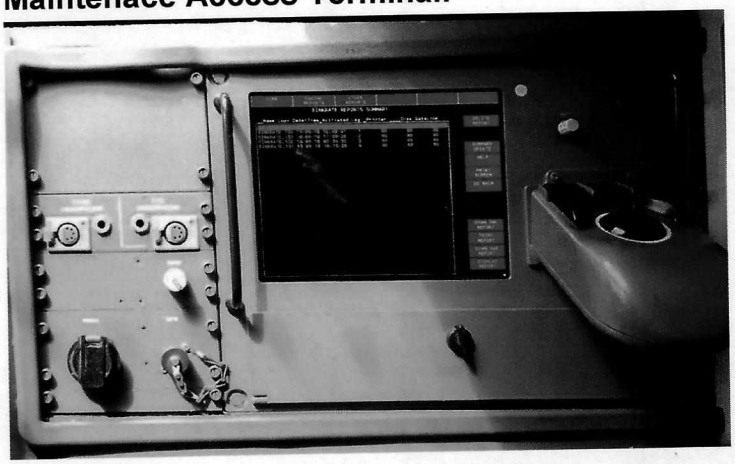


Fig 4: ***Maintenance Access Terminal***

The maintenance access terminal is located behind the Right hand Seat in the cockpit. It has the option for the generation of the "Sink" report. The values generated by it are to be used for the C.G Load factor Chart for determining the vertical load factor.

1.7 Meteorological Information:

1.17.1 The depach documents contained following weather information

WIND DATA, ISA AND TEMPERATURE FOR FIXED LEVELS

	FL290	FL330	FL370	FL410
POINT	WIND ISA TMP	WIND ISA TMP	WIND ISA	TMP WIND ISA TMP
MURRY	270/043 P13 -29	266/046 P11 -39	267/053 P07	-49 268/052 M02 -59
SILVA	270/044 P13 -29	267/047 P11 -39	267/053 P07	-49 268/052 M02 -59
LIMES	270/046 P13 -29	266/049 P11 -39	266/054 P07	-49 268/053 M02 -58
VHHH	271/048 P13 -29	266/050 P11 -39	266/055 P07	-50 269/054 M02 -58

DESCENT SPOT WIND DATA

WIND DIR/ SPD	ALT	WIND DIR/ SPD	ALT	WIND DIR /SPD	ALT	WIND DIR/SPD	ALT
271/048	29000	283/042	21000	297/033	13000	317/012	7000
ISA DEV	P13		P16		P14		P09
TEMP	M29		M11		P04		P10

1.17.2 (METAR) VHHH of 06:00 Hrs IST (8:30 Hong Kong local time)
280030Z 05006KT 020V080 9999 FEW030 SCT040 22/14 Q1016 NOSIG

1.8 Aids to Navigation:

N/A

1.9 Communications :

N/A

1.10 Aerodrome Information:

`1.10.1 Runway Physical Chracteristics

RWY Designator	True and MAG BRG	Dimensions of RWY (m)	Strength (PCN) and Surface of RWY – SWY	Threshhold Co-ordinates	THR ELEV and highest point of TDZ of Precision APP RWY	Slope of RWY-SWY	CWY Dimensions (m)	Strip Dimensions (m)	Remarks
07 L	070° 54'T 073° 54' M	3 800 × 60	72/F/B/W/T Asphalt	22 18 39.30 N 113 53 52.67E	22 Ft	NIL	300 × 150	3 920 × 300	Full Length of RWY is grooved RESA 240 × 150 m
25R	250° 54'T 253° 54' M	3 800×60	72/F/B/W/T Asphalt	22 19 16.04N 113 55 46.69 E	22 Ft	NIL	300 × 150	3 920 × 300	Full Length of RWY is grooved RESA 240 × 150 m
07R	070° 54'T 073° 54'M	3 800×60	72/F/B/W/T Asphalt	22 17 48.03N 113 53 57.99 E	22 Ft	NIL	300 × 150	3 920 × 300	Full Length of RWY is grooved RESA 240 × 150 m
25L	250° 54' T 253° 54'M	3 800×60	72/F/B/W/T Asphalt	22 18 26.75 N 113 55 58.15 E	22 Ft	NIL	300 × 150	3 920 × 300	Full Length of RWY is grooved RESA 240 × 150 m

1.10.2 Declared Distances

RWY Designator	TORA (m)	TODA (m)	ASDA (m)	LDA (m)	Remarks
07 L	3 800	4 100	3 800	3627	THR displaced by 173 m. When entering RWY from TWY A3 the TORA/ASDA IS 3306m.
25 R	3 800	4 100	3 800	3626	THR displaced by 174 m. When entering RWY from TWY A 10 the TORA/ASDA is 3247 m.
07R	3 800	4 100	3 800	3640	THR displaced by 160 m. When entering RWY from TWY J3 the TORA/ASDA IS 3130 M When entering RWY from TWY K2 the TORA/ASDA is 2720m.
25 L	3 800	4 100	3 800	3800	When entering RWY from TWY J9 the TORA/ASDA is 3200 m. When entering RWY from TWY K6 the TORA/ASDA is 2880 m.

Note 1: The nosewheel guidelines from the lead-on taxiways A1, A12, J1, J11, K1 and K5 intersect the runway centreline 100m from the commencement of the TORA/TODA/ASDA

Note 2: The nosewheel guidelines from the lead-on taxiways A2, A11 and J 10 intersect the runway centreline 100m from the commencement of the TORA/TODA/ASDA.

Note 3: The nosewheel guidelines from the lead-on taxiways J2 intersects the runway centreline 100m from the commencement of the TORA/TODA/ASDA

Note 4: The TORA/ASDA when entering RWY from taxiways A3, A10, J3, J9, K2 and K6 is measured from the intersection of the lead on taxiways centreline and runway centreline.

VHHH AD 2.3 OPERATIONAL HOURS

1	AD Administration	H24
2	Customs and immigration	H24
3	Health and sanitation	H24
4	AIS Briefing Office	H24
5	ATS Reporting Office	H24
6	MET Briefing Office	H24
7	ATS	H24
8	Fuelling	H24
9	Handling	H24
10	Security	H 24
11	De-icing	H24

1.10.3 Rescue and Fire Fighting Services

1	AD Category for fire fighting	Category 10
2	Rescue equipment	Yes. Additional: (1) 2 rescue launches with rescue and fire fighting (foam with water) facility and life rafts. (2) 8 high speed rescue boats
3	Capability for removal of disabled aircraft	Specialized aircraft recovery equipment available for up to and including B747-400 size aircraft. The Airport Authority Hong Kong is the co-ordinator for the removal of disabled aircraft. Various lifting jacks, gantry crane, tractors, portable lighting and other miscellaneous equipment can be provided by aircraft engineering companies.
4	Remarks	If pilots wish to communicate direct with RFFS, they should inform ATC

1.11 Flight Recorders:

1.11.1 Cockpit Voice Recorder:

CVR was not removed as event was not reported

1.11.2 Digital Flight Data Recorder:

- The aircraft started descent into Hong Kong at 05:16 Hrs IST (23:46:50 UTC).
- The aircraft was established on ILS(LOC & GS) by 2000ft (Baro Altitiude).
- There was no significant deviation observed from the DFDR data after the aircraft was established on ILS (LOC & GS).
- The airplane descending from 1000 feet radio altitude configured for a flaps 30 landing with the speedbrakes armed while on approach to Runway 07L.
- The autopilot was engaged in glideslope (G/S) and localizer (LOC) modes and the autothrottle engaged speed (SPD) mode at time 05:53:47 Hrs IST (00:23:47UTC). The autopilot was disengaged at time 5:54:03 Hrs IST (00:24:03 UTS) at 843ft RA while the autothrottle remained engaged until after touchdown,
- The reference landing speed (VREF) was recorded at 140 knots and during the approach the computed airspeed was maintained at approximately 145 knots (VREF+5).
- The descent rate was maintained at an average of 800 feet/minute during the approach.
- The wind direction was variable but was primarily from an average of 50 degrees and the wind speed was approximately 8 knots. The airplane primarily experienced a left quartering headwind during the approach at an average magnitude of 8 knots with some variation in the direction as touchdown neared. Due to the crosswind, the airplane was in a 1 to 2 degree left crab angle (opposite of drift angle) until touchdown.
- Flare was initiated at time 5:55:03 Hrs IST (00:25:03 UTC) with a pull of the column at a radio altitude of 36 feet. The pitch attitude increased from 0.7 degrees nose-up to 3.25 degrees nose-up during the flare.
- As the pitch attitude increased, the descent rate was arrested at 700 feet/minute and began to decrease until touchdown.
- Touchdown occurred at 05:55:06 Hrs IST(00:25:06 UTC) and vertical load at time of landing was 3.23 g.

Analysis report of M/s Boeing is attached as **Appendix-A**

1.12 Wreckage and Impact Information.

N/A

1.13 Medical and Pathological Information:

Both the pilots underwent preflight medical examination at Delhi on 27/04/2017. The result of the test was negative.

1.14 Fire:

There was no fire.

1.15 Survival Aspects:

The incident was survivable.

1.16 Tests and Research:

Nil

1.17 Organizational and Management Information:

M/s Jet Airways is a scheduled airline. It has scheduled operator permit No. S-6A. The Jet Airways Group currently operates a fleet of 119 aircraft, comprising Boeing 777-300 ERs, Airbus A330-200/300, Next Generation Boeing 737s and ATR 72-500/600s. M/s Jet Airways has training facility for the pilots located at Mumbai and Bangalore. The Engineering training facility for the maintenance of the aircraft is established at Mumbai.

1.17.1 Flight Data Monitoring (FDM)

M/s Jet Airways has established Flight data monitoring and analysis programme in compliance DGCA CAR Section 5 Series F II. It is a non-punitive programme. Flight data of all the flights are monitored for exceedance. To accomplish this a separate analysis unit has been established Monthly FDM reports of exceedances of parameters are generated for all types of aircraft for review and Flight analysis by dedicated Safety Officials. DFDR data is processed in Flight Data Monitoring software (AIRFASE) categorizes parameter exceedance (called "Events") in 3 Levels of severity - **High, Medium and Low**. Exceedance analysis is shared with Fight Operations and engineering departments.

1.17.2 Route and Aerodrome Competence Qualification

OMD Part I Section 4 of M/s Jet Airways.

1.17.3 Route Competence Training

(DGCA OPS Circular 2/2012 Revision **1 Para 3)**

Jet Airways has divided its route network into the following specific areas for the purposes of establishing the route competence of the pilot based on the

characteristics given in Section 1 Para 4.1.6.1 the operating routes are either assessed as Complex or Less Complex as follows:

Type of Route	Route Complexity
High Altitude Operations (Leh and Thoise)	Complex Route
NAT-HLA	Complex Route
Indian Sub-Continent	Less Complex
Europe	Less Complex
Middle East	Less Complex
South Asia and Far East including Bay of Bengal	Less Complex

Depending on the complexity of route, as assessed, Jet Airways will provide pilots' with training and/or briefing before flying into, out of, or over a particular area, as appropriate:
For the less complex routes, familiarisation by the self-briefing with route documentation (Jeppesen), or by means of programmed instruction; and

For the complex routes, in addition to the self-briefing, in-flight familiarisation as a PIC, Co-pilot or Observer Under supervision, or familiarisation in a simulator using a database appropriate to the route. For initial qualifications, refer to Special Operations Training Section 1 Chapter 4, Para 4.2.7.

When a pilot is assigned to operate into an area for which he is not currently qualified, or for which a previous area qualification has expired, then the applicable standard area briefing and pilot to whom PIC of a flight may be delegated, any special area qualification requirements must also be completed. The relevant training form shall be completed by the Training Captain indicating successful completion of training requirements.

1.17.3 **Training from the RHS seat**

a) For the training of the instructors the CAR Section 7 Series I Part II inter alia provides as follows:
Para (2.3.1)Assessment check of at least 2 hours with the trainee Instructor in the right hand seat and the Examiner in left hand seat acting as pilot under training during which the trainee instructor shall demonstrate his skill in handling the aircraft and imparting training in normal, abnormal and emergency conditions and taking corrective actions.

b) Appendix 4 to CAR Section 8 Seiries F part II prescribes as follows:
"PICs (commanders) whose duties also require them to operate in the right-hand seat and carry out the duties of co-pilot, or PICs required to conduct training or examining duties from the right-hand seat, shall complete

additional training and checking as specified in the Operations Manual, which may be concurrent with the pilot proficiency checks prescribed in this CAR. This additional training must include at least the following: (a) An engine failure during take-off; (b) A one engine inoperative approach and go-around; and (c) A one engine inoperative landing".

The validity of RHS training shall be 12 months and may be combined with aeroplane/FSTD training. The validity for the RHS check shall be 6 months. RHS check is not part of the PPC.

1.17.4 **Aerodrome Competence Training**

(DGCA OPS Circular 2/2012 Revision 1 Para 4)

Jet Airways shall ensure that a PIC complete training and evaluation that qualifies him to operate into the airports used in the Company's route network. This training shall focus on the airports that require special consideration due to obstructions, physical layout, lighting, approach aids, arrival, and departure, holding and instrument approach procedures, operating minima or procedures required in response to high traffic density.

The aerodromes covered within Jet Airways route network are categorised as Category A, B and C, depending on their complexity. Category A aerodrome is least demanding whereas, Category B and C are progressively more demanding aerodromes.

The following qualification requirements apply to the PIC, prior to operating to a Category A, B or C aerodromes:

For a category A aerodrome, the PIC shall be briefed, or self-briefed by means of programmed instruction, and shall certify that he has carried out these instructions. Certification that this briefing has been carried out is indicated by the PIC completing and signing the appropriate area briefing section of the form;

For a Category B aerodrome, the PIC shall be briefed, or self - brief by means of programmed instruction or reference to appropriate documentation and/or other materials provided for this purpose. Certification that this briefing has been carried out is indicated by the PIC completing and signing the appropriate area briefing section of the form;

For a Category C aerodrome, specific training requirements shall be specified for the PIC and, in some cases, for a co-pilot. This training can include specific briefing, CBT, simulator training and line training requirements. Confirmation

that the training requirements have been fulfilled shall indicated by completion of the appropriate Category C Aerodrome Qualification form.

Note : Aerodrome qualification route checks are to be carried out on two sectors to check performance in arrival/approach/landing and take-off/ departure (CAR Section 8, Series F-Part II, Appendix 9-Para 1 refers).

1.17.5 .The Hong Kong Aeronautical Information Publication (AIP)

The AIP of Hong Kong regarding aerodrome qualification recommends as follows:

5.4 As stated, whilst regulatory authorities may impose additional requirements on operators registered with them, the minimum suggested requirement is a self briefing document to be issued to pilots highlighting the following:

a) terrain at and within the environs of the airport;
b) departure, arrival, missed approach procedures, gradients and DME limits required;
c) familiarity with the Windshear and Turbulence Warning System (WTWS) operation and terminology;
d) Hong Kong and specific airport weather characteristics and seasonal variations;
e) location of nearby aerodromes Shenzhen, Macao and Zhuhai, and the delineation of the Hong Kong TMA boundary in relation to these aerodromes.
f) ground handling and breakaway thrust requirements.

5.5 A system should be in place to ensure flight crew remain current with the Hong Kong International Airport brief on an annual basis or at least prior to each operation to the airport, if such operations are less frequent 5.6 It is recommended that all operators complete flight crew familiarisation in accordance with para 5.4 above.

1.17.6 Reporting of Hard Landing

Regarding reporting of the hard landing para 17.3.18.22 of Jet Airways Operations Manual Part A states as follows:

Typical sink rates at touchdown are of the order of 120 to 240 ft per minute, and even a hard landing rarely exceeds 360 ft per minute. Aircraft are certified with a sink rate of 600 ft per minute at the limit maximum Landing Weight and a sink rate of 360 ft per minute at the limit Maximum Take-off Weight.

A hard landing shall be considered to be any unusual or abnormally hard touchdown after which it is prudent for flight crew to report so that special aircraft inspection will be carried out by Engineering.

A hard landing is not a fault; at most it is a flaw in technique or an error of judgment and/or influence of changes in wind direction/speed.

Hard landings can occur due to various reasons, such as:
Incorrect technique (flare and/or thrust reduction).
Sudden or rapid wind (speed and/or direction) change at touchdown in gusty conditions.
Sloping or undulating runway surface in the touch-down zone area.
Note 1 : Flight crew are not authorized to certify aircraft release in case of Hard Landing. Specific non-schedule inspections are required to be carried out by maintenance personnel.
Note 2: Suspected Hard landing shall be recorded in the Aircraft Technical Log and shall specify all of the following:

- Landing was hard Nose Gear landing or not;
- Landing included a hard Nose Gear touch down after de-rotation or not;
- Landing was three point landing or not;
- Landing was a Nose Gear first landing or not.

Note 3: if the aircraft is damaged due to an hard landing which necessitates repair before further flight an ASR shall be raised.

1.18 Additional Information:

Nil

1.19 Useful or Effective Investigation Techniques:

Nil

2. ANALYSIS

2.1 Conduct of Flight

2.1.1 Route/Aerodrome familarisation:

M/s Jet Airways has declared Hong Kong as category B aerodrome. For the category B aerodrome OMD prescribes that the PIC shall be briefed or self-briefed by the programmed instructions, and shall certify that he has carried out these instructions. Certification that this briefing has been carried out is indicated by the PIC completing and signing the appropriate briefing section of the form.

The AIP Hong Kong in addition requires the briefing to include the following:

(a) terrain at and within the environs of the airport;

b) departure, arrival, missed approach procedures, gradients and DME limits required;

c) familiarity with the Windshear and Turbulence Warning System (WTWS) operation and terminology;

d) Hong Kong and specific airport weather characteristics and seasonal variations;

e) location of nearby aerodromes Shenzhen, Macao and Zhuhai, and the delineation of the Hong Kong TMA boundary in relation to these aerodromes;

f) ground handling and breakaway thrust requirements.

CAR Section 8 Series O Part II requires briefing to include:

a) the route to be flown, and the aerodromes which are to be used. This shall include knowledge of:

1. the terrain and minimum safe altitudes;
2. the seasonal meteorological conditions;
3. the meteorological, communication and air traffic facilities, services and procedures;
4. the search and rescue procedures; and
5. the navigational facilities and procedures, including any long range navigation procedures, associated with the route along which the flight is to take place; and

b) Procedures applicable to flight paths over heavily populated areas and areas of high air traffic density, obstructions, physical layout, lighting, approach aids and arrival, departure, holding and instrument approach procedures, and applicable operating minima.

For this flight the briefing package was handed over for self briefing before the departure and it does not contain certain details required by AIP Hong Kong and including :

- Aerodrome details (Runway length & designator, airspace details etc). Taxiway restrictions etc.
- Different airways which need to be taken to Hong Kong due to Typhoon activity in South China Sea.
- Alternate airports (Enroute & Destination)

- Types of approaches available at Hong Kong.
- Company minima and whether CMV is applicable as per DGCA CAR on AWO.
- Standard taxi routings for departure and arrival.
- Communication failure procedure.
- Fuel dumping area if any (There is a defined area in Hong Kong).
- the seasonal meteorological conditions
- Categorization of Typhoon (Level 1,2,3,4, 5 etc) and the winds associated with them.

The Operations Manual Part "C" is generic and also do not contain the required details. Jepesson is refrerred for these information as preflight briefing folder does not contain the requisite details.

This system of information dessimination is not adequate as both requisite material and time is not adequate for programmed briefing

2.1.2 **Approach and Landing**

The trainee pilot/PF felt that he was not adequately rested before the route check though his duty was within the FDTL requirements. The airport has complex approach due to proximity to the hills, different procedures from single engine Go Around and missed approach and steep Go Around gradient. He had never been to Hong Kong on the training flight of M/s Jet Airways.

The airplane descending from 1000 feet radio altitude configured for a flaps 30 landing with the speedbrakes armed while on approach to Runway 07L.The autopilot was disengaged at time 5:54:03 Hrs IST (00:24:03 UTS) at 843ft RA while the autothrottle remained engaged until after touchdown.

During the approach the computed airspeed was maintained at approximately 145 knots (VREF+5). The descent rate was maintained at an average of 800 feet/minute during the approach.

Flare was initiated at time 5:55:03 Hrs IST (00:25:03 UTC) with a pull of the column at a radio altitude of 36 feet. The pitch attitude increased from 0.7 degrees nose-up to 3.25 degrees nose-up during the flare. As the pitch attitude increased, the descent rate was arrested at 700 feet/minute and began to decrease until touchdown. . During this process there were frequent push and pull inputs (Ref. Fig. 5). As a result the pitch attitude achieved during the flare was less than required and the rate of descent was also not sufficiently reduced. Also the vertical load factor "g" was 3.23 during the touchdown.

The pitch angle variations along with elevator deflection in the incident flight was compared with three other normal landings at Honkong as detailed below:

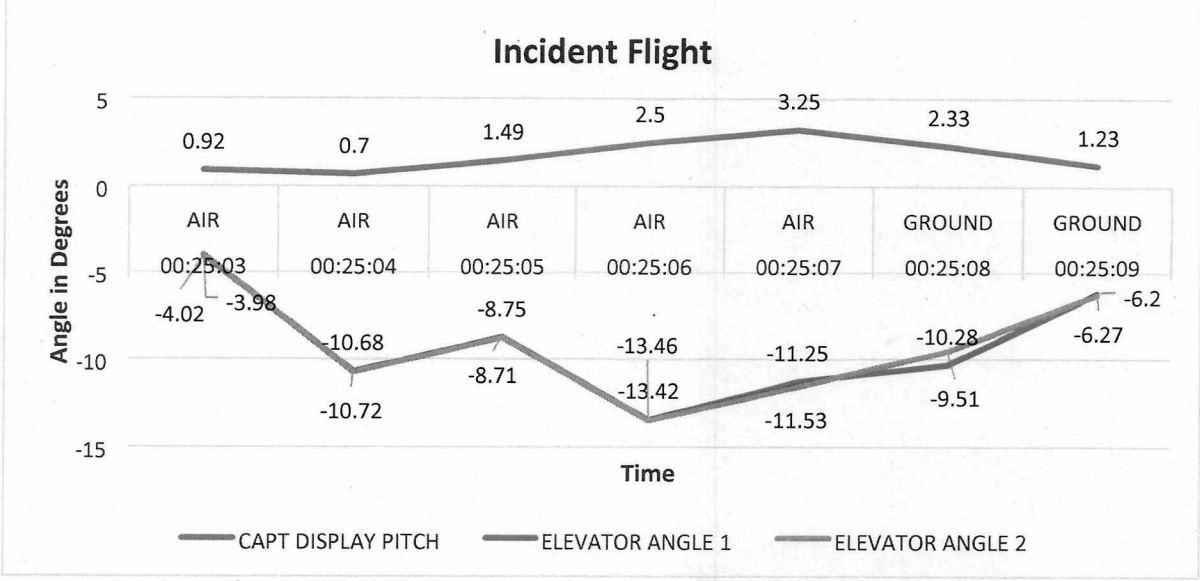


Fig. 5: ***Pitch Attitude variation and elevator defelection***

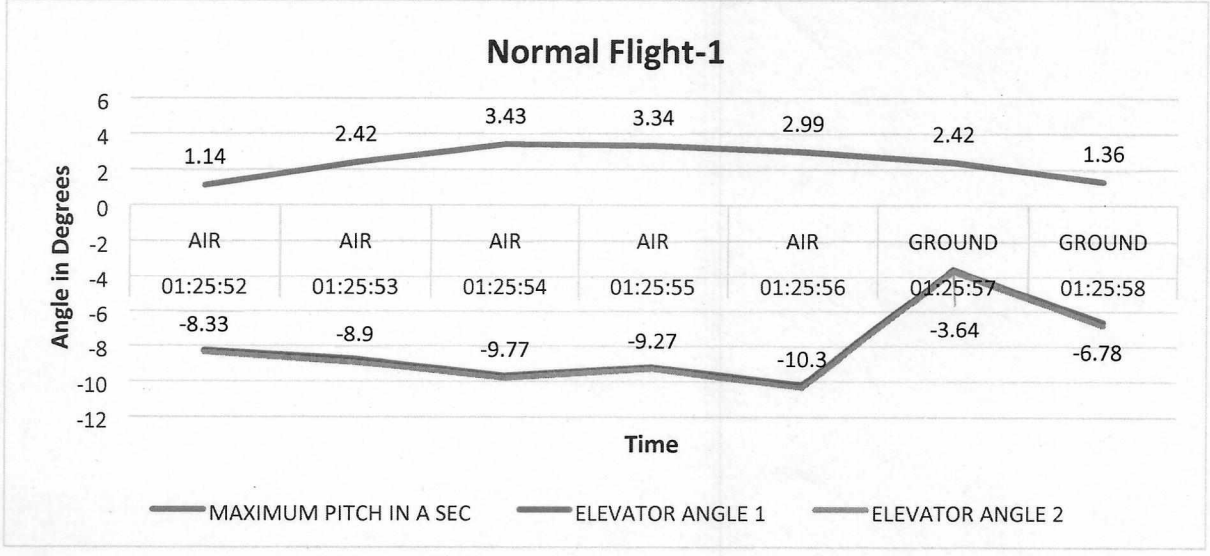


Fig. 6: ***Pitch Attitude variation and elevator defelection***

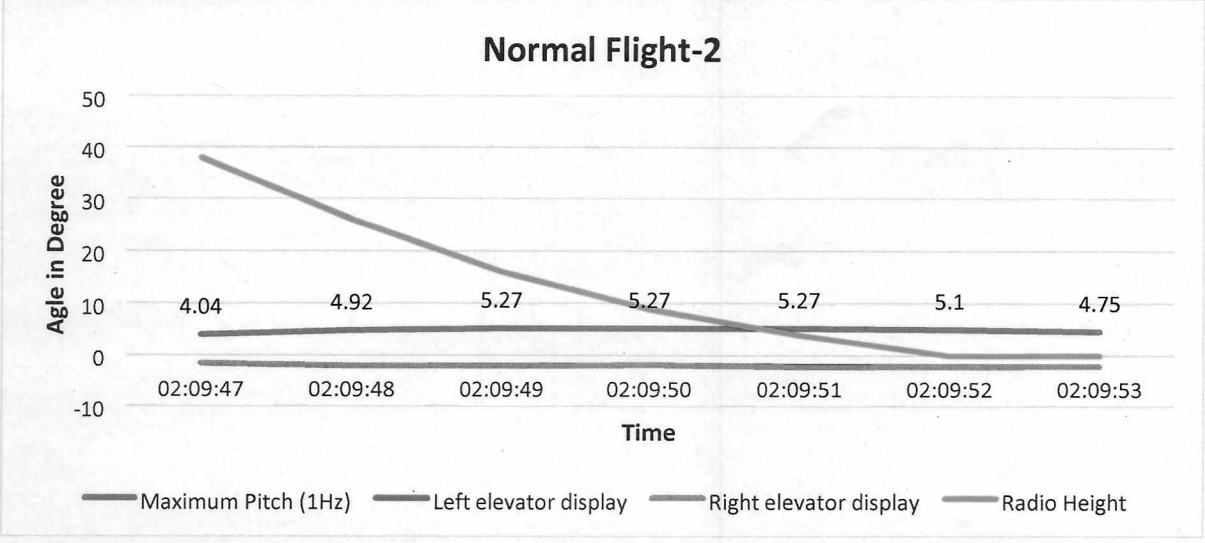
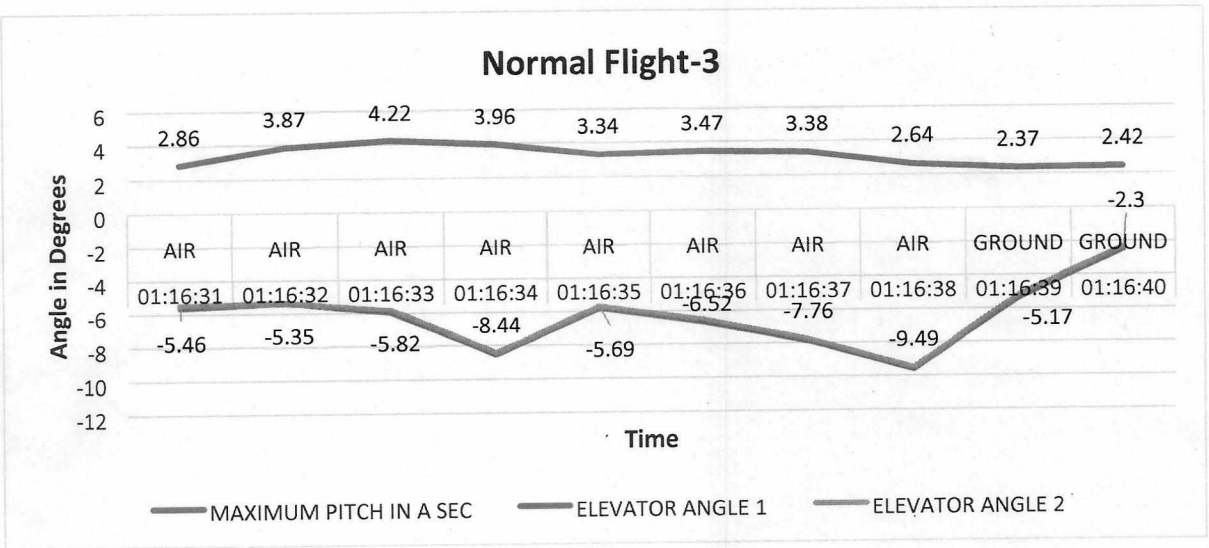


Fig. 7: ***Pitch Attitude variation and elevator defelection***



From the comparison it is evident that there was large variation in the elevator deflection. Initially during the flare, he put the nose down and then pulled up, and this process continued till touch down. During the incident flight the pitch attitude of 3.25 degree was attained just before touch down.

Also the flare length attained in the indicent flight was compared with other three landings as presented below:

SNO	Sector	Length of Flare (meters)
1	Incident Flight	372.60
2	Normal Flight-1	488.96
3	Normal Flight-2	399.19
4	Normal Flight-3	696.47

It is seen the length of the flare is less in the incident flight.
Thus the flare was inadequate. This resulted in heavy landing. This may have also been contributed due to the trainee anxiety and fatigue.

2.2 **Reporting of the Hard landing Occurrence**.

Jet Airways has a process incorporated in their Ops manual Part –A for reporting of hard landings in the aircraft tech log along with the details specified in the Ops manual.

Further the procedure requires an ASR to be raised if an aircraft is damaged due to a hard landing which necessitates repair before further flight.

During the incident the maximum vertical load factor at the time of landing was 3.23 g. As per crew the aircraft shuddered after landing.

The crew in their assessment did not feel that the hard landing was made. Also no complaint from any passenger was reported. Accordingly, they did not make any

entry to this effect in the Tech Log/ Voyage report.

Boeing in its analysis has stated **that the magnitude of vertical load factor translated to the CG was above the threshold for hard landing, indicating that the Phase IB inspection was required, regardless of the findings of the Phase IA inspection. Boeing report also mentions** that **" the flight crew's judgment is the most reliable criterion to use for determining if a hard landing has occurred. Data alone are insufficient to make this determination".**

Further unlike few other aircraft load report/warning on EICAS is not generated following the hard landing. Using the "Sink Report" generated by Maintenance Access Panel, load factor can be ascertained using the load factor chart with some degree of accuracy by the engineering. However, they will carry out this exercise only if suspected hard landing is reported by the crew.

As seen above, the fact that hard landing was made, was not quite clear to the crew accordingly they made no entry in the Tech Log/ Voyage Report about the hard landing.

2.3 **Intervention by the Trainer/Examiner:**

During the flare the rate of descent was not sufficiently reduced and the rotation was not adequate. The pitch attitude achieved was 3.25 degree Nose Up just before touch down.There was no intervention from the DE as he felt that it would aggrevate the situation. Also he was aware that the trainee has flown as PIC with Etihad Airways on B-777 aircraft and he had undergone nine satisfactory route checks with Jet Airways.

In flight Instructors/Examiner should be able to multitask - simultaneously instructing, observing, performing PM duties and remaining ready to take the controls at a moment's notice. From the Left seat pilot work the throttle with right hand and the control stick with left; from the RHS seat, the hand positions are reversed.

For the training of the instructors the CAR Section 7 Series I Part II provides training and assessment of an instructor from the right hand seat. Further appendix 4 to CAR Section 8 Seiries F part II provides for periodic additional training and assessment of PIC's (commanders) whose duties also require them to operate in the right-hand seat and carry out the duties of co-pilot, or PIC's required to conduct training or examining duties from the right-hand seat, as specified in the Operations Manual. This additional training includes at least the following: (a) An engine failure during take-off; (b) A one engine inoperative approach and go-around; and (c) A one engine inoperative landing.

Thus the regulations adequately provide for the training of the instructors/Examiner for the performance of their stated job.

However large number of incidents take place below 50 ft where in it becomes difficult for the trainer/examiner to take decision and act. Based on the requirements of the CAR Section 8 Seiries F part II, Airline Operators including Jet Airways have developed their check proformas but the following elements during the training are covered by only by a few Airline Operators.

S.No.	Training Exercise
1	Over Controlling during Approach – No Retard
2	High Rate of Descent after 50 Feet – Weak Flare – Take Over
3	Over Flare - Balloon
4	High Flare followed by a Go Around
5	High Cross winds – Drifting at low altitude
6	High Bank Input before/during flare
7	Take off at RTOW – Fast Rotation/Early Rotation/Over Rotation/delayed rotation
8	Over Controlling in roll during flare and early reduction of thrust – Take Over

2.4 Route Familarzation:

Para 9.4.3.3 of DGCA CAR Section 8 Series O Part II states that

"A pilot-in-command shall have made an actual approach into each aerodrome of landing on the route, accompanied by a pilot who is qualified for the aerodrome, as a member of the flight crew or as an observer on the flight deck, unless:

a) the approach to the aerodrome is not over difficult terrain and the instrument approach procedures and aids available are similar to those with which the pilot is familiar, and a margin approved by DGCA is added to the normal operating minima, or there is reasonable certainty that approach and landing can be made in visual meteorological conditions; or

b) the descent from the initial approach altitude can be made by day in visual meteorological conditions; or

c) the operator qualifies the pilot-in-command to land at the aerodrome concerned by means of an adequate pictorial presentation; or

d) the aerodrome concerned is adjacent to another aerodrome at which the pilot-in-command is currently qualified to land."

The trainee pilot had flown to Hong Kong as PIC during the last one year in B777 type of aircraft with Etihad Airways. Futher, in line with the requirements of the regulations he was given a briefing package before the departure. But it was a route check for the trainee. His SLF's have been conducted to European destinations and one to Singapore This is an airport with approach through terrain. Different airlines have their own SOP's , which may vary.

Therefore there was a need for adequate familirization during SLF while flying with M/s Jet Airways.

3. Conclusions

3.1 Findings

3.1.1 The Operations Manual Part "C" of M/s Jet Airways is generic and also do not contain the required details. Jepesson is refrerred for these information as preflight briefing folder does not contain the requisite details. The details of the information required for briefing by the AIP Hong Kong has neither been included in the briefing package nor in the Operations Manual Part C.
This system of information dessimination is not adequate as both requisite material and time is not adequate for programmed briefing.

3.1.2 During the flare the required rotation/pitch attitude was not achieved. The rate of descent was also not sufficiently reduced.

3.1.3 Due to the rostering schedule trainee was fatigued although it was within his FDTL.

3.1.4 Soon after touchdown, 3 successive increasing peaks were observed in the vertical acceleration, with values of 0.65, 0.82, and 2.23 g's (normal load factor of 1.65, 1.82, and 3.23 g's, respectively). The maximum peak in vertical acceleration occurred 0.7 seconds after the estimated touchdown time.

3.1.5 The fact that hard landing was made, was not quite clear to the crew accordingly they did not make an entry in the techlog about the hard landing.

3.1.6 A large number of incidents take place 50 ft below where in, it becomes difficult for the trainer/examiner to take decision and act. Based on the requirements of the CAR, Airline Operators have developed their check proformas which do not cover all the elements.

3.1.7 The incident of hard landing was detected during the Flight Data Monitoring and communicated to engineering on 02.05.2017 informing that VT-JEQ /27.04.2017/9W078/ DEL-HKG had a touchdown vertical "g" of 3.23 and advising

inspection of the aircraft. Work order No. 2671985 dated 03.05.2017 was raised and closed for the hard landing inspection. Hard landing inspection was carried out as per AMM 05-51-01 and nose landing gear and fwd fuselage inspection was carried out as per AMM 05-51-36 found satisfactory . During Phase 1A and 1B of hard landing inspection there were nil findings.

3.2 **Cause :**

The Incident occurred due to frequent change in pitch input during the landing phase of flight & touchdown with inadequate flare.

Contributory Factors:

a) Fatigue of the trainee pilot.
b) Lack of familarity with the Airport.

4. Recommendations:

4.1 Airline Operators may reiterate the procedures associated with the reporting of suspected hard landings and the information available to assist decision making on reporting for the aircraft types operated.

4.2 DGCA may consider standardisation of the check proforma for the trainers and include following elements as part of the training/assessment

1	Over Controlling during Approach – No Retard
2	High Rate of Descent after 50 Feet – Weak Flare – Take Over
3	Over Flare – Balloon
4	High Flare followed by a Go Around
5	High Cross winds – Drifting at low altitude
6	High Bank Input before/during flare
7	Take off at RTOW – Fast Rotation/Early Rotation/Over Rotation
8	Over Controlling in roll during flare and early reduction of thrust – Take Over

4.3 DGCA may consider directing Airline Operators to adopt conducting SLF to an International Destination where the subsequent route check is planned.

4.4 M/s Jet Airways may review its process of providing programmed briefing and include all the information mandatorily required by DGCA-India regulation and local regulations.

4.5 Airline Operators rostering section may give due consideration while rostering a crew for line Assessment/Route Check.

15/10/2018

(Maneesh Kumar)
Director Air Safety
Inquiry Officer-VT-JEQ

APPENDIX-A

COORDINATION SHEET

Group Index: **FLIGHT SCIENCES – AIRPLANE CHARACTERISTICS & LOADS: SC17777A-006**

Model No.: **777-300ER / GE**

Subject: **Analysis of Jet Airways (JPL) 777-300ER (WD769/VT-JEQ) Hard Landing on April 28, 2017**

References: *a) Service Request 4-3749374580, VT-JEQ, 777-300, HARD LANDING, dated May 2, 2017*
b) 777 Aircraft Maintenance Manual (AMM) for Jet Airways, The Boeing Company, Revision Date: January 5, 2017

Abstract: JPL reported that a 777-300ER experienced a hard landing at Hong Kong International (HKG) on April 28, 2017. JPL evaluated the QAR data and discovered that the vertical load factor reached 3.23 g's during landing and proceeded to perform a Phase IA hard landing inspection per the AMM with no findings. Analysis of the QAR data show that the airplane did touchdown with a vertical load factor of 3.23 g's at a roll angle of 1.3 degrees, which is above the 777 CG load factor threshold to waive a Phase IB inspection specified in the AMM. Had the pilot called the landing hard, Phase IA and IB inspections would be required based on the conditional inspection logic in the AMM. However, without the pilot's determination, performing the inspections would be at the airline's discretion. The calculated closure rate at touchdown was 8.1 feet/second which is below the design limit load of the main gear.

Action: *Please share content with the appropriate parties.*

Enclosure:	Enclosure Description:	Number of Pages:
A	Aero-B-BBA1-C-17-072 Figures	4

Discussion:

Event Report
In the Reference (a) Service Request, Jet Airways (JPL) reported that a 777-300ER (WD769/VT-JEQ) experienced a hard landing at Hong Kong International Airport (HKG/VHHH) on April 28, 2017. The report from JPL stated the following:

> *Subject aircraft had a reported vertical G of 3.23 on the 27th of April, 2017 (find the attched excel data sheet) in one of the samples of the frame 11138-2 (SfCount-44553) at time 0:25:07.*
>
> *JPL has performed the phase 1A inspection as per AMM and found satisfactory.*
>
> *Desired Action*
> ==========
> *JPL is sending the QAR data of the subject airplane via message courier. And would request Boeing to review the data to ascertain if any further inspection is required or not. Airplane is scheduled for revenue flight in the late hours today. Request a response a AOG basis.*

The quick access recorder (QAR) data were provided to Boeing for analysis.

Weather Report
An Aviation Routine Weather Report (METAR) was provided that was posted at 08:30 AM local time, the time of the subject landing was 8:25 AM local time. The METAR stated the following:

METAR VHHH 280030Z 05006KT 020V080 9999 FEW030 SCT040 22/14 Q1016 NOSIG

METAR indicates that the winds were from the northeast at 50 degrees, but varied from 20 to 80 degrees, with a magnitude of 6 knots. The ceiling was unlimited with scattered clouds and a visibility of 6.2 miles.

QAR Data Analysis
The provided QAR data are non-time-aligned, which means that each parameter has lost its original timestamp. These data are buffered and output in "clusters" of data, corresponding to common sample rates. Then, post-processing tools evenly distribute the data samples throughout each sample interval (one second in this dataset) based on sample rate, without knowledge of when that event actually occurred on the airplane. For example, a parameter that is recorded at 4 samples per second (sps) will have the recorded data points evenly distributed at 0.0, 0.25, 0.5, and 0.75 seconds within a given second. As a result, there may be an error in time when comparing recorded data points to Greenwich Mean Time (GMT) and to other parameters. Thus, caution should be exercised when interpreting these data.

Time history plots of the pertinent longitudinal and lateral-directional parameters are attached as Figures 1 through 4. In addition to an evaluation of the recorded parameters, a kinematic consistency (KinCon) analysis was conducted on the provided QAR data. KinCon is used to correct inherent inconsistencies often present in recorded data because of sample rate differences, multiple independent data sources, and the presence of instrumentation biases. The KinCon process uses integrated acceleration data to ensure basic inertial parameters such as altitude, ground speed, and drift angle are compatible and comparable. The output is a kinematically consistent set of data with acceleration biases removed, allowing calculations of wind data and other information.

The QAR data show the airplane descending from 1000 feet radio altitude configured for a flaps 30 landing with the speedbrakes armed while on approach to Runway 07L (verified by latitude/longitude data [not shown] and magnetic heading) at HKG (Figures 1 and 2). The autopilot was engaged in glideslope (G/S) and localizer (LOC) modes and the autothrottle engaged speed (SPD) mode at time 16,540 seconds. The autopilot was disengaged at time 16,555 seconds while the autothrottle remained engaged until after touchdown (Figure 1). The reference landing speed (VREF) was recorded at 140 knots and during the

approach the computed airspeed was maintained at approximately 145 knots (VREF+5). The descent rate (negative calculated vertical speed) was maintained at an average of 800 feet/minute during the approach. The calculated wind profile agreed well with the recorded ship system winds. The wind direction was variable but was primarily from an average of 50 degrees and the wind speed was approximately 8 knots. Runway 07L has a true heading of 71 degrees. This means that the airplane primarily experienced a left quartering headwind during the approach at an average magnitude of 8 knots with some variation in the direction as touchdown neared. Due to the crosswind, the airplane was in a 1 to 2 degree left crab angle (opposite of drift angle) until touchdown.

Flare was initiated at time 16,613.5 seconds with a pull of the column at a radio altitude of 30 feet (Figure 1). The pitch attitude increased from 0.7 degrees nose-up to 3.4 degrees nose-up during the flare. As the pitch attitude increased, the descent rate was arrested at 700 feet/minute and began to decrease until touchdown.

Touchdown occurred as early as time 16,616.5 seconds as indicated by the sudden decrease in longitudinal acceleration (Figure 3). The main gear tilt discretes transitioned from GROUND to AIR at time 16,617 seconds. Soon after touchdown, 3 successive increasing peaks were observed in the vertical acceleration, with values of 0.65, 0.82, and 2.23 g's (normal load factor of 1.65, 1.82, and 3.23 g's, respectively). The maximum peak in vertical acceleration occurred 0.7 seconds after the estimated touchdown time. The airplane touched down at a gross weight of approximately 486,080 LB (below the maximum landing weight [MLW] of 554,000 LB) with a left bank angle of about 1.3 degrees (Figure 4). The computed airspeed at touchdown was 143 knots (VREF+3). After touchdown, the crew input right rudder pedal to de-crab the airplane. The lateral acceleration reached 0.38 g's to the right as the speedbrakes extended and the weight of the airplane settled onto the main gear (Figures 3 and 4). By time 16,621 seconds, the nose of the airplane was lined up with the runway heading and the remainder of the landing rollout continued without incident (not plotted).

Touchdown Analysis

In order to understand the loads acting upon the main landing gear at touchdown, the airplane gross weight and vertical load factor must be considered along with an accurate vertical speed. The vertical speed parameter was recorded on the QAR at 4 sps. As a result, these data do not provide a precise or accurate vertical speed at touchdown. The KinCon analysis produced a kinematically consistent, higher sample rate vertical speed at the airplane center of gravity (CG). The calculated vertical speed at the CG was then translated to the main landing gear to determine the closure rate of the left main gear with the ground. Closure rate takes into account the runway slope near the point of touchdown. The effect of an upsloping (positive) runway would increase the closure rate of the main landing gear with the runway compared to the vertical speed of the airplane CG. The effect of a downsloping (negative) runway would decrease the closure rate of the main landing gear with the runway compared to the vertical speed of the airplane CG. In addition, roll rate and pitch rate at touchdown are also accounted for in the main landing gear closure rate.

Table – Summary of Vertical Acceleration and Vertical Speed Information

		Recorded on QAR			Calculated by KINCON	
Location	Estimated Rwy Slope Near Tchdn[1]	Roll Angle at Tchdn (deg)	Max Vertical Acceleration[2] (g's)	Recorded Vertical Speed @ Tchdn[3] (ft/sec)	CG Vertical Speed @ Tchdn[3] (ft/sec)	Left Main Ldg Gear Closure Rate[4] @ Tchdn (ft/sec)
HKG Rwy 07L	0.00%	1.3	2.23	-6.7	-8.4	8.1

[1] A positive runway slope indicates an upward slope, and will result in a higher closure rate compared to a runway with no slope. Calculated Vertical Speed at the CG is calculated independent of runway slope. Runway 07L slope was unknown in the touchdown zone, so slope was not considered in the calculation.

[2] Vertical acceleration (COG_NORMAL_ACCEL_ADIRU) is recorded at 10 sps (10 Hz) on the QAR. The recorded vertical acceleration represents incremental acceleration from 1-g flight. The Reference (b) Aircraft Maintenance Manual (AMM) acceleration thresholds are in terms of vertical load factor, which includes gravity. As a result, 1.0 should be added to the COG_NORMAL_ACCEL_ADIRU value before comparing to the AMM threshold.

[3] A negative vertical speed is equivalent to positive sink rate.

[4] Positive closure rate indicates the main landing gear are approaching the runway at the rate specified. A larger positive number indicates the main landing gear are approaching the runway at a faster rate.

The closure rate of the main landing gear with the ground is a critical component in understanding the loads incurred by the main landing gear during touchdown. The main landing gear are designed to withstand a closure rate of 10 feet per second (fps) at zero roll angle (represents limit load). The calculated touchdown closure rate of 8.1 fps was below the design limit of 10 fps (Figure 3).

Aircraft Maintenance Manual (AMM) Conditional Inspections

Section 05-51-01 of the AMM defines the maintenance practices for hard landings, overweight hard landings, or high drag or high side load conditions. The inspection is divided into two phases (Phase I and Phase II), and Phase I is divided into two phases (Phase IA and Phase IB). Phase IA is a visual inspection, Phase IB contains inspections that require special tools or access to the airplane, and Phase II is a detailed structural inspection. AMM Section 05-51-01 defines the conditions upon which each phase should be completed, and those conditions are outlined below.

05-51-01 Hard Landing or High Drag/Side Load Landing

Section 05-51-01, Chapter (1)(C) states that a high drag or high side load condition occurs if one or more of the following conditions are met:

(a) The flight crew reported a high drag load or high side load event
(b) The airplane ran off the prepared surface
(c) The airplane landed short of the prepared surface
(d) The airplane made a landing and two or more tires were blown
(e) One or more of the landing gear hit an obstacle or were hit by an obstacle.

JPL did not report any of these above conditions, and the data do not indicate evidence of any of these conditions. Therefore, no inspections would have been required in response to the high drag/side load condition.

Hard Landing

Section 05-51-01, Chapter (1)(D) states that a hard landing occurs if one of the following conditions is met:

(a) The landing is reported by the flight crew as "hard".
(b) It was a landing where the nose gear contacted the runway before the main gears.

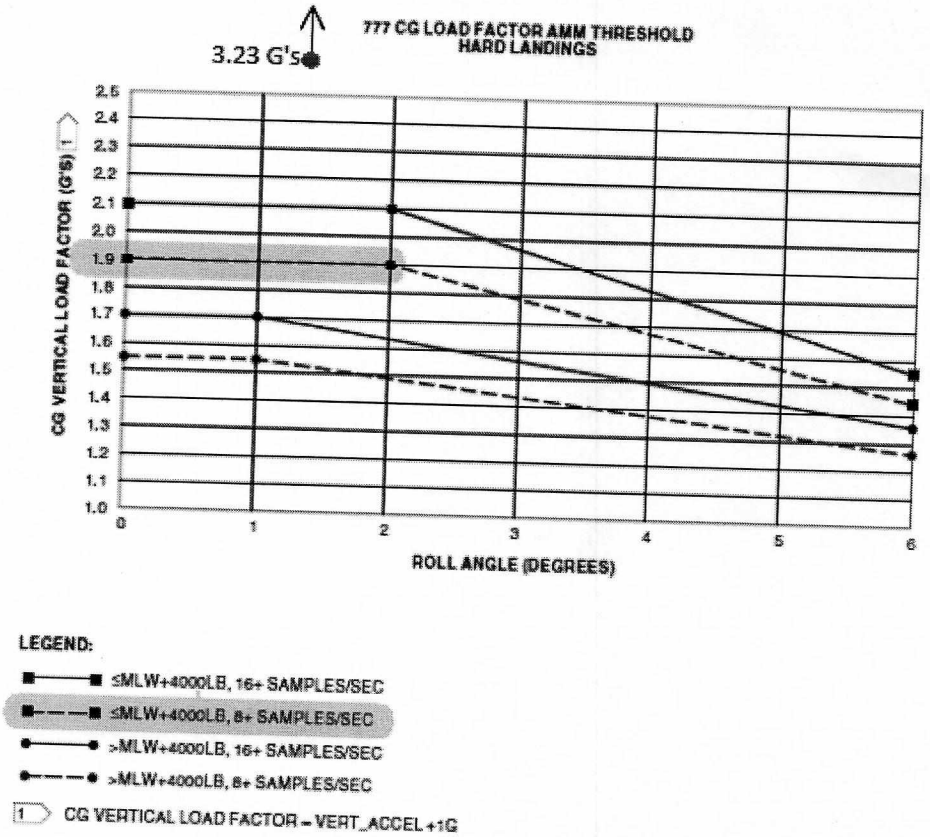
It was reported that the subject landing was not reported as "hard" by the flight crew. If it had been, the inspection logic in the AMM would then need to be evaluated to determine the required inspections.

Overweight Hard Landing

Section 05-51-35, Chapter (1)(E) states that for the purpose of this conditional inspection, an overweight landing occurs when the landing weight is greater than the maximum design landing weight (MLW) plus 4000 pounds. The airplane landed at a gross weight below MLW, so this section would not apply.

Inspection Logic

Section 05-51-01, Chapter (1)(F) outlines the inspection logic, which is also presented in flowchart format (AMM Figure 201). If the flight crew reported a hard landing, the Phase IA and Phase IB inspections would have been required prior to the next flight. If flight data had been available, then it is advised to check the vertical load factor and roll angle against the 777 CG Load Factor AMM threshold. If the data indicate a vertical load factor below the threshold, and no damage is found during the Phase IA inspection, the Phase IB inspection may be waived. The graphic below shows the AMM vertical load factor threshold, with the maximum vertical load factor and roll angle at touchdown for the event landing overlaid on the graphic (red dot symbol). The magnitude of the vertical load factor was off the scale of the graphic. For this comparison, the 8+ sps curve must be used along with the appropriate touchdown weight (yellow highlight).



Based on the graphic above, the magnitude of vertical load factor translated to the CG was above the threshold for hard landings, indicating that the Phase IB inspection could not have been waived, regardless of the findings of the Phase IA inspection. Note that a Phase IA inspection is not required unless the flight crew reported a hard landing. The inspections would be at the airline's discretion.

Conclusion

If the subject landing had been reported as "hard" by the flight crew, Phase IA and IB inspections would have been required prior to the next flight. If flight data had been available, an evaluation could have been performed to determine if the Phase IB inspection could be waived. Analysis of this landing indicates that the vertical acceleration experienced by WD769 was above the AMM threshold, indicating that the Phase IB inspection could not have been waived, regardless of the findings of the Phase IA inspection, if the pilot had called the landing hard. If using data alone, without the pilot's call, the inspections are at the airline's discretion. At touchdown, the closure rate of the main landing gear with the runway was 8.1 feet/second

(assuming a zero runway slope) which is below the design limit of the gear. Boeing maintains that the flight crew's judgment is the most reliable criterion to use for determining if a hard landing has occurred. Data alone are insufficient to make this determination.

Appendix "B"

GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AGL	:	Above Ground Level
AMM	:	Aircraft Maintenance Manual
ASR	:	Air Safety Report
ASDA	:	Acceleration Stop Distance Available
ATPL	:	Air Transport Pilot License
ATS	:	Air Traffic Services
AWO	:	All Weather Operation
CAR	:	Civil Aviation Requirements
CBT	:	Computer Based Training
CG	:	Centre of Gravity
CVR	:	Cockpit Voice Recorder
DE	:	Designated Examiner
DGCA	:	Director General of Civil Aviation
DIR	:	Direction
DME	:	Distance Measuring Equipment
EOEP	:	Engine Out Escape Procedure
EICAS`	:	Engine Indication and Crew Alerting System
FC	:	Flying Cycle
FH	:	Flying Hour
FMC	:	Flight Management Computer
FRTOL	:	Flight Radio Telephone Operators License
GS	:	Glide Slope
GA	:	Glide Angle

HGK	:	Hong Kong
ILS	:	Instrument Landing System
IR	:	Instrument Rating
IST	:	Indian Standard Time
LDA	:	Landing Distance Available
LOC	:	Localizer
METAR	:	Meteorological Aerodrome Reports
MCP	:	Mode Control Panel
MLW	:	Maximum Landing Weight
OMD	:	Operational Management Domain
PIC	:	Pilot-in-Command
PPC	:	Pilot Proficiency Check
R/C	:	Route Check
SOP	:	Standard Operating Procedure
SPD	:	Speed
T/D	:	Touch Down
TODA	:	Take-off Distance Available
TORA	:	Take-off Run Available
TMA	:	Terminal Area
UTC	:	Universal Coordinated Time