



**Report of the Board of Review on the Accident to Boeing MD-11 B-150 at
Hong Kong International Airport on 22nd August 1999**

**Pursuant to Civil Aviation (Investigation of Accidents) Regulations,
Cap. 448, Laws of Hong Kong**

Before

Ernest Michael Kam Hung LIN (Chairman)

And

Captain William Dennis LOWE (Assessor)

And

Mr. Peter Francis SHEPPARD (Assessor)

**Hong Kong SAR
November 2004**

Appearances

Mr. S. WESTBROOK, SC	(Instructed by the Department of Justice) Appeared as Counsel on behalf of the Review Board
Mr. N. WATKINS	(Of Messrs. Stevenson, Wong & Co., Solicitors) for China Airlines and Captain LIU Cheng Hsi, applicants for the review
Mr. Y.L. CHEUNG	(Instructed by the Department of Justice) Appeared as Counsel for the Hong Kong Observatory
Mr. A. DERBIE	(Of Hong Kong Airport Authority) Appeared as Counsel for the Hong Kong Airport Authority
Mr. C. SUSSEX, SC	(Instructed by Herbert Smith & Co., Solicitors) Appeared as Counsel for Boeing Commercial Airplane Group
Mr. Y.L. CHEUNG	(Instructed by the Department of Justice) Appeared as Counsel for the Inspector of Accidents

TABLE OF CONTENTS

	PAGE
1. Preliminary	4
2. Matters Leading to the Review Hearing	5
3. The Scope and Function of the Board of Review	7
4. Summary of the Proceedings Pursuant to Regulation 14(9)	10
5. The Evidence of Captain O.J. EVERIS (for CAL)	12
6. The Evidence of Mr. John ANDERSON (for Boeing)	24
7. The Evidence of Mr. SHUN Chi-ming (for Hong Kong Observatory)	27
8. The Evidence of Mr. Ricky LEUNG Wing-kee (for HKAA)	29
9. The Evidence of Professor Michael GRAHAM (for HKAA)	30
10. The Evidence of Mr. Robert BENZON (for Inspector of Accidents)	31
11. The Evidence of Captain M.S. DAVIS (for Inspector of Accidents)	34
12. The Evidence of Captain O.J. EVERIS (recalled)	39
13. Other Evidence	41
14. Decisions of the Board	41
15. Costs	48

1. Preliminary

The Accident

1.1 At 1843 hours local time on 22nd August 1999 an accident occurred when CI642 ('CI642') was landing at the Hong Kong International Airport ('HKIA') under inclement conditions. At the time the weather of the Special Administration Region was under the influence of Severe Tropical Storm 'Sam' with the associated strong gusting wind from the northwest and heavy rain. As it touched down on the wet runway the hard impact caused the aircraft's right main landing gear to collapse, followed immediately by the separation of the right wing and an outbreak of fire. It finally came to rest inverted on a grassy area to the right of the runway. As the result of the accident 3 passengers died and 219 persons (including passengers and crew members) were admitted to the hospital with 50 suffering serious injuries and the rest sustaining minor injuries. The aircraft, a Boeing MD-11, was operated by China Airlines ('CAL') and scheduled to fly from Bangkok to Taipei with Hong Kong as its intermediate stop.

The Investigation

1.2 Pursuant to Part II of the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Cap. 448 sub. leg. B, Laws of Hong Kong) ('the Regulations'), on 5th October 1998 the Chief Executive appointed Mr. Albert LAM Kwong Yu as the Chief Inspector of Accidents to carry out investigations into the circumstances and causes of the accident. On 23rd August 1999 Mr. Y.K. LEUNG of Hong Kong Civil Aviation Department was appointed as the Inspector of Accidents. With the assistance provided by the Aviation Safety Council of Taiwan, China, the Air Accident Investigation Branch of the United Kingdom, the National Transportation Safety Board of the USA ('NTSB') and Boeing Commercial Airplane Group (USA), the Inspector compiled a draft report on the accident. The draft set out, *inter alia*, an analysis of the relevant facts and the Inspector's conclusions as to the causes and probable contributory causes of the accident.

1.3 Pursuant to Regulation 11(1), on 11th June 2001, a notice enclosing the said draft was served on the following parties: -

National Transportation Safety Board
Boeing Commercial Airplane Group
China Airlines
Hong Kong Observatory
Hong Kong Airport Authority
Captain Gerardo LETTICH, commander of CI642
Captain LIU Cheng Hsi, co-pilot of CI642

1.4 Having considered further representations from some of the interested parties on the draft, the Inspector finalized and completed a report ('the Report') and forwarded the same to the Director-General of Civil Aviation ('the Director') under Regulation 10 in April 2002. Copies of the Report were also respectively served on all interested parties pursuant to Regulation 11(4).

1.5 As part of its conclusions the Report identified the causal factor of the accident in para. 3.2.1 as

"the commander's inability to arrest the high rate of descent existing at 50 ft RA".

2. Matters Leading to the Review Hearing

2.1 On 19th April 2002, China Airlines and the then co-pilot Captain LIU Cheng Hsi of CI642 respectively served a Notice of Review (hereinafter referred to collectively as 'the Notices') on the Director pursuant to Regulation 12. The Notices, identical in substance, contend that certain parts of the findings and conclusions in the Report would adversely affect the applicants' reputations and seek to review the same. For the sake of convenience we shall refer to both applicants collectively as 'CAL'. In addition to the causal factor mentioned above, 3 probable contributory causes to the high rate of descent (i.e. Causal factor 3.2.2) and a number of other findings (i.e. Findings 3.1.7, 3.1.8, 3.1.9, 3.1.14 and 3.1.16) in the Report are also challenged. The original grounds of challenge are set out in Attachment A of the Notices. The same have subsequently been amended as described below.

2.2 Pursuant to Regulation 13, on 5th September 2002 the Chief Executive of the SAR appointed a Board of Review ('the Board') consisting of the following members:

Chairman: Ernest Michael Kam Hung LIN, Principal Magistrate of Kowloon City Magistrates' Courts

Assessors: Captain William Dennis LOWE, and

Peter Francis SHEPPARD

2.3 Pursuant to Regulation 14(2), a preliminary meeting was held on 13th February 2003 whereupon the Board directed, inter alia, that the review hearing should commence on 16th June 2003 with an estimated length of 2 weeks. The original date was later vacated and rescheduled to commence on the 17th November 2003 at the joint application of the parties. The Board also directed that in addition to the 2 applicants, the following parties be granted leave to participate in the review hearing:

Captain Gerardo LETTICH (the ‘commander’)
Hong Kong Airport Authority (‘HKAA’)
HK Observatory (‘HKO’)
Boeing Commercial Airplane Group (‘Boeing’)

2.4 Captain LETTICH was the commander of CI642 on the day of the accident. The Board was made aware of his concern in the review proceedings by a letter dated 7th November 2002 forwarded to the Board members by Mr. Francis Kwan, Senior Government Counsel attached to Planning, Environment, Lands and Housing Unit (Litigation) of the Department of Justice. In the said letter, the commander stated that despite his concern, he lacked the resources to attend either in person or by way of a representative; nonetheless he would like to raise certain factual issues for the Board’s consideration during the review hearing. Although he did not comply with the statutory requirements of serving a Notice of Review and/or applying for leave to participate in the review hearing in the preliminary meeting, it was the Board’s view that since the commander’s reputation could be adversely affected by the findings and conclusions in the Report, he should be treated as a party and accorded the same rights as other parties to the proceedings. It was therefore ordered that he would be entitled to attend the hearing, adduce evidence, make submissions, examine and cross-examine witnesses pursuant to Regulation 14(2) if he so wished.

2.5 The Board’s order was communicated to the commander by the Chairman’s letter dated 14th February 2003. The commander acknowledged and welcomed such decision by a letter dated 6th March 2003 from his residence in Italy. That was his last communication with the Board. His name was included in the common mailing list used by the parties for serving correspondence as well as all other documents pertaining to the review application. Prior to the review hearing in November 2003, the commander was informed in writing that an extra set of documents to be used for the review hearing had been specifically prepared and would be made available to him should he choose to attend. He made no response to such information. He did not attend the review hearing either personally or by way of a representative; nor did he participate or contribute in any other manner.

2.6 On 27th March 2003, by a written ruling the Board refused an application made by CAL for discovery on the basis that the Regulations do not confer a general power on the Board to order discovery amongst the parties and before the review hearing.

2.7 Shortly before the review hearing, CAL gave notice of its intention to amend the grounds of review. The amendments revealed that CAL no longer contended that the aircraft, shortly before touchdown, was affected by a severe downdraft or microburst; instead the accident was attributed to a loss of

lift caused by “*abruptly shifting winds*” or “*windshear*”. Further, allegations that the accident was contributed to by certain type-specific responses in the controls of the MD-11 and/or by the design of the landing gear and the wing main spar were abandoned. The revised position adopted by CAL was based on the latest “*derived winds*” calculated in 2003 by Mr. John ANDERSON of Boeing. CAL relied on the latter’s hypothesis to explain the accident. The changes in the applicants’ position were formally recorded in the revised Attachments A to the Notices of Review and filed at the commencement of the hearing.

3. The Scope and Function of the Board of Review

3.1

The mechanism of the review proceedings under the Regulations was activated by the service of a written notice of review to the Director within the time frame set out in Regulation 12 as noted in section 2.1 above. The Regulations provide that the subject matter of the review can only be in relation to “*the findings and conclusions*” which may likely affect the reputation of the applicants adversely. Thus it is clear that the only parts of the Report open to review are the findings and conclusions and only on condition that they may adversely affect the reputation of the applicants.

3.2

Moreover, the standing of a person to serve a notice of review is further restricted, according to Regulation 11(1), to interested parties such as the commander, operator or

“*any person whose reputation is, in the Inspector’s opinion, likely to be adversely affected by the report*”.

3.3

The members of the Board have been appointed by the Chief Executive pursuant to Regulation 13. As stipulated, the Chairman is a magistrate and the assessors have been appointed by reasons of their “*aeronautical or aeronautical engineering qualifications*” and “*special skill or knowledge relevant to the conduct of the review*”. Captain LOWE retired recently after 37 years’ service as a pilot (including a long period as Chief Pilot) to British Airways. As a Chief Pilot part of his duties was to review all incidents and accidents to all aircraft operated by British Airways. Mr. SHEPPARD recently retired after serving 27 years as an Inspector of Accidents in the United Kingdom specializing in flight data recording analysis. As an Inspector of Accidents he had been involved in the investigations of over 100 aircraft accidents. The qualifications and expertise of the members of the Board have not been challenged.

3.4

Regulation 14(4) endows the Board with all the powers of an Inspector, the full extent of which are set out in Regulation 9. However, as noted in Regulation 9, such power is to be exercised

“For the purpose of investigation of any accident to which these regulations apply, or any inquiries undertaken with a view to determining whether any such investigation should be held.”.

3.5

Moreover, the relevant parts of Regulation 14(5) also provide thus:

- “(5) (a) *Where new and important evidence is given at the review, which was not given at the Inspector’s investigation, the board may, on an application by the Chief Inspector, discontinue the review, and the Chief Inspector shall thereupon cause the investigation to be reopened.*
- “(b) *Where at any time during the review the board are satisfied that any of the findings and conclusions in the Inspector’s report do not adversely affect the reputation of the person in respect of whom the notice of review was served, the board may discontinue the review in respect of those findings and conclusions.”*

3.6

The Regulations when read together indicate that the Board’s powers, though identical to those of the Inspector, are confined within narrower parameters than those of the Inspector: such powers can only be exercised for, and within the parameters of, the review of the particular findings and conclusions set out in the Notices and only when members of the Board are of the view that the same may adversely affect the reputation of the party or parties concerned. It is thus clear that the review proceedings are not an investigation independent of or in addition to the investigation already carried out by the Inspector. The Board has no general power to investigate. It was for this reason that the Board rejected CAL’s application for discovery on 27th March 2003.

3.7

At the completion of the review, under Regulation 14(9) the Board is tasked to prepare a report to the Chief Executive

“containing a summary of the proceedings at the hearing and either confirming or rejecting in whole or in part those findings and conclusions of the Inspector which were the subject of the review, together with its reasons therefor”.

3.8

As a preliminary ruling the Board accepts that the findings and conclusions under challenge are *prima facie* proper subjects for review under the Regulations. It also agrees that the findings and conclusions would have possible adverse effects on the reputation of China Airlines, the co-pilot and commander of CI642 and that the Applicants have the proper standing to serve the Notices.

3.9 If, however, at the end of the review hearing the Board decides that the challenged findings and conclusions are factually accurate, relevant and justified by the available evidence, the Board will confirm the same irrespective of their possible effects on the reputations of the individuals concerned. In discharging its duties, the Board is aware that these proceedings afford the affected parties a second opportunity to be heard, whilst bearing in mind the spirit of the legislation set out in Regulation 4:

“4. Purpose of Accident Investigation

The fundamental purpose of investigating accidents under these regulations shall be to determine the circumstances and causes of the accident with a view to the preservation of life and the avoidance of accidents in the future; it is not the purpose to apportion blame or liability.”

3.10 In its Closing Submissions CAL contended that, since the Board had no jurisdiction either to “*review, confirm or reject any findings or conclusions in the Report which were not the subject of the review*” or “*to review recommendations made in the Report and/or make recommendations which were not in the Report*”, this Board should exclude from its consideration the following matters which were outside the scope of the review (so it was said), notwithstanding that they featured prominently in the course of the hearing:

- Crosswind landing technique
- Crosswind landing limits for MD-11
- Conversations recorded on CVR transcript relating to issues other than those arising from a challenged finding or conclusion
- Training methodology
- Calling in for previous aircraft landing information
- Matters relating to Go-around as an option and its related procedure
- Autoland
- Stability of final approach
- Recommendations
- ILS approach

3.11 Although CAL’s submissions relating to the limits of the Board’s jurisdiction are helpful, one must not lose sight of the fact that the substance of the review is related to the cause (Report 3.2.1) and all the probable contributory causes to the accident (Report 3.2.2) as set out in the conclusions of the Report. Furthermore, since it is incumbent upon the Board to give reasons for confirming or rejecting the findings and conclusions or any part thereof under Regulation 14(9), it would not have properly discharged its statutory duties if it simply disregarded all evidence relating to other possible causal factors contributing to the accident. If the existence of any other causal factors constitutes a reason for rejecting or confirming the findings or conclusions in the Report, such evidence will be within the proper scope of the review and

the Board would be under a statutory duty to consider and allude to the same in its reasons. In so doing, the Board is but carrying out its statutory duty by assessing the validity or otherwise of the Inspector's findings and conclusions relating to the cause of the accident under review and should not be seen as embarking on an investigation of its own.

3.12 In its Closing Submissions, Boeing produced 2 sets of newly prepared charts. By a letter to the Board dated 16th January 2004, HKO objected to the production of the charts and asked this Board to disregard them entirely on the basis these were new evidence which all interested parties had not been given an opportunity to analyze and challenge either before or during the review hearing. The said letter also enclosed HKO's comments on the charts should the Board decide to consider the evidence nonetheless. The Board takes the view that the charts are means with which Boeing further expands the points already made in the review hearing and are therefore relevant to these proceedings. We decided that both the Boeing submissions and HKO's comments on the same are relevant and should be taken into consideration for the purpose of these proceedings.

3.13 The revised Attachment A to the Notices suggests the replacement and addition of certain causal factors to the Report. As is rightly conceded by CAL in its Closing Submissions, the Board has no jurisdiction to re-write the Report. Nonetheless the suggestions would be considered by the Board for the purpose of deciding whether or not to confirm or reject any part of the findings and conclusions under review.

4. **Summary of the Proceedings Pursuant to Regulation 14(9)**
(Sections 5-13 below)

4.1 The review hearing took place over 9 working days from 17th to 27th November 2003 in Court 7 of the High Court of the HKSAR. Pursuant to Regulation 13(4) the hearing was held in public.

4.2. Except for Captain DAVIS and Mr. Robert BENZON (the 2 witnesses called by the Inspector whose statements were served during the review hearing) all expert reports or statements had been filed and circulated in accordance with the directions given prior to the commencement of the review hearing. In all a total of 7 witnesses gave evidence on oath to expound on the opinions already set out in their respective statements or reports.

4.3 The followings are the witnesses in the order of their appearance:

- Captain O.J. EVERIS (for CAL)
- Mr. John ANDERSON (for Boeing)
- Mr. SHUN Chi-ming (for HKO)

- Mr. Ricky LEUNG (for HKAA)
- Mr. Robert BENZON (for the Inspector)
- Professor GRAHAM (for HKAA)
- Captain M. S. DAVIS (for the Inspector)
- Captain O.J. EVERSON (for CAL) (recalled)

4.4 Despite the invitation of this Board, the commander did not attend the review hearing either personally or through a representative. His failure to attend or to further communicate with the Board in any way is taken as an indication that he had waived his rights to be heard or to contribute in any manner to the hearing. We therefore decided to proceed with the review hearing as scheduled. Nonetheless members of the Board have taken note of the matters he raised in his letter of 7th November 2002.

4.5 It is noted that none of the witnesses called gave direct factual evidence relating to the accident itself. In particular, none of the persons on board CI642, noticeably the commander, the then co-pilot LIU Cheng Hsi, or indeed any crewmember on board any aircraft landing prior to or after the accident were called to give evidence of their personal observations.

4.6 Before the hearing the Chairman of the Board received a letter dated 10th November 2003 from the President of the Hong Kong Airline Pilots Association. In the letter the President conveyed the Association members' concern in the review hearing and drew the Board's attention to certain factual issues. The Board welcomes such input and appreciates the effort. Having discussed with Counsel for the Board, we decided to address those issues by putting questions to the witnesses called by the parties rather than calling witnesses on our own.

4.7 The proceedings were instantaneously transcribed into computer. Hard copies of the transcript for the day's proceedings were distributed to all parties in the same evening. At the end of the review hearing each party (as well as each member of the Board) has an accumulated folio comprising the full transcripts of the review hearing with each day's record grouped in one section. By agreement the costs of preparing the transcripts were borne equally by the parties. The Board would like to express its appreciation for such arrangement. Except for Boeing who submitted a list of suggested corrections to the transcripts relating to Mr. ANDERSON's testimony, none of the other parties took issue on the accuracy of the transcripts. The Board notes that the suggested corrections submitted by Boeing do not affect the substance of Mr. ANDERSON's testimony. Furthermore, none of the other mistakes in the transcripts, which members of the Board managed to identify, has any significant bearing on the substance or tenors of the respective testimonies and submissions. In this report we shall, whenever appropriate, refer to the evidence given during the hearing and quote the exact words used by the witnesses.

4.8

After the review hearing, the parties put in written closing submissions to the Board according to an agreed timetable. This was followed by the written advice of the Counsel for the Board on 30th January 2004. The said submissions and advice are copied to all the parties to the review hearing. In his written advice Counsel for the Board helpfully included a draft summary of the evidence which we have drawn on extensively when preparing the following summary of evidence in accordance with Regulation 14(9). For the purpose of convenience and uniformity, we adopt the glossary appearing at pp. i-iii of the Report.

5.

The Evidence of Captain O.J. EVERE

5.1

Captain EVERE, the only witness called by the Applicants, gave evidence as an expert witness. He had served 21 years in the Royal Canadian Air Force and later worked as a test pilot for McDonnell Douglas on, amongst other aircraft, the MD-11. His duties included the training of the first customers of MD-11. He joined China Airlines in 1993 as a line pilot on the MD-11 and later as an instructor pilot. From 1996 he was a line pilot for Boeing 747s until his retirement from line flying in 1998. He was re-employed by China Airlines in early 2000 when he became involved in the investigation of this accident.

5.2

Captain EVERE began his evidence by way of a presentation. In short, his view was that the commander flew the aircraft skillfully to 30 ft RA before it made an unavoidably hard landing owing to the abruptly shifting wind conditions during the last 1.5 seconds before touchdown. He further contended that subsequent simulations had shown that only autopilot could land the plane safely and that none of the human pilots had been able to land safely in the simulated conditions. The Board notes that the force of this last argument was somewhat diminished after Boeing discovered that important mistakes had been made whilst inputting some data for the simulations in 2000.

5.3

Captain EVERE admitted that the conclusions in his original report were incorrect as to the source of the high rate of descent ('ROD') just before touchdown, relying as he did originally on theories of severe downdraft or microburst. Instead he embraced without reservation the new report from Mr. John ANDERSON of Boeing which attributed the high ROD to 4 factors:

- i. A sudden wind shift, which resulted in a headwind loss of 14 knots and a right crosswind increase of 20 knots.
- ii. A right control wheel input (to counter the increase in crosswind) raised the flight spoilers on the right wing causing a reduction in lift.

- iii. A small downdraft of approximately 2.5 knots.
- iv. A residual nose down pitch rate from a previous pilot correction.

5.4 His position could be represented by the following paragraph at page 4 of his revised report, where he contended that

“... the new data clearly show that in challenging weather conditions, the pilot skillfully maneuvered his aircraft to a point on the centerline of the runway from which a flare for landing would normally be made – about 30 ft above touchdown, with zero drift, adequate speed, and fully prepared for a normal landing; at that point he experienced a sudden large wind shift and, as described above, a large loss of lift, from which it was not possible to recover before touchdown”.

5.5 Captain EVERE went on to criticize certain technical inaccuracies in the Report and then concluded that the Report

“seems to have been systematically constructed so as to justify a conclusion of pilot error as the cause of the accident”,

when in fact the pilot was not to blame.

On Finding 3.1.7:

“The descent clearance was given to C1642 at 1014. Shortly after commencing descent at 1017, the commander commenced the approach briefing for the wrong runway. No mention was made of the warnings of severe turbulence or significant windshear, or that the ATIS reported that RW 25R was available. This briefing given by the commander did not meet the China Airlines Operations Manual requirements in respect of either timing or content.”

5.6 Whilst not denying the accuracy of the above finding, he objected to the “innuendo” that the matters found were in any way relevant to the accident since –

- i. The approach briefing for the wrong runway was later corrected and in sufficient time.
- ii. ATIS warnings of severe turbulence and windshear were so obvious as to require no specific mention.
- iii. The availability of Runway 25R was irrelevant since the wind strength there was outside the aircraft limits.

iv. It was possible that a fuller briefing was given outside the last 30 minutes of the CVR reviewed by the Inspector.

5.7 The Board notes that CAL put in no evidence or statement from the pilots on board CI642 to support this last possibility.

On Finding 3.1.8:

“The co-pilot twice provided incorrect information to the commander during the descent and approach.”

5.8 Captain EVERES did not deny the finding was factually accurate, but contended that a balanced report should go on to state that the incorrect information given was later corrected in good time and played no part in the accident.

On Finding 3.1.9:

“The approach was de-stabilised at about 250 ft by an excessive application of power, which increased the indicated airspeed to 175 knots, 15 knots above the correct final approach speed.”

5.9 Captain EVERES went through the FDR data to support his view that the application of power at about 250 ft was reasonable and necessary to stabilize the final approach. He pointed out that this had been recognized earlier in the Report para. 3 at 1.11.6, which was thus a good example of the inconsistencies of the Report.

5.10 After it was pointed out to him in cross-examination that whereas the commander's original target speed was 170 knots, ATC had later called for a reduction to 160 knots, Captain EVERES agreed that it was wrong for the commander to ignore this acknowledged instruction from ATC.

On Finding 3.1.14:

“Neither pilot perceived the increasing rate of descent and decreasing indicated airspeed as the aircraft approached the landing flare.”

5.11 Captain EVERES objected to this finding as there was no hard evidence of the pilots' perception and that conjecture had no place in a flight accident report. He went on to assert that by the actions of the pilot as recorded by the FDR, it was clear that he had understood that the ROD was higher than it should have been. The Board notes that, by the same reasoning, it must follow that a different interpretation of the FDR could lead to the opposite conclusion as to the pilots' perceptions. However, according to Captain EVERES, the pilot's elevator inputs indicated that he was aware of the increasing ROD, which was

decreased 4-3 seconds before touchdown, when, it was said, the other factors referred to in Mr. ANDERSON's report had caused the ROD to increase again until impact.

5.12 However, Captain EVERES did agree that the finding in the Report was supported by the written statement made by the commander that he only noticed the increased ROD *"just before touching down"*, which Captain EVERES estimated to be at about half a second before touchdown, when it was too late to alleviate the situation. The Board also notes that the co-pilot in his statement also stated that he did not notice the increasing ROD.

On Finding 3.1.16:

"The maximum allowable landing weight for MD11, Registration B-150, was 430,000 lbs (195,454 kg). The estimated landing weight for C1642 at the time of the accident was 429,557 lbs (195,253 kg), therefore the aircraft approached the flare only 443 lbs (201 kg) below maximum landing weight, with the thrust levers already fully retarded which, in combination with a probable loss of headwind component, led to a loss of airspeed of 20 knots and an increasing rate of descent which reached approximately 18 feet per second at touchdown."

5.13 Captain EVERES pointed out that the estimated landing weight of the aircraft on landing of 429,557 lbs was incorrect. The tabulated FDR data at Report App A13-1-2 showed the weight was actually 427,000 lbs (i.e. 2,800 lbs below the aircraft's Maximum Landing Weight 'MLW') and not 443 lbs under as stated in the Report. In any event, Captain EVERES stated that this was well within the normal operation limits of the aircraft, had nothing to do with the accident and therefore *"did not merit the gravity of a finding"*.

5.14 He further commented that the fact that the aircraft approached the flare with the thrust levers already fully retarded was also not worthy of comment since the MD-11 is designed to land on autothrottles. He referred to the MD-11 Flight Manual which states

"Autothrottles should be used for all landings and will begin to retard after passing 50 feet above ground level".

5.15 However, on looking at the FDR data (Report App A13-2-2) Captain EVERES agreed that on this occasion, for some unexplained reasons, instead of beginning to retard at 50 ft RA the throttle lever was already fully retarded by approximately 70 ft and the pilot had made no apparent attempt to override this manually.

5.16 Captain EVERES agreed with the final findings in this paragraph in that there was a loss of headwind and an increasing ROD to approximately 18 feet per second at touchdown.

On Causal Factor 3.2.1:

“The cause of the accident was the commander’s inability to arrest the high rate of descent existing at 50 ft RA.”

5.17 Captain EVERES disputed that the cause of the accident was the commander’s inability to arrest the high ROD from 50 ft RA. In his view,

- i. The rate of descent had decreased from 50 ft to about 30 ft (i.e. from about 16 fps to about 12 fps) during that period before increasing again to about 18 fps at touchdown. From 30 feet to touchdown there was about 1.5 seconds and it all went wrong within this span of time.
- ii. The descent was stabilized until 30 feet with a ROD of around 11-12 fps. At about 50 ft the commander executed a large up elevator deflection of over 10°, resulting in a pitch angle of just over 4° up and a decreasing ROD to about 12 fps. At this critical point, a down elevator deflection of 8° was commanded. According to Captain EVERES this was because the previous up elevation command had given the commander more “recovery” than he wanted, which, if it continued, could result in tailstrike (which occurs at 10° pitch or more) or landing too far down the runway, which was undesirable, especially in wet conditions. This down elevator command had the apparently desired effect of reducing pitch from 4° to nearly 3°, but also had the negative effect that ROD began rapidly increasing again. At this point, as the aircraft should have been flaring for touchdown and landing with a sink rate of just 2-4 fps, the wind suddenly shifted to the right, causing a loss of lift from the reduced headwind component and an increased crosswind.
- iii. Despite increasing up elevator commands, the ROD continued to increase. Within 1½ second, the aircraft made ground contact with a sink rate of 18 fps, which was well beyond the design limits of the aircraft and which then caused it to break up.
- iv. With throttles at idle, more power was not an option, since he estimated that the engines from that state would take 4-6 seconds to “spool up” i.e. to generate sufficient power to give any significant lift.
- v. The sudden crosswind also caused the commander to execute a right control wheel input to counter the crosswind by going right wing down;

this was achieved by raising the spoilers on the right wing, which also had the effect of reducing lift on that wing.

- vi. Consequently, the cause of the accident was not the commander's inability to arrest the high ROD, or at least any avoidable inability to do so, but rather the 4 factors referred to in section 5.3 above.
- vii. In Captain EVER'S view, no criticism could be made of the commander's failure to execute a go-around at any point. In order to make such a decision, there must be a "trigger" and there was none in this case until 21 ft and below, at which point it was too late to execute one cleanly.

On Probable Contributory Causal Factor 3.2.2(i):

"The commander's failure to appreciate the combination of a reducing airspeed, increasing rate of descent, and with the thrust decreasing to flight idle."

5.18

This has already been dealt with above. The problematic reduction in airspeed and increasing ROD did not occur until the last 1.5 seconds of the flight, when it was too close to the ground for the commander to alleviate the situation. At this point the thrust had decreased to idle as programmed.

On Probable Contributory Causal Factor 3.2.2(ii):

"The commander's failure to apply power to counteract the high rate of descent prior to touchdown."

5.19

With the thrust levers at idle as programmed, there was not sufficient time to "spool up" the engines to provide sufficient power to generate lift; hence this was not an option at that time in order to counteract the high ROD.

On Probable Contributory Causal Factor 3.2.2(iii):

"Probable variations in wind direction and speed below 50 ft RA may have resulted in a momentary loss of headwind component and, in combination with the early retardation of the thrust levers, and at a weight only just below the maximum landing weight, led to a 20 knots loss in indicated airspeed just prior to touchdown."

5.20

Captain EVER'S agreed that probable variations in wind direction and speed below 50 ft were a contributory, if not the major, cause of the accident. On the other hand, the other factors mentioned i.e. early retardation of the thrust levers and the weight being just below MLW, had nothing to do with the accident.

Replacement Causal Factors

5.21

Captain EVERE suggested the causal factors in the Report should be replaced to include the followings:-

- i. The failure of the aircraft which landed immediately ahead of CI642 to report or warn of the similar windshear the pilots experienced on landing.
- ii. The failure of the Windshear and Turbulence Warning System ('WTWS') to warn CI642 of windshear.
- iii. The windshear effect caused possibly by the combined conditions of the PTB's location and the prevailing wind: with the wind from the North West quadrant, the landing zone was at the lee of the PTB. On this point Captain EVERE conceded that he lacked the expertise in building dynamics to state this for a fact.
- iv. The 4 factors mentioned by John ANDERSON at a time-critical point before landing (see section 5.3 above).

5.22

In relation to the first 3 factors in section 5.21 above, we note that Captain EVERE did accept in cross-examination that

- i. The pilot in the aircraft immediately before CI642 landed safely and might not have thought the conditions (beyond the obviously strong, gusty winds) extreme enough to warrant reporting as 'windshear'. Captain EVERE did also note that the captain of the aircraft ahead stated afterwards "*at approx. 200 to 100 feet the aircraft encountered some violent wind gusts and the speed was fluctuating plus or minus 10 to 15 knots*" and that "*a rapid thrust application in the flare was manually initiated due to a large airspeed reduction*". However Captain EVERE insisted that the aforesaid conditions amounted to 'windshear' although they might fall short of the technical definition of the term.
- ii. The last windshear warning from ATIS was at 10:06 UTC (i.e. about half an hour before CI642 landed); thereafter the WTWS warned only of "*moderate turbulence*" and ATC passed information to CI642 about the wind strength and direction on 5 occasions in the last 30 minutes before landing. The fluctuations during that period were not sufficiently large to be classified as 'windshear'; the warning for which would only be issued by the WTWS system when there is a change of at least 15 knots (see sections 7.3, 7.4 and 7.8 below).

- iii. He was not in a position to disagree with Professor GRAHAM's findings that the location of the PTB was far enough away from the runway so as to have only a minimal effect on landing aircraft, given the prevailing wind strength and direction.

5.23 The following matters emerged from cross-examination by Counsel for the Board :

- i. Captain EVERESE gave evidence in the capacity as an expert witness. He maintained that no criticism could be made against the commander or co-pilot of CAL in the circumstances of this case. He had been an employee of CAL between 1993-1998 and rejoined the company in February 2000 for the "*primary reason*" of dealing with this investigation. His status as an expert thus was far from independent.
- ii. Captain EVERESE accepted that if a pilot has any doubt about his ability to land the aircraft safely in the prevailing weather conditions, he should either go-around or divert to another airport. In that afternoon both options had been exercised at various times by other aircraft which approached HKIA. There was no indication that either pilot of CI642 was aware of this. Nor did they ask the ATC for such information. Captain EVERESE agreed that it would be "*a very good idea*" to recommend that China Airlines include in their flight manuals a routine requirement to ask Air Traffic Control in obviously difficult weather conditions, whether the preceding aircraft had been either going around or diverting.
- iii. The crosswind limits for the MD-11 are 30 knots dry 25 knots wet (Report 1.18.1). The relevant part of MD-11 S.O.P. reads –

"OPERATIONAL LIMITS

The max. demonstrated crosswind component is 30 knots. However, a component at or near 25 knots with higher gusts should be considered operationally unacceptable."

- iv. The last wind check received (at about 400 feet) was "*28 knots gusting 36 knots*" from 320°. That would give a crosswind component of up to 25 knots. Although HKIA has a grooved runway which improves grip in the wet, the conditions were so marginal that the pilot ought to have been actively considering a go around as he approached HKIA.
- v. Assuming that Boeing's latest calculations of the derived winds were reasonably accurate, the derived data relating to headwind loss and crosswind increase probably meant only that the wind had changed direction momentarily, which was, according to Captain EVERESE, "*not surprising at all*" in the aftermath of S.T.S. Sam. Similar conditions

were probably encountered by all the other aircraft at some point in their approach, yet none found themselves in a predicament similar to that of CI642.

- vi. During the last few minutes before landing there was confusion in the cockpit as to which runway the landing was to take place on and the correct go-around procedure. Furthermore, the commander continued his approach at 170 knots despite the acknowledgement by the co-pilot of ATC's instruction to reduce speed to 160 knots.
- vii. Captain EVERES maintained that with appropriate adjustments, there was nothing inherently unsafe in an aircraft landing at close to its MLW; it might even improve stability. The Board notes that this was accepted by Captain DAVIS in the course of his evidence.
- viii. Captain EVERES did not dispute the structural evidence from Boeing that the design sink rate for the MD-11 on a symmetrical landing is 10 fps and that the kinetic energy which must be absorbed to decelerate an aircraft is a function of the velocity squared i.e. the energy to be absorbed by the landing gear for a 20 fps sink rate is four times that for a 10 fps ROD.
- ix. FDR Data

Captain EVERES was taken through the FDR Data traces at Appendix A13 of the Report and commented as follows:-

a. Glideslope

The 3° glideslope was almost perfectly maintained until the autopilot was switched off at 500 ft. Thereafter the aircraft deviated from almost one dot high to more than one dot low. This, he said, was within the criteria for a stabilized approach (i.e. plus or minus one dot).

b. Localizer

There were similar deviations here after the autopilot was disengaged, but again Captain EVERES maintained that they were within acceptable limits.

c. Thrust

He agreed it was possible that the thrust was not working as programmed since the levers were already retarded to idle at 70 feet, when the process should have begun at 50 feet and be

completely retarded by touchdown. He further agreed that the pilot could easily have overridden this situation by simply placing his hand on the levers and arresting their backward movement but it was clear that the pilot did not do so.

d. Speed

The groundspeed remained fairly constant at about 150 knots until it rose to 160 knots at 100 ft, where it remained until just before touchdown. Calibrated Air Speed showed greater fluctuations, but was generally 10-15 knots higher, which indicated a headwind of similar magnitude. In the last 100 feet the difference varied between 4-12 knots, except at around 20 ft, where, for the first time, the groundspeed exceeded the Calibrated Air Speed, indicating a slight tail wind of about 3 knots. This corresponds broadly with Mr. ANDERSON's Report which found the headwind component dropped from 11 knots headwind to 3 knots tailwind in the last 22 ft.

e. Rudder

Rudder inputs were small until the autopilot was disengaged; thereafter comparatively large deflections were commanded, increasing to around 20° shortly before touchdown. Captain EVERE'S stated that this was "*required*" to "*zero the drift*" and that these rudder inputs were necessary because of the crosswind.

f. Roll Attitude

Roll Attitude was quite stable until autopilot was disengaged; thereafter the aircraft was rolling up to 10° or more both left and right. Captain EVERE'S maintained that these inputs were normal to keep the aircraft aligned on the centreline of the runway.

g. Elevator

As shown by the FDR data, the pattern revealed was similar to the Roll Attitude: very large deflections in both directions from 200 feet and below.

x. The Landing

The 3° glideslope translates to a descent rate of approx. 12-14 fps (720-840 fpm). Captain EVERE'S stated that according to the manufacturer's recommended procedures, in these difficult conditions, the ROD should start to decrease from approximately 40 ft above ground until

touchdown, by which time it should have reduced to about 3 fps. This result is achieved by ‘flaring’ the aircraft as it comes in to land and by bringing the nose up with elevator up commands.

a. Crosswind landing technique

Captain EVERES noted that the Report (i.e. para. 2.2.2) did not criticize the pilots’ crosswind approach technique and did not find it contribute to the accident. Captain EVERES also described the crosswind landing technique in an MD-11, and claimed that it was correctly employed by the commander on this approach. This involved initially flying the aircraft so that its heading was offset from the Runway direction to the extent that the aircraft’s track over the ground was aligned with the runway direction. At a certain altitude (approximately 200-100 ft) the aircraft should be aligned with the runway using rudder and offsetting the drift by lowering the appropriate wing. This situation is maintained through the flare so that the initial touchdown will be expected to be one undercarriage bogey (this is also referred to in section 10.10 below).

Any attempt to de-crab the aircraft and align it with the runway only just before touchdown would be, in Captain EVERES’ words, “*a very hazardous maneuver and we would not attempt that especially in these conditions*”

The Board notes from the FDR data that variable but generally increasing rudder was applied as the aircraft came in to land and that its heading was never aligned with the runway (i.e. at 253°) until touchdown. Hence, it is clear that the recommended crosswind landing technique as described by Captain EVERES was not employed on this occasion.

b. Rate of Descent (ROD)

The Board notes that ROD appeared on the chart at CAL/29 in Captain EVERES Report. In tabular form it reads –

<u>Height</u> (feet)	<u>ROD</u> (feet per second)
100	11
90	12
80	12
70	14
60	16
50	16
40	12

30	13
20	14
10	17
0	18-20

It can be seen that the increasing ROD from 80 feet had been reversed by 40 feet, at which point, the aircraft should have begun to flare for landing, thereby touching down at 3-4 fps; but instead the ROD kept on increasing until it reached 18-20 fps at impact.

Captain EVERES accepted that this increasing ROD was at least partly caused by the pilot reversing the elevator deflection from 10° up to 8° down at 40 feet RA. Although the pilot later reversed it again to up-elevator from about 20 feet above ground, it did not achieve any significant reduction in the ROD. This was the fourth factor mentioned by Mr. ANDERSON in his report (referred to in section 6.8 iv. below)

Captain EVERES suggested that this extraordinary or, in his words, “*unfortunate*”, nose-down input at approximately 40 feet was made because the pilot might have been worried that his pitch-up attitude was increasing so fast as to cause a tailstrike in landing. However, the Board notes that tailstrike does not occur until the aircraft is 10° nose up on landing, whereas this particular aircraft had never achieved more than 4° nose up at any stage during the landing.

Captain EVERES explained that the increasing ROD at this point was contributed to by the other 3 factors i.e. the windshift, right control wheel (to counter the crosswind increase) and (perhaps) a slight downdraft of 2.5 knots.

However, he accepted that a crosswind of this magnitude would not normally cause an aircraft to crash, that the right control wheel might have been added in part to counteract the continuing heading decrease caused by the rudder application, rather than any sensation of increased crosswind (which would have been difficult to detect) and the downdraft, if it existed at all, was quite small.

Nevertheless Captain EVERES insisted that the subsequent hard landing was entirely due to factors outside the commander’s control.

5.24 In short, Captain EVERES contended that the manner in which the commander and the co-pilot handled the aircraft could not be faulted: all inputs were appropriate and were made to cope with the conditions and, even if he had

been a check pilot observing on board at the time, he would not have recommended a go-around for any reason (except possibly at 30 feet or so if he had known the ROD “*was going to increase like it did, but we did not, nobody did*”).

6.

The Evidence of Mr. John ANDERSON (for Boeing)

6.1

Mr. John ANDERSON is a qualified aerospace engineer employed by Boeing for the last 7 years in its Aerodynamic Stability and Control Department. The principal task undertaken by Mr. ANDERSON was to take the FDR Data and apply to it Boeing’s Kinematic Consistency Programme in order to derive, in particular, the headwind, crosswind and vertical wind components affecting the aircraft as it came in to land. The methodology was described in his report and further orally explained during the review hearing. One of the key objectives of the exercise was to investigate the severe downdraft theory originally put forward by CAL. The derivation done in 2003 was a version of the same exercise performed in 2000, but updated to reflect improved methodology and to correct certain errors identified in the original derivation.

6.2

After outlining the assumptions and limitations of the method (summarized at section 6.3 below), Mr. ANDERSON identified the factors which he believed would lend support to the accuracy of the conclusions reached.

6.3

Limitations on the methodology included –

- i. Limitations in parameters and sample rates of FDR data.
- ii. The original longitudinal acceleration data were not valid and had to be calculated from other data.
- iii. The sideslip angle was not recorded by the FDR and must be calculated from other data.
- iv. The angle-of-attack data had to be re-calculated.

6.4

As a result, Mr. ANDERSON suggested that the derived winds were valid within an error margin of 10-15%, although the Board notes that such estimation was based apparently on instinct rather than the result of any scientific measurement of variation.

6.5

The Board also notes that one of the validation exercises carried out was to compare the 2003 derived winds with the HKO’s one-second Anemometer Data. The anemometer gave wind speeds varying between 14-28 knots with a mean of about 22 knots, whereas the derived winds varied between 21-49 knots with a mean of over 30 knots and showed much greater apparent fluctuations.

6.6 It is also noted that the commander in his statement stated that “*the wind indication on our instrument panel was between 290-310 degrees and 29 knots at 300 feet*”, whereas Mr. ANDERSON’s calculations at that height (about 20 seconds before touchdown) showed a heading of 320-330 degrees and winds of 40-50 knots. By way of comparison, the one second Anemometer data for the period 25-15 seconds before touchdown (UTC Time 10:43:01 – 10:43:11) showed wind directions fluctuating between 283°-345° and wind speeds at 18-23 knots on Runway 25L whereas 25R showed fluctuations of 314°-321° with wind speeds between 37-43 knots (see Report A5-3-2).

6.7 In answer to questions put by Mr. SHEPPARD, the Assessor, Mr. ANDERSON conceded that additional factors such as the calculated sideslip angle and the exercise of engineering judgment used in the analysis might further affect the accuracy of the calculations.

6.8 With these limitations in mind, Mr. ANDERSON came to the following findings and conclusions: -

- i. During the final approach, at above 200 feet, the accident aircraft experienced an average headwind of 12 knots, with an average variation of +/-4 knots. The average crosswind above 200 feet was 40 knots, varying +/-5 knots and the vertical winds were centred around 0 or generally small. However, below 200 feet, the average headwind decreased to 10 knots, but the variation increased to +/-8 knots. Similarly, the average crosswind decreased to 32 knots, but again the average variation increased to +/-15 knots. These winds, particularly the variations below 200 feet were relevant to the descent rate of the accident aircraft at ground impact.
- ii. The rate of descent of the accident aircraft was affected by a number of factors that would influence the lift of the aircraft. These factors included
 - angle of attack
 - headwind
 - vertical wind
 - the spoiler deflection on the wing associated with crosswind

Any change to any of these factors would affect the lift of the aircraft.

- iii. A review of the FDR data indicated that at the last 80 feet (6 seconds prior to ground contact), there were significant changes in each of the 4 factors affecting the lift of the aircraft, and hence the rate of descent at ground impact.

iv. The analysis made by Mr. ANDERSON demonstrated that at about 22 feet, the aircraft was descending at about 15 feet per second. From this point onwards and prior to ground contact the FDR analysis and the 2003 winds showed the following data:

- a sudden wind shift resulting in a 14 knot headwind loss and a 20 knot crosswind increase
- a downdraft of approximately 2.5 knots
- the raising of the right spoilers
- a residual airplane nose-down pitch rate from a previous pilot command.

6.9 Mr. ANDERSON was only able to say that these factors were operative for three quarters of a second to one second just before touchdown. In particular Mr. ANDERSON felt able to firmly reject China Airlines' original "*severe downdraft*" suggestion.

6.10 The Board notes that during his oral testimony Mr. ANDERSON did not assign any relative degree of importance to these 4 factors and no simulation had been performed to assess the interplay of various factors; for example, the likely effect on the aircraft if the nose up elevator deflections had been maintained at 40 feet to 20 feet instead of the nose down commands actually inputted. As part of its closing submissions Boeing referred to further simulations carried out by Mr. ANDERSON after the review hearing. He concluded that

"if there were no wind variations and associated spoiler variations during the last 3 seconds, the descent rate at touchdown would be reduced to 14 feet per second" (see sections 13.1 and 13.2 below).

6.11 Mr. ANDERSON also commented on the factors that could affect lift and ROD. He broke the final stages of the descent into 4 phases of approximately 2 seconds each. The Board noted that if one examined his headwind and crosswind components, the fluctuations in tabular form were as follows: -

<u>Height</u>	<u>Headwind</u>	<u>Crosswind</u>
79-68 ft	4 knots decrease	15 knots increase
68-41 ft	10 knots increase	16 knots decrease
41-22 ft	little change	10 knots decrease
22-0 ft	14 knots decrease	20 knots increase

6.12 The Board notes that it was thus apparent that there were significant headwind and crosswind fluctuations all the way down from 80 feet. Such phenomena were not just confined to the last 20 feet or so.

6.13 During cross-examination by Counsel for the Board the following points emerged:

- i. Mr. ANDERSON stated that the correlation between his derived 2003 winds and the anemometer data was quite good for wind direction but was “*on the low side*” for wind speed. On the other hand when compared to all 4 touchdown anemometers, there was some broad correlation albeit over a very wide bracket.
- ii. The commander commenced the alignment maneuver about 15 seconds before touchdown but it was completed only at the moment of touchdown.
- iii. The commander used left rudder to align the aircraft and attempted to balance it with a right control wheel/aileron input.
- iv. The second of Mr. ANDERSON’s four factors which caused loss of lift was “*Right control wheel (to counter the crosswind increase)*”. This was commanded just half a second after the crosswind increased. Mr. ANDERSON was unable to say how the pilot could have sensed and reacted to it in such a short time; the other possibilities were that this command was to control roll oscillation or previous rudder input. However, in re-examination, Mr. SUSSEX, S.C. pointed out that whilst rudder remained fairly constant at 18°-20°, right control wheel from zero to about 70° degrees was commanded; also that lateral acceleration increased from 0.08g to 0.2g i.e. a 200 lb man would experience a force of 24 lbs for this 0.12g increase. However, it can be seen from the charts at p. 21 and 27 of Mr. ANDERSON’s report that by the time lateral acceleration had increased to 0.2g at time 250 seconds on his chart, the control wheel input of 70° had already been executed (See Appendix I and II).

6.14 Finally, the Board notes that Mr. ANDERSON was not referred to or asked to comment on the email or letter referred to in section 11.12 below.

7. The Evidence of Mr. SHUN Chi-ming (for HKO)

7.1 Mr. SHUN, a physicist by qualification, is a Fellow of the U.K. Royal Meteorological Society and has published research studies on windshear and turbulence. He is a Senior Scientific Officer employed of the Hong Kong Observatory. He is responsible for setting up various weather sensing equipment in HKIA, including the Terminal Doppler Weather Radar (TDWR) to provide alerts for microburst and windshear at HKIA and the Light Detection and Ranging System (LIDAR) for windshear detection in dry weather. In addition he oversees the operation of the Windshear and

Turbulence Warning System (WTWS) at HKIA. For this hearing Mr. SHUN produced an expert report dated 8th October 2003.

7.2 HKO has the authority and responsibility to set up and maintain weather reporting and alerting systems. The HKO weather sensors accord with ICAO recommended practice and guidelines. In particular a number of anemometers are installed in various locations at the height of 10 metres to give the wind speed and direction readings on the two runways in both directions and at mid-point (for exact locations see Report A3-1). The equipment installed at HKIA is regarded as state-of-the-art.

7.3 Mr. SHUN explained the internationally recognized definition of ‘windshear’ is-

“A sustained change in wind direction and speed for more than a few seconds, resulting in a change in the headwind or tailwind of 15 knots or greater resulting in a change in the lift to an aircraft”,

whereas ‘turbulence’ is –

“a rapid irregular movement of air, which brings rapid changes, jolts or bumps i.e. ups and downs to an aircraft but will not significantly affect its flight path in general”.

7.4 To qualify as ‘windshear’, the change in wind direction must be sustained for at least more than 3 seconds and the change must involve a loss or gain of 15 knots or more in wind speed. To Mr. SHUN’s understanding these changes must be so sustained before they can affect an aircraft’s trajectory.

7.5 At the time of the accident to CI642, all systems were functioning normally and no incidence of either windshear or microburst was recorded. The last windshear warning from WTWS was issued at 10:16 hours (UTC). Thereafter, until the accident at 10:43 hours the equipment measured and warned only of Moderate Turbulence.

7.6 As for the report of Mr. ANDERSON and the Boeing “*derived winds*”, Mr. SHUN pointed out that none of the changes in headwind exceeded 15 knots nor were the changes sustained for more than 3 seconds, so on neither count did these changes qualify as windshear; they only indicated turbulence. He also analyzed the downdraft over the last 6 seconds which averaged just half a knot which he said “*can only be regarded as near zero*”.

7.7 Mr. SHUN also questioned the validity of the ‘intuitive’ margin of error in the Boeing derived winds of 10%-15%. He gave various factors which would result in a much wider margin of error.

7.8 According to Mr. SHUN's reckoning, for a change of 11 knots headwind to 4 knots tailwind, there should be a windshift to about 350° but there was no evidence on any of the anemometers of such a pronounced and sustained change in wind direction. The biggest fluctuations were on the RW25L one-second data (Report A5-3-2) where the highest recorded figures of 345° and 339° were immediately followed one second later by the figures of 306° and 294°.

7.9 Mr. SHUN opined that this indicated some extremely brief fluctuations, but not sustained windshifts of any magnitude. The 10-second mean wind data (Report A5-2-9) in the last 60 seconds before touchdown all showed wind directions in the range of 310°-320° although this data did show speed variations of 12 knots over the same period.

7.10 There was, accordingly, little or no objective support from the recorded data, especially from the anemometer readings, for the suggestion that CI642 had suffered a 14 knot decrease in headwind component and a 20 knot increase in crosswind for any significant length of time. In Mr. SHUN's view any effect on the aircraft of the recorded fluctuations should have been minimal.

8. The Evidence of Mr. Ricky LEUNG Wing-kee (for HKAA)

8.1 Mr. LEUNG is a Civil and Structural Engineer by training. Since joining the Civil Aviation Department he had been involved in all the various stages of the construction of HKIA from its planning and design through construction to operation. He is currently the Senior Manager of Buildings and Infrastructure at HKIA. His evidence concerns the location of the Passenger Terminal Building ('PTB').

8.2 Mr. LEUNG confirmed para. 2.5.1 of the Report i.e. that the design of HKIA complies with all aspects of the ICAO standards and guidelines and that the proximity of the PTB to the runways meets all the required standards under ICAO Annex 14. There is a distance of 1540 m between the 2 runways with the PTB in the middle at one end (see Report A3-1); the closest points of the PTB to the runways vary from 500 metres to 700 metres. The PTB varies in height from 12 metres to 19 metres, well below the maximum permissible height allowed by ICAO Annex 14. The runways are the equivalent of 25-30 PTB building heights from the PTB.

8.3 In answer to questions from the Board, Mr. LEUNG agreed that a Boeing 747 aircraft is large enough to have the same effect as a building in disturbing airflow. However, in tropical storm conditions, the HKAA would always try to accommodate as many aircraft as possible on the air-bridges and few would be kept on remote stands. As for those parked in the lee of the PTB, he felt

that any effect would be minimal, although he deferred to Professor GRAHAM's opinion on such matter.

9.

The Evidence of Professor Michael GRAHAM (for HKAA)

9.1

Professor GRAHAM gave evidence via videolink from London. He is a professor of Unsteady Aerodynamics at the Aeronautical Department of Imperial College London. He holds a PhD in aeronautical engineering and has published numerous articles, many of which study wind flows over buildings. For this hearing Professor GRAHAM produced 2 reports which dealt with the suggestion that the PTB may have been a cause or factor in the windshear phenomenon allegedly experienced by CI642.

9.2

With the wind coming from the northwesterly direction (i.e. at around 310°, as it was at the time of the accident), the landing area on Runway 25L is downwind to the PTB. Professor GRAHAM opined that in view of the distance the PTB from the landing area on Runway 25L (more than 500m) and therefore, as calculated, 25 to 30 such building heights away, any effect of the PTB on the airflow would have been negligible. Hence the PTB could not have contributed to the accident to CI642.

9.3

Over the distances involved and given the curved nature of the roof of the PTB which would cause less disruption to airflow than a rectangular building, Professor GRAHAM estimated that the turbulence caused by the building would have decayed to less than 15% of its undisturbed value, at probably about 10%. For a 30-40 knot wind, the value is hence 3-4 knots of disturbance.

9.4

Professor GRAHAM was also asked to comment on the wind data in Appendix 5 to the Report. He warned against comparing data from the 2 runways without taking into account direction and the separation between them. At the wind speeds under review, it would take about 40-50 seconds to cover the 1540 metres between 25R and 25L. Also, with wind coming from the northwest, the best comparison would be the mid-point of 25R and the touchdown area of 25L. Taking a 2-minute data to exclude short-term fluctuations, the data showed, at the time of the accident:

<u>25R mid-point (10:42:40)</u>	<u>25L Touchdown (10:43:20)</u>
Direction	318°
Speed	38 knots
Gusts	45 knots
	317°
	26 knots
	36 knots

9.5

Comparison of other times showed a similar pattern i.e. the wind direction was much the same but the wind speed was generally 10-12 knots higher on RW 25R.

9.6 In Professor GRAHAM's opinion, this was primarily accounted for by the 25R winds being measured as they came directly off the sea, whereas by the time they reached 25L, they had passed over 1.5 km of land. However, the readings did show a drop of about 4-5 knots in wind speed in the anemometer in the lee of the PTB on 25L compared to the mid-point on that runway, so that was probably the extent of the PTB effect i.e. at the time of the accident there was a reduction in speed of maybe 4 knots on average but wind direction was generally unaffected.

9.7 Professor GRAHAM concurred with the suggestion that consideration be given to installing more anemometers in the 25R/25L touchdown areas to gain a better understanding of the wind patterns in that area.

10. The Evidence of Mr. Robert BENZON (for Inspector of Accidents)

10.1 Mr. BENZON is the Chief of the Major Investigations Division at the U.S. National Transportation Safety Board ('NTSB'). A former US Air Force pilot, he had been involved in over 60 aviation investigations both in the U.S. and overseas including the Lockerbie disaster in 1988 and the loss of the Space Shuttle Columbia. For this review hearing, he gave oral testimonies in addition to a written statement filed during the hearing.

10.2 The NTSB was officially involved in the investigation since both the airframe and the engines of the Boeing MD-11 were of U.S. manufacture. Mr. BENZON is a U.S. accredited representative under ICAO Annex 13, which sets out guidelines for member states to follow in the investigation of aircraft accidents. The investigation was under the control of the Inspector of Accidents Mr. Y.K. LEUNG of the Hong Kong Civil Aviation Department ('CAD') at the direction of the Chief Inspector of Accidents pursuant to Section 8 of the Regulations. Representatives from the Aviation Safety Council of Taiwan, China, and China Airlines were also involved in the investigation.

10.3 Mr. BENZON and his team were invited by the Inspector to assist in an advisory role. They arrived in Hong Kong within 40 hours of the accident to guide the local authorities in the investigation of what, for Hong Kong, was a rare major accident.

10.4 In Mr. BENZON's view, the investigation was technically thorough following, virtually to the letter, all the guidelines, recommended practices and standards laid down in ICAO Annex 13.

10.5 Together with Boeing, NTSB gave specific assistance on the interpretation of the FDR data as well as meteorological issues and survival factors. He believed that he and his team contributed probably several thousand hours to

the investigation. This involved several long visits to Hong Kong and also visits by the Hong Kong investigators to the U.S.A. They reviewed the first and subsequent drafts of the Report and gave advice on the same.

10.6 Mr. BENZON stated that he was satisfied with the Report in its final form and also with the recommendations it contained. He did not agree with Captain EVER'S contention that the Report was systematically drafted to put the blame on the pilot.

10.7 He noted, pursuant to a decision made by CAD, that the Flight Data Recorders were sent to England for downloading and production of the original FDR data; this was done in the presence of the NTSB's aircraft performance specialist. He also noted that NTSB personnel had occasionally provided some direct drafting or input to the report, but the decision as to what to include or exclude was ultimately for the Inspector. He agreed that it would have been useful to include data or calculations in Appendix A13 of the Report for the angle of attack, aileron and spoiler deflections but he could not say why they were omitted. The Board notes that this information was contained in Mr. ANDERSON's report.

10.8 He did not agree "*wholeheartedly*" that Mr. ANDERSON's analysis represented the best estimate of the reasons for the increased ROD prior to touchdown. He felt it was more important to look at the "*big picture*" of events leading up to the accident, rather than focus on the last 1.5 seconds or part of it, where some misjudgment or wind changes might have occurred. He did not think the Report deficient in failing to analyze the last few seconds of CI642 in the same detailed manner, as did Captain EVER'S and Mr. ANDERSON for this review hearing.

10.9 In particular, he and his team were of the view that desktop computer simulation was a valid method to compare the 2000 and the 2003 derived winds and he was comfortable with the conclusion in relation to the capabilities of a human pilot to land the aircraft in the same difficult weather conditions being determined by a desktop computer simulation.

10.10 He was referred to the NTSB Aircraft Accident Report into the MD-11 crash landing at Newark, New Jersey in July 1997, where, after a heavy landing, the aircraft also lost its undercarriage and one wing before coming to rest inverted. The said report quoted the following passage for the crosswind landing technique in the FedEx Flight Manual: -

"Crosswind landings are accomplished by flying the final approach in a wings level attitude with a crab into the wind. At approximately 200 feet AGL, align the fuselage with the runway by smoothly applying rudder and maintain runway centerline by lowering the upwind wing. In high crosswinds, consideration should be given to commencing the align

maneuver (de-crab) prior to 200 feet AGL. The align maneuver shall be established by 100 feet AGL. The manual cautions that excessive sink rates and subsequent tailstrikes have occurred as the result of a late or abrupt align (de-crab) maneuver”.

10.11 Whilst noting that different airlines may recommend different techniques in their in-house flight manuals, Mr. BENZON agreed it was clear from the FDR data that CI642 was not aligned until just before touchdown. It was certainly not aligned by 100 feet as recommended by the said FedEx Flight Manual, nor by 50 feet as stated in para. 2.2.2 of the Report which, at least to that extent, was inaccurate.

10.12 Mr. BENZON also commented on a hand held video recording of the crash taken by an off-duty pilot in a car parked outside the perimeter fencing. Because of the camera angle, the final few seconds before ground contact were furthest from the cameraman and realistically of limited value. Accordingly in his view the FDR data were much more useful for the purpose of analyzing exactly what happened in the last few seconds of the flight.

10.13 Although members of the Board and certainly most of the interested parties had heard of and viewed the said video recording at some point before the review hearing, none of the parties saw fit to call for the production or viewing of the same as part of the evidence for the review. Members of the Board took a view similar to that of Mr. BENZON and decided not to call for its production during the review hearing.

10.14 Mr. BENZON further noted that there was no finding on the fact that the commander did not order a go-around in the Report. Whilst acknowledging that different people could legitimately write different reports on the same incident, emphasizing different aspects, he personally felt that a good case could be made out for saying that a go-around should have been ordered because –

- i. The First Officer had later said the turbulence was so severe that it could not be re-created in Boeing’s simulator; therefore the conditions must have been extreme enough to consider a go-around.
- ii. The aircraft was operating in restricted visibility because of the rain, and
- iii. At 40 feet from the ground, the commander found the prevailing conditions were such that he found it necessary to change elevator deflection from 10° up to 8° down (i.e. a total of 18°). If a pilot has to make such a drastic movement so close to touchdown, he should probably decide to go-around.

10.15 In Mr. Benson's opinion, these are indications of an unstable approach which would have justified a go-around decision.

10.16 Mr. BENZON also stated that he was unable to express any worthwhile opinion as to the validity of the Long Beach flight simulations in 2000, given the recalculations were done in 2003 and particularly since he was not personally involved in the exercise.

11. The Evidence of Captain M. S. DAVIS (for Inspector of Accidents)

11.1 Captain DAVIS joined the CAD of Hong Kong in 1995 and is currently Chief of the Flight Standards and Airworthiness Division. He was part of the CAD team responsible for investigating this accident. He was with the U.K. Royal Air Force from 1954-1972 with his duties including flying fighter aircraft. He retired with the rank of Wing Commander. After a brief spell with the Abu Dhabi Air Force, he spent 20 years with Gulf Air (until 1995) in senior management positions in Operations and Training (mostly B737 and Airbus) with special responsibility for pilot training programmes. For this review hearing, he gave a written statement in addition to his oral testimonies.

11.2 From the CVR Captain DAVIS noted several instances of breakdown in Cockpit Resource Management ('CRM') indicating confusion, misunderstandings and poor communications between the 2 pilots. These might have placed unwanted pressure on the crew in the already very difficult conditions. These included –

- Briefing for wrong runway
- Incomplete briefing
- Descent/Approach check list not completed
- Obscure use of language not easily understood e.g. "*If you land haven't, please be sure, people going out, very important*" (Report A10-4).

11.3 In Captain DAVIS' view, the trouble started almost as soon as the autopilot was disengaged at about 500 ft and the approach was unstable from this point onwards, as shown by the following data: -

- Glideslope went high and then low,
- Localiser deviated to left,
- ROD was excessive, reaching over 1300 fpm at 200 feet to get back on glideslope, and
- Excessive elevator deflections to control and correct the ROD.

11.4 According to Captain DAVIS, all these culminated in an ever-increasing ROD from 30 feet to impact.

11.5 Captain DAVIS pointed out that some of these early problems could have been avoided had the pilot followed the China Airlines SOP and “*used the ILS whenever it provides adequate threshold clearance height, regardless of weather conditions*” instead of flying the aircraft visually from 500 feet and below, after disengaging the autopilot.

11.6 Under these circumstances, Captain DAVIS was of the view that the pilot should have remained on instruments, with or without autopilot, to somewhere near decision height. “*In these conditions the longer he can stay on autopilot, the better*”. In the last 1½ seconds of the flight, which is when Captain EVERES claimed the flight suddenly and unexpectedly went wrong, it was, in Captain DAVIS’ view, already too late to reverse or correct all that had gone before.

11.7 As for the challenged paragraphs in the Report, he opined that all the findings and causal factors therein were correct and supported by the evidence. If the pilot had been able to decrease the ROD, the accident would have been avoided.

11.8 In Captain DAVIS’ view, the increasing ROD until ground contact was largely the result of pilot handling rather than any change in wind speed and direction, especially in the last second or so of the flight. In particular, the final input of nose up elevator which only began at about 20 feet (after a nose down input from 40 to 20 feet) was too late to reverse the excessive ROD, in view of the aircraft’s inertia and the consequent delay in aircraft response to the up elevator input.

11.9 Captain DAVIS maintained that Boeing’s work with both the 2000 derived winds and the 2003 desktop simulations showed that there existed a set of flight control inputs which could enable the pilot to land the aircraft safely. As for the 2000 simulations, there were doubts expressed as to the simulator’s ability to cope with the winds put into it. Neither Boeing nor NTSB recommended to do further simulation tests with the 2003 winds. Accordingly, he did not accept the suggestions that the 2000 simulations proved that no human pilot could land safely in either the 2000 or 2003 derived winds.

11.10 Captain DAVIS agreed that in the last 1.5 seconds it was too late to apply power to salvage the flight; however he maintained the validity of Causal Factor 3.2.2(ii) on the basis that power should have been kept available from 50 to 40 feet downwards to counteract the high ROD. Although Captain DAVIS accepted that Counsel for CAL Mr. WATKINS was correct in pointing out from the Report A13-1-2 that the calibrated airspeed at 45 feet was 172 knots, he opined that the airspeed decayed from there to about 152 knots at ground impact. Accordingly, in his view, the pilot could and should

have applied power below 50 feet to help increase the pitch and reduce the high ROD.

11.11 Captain DAVIS further noted that

- i. The 2000 simulation was performed on a training simulator and not an engineering simulator as contended by Captain EVER. No one had been able to establish whether the training simulator was able to replicate the actual winds.
- ii. Since it was conceded by Boeing that updrafts and downdrafts were incorrectly reversed in the 2000 derived winds, the results became even less reliable as an indicator of the capability of a human pilot to land safely in the conditions experienced by CI642.

11.12 Counsel for Boeing Mr. SUSSEX S.C. referred Captain DAVIS to an e-mail from John O'CALLAGHAN of the NTSB dated 3rd April 2003 where he stated

"while we (referring to NTSB and Boeing Staff) did not discuss conclusion #2 explicitly, I think we would agree that, intuitively, the new winds do not affect conclusion #2" (i.e. that landing the plane by hand was challenging; landing successfully on the first try was difficult.)

11.13 Captain DAVIS was not prepared to agree with this conclusion, intuitively or otherwise.

11.14 The Board notes that the same remark was not repeated in the formal letter sent by NTSB to Captain DAVIS on 29th May 2003.

11.15 Captain DAVIS also pointed out that as the weather conditions that day were beyond the limit of the autolanding system of MD-11, landing by autopilot was not an available option.

11.16 Captain DAVIS further clarified that the principal causal factor in 3.2.1 of the Report (i.e. *"the cause of the accident was the commander's inability to arrest the high ROD existing at 50 ft RA"*) was to refer to the commander's inability to do so, as measures and controls were available to him to arrest the high ROD before the situation ran out of control.

11.17 On Captain EVER'S' repeated contention that it was normal procedure to land the MD-11 on autothrottles, Captain DAVIS referred to page 111 of the MD-11 Flight Manual, the relevant parts of which read: –

“BEFORE LANDING WINDSHEAR

1. PREVENTION

When conditions are such that moderate windshear may be encountered, even though not reported, the following precautions are recommended ...

(5) To avoid large thrust and/or trim changes in response to sudden airspeed increases (headwind shear), manually restrain the throttles from being driven back to idle”.

11.18 Captain DAVIS pointed out that it was clear, from the FDR data, that the pilot did not do this; if he had, the response time of the engines to a call for power would have been cut down by about half.

11.19 According to page 4 of the said Flight Manual the crosswind landing technique was described as: –

“Keep wings level, maintaining runway alignment during approach mainly by crabbing until approaching threshold. Then use side-slip method to touch-down”.

11.20 Captain DAVIS pointed out that the term “*approaching threshold*” was somewhat imprecise and that the FedEx Flight Manual recommended commencing the de-crab at 200 ft (or even earlier in high crosswinds) so that the alignment maneuver could be established by 100 ft.

11.21 That was the reason why one of the recommendations (Report 4.5) was for China Airlines and Boeing to amend and improve the stated crosswind landing procedures in the MD-11 Manual.

11.22 Nevertheless, Captain DAVIS agreed that alignment was certainly not established either at 100 feet or even 50 feet, so that the commander could not be said to have followed MD-11 SOP for a crosswind landing in any event.

11.23 In Captain DAVIS’ view, the nose-down input from 40ft to 20ft was absolutely the opposite of what the pilot ought to have been doing at that point. He conjectured that the pilot might have been anxious to get the aircraft on the ground, but that maintaining the pitch angle would only have meant landing perhaps a little long, which was insignificant given the length of runway at HKIA, even in wet conditions. In his view, maintaining the up elevator deflection would result in maintaining the 4° pitch up and the chance of a tailstrike (which only occurs at a pitch angle of 10°) was not a realistic possibility.

11.24 When asked what the pilot could and should have done to arrest the high ROD existing at 50 ft, Captain DAVIS replied –

- i. He should have arrived at 50 feet with a descent rate of no more than 800-850 fpm (i.e. 13-14 fps).
- ii. He should have had power available to deal with any temporary loss of lift.
- iii. He should have kept the pitch up and accepted landing a little longer if necessary.

11.25

On para. 2.5.1 of the Report, Captain DAVIS clarified that where the Report says “*both the previous landing aircraft and CI642 did experience some windshear as they entered the flare*”, this meant only that they experienced some loss of headwind component; it was not necessarily ‘windshear’ according to the precise definition given by Mr. SHUN for HKO.

11.26

Captain DAVIS also explained that despite it having been actively considered, there was no finding that the commander should have executed a go-around. In his view, this was the commander’s decision and it would not serve the purposes of the Report to include it. He also accepted that this was a matter upon which reasonable minds might differ.

11.27

At the conclusion of Captain DAVIS’ evidence, he agreed to the following suggestions put to him by one of the Assessors, Captain LOWE, viz.

- i. There are 2 basic types of crosswind landing technique; one of which involves using the rudder to “*kick around*” the aircraft just before touchdown and the other involves aligning the aircraft’s heading with that of the runway well before touching down using a combination of rudder and aileron inputs. Neither of these techniques was properly performed by the commander of CI642.
- ii. The pilots of CI642 began putting on left rudder at 420 feet; this was not off set by the right aileron. As a result the aircraft unsurprisingly started to go left of the localizer; eventually the rudder application was removed at about 300 feet and the residual heading then began to return the aircraft to the localizer.
- iii. Despite the crosswind being quite steady until at about 200 ft, the control fluctuated in both directions for no clear reason.
- iv. At about 150 feet on heading 266°, the alignment maneuver started and the pilot commanded variable amounts of rudder, eventually to a maximum of about 20°. Such approach cannot be described as stable.

- v. One would have expected the left rudder to be balanced by right aileron and right wing down in order to approach in a stabilized way. But instead from the Roll Attitude (Report A-13-2-1), one can see that there were relatively large oscillations from 150 feet in the sequence left and right for a number of times until ground impact. This again points very clearly to a de-stabilized approach.
- vi. There should have been a gap, from at least 50 feet (and probably much earlier), when the aircraft was stabilized on the runway heading and with drift offset by a constant right wing down deflection. This did not occur.

12. The Evidence of Captain EVERE (recalled)

12.1 Since the last 2 witnesses called by the Inspector of Accident did not put in their witness statements until after Captain EVERE testified, the Board took the view that it was fair and proper to afford Captain EVERE an opportunity to comment on the new evidence. He was recalled for this purpose.

12.2 Captain EVERE emphasized that the training simulator at Long Beach was, in fact, both an engineering and training simulator; it was a unique and very expensive simulator which provided the best possible vehicle for evaluating human pilot responses. He accepted however, that it was difficult for any simulator to duplicate the conditions as derived for that day.

12.3 Whilst Captain EVERE accepted that, under those conditions, the MD-11 Flight Manual recommended manually restraining the autothrottles from returning to idle, in this case it would have made no difference, since the final headwind loss occurred during the flare from 20 feet and below, when the throttles would be back in any event. The Board notes however that the previous flight CX405 had applied power in the flare to counter the headwind loss.

12.4 In Captain EVERE's view, the large pilot input into various controls e.g. elevators after the autopilot was switched off, are not indications of an unstable approach, but rather that human pilots do not have the same sensors available to make constant small corrections and that larger corrections by a human pilot are quite normal.

12.5 After the Assessor Mr. SHEPPARD pointed out Boeing's advice at page 40 of the Newark MD-11 crash enquiry, namely

"As a general 'rule of thumb' if large power and/or control deflections are required to maintain the desired flight path and/or alignment with the runway, then a go-around is warranted"

and asked for Captain EVER'S' comment, the latter stated that he interpreted “*large control deflection*” meant control deflection approaching the maximum, but in his view, the weather conditions that day required large control inputs, and that did not mean the approach was unstable.

12.6 Captain EVER'S interpreted the FDR data to indicate that aligning the aircraft with the runway was started at 300 feet rather than 150 feet but he agreed it should have been completed before the flare which should take place at 40-30 feet. He surmised that the pilot might have had difficulty in achieving this because of the increasingly large fluctuations in crosswinds at 200 feet and below. Nevertheless he was of the view that the China Airlines criteria for a stable approach had been maintained. A stable approach with a single set of flight controls was never achieved because of the varying crosswinds. He also accepted that alignment was not achieved until touchdown.

12.7 Captain EVER'S went on to suggest that the unusually large 10°-12° up-elevator input at about 50 feet produced a larger than expected lift because of an “*assist*” (or headwind increase). Captain EVER'S then calculated that if that 10° elevator input was maintained for another 3-4 seconds, the aircraft pitch up would have increased from 4° to about 10°, which would have been within tailstrike range. Therefore, he reasoned, the pilot commanded 8° down elevator to correct this, which reduced the aircraft pitch to about 3°. Unfortunately, as he put it, at this point the aircraft suffered loss of lift because of a “*significant*” downdraft (0 – 2.5 knots), with an aileron deployment to counter the crosswind and a 14-knot loss of headwind made the hard landing unavoidable. When it was suggested that, at this critical part of the flight when the aircraft should be flaring for the landing, the pilot might have reduced the 10° up-elevator slightly, but certainly not so far as to go 8° down, Captain EVER'S conceded
“*the pilot maybe put a little too much on*”.

12.8 Captain LOWE enquired how the pilot was able to detect and counter the crosswind increase so quickly as suggested. At first Captain EVER'S argued that it was either visual or the pilot could feel it, but later accepted that with all other control movements going on at the same time, especially those of the rudder, it would not have been easy and he did not know how the pilot could have done so.

12.9 As for the spoiler deflection which was said to have helped destroy lift during the last 1.5 seconds of the flight, Captain EVER'S agreed that it was deployed, retracted and then deployed again to only a partial extent so that the effect on lift might not have been as great as has been suggested.

12.10 This concluded the evidence at the hearing.

13**Other Evidence****13.1**

After the hearing, as part of its closing written submissions, Boeing produced 2 additional charts which Mr. ANDERSON had prepared after further work on an engineering simulator to give more scientific support to his evidence as to the effect on the ROD of his first 3 factors. His conclusion was that without those factors, i.e. if the headwind and crosswind had remained steady in the last 3 seconds of flight, the ROD at ground contact would have been 14 fps, instead of 20 fps. The Board notes that Mr. ANDERSON had not been previously able to assign any degrees of importance in respect of the 3 factors either in his report or in the course of his oral testimony and the new conclusion has somewhat altered his evidence.

13.2

Although these calculations had not been subjected to the scrutiny of other parties by way of cross-examination, the Board nonetheless decides to include such evidence for this review hearing. The Board notes that the newly calculated ROD (which constitutes an “*extremely hard landing*”) would still have been well beyond the structural limits of the landing gear (i.e. 10 fps) of the MD-11 even for a symmetric landing. This rate was comparable to the sink rate (13.5 fps) of the Newark MD-11 crash in July 1997 (see Report 1.18.8) which also caused the aircraft in question to break up.

14.**Decisions of the Board****14.1**

The Board refers to the limitations of its jurisdiction expounded above. We would like to reiterate that the purpose of this hearing is not to carry out a new enquiry or to re-write the Report simply on the basis that members of the Board may form different opinions on what findings should be made and included, what conclusions should be drawn and how they should be drawn or how the Report should be written. The Board’s statutory duty is to review the particular conclusions under challenge. For the sake of economy we will not go through every thing said during the review hearing. As much as possible, we will refrain from commenting on the collateral issues but instead confine ourselves to the specific passages under challenge.

14.2

It is noted that none of the parties made any submissions on the standard and burden of proof in this review hearing. The Board takes the view that the standard of proof in civil proceedings should apply: this review hearing obviously being a civil hearing under the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, the civil standard should apply and the burden of proof should rest on the party making the assertions. The standard is one of balance of probabilities.

14.3 Both the Inspector and HKO took issue with the independence of Captain EVERES as expert witness. He was the only witness called by CAL. He was an employee of China Airlines before his retirement. He was re-employed for the purpose of the accident investigation and this review hearing. The general tenor of his evidence was that the commander and co-pilot could not be faulted. The Board also notes that on most occasions, he adopted an interpretation of the available data most favourable to CAL's case rather than presenting a balanced view which is expected of an independent expert. His status and the contents of his evidence therefore fall short of what is expected of an expert, whose position and evidence should possess the following qualities:

- i. Expert evidence presented to the Court should be, and should be seen to be, the independent product of the expert, uninfluenced as to form or content by the exigencies of litigation.
- ii. An expert witness should provide independent assistance to the Court by way of objective unbiased opinion in relation to matters within his expertise. An expert witness should never assume the role of an advocate.
- iii. An expert witness should state the facts or assumptions upon which his opinion is based. He should not omit to consider material facts which could detract from his concluded opinion.
- iv. An expert witness should make it clear when a particular question or issue falls outside his expertise.

(See the judgment of Cresswell J., in The Ikarian Reefer [1993] Lloyds Law Rep. (Vol.2) 68, at p. 81.)

14.4 Having considered the evidence as a whole, we do not find Captain EVERES' assertion that the Report had been '*systematically constructed so as to justify a conclusion of pilot error as a cause of accident*' either justified by evidence or a fair indictment of the Report.

Finding 3.1.7

"The descent clearance was given to C1642 at 1014. Shortly after commencing descent at 1017, the commander commenced the approach briefing for the wrong runway. No mention was made of the warnings of severe turbulence or significant windshear, or that the ATIS reported that RW 25R was available. The briefing given by the commander did not meet the China Airlines Operations Manual requirements in respect of either timing or content."

14.5 Ruling of the Board:

Application for Review refused. We confirm the finding.

14.6 In relation to the matters raised in the first three sentences of the finding cited above, the Board takes the view that they are factually correct and relevant to the ultimate conclusion reached by the Inspector. For the purpose of clarification, according to the CVR, the briefing given by the commander at 1017 hours was technically correct. Subsequent verbal exchanges from 1019 hours in the cockpit suggested that there were differences in the crew members' understandings as to which RW was available. It was not until 1036 hours when the localizer for RW 25R became active that the confusion was finally rectified.

14.7 In view of the inclement conditions, the Board also considers that additional warnings by the commander in relation to the significant turbulence or windshear on approach would have been beneficial even if the topic had been previously discussed amongst the crew members.

14.8 In relation to the matters raised in the last sentence of the above finding, the Board finds them factually correct according to the evidence available. No such briefing was recorded during the half hour of CVR data, although the appropriate items might have been covered earlier in accordance with the CAL Manual. However, as noted in section 5.7 above, there was no direct evidence to support this suggestion.

14.9 The Board also notes that no record was detected on the CVR regarding calls made in relation to the Transitional Level.

Finding 3.1.8

“The co-pilot twice provided incorrect information to the commander during the descent and approach.”

14.10 Ruling of the Board:

Application for Review refused. We confirm the finding.

14.11 The finding was factually accurate according to the CVR. The Board also takes the view that such finding was relevant in that the co-pilot's error led to the set up of the approach procedures for the incorrect runway.

Finding 3.1.9

“The approach was de-stabilised at about 250 ft by an excessive application of power, which increased the indicated airspeed to 175 knots, 15 knots above the correct final approach speed.”

14.12 Ruling of the Board:

Application for review refused. We confirm the finding.

14.13 We take the view that while the substance of the finding is accurate, this paragraph needs further amplification in that there was no evidence that the aircraft complied with the requested 160 knots approach speed. We also note that the reference to the speed increment in the finding was incorrect in that the aircraft had acknowledged the ATC direction to fly at 160 knots, at 10:38:36 UTC. The approach had also deviated from both the Glideslope and Localizer before the power application. We are of the view that identifying only the power speed as an example does not adequately describe the lack of stability during the final approach. Some of the other examples have been described in section 11.27 above.

Finding 3.1.14

“Neither pilot perceived the increasing rate of descent and decreasing indicated airspeed as the aircraft approached the landing flare.”

14.14 Ruling of the Board:

Application for review refused. We confirm the finding.

14.15 We consider this paragraph a fair assessment of the situation: it is a conclusion supported and justified by the available evidence. While there is evidence of a slight reduction in the rate of descent (to a value which was still excessive) initiated towards the latter portion of the height band at which point the flare should normally have been initiated, it was subsequently reversed by a very large down elevator input. We find this unacceptable anywhere in the final approach and increasingly so in the last 40 feet before touchdown, when the rate of descent should be reducing to a fraction of which existed on this occasion.

14.16 We would also like to add that during the last 10 feet or so before touch down (when it would have been too late to take any effective corrective action anyway), the visual cues must have given the pilots an indication that the ROD had been many times greater than the norm. That the commander noticed the increased ROD *“just before touching down”* (see section 5.12 above) and that the co-pilot did not notice the increasing ROD at all lend support to the accuracy of the above finding.

Finding 3.1.16

“The maximum allowable landing weight for MD11, Registration B-150, was 430,000 lbs (195,454 kg). The estimated landing weight for C1642 at the time of the accident was 429,557 lbs (195,253 kg), therefore the aircraft approached the flare only 443 lbs (201 kg) below maximum landing weight, with the thrust levers already fully retarded which, in combination with a probable loss of headwind component, led to a loss of airspeed of 20 knots and an increasing rate of descent which reached approximately 18 feet per second at touchdown.”

14.17 Ruling of the Board:

Application for review allowed in part. We reject the part of the finding referring to the maximum landing weight but confirm the rest of the finding.

14.18 The final statement of this paragraph is factually correct, i.e. a rate of descent in excess of approximately 18 feet per second existed at touchdown. The Board agrees that the early retardation of throttles and a probable loss of headwind component contributed marginally to such excessive rate.

14.19 We disagree however with the finding’s implication that the higher landing weight and the consequential slight increase in drag of the aircraft was a significant factor. Indeed in these conditions other arguments in favour of a heavier rather than a lighter aircraft are possibly more compelling. We feel that this paragraph, though factually accurate, may not be adequate in its failure to refer to the excessive rate of descent being associated with the commander’s inappropriate control inputs, particularly at below 75 feet.

Causal Factor 3.2.1

“The cause of the accident was the commander’s inability to arrest the high rate of descent existing at 50 ft RA.”

14.20 Ruling of the Board:

Application for Review is refused. We confirm this causal factor.

14.21 We agree with the general tenor of the Inspector’s determination in light of the evidence available. We agree that the commander’s performance before touchdown was a significant factor contributing to the accident.

14.22 However, we take the view that as in most accidents, no single factor or person could or should be isolated and held solely responsible for their occurrences. We are of the view this tragic accident was caused by a number

of factors including meteorological phenomenon and human judgment errors which had accumulated and multiplied during the flight and, more particularly, during the latter portion of the descent. Some of these factors have been canvassed at paras. 3.2.2 and 3.2.3 of the Report. We also wish to add that the decision to continue the approach in the prevailing crosswind conditions, which at some points were outside the crosswind limits for the MD-11, could be considered ill-advised. It may have been more prudent to abandon the approach and execute a go-around in such conditions. We are further of the view that to attribute the cause in this unfortunate accident to one singular event or factor is an over simplification; particularly bearing in mind the fundamental purpose of the investigation as set out in Rule 4 of the Regulations is “*not to apportion blame and liability*” but “*for the preservation of life*” and “*avoidance of accidents in the future*”.

14.23 The Board would like to thank Mr. ANDERSON for his efforts to reconstruct the wind conditions at the time of the landing. We accept that he and his team have done their best to assist the Board. Yet for the limitations of the methodology adopted (set out in sections 6.3, 6.4 and 6.5 above) and the 10-15% error margins conceded by Mr. ANDERSON, we take the view that the FDR data are the best evidence available to assess the pilot’s ability to land safely in the prevailing meteorological conditions. We also note that, even according to the Boeings’ closing submissions, in a subsequent MD-11 engineering simulation in which all other 3 factors were excluded, the ROD would have been 14 fps; a sink rate which would have exceeded the structural limits of the aircraft in any event.

14.24 While we agree that at a certain point the situation might have deteriorated to such a state that no human intervention could have averted an accident, we are of the view that it was the responsibility of the commander and co-pilot to take the appropriate preventive and corrective measures before reaching such a critical point. Thus even if we accepted (which we do not) the accident was solely attributable to the 4 factors identified by Mr. ANDERSON (see section 6.8 iv. above), the fact that the situation had arisen at all was indicative of the cockpit crew’s inability on this occasion to deal with the adverse conditions to either land the aircraft safely or to exercise more prudent options such as executing a go-around or diverting to another airport.

14.25 In particular, from the evidence available (and even according to Mr. ANDERSON’s 2003 derived winds), we find the prevailing wind conditions at the time of the landing did not amount to ‘windshear’ according to the internationally recognized definition of the phenomenon and therefore did not warrant a windshear alert (see Mr. SHUN’s evidence summarized at sections 7.3 and 7.4 above). We find any criticism, either express or implied, of the failure to issue a windshear alert on the part of HKO or AAHK was unsupported by the evidence available.

14.26 In the revised Notice of Review, CAL suggested that “*the presence of strong northwesterly winds blowing over the PTB towards the approach path runway 25L*” was a causal factor missing from the Report. Apart from the bare allegations by Captain EVERE (who admitted in the course of his evidence not to have the relevant expertise on the subject), there was no evidence to support such a contention. On the contrary, this possible causal factor was ruled out by the evidence of Mr. Ricky LEUNG, who vouchsafed that the construction of HKIA had complied with all applicable international standards, and the evidence of Professor GRAHAM, who opined that given the height of the PTB and the distance from the runway, the effect of the PTB could only have been negligible at the time of landing. Accordingly, we do not find any merit at all in this contention.

14.27 However, we note that Professor GRAHAM in his evidence suggested that the installation of more anemometers would provide better and more detailed understanding of the wind conditions in this and other runways. We agree that such knowledge is crucial to air traffic safety, particularly in inclement conditions similar to the situation under review. We urge the relevant authorities to give consideration to such suggestion.

14.28 We also take the view that the following factors compounded the situation and rendered the hard landing ultimately inevitable:

- The autopilot was switched off at 500 ft, thereby contributing to the unstable nature of the approach.
- The pilot did not make an ILS approach as recommended by CAL’s SOP.
- The crosswind landing procedure as recommended by CAL was not correctly performed.
- No power was available at below 70 feet to correct the excessive ROD.
- The commander’s large down elevator input at approximately 35 feet RA.
- The momentary loss of headwind component in the last 1 to 1.5 seconds of the landing.

Causal Factor 3.2.2

“*Probable contributory causes to high rate of descent were:*

- (i) *The commander’s failure to appreciate the combination of a reducing airspeed, increasing rate of descent, and with the thrust decreasing to flight idle.*
- (ii) *The commander’s failure to apply power to counteract the high rate of descent prior to touchdown.*
- (iii) *Probable variations in wind direction and speed below 50 ft RA may have resulted in a momentary loss of headwind component and, in*

combination with the early retardation of the thrust levers, and at a weight only just below the maximum landing weight, led to a 20 knots loss in indicated airspeed just prior to touchdown.”

14.28 Ruling of the Board:

Application for review allowed only in part. We reject the part of the causal factor relating to the maximum landing weight in para. (iii) being a possible significant contributing cause to the high rate of descent. We confirm the rest of the conclusion. Apart from our reservations below, we agree that the factors listed were the contributing factors leading to the high rate of descent immediately before touchdown.

14.29 We take the view that para (i) would be more comprehensive if it had also described the failure to mitigate the situation at the late stage of approach by considering other options available such as go-around. The use of the term ‘crew’ rather than ‘commander’ in the above paragraph would have been more appropriate.

14.30 Para (ii) could also have been expanded to describe the possible reasons behind the error judgment such as CRM issues, turbulence, crosswind technique and the auto-throttle override. We also take the view that the commander’s crosswind technique was incorrectly dismissed as a factor in the Report.

14.31 In relation to para. (iii), we are of the view that the reference to aircraft weight is possibly misleading as any increase in drag resulting from the aircraft weight would have been minimal and a heavier aircraft would have more inertia and possibly greater stability in these particular circumstances. Furthermore, the extra fuel carried would have allowed for a wider range of aircraft diversion options, thereby relieving some of the pressures on the crew to avoid a go-around.

15. Costs

15.1 The relevant part of Regulation 14(7) provides that

“the board may, if it thinks fit, order a person who appears or is represented at the review to pay in respect of the board’s cost such reasonable sum as may be specified in the order”.

15.2

We take the preliminary view that if such discretionary power is to be exercised at all, the only parties that can be affected are the applicants to these proceedings. However we feel that the affected parties should be given an opportunity to be heard before we decide whether such order should be made at all and if so, the contents of the order. In order not to further delay the publication of the Board's rulings on the review applications, we propose to reserve this issue until after the Board has had the benefit of the submissions of the Applicants and Counsel for the Board. The parties would be invited to make submissions by the Board in due course.

Dated this **30th** day of November, 2004.

(Original Signed)

ERNEST MICHAEL KAM HUNG LIN

(Original Signed)

PETER FRANCIS SHEPPARD

(Original Signed)

WILLIAM DENNIS LOWE

ATIS

to be included when appropriate
 * Tick or delete as appropriate.

ATMD - 7 (Revised 6/99)

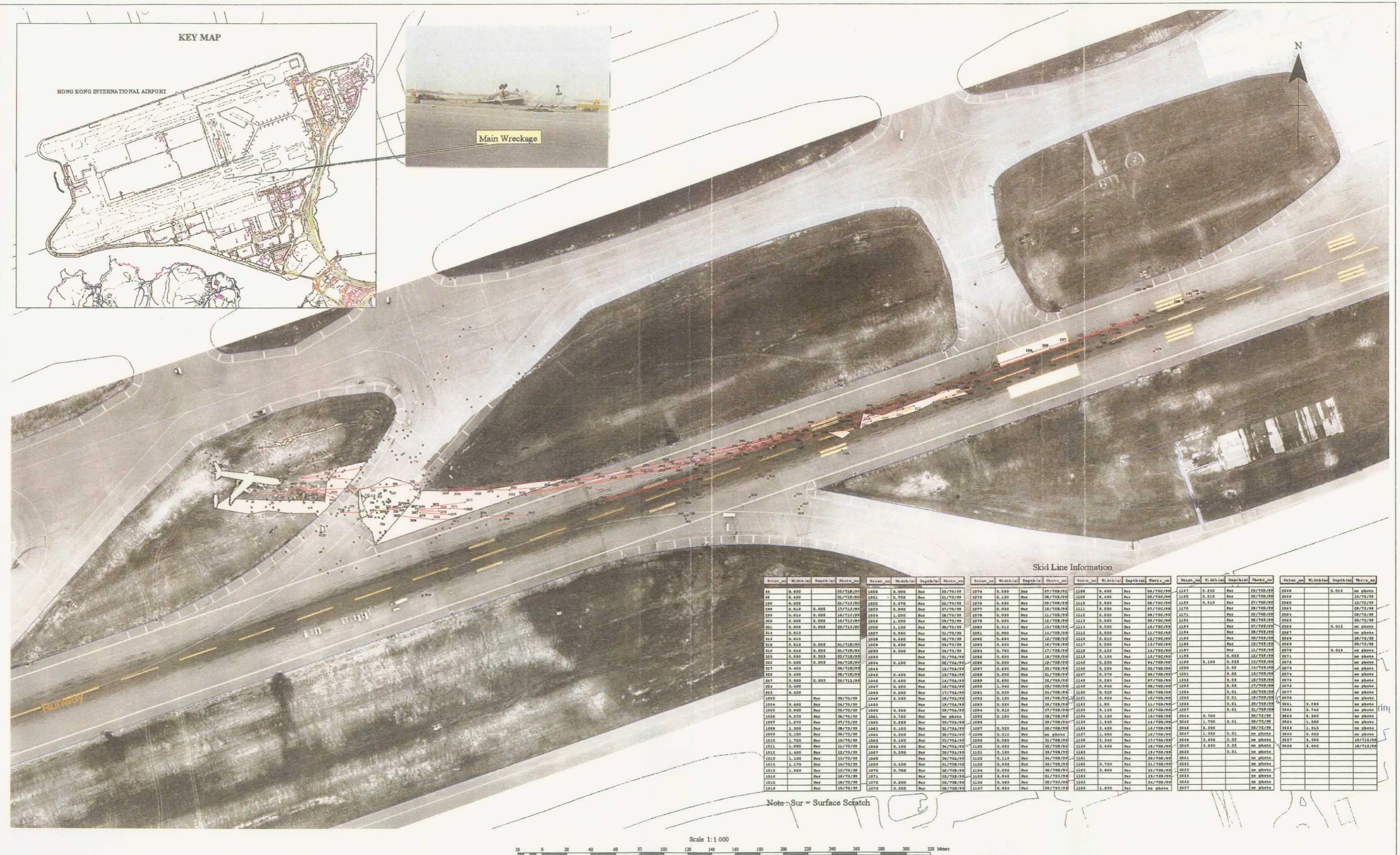
1. Hong Kong International Airport Information W at time 0940
2. Runway in use: ✓ 25L RWY 25R AVBL ON REQ
 for Arrival, for Departure
3. Expect: (type of Approach/Departure)
 ILS-DME Approach
 LLZ-DME Approach
 Others _____ (specify)
 Arriving cargo flights expect RWY 07R/25L ILS-DME/LLZ-DME Approach
4. Significant runway surface conditions, NAVAIDS status and other essential information*
 Runway surface wet / damp
 Others BRAKING ACTION REPORTED AS GOOD
 _____ (specify)
5. Surface Wind
 Maximum/Gusts Degrees 320 Knots 30 MAX 45 kts
 Degrees _____ Knots _____
6. Visibility 1400 Km/m RVR 07L/25R* _____ m*
IN 07R/25L* _____ m*
7. Present weather*
 Thunderstorm/Heavy Rain/Rain/Light Rain/Drizzle/Passing Showers/Fog/Haze/
 Others _____ (specify)
8. Cloud below 5000ft AMSL F1W 1000 SLT 1600
9. Surface wind/visibility/cloud base changing rapidly due _____
10. Temperature 25 Dew point 24 QNH 986 hPa
11. Significant Met phenomena in approach, take-off & climb-out areas*
 Expect significant wind shear ~~reduc~~ /severe turbulence/in vicinity ~~CB~~ on APP/DEP
 Others _____ (specify)
12. Trend-type landing forecast TEMPO VIS 1000M
13. Acknowledge information W on freq. 119.1/119.35* for Arrival & 129.9/124.65/122.55* for Departure

to be included when appropriate
 * Tick or delete as appropriate

1. Hong Kong International Airport Information at time 1606
2. Runway in use : 25L RWY 25R AVBL ON R7Q
 for Arrival, _____ for Departure
3. Expect : (type of Approach/Departure)
 - ILS-DME Approach
 - LLZ-DME Approach
 - Others _____ (specify)
 - Arriving cargo flights expect RWY 07R/25L ILS-DME/LLZ-DME Approach
4. Significant runway surface conditions, NAVAIDS status and other essential information*
 - Runway surface wet/damp
 - Others Braking action reported as good _____ (specify)
5. Surface Wind

Maximum/Gusts	Degrees	300	Knots	35
	Degrees		Knots	
6. Visibility 800 ~~km/m~~ 1N

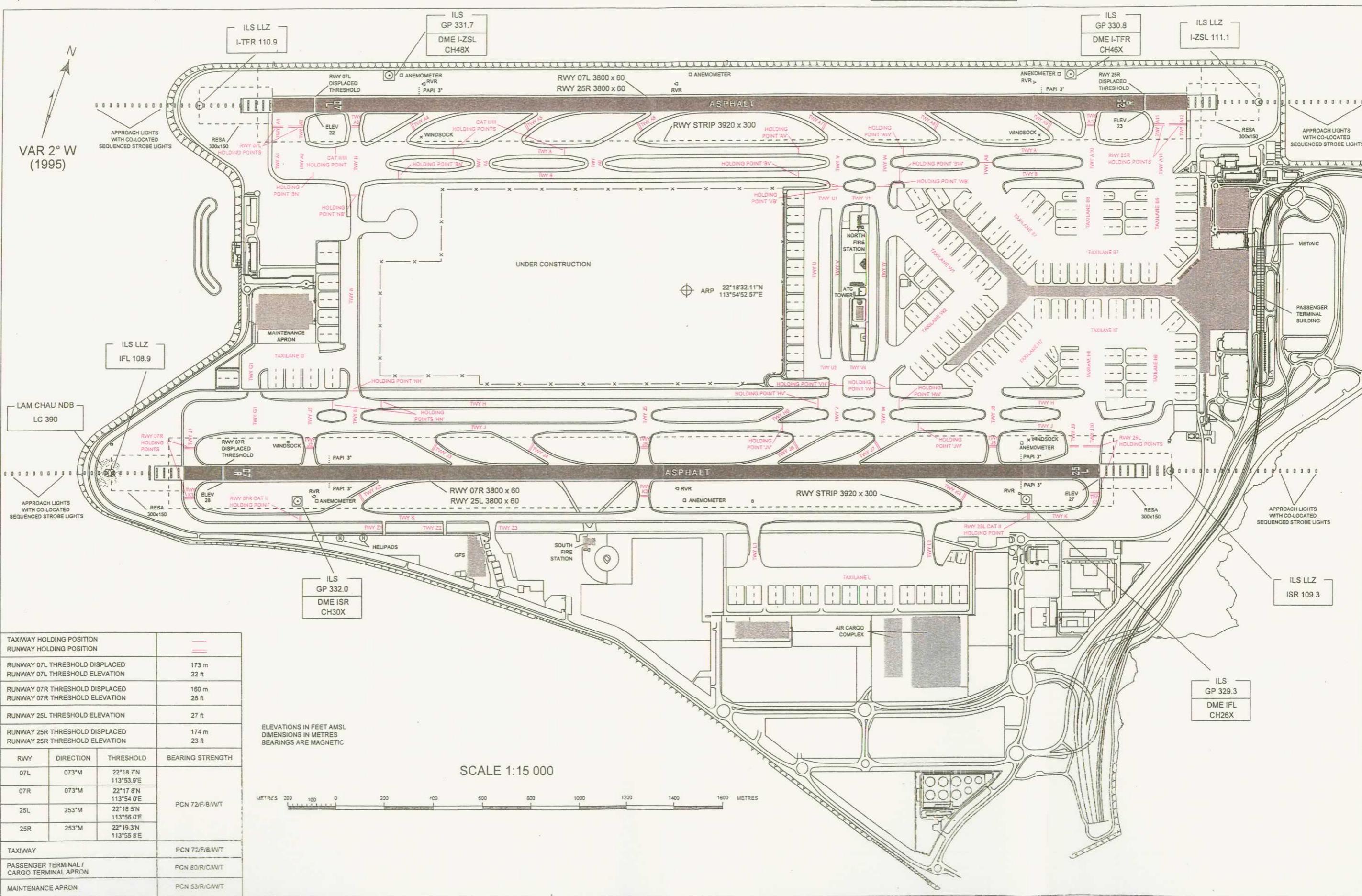
RVR	07R/25R	m
	07R/25L	650 m
7. Present weather*
 - Thunderstorm/Heavy Rain/Rain/Light Rain/Drizzle/Passing Showers/Fog/Haze
 - Others _____ (specify)
8. Cloud below 5000ft AMSL FEW 1000 SCT 1600
9. Surface wind/visibility/cloud base changing rapidly due _____
10. Temperature 25 Dew point 24 QNH 986 hPa
11. Significant Met. phenomena in approach, take-off & climb-out areas*
 - Expect significant wind shear ~~moderate~~ severe turbulence ~~in vicinity of CB on APP/DEP~~
 - Others _____ (specify)
12. Trend-type landing forecast _____
13. Acknowledge information on freq. 119.1/119.35 for Arrival & 129.9/124.65/122.55 for Departure



AIP HONG KONG

AERODROME CHART
(AERODROME LAYOUT)22° 18'32.11"N
113° 54'52.57"E

ELEVATION 19 FT AMSL

TWR 118.4 / 118.2
GMC 121.6 / 122.55HONG KONG
INTERNATIONAL AIRPORT

One-minute mean RVR data – RW 25L/25R

Ending-time (hh:mm:sec)	RW 25L			RW 25R		
	Touchdown (m)	Mid-point (m)	Roll-out (m)	Touchdown (m)	Mid-point (m)	Roll-out (m)
10:25:00	1000	900	900	600	800	1000
10:25:10	1000	900	900	650	800	1000
10:25:20	1000	900	900	650	800	1000
10:25:30	1100	900	1000	650	800	1000
10:25:40	1100	900	1000	650	800	1100
10:25:50	1100	1000	1000	650	800	1100
10:26:00	1100	1000	1000	600	900	1100
10:26:10	1100	1000	1000	600	900	1100
10:26:20	1100	1000	1000	600	800	1100
10:26:30	1100	1000	1000	600	900	1000
10:26:40	1100	1000	1100	600	800	1000
10:26:50	1000	1000	1100	600	800	1000
10:27:00	1000	1100	1100	650	800	1000
10:27:10	1000	1100	1100	650	800	1000
10:27:20	1000	1200	1100	650	800	1000
10:27:30	1000	1300	1100	650	800	1100
10:27:40	1000	1300	1100	650	900	1100
10:27:50	1100	1200	1100	650	900	1100
10:28:00	1100	1200	1100	650	900	1100
10:28:10	1200	1200	1100	650	900	1100
10:28:20	1200	1200	1100	650	800	1100
10:28:30	1200	1200	1100	650	800	1100
10:28:40	1200	1200	1100	600	800	1100
10:28:50	1200	1300	1100	600	800	1100
10:29:00	1200	1300	1100	600	800	1200
10:29:10	1200	1300	1100	600	800	1200
10:29:20	1300	1400	1100	600	900	1200
10:29:30	1300	1400	1100	600	900	1200
10:29:40	1300	1400	1100	650	900	1200
10:29:50	1300	1400	1100	650	900	1200
10:30:00	1300	1500	1100	700	900	1200
10:30:10	1300	1500	1100	700	900	1100
10:30:20	1300	1500	1100	700	900	1100
10:30:30	1300	1500	1200	700	900	1100
10:30:40	1200	1500	1200	700	900	1100
10:30:50	1300	1400	1200	700	900	1000
10:31:00	1300	1300	1200	750	900	1000
10:31:10	1300	1300	1300	750	900	1000
10:31:20	1400	1300	1300	750	900	1000
10:31:30	1400	1300	1300	750	900	1000
10:31:40	1400	1400	1300	750	900	1000
10:31:50	1500	1500	1200	750	900	1000
10:32:00	1500	1600	1200	750	900	1100
10:32:10	1500	1600	1200	750	900	1100

One-minute mean RVR data – RW 25L/25R

Ending-time (hh:mm:sec)	RW 25L			RW 25R		
	Touchdown (m)	Mid-point (m)	Roll-out (m)	Touchdown (m)	Mid-point (m)	Roll-out (m)
10:32:20	1500	1500	1200	750	900	1100
10:32:30	1500	1500	1200	750	900	1100
10:32:40	1500	1400	1200	750	900	1100
10:32:50	1500	1400	1200	750	900	1100
10:33:00	1600	1400	1200	750	900	1100
10:33:10	1600	1500	1200	700	1000	1200
10:33:20	1600	1500	1200	700	1000	1200
10:33:30	1600	1600	1200	700	1000	1200
10:33:40	1600	1700	1300	700	1000	1200
10:33:50	1700	1700	1300	650	1000	1200
10:34:00	1700	1600	1300	650	1000	1200
10:34:10	1700	1600	1300	650	1000	1200
10:34:20	1700	1600	1300	650	1000	1200
10:34:30	1700	1600	1300	700	1000	1200
10:34:40	1700	1600	1300	700	1000	1200
10:34:50	1700	1600	1400	700	1000	1100
10:35:00	1600	1600	1400	750	1000	1100
10:35:10	1600	1600	1400	750	1000	1100
10:35:20	1600	1600	1400	750	1000	1100
10:35:30	1700	1600	1500	750	1000	1100
10:35:40	1700	1600	1500	750	1100	1100
10:35:50	1700	1600	1600	750	1100	1200
10:36:00	1700	1600	1600	750	1100	1200
10:36:10	1700	1700	1600	800	1100	1300
10:36:20	1700	1700	1600	800	1100	1300
10:36:30	1600	1700	1600	800	1100	1400
10:36:40	1600	1700	1600	800	1100	1500
10:36:50	1600	1700	1600	800	1100	1500
10:37:00	1800	1600	1600	800	1100	1500
10:37:10	1800	1700	1600	900	1100	1500
10:37:20	1800	1600	1600	900	1100	1500
10:37:30	1800	1600	1700	900	1100	1500
10:37:40	1600	1500	1700	900	1100	1500
10:37:50	1500	1500	1700	900	1100	1500
10:38:00	1500	1500	1700	900	1100	1500
10:38:10	1500	1500	1700	900	1100	1500
10:38:20	1600	1600	1700	900	1200	1500
10:38:30	1700	1600	1700	900	1200	1500
10:38:40	1800	1800	1700	900	1200	1500
10:38:50	1800	1800	1700	900	1200	1500
10:39:00	1900	1900	1700	900	1300	1500
10:39:10	1900	1900	1700	900	1300	1500
10:39:20	1900	2000	1700	900	1300	1400
10:39:30	1800	2000	1700	900	1300	1400

One-minute mean RVR data – RW 25L/25R

Ending-time (hh:mm:sec)	RW 25L			RW 25R		
	Touchdown (m)	Mid-point (m)	Roll-out (m)	Touchdown (m)	Mid-point (m)	Roll-out (m)
10:39:40	1800	2000	1700	900	1300	1400
10:39:50	1800	2100	1700	800	1300	1400
10:40:00	1800	2100	1700	800	1300	1400
10:40:10	1800	2100	1700	800	1300	1400
10:40:20	1800	2100	1800	800	1200	1400
10:40:30	1700	2200	1800	800	1200	1400
10:40:40	1600	2200	1800	800	1200	1400
10:40:50	1600	2000	1800	800	1200	1400
10:41:00	1600	1900	1700	900	1200	1500
10:41:10	1600	1900	1700	900	1200	1500
10:41:20	1600	1900	1700	900	1300	1500
10:41:30	1600	1900	1600	900	1300	1500
10:41:40	1700	1900	1600	900	1300	1500
10:41:50	1800	2200	1600	900	1300	1500
10:42:00	1800	2300	1700	900	1300	1400
10:42:10	1800	2300	1700	900	1300	1400
10:42:20	1800	2200	1700	900	1300	1400
10:42:30	1800	2200	1800	900	1300	1400
10:42:40	1900	2200	1800	900	1300	1400
10:42:50	1900	2200	1800	900	1300	1500
10:43:00	1900	2200	1800	900	1400	1500
10:43:10	1900	2200	1800	900	1400	1500
10:43:20	1900	2200	1800	900	1400	1600
10:43:30	1900	2200	1800	1000	1500	1600
10:43:40	2000	2300	1800	1000	1500	1700
10:43:50	2000	2300	1800	1000	1500	1700
10:44:00	1800	2400	1900	1000	1500	1700
10:44:10	1700	2300	1900	1000	1500	1700
10:44:20	1600	2300	1900	1000	1500	1600
10:44:30	1600	2300	1900	1000	1500	1600
10:44:40	1600	2300	1900	1000	1400	1600
10:44:50	1600	2300	1800	1000	1400	1600
10:45:00	1700	2300	1800	1000	1400	1600

Two-minute mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	Direction (degrees)	RW 07L		RW 07R	
		Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)
10:25:00	317	34	50	306	30
10:25:10	317	34	50	306	31
10:25:20	317	34	50	308	31
10:25:30	316	35	50	308	31
10:25:40	317	36	50	309	31
10:25:50	316	36	50	310	32
10:26:00	315	36	50	311	33
10:26:10	314	36	49	311	33
10:26:20	315	36	49	312	32
10:26:30	315	37	49	314	32
10:26:40	314	37	49	315	31
10:26:50	315	38	49	315	29
10:27:00	315	38	49	315	29
10:27:10	315	39	49	314	29
10:27:20	316	40	49	314	29
10:27:30	317	40	50	313	29
10:27:40	316	40	50	313	29
10:27:50	317	40	50	313	29
10:28:00	317	40	50	313	29
10:28:10	317	39	50	313	28
10:28:20	316	39	50	310	29
10:28:30	315	39	50	310	29
10:28:40	315	39	50	308	30
10:28:50	315	38	50	308	31
10:29:00	315	38	50	308	32
10:29:10	315	39	50	308	32
10:29:20	315	38	50	307	31
10:29:30	315	38	44	307	31
10:29:40	316	38	44	307	31
10:29:50	316	38	44	306	31
10:30:00	316	38	44	306	31
10:30:10	317	39	46	306	30
10:30:20	317	39	46	305	30
10:30:30	317	39	46	307	31
10:30:40	317	39	46	307	31
10:30:50	317	40	46	307	30
10:31:00	318	41	46	307	30
10:31:10	318	41	46	307	30
10:31:20	318	41	47	307	30
10:31:30	317	41	47	308	30
10:31:40	317	41	47	308	30
10:31:50	317	41	47	308	36

Two-minute mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	Direction (degrees)	RW 07L		RW 07R	
		Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)
10:32:00	317	42	47	308	31
10:32:10	317	41	47	309	32
10:32:20	317	40	47	309	32
10:32:30	317	40	47	309	32
10:32:40	317	39	47	309	32
10:32:50	317	39	47	309	32
10:33:00	317	39	47	309	32
10:33:10	317	38	47	309	32
10:33:20	317	37	45	310	32
10:33:30	317	37	45	310	31
10:33:40	316	37	45	310	31
10:33:50	316	37	45	310	30
10:34:00	317	36	45	310	30
10:34:10	316	37	45	309	28
10:34:20	316	37	45	309	28
10:34:30	317	37	45	309	28
10:34:40	317	38	47	309	27
10:34:50	317	38	47	310	27
10:35:00	316	38	47	310	27
10:35:10	316	38	47	311	26
10:35:20	317	38	47	312	26
10:35:30	316	37	47	314	25
10:35:40	316	37	47	315	25
10:35:50	315	36	47	315	25
10:36:00	315	36	47	315	25
10:36:10	316	36	47	316	25
10:36:20	316	36	47	317	25
10:36:30	316	36	47	317	25
10:36:40	316	35	45	317	25
10:36:50	316	35	45	318	25
10:37:00	316	34	40	318	25
10:37:10	317	35	46	316	26
10:37:20	317	36	46	316	26
10:37:30	317	36	46	315	26
10:37:40	317	37	46	314	27
10:37:50	318	37	46	313	27
10:38:00	317	37	46	313	27
10:38:10	317	37	46	313	27
10:38:20	316	37	46	312	28
10:38:30	316	37	46	311	28
10:38:40	315	37	46	311	28
10:38:50	315	37	46	311	28

Two-minute mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	Direction (degrees)	RW 07L		RW 07R	
		Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)
10:39:00	314	38	46	311	29
10:39:10	314	37	42	310	29
10:39:20	313	37	44	310	29
10:39:30	313	37	44	310	29
10:39:40	313	38	44	311	29
10:39:50	313	38	46	311	29
10:40:00	313	38	46	311	29
10:40:10	313	39	46	312	30
10:40:20	314	39	46	312	30
10:40:30	314	38	46	312	30
10:40:40	314	38	46	311	30
10:40:50	313	38	46	310	31
10:41:00	313	37	46	310	31
10:41:10	313	37	46	309	31
10:41:20	313	37	46	309	31
10:41:30	312	36	46	309	32
10:41:40	312	36	46	308	32
10:41:50	312	36	45	308	32
10:42:00	312	35	44	308	32
10:42:10	312	35	43	308	31
10:42:20	312	35	44	308	31
10:42:30	312	36	44	308	31
10:42:40	312	36	44	308	30
10:42:50	312	36	44	309	30
10:43:00	313	36	44	310	29
10:43:10	313	36	44	311	28
10:43:20	314	35	44	311	28
10:43:30	315	35	44	310	28
10:43:40	315	34	44	310	28
10:43:50	315	34	44	311	27
10:44:00	315	33	44	311	27
10:44:10	314	32	44	311	27
10:44:20	315	32	42	312	27
10:44:30	315	32	42	311	27
10:44:40	316	32	41	310	28
10:44:50	316	32	39	310	28
10:45:00	317	32	39	310	29

Two-minute mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R			RW 07R/25L		
	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:25:00	324	38	47	305	33	40
10:25:10	324	37	44	305	34	40
10:25:20	324	38	47	306	33	40
10:25:30	325	39	47	308	33	40
10:25:40	325	39	47	308	34	43
10:25:50	325	39	47	309	34	43
10:26:00	324	40	47	309	35	43
10:26:10	324	40	47	310	35	43
10:26:20	324	40	47	309	36	43
10:26:30	323	40	47	309	36	43
10:26:40	323	40	47	309	36	43
10:26:50	323	40	47	309	36	43
10:27:00	323	40	47	309	36	43
10:27:10	324	41	47	311	35	43
10:27:20	324	40	47	310	35	43
10:27:30	324	40	48	310	35	43
10:27:40	324	39	48	310	35	42
10:27:50	324	39	48	310	35	42
10:28:00	323	40	48	310	35	42
10:28:10	323	40	48	310	35	42
10:28:20	324	40	48	311	35	42
10:28:30	324	40	48	311	35	42
10:28:40	324	40	48	310	35	42
10:28:50	324	40	48	309	35	42
10:29:00	323	40	48	309	35	42
10:29:10	324	40	48	309	36	42
10:29:20	324	40	48	310	36	42
10:29:30	324	40	45	310	36	42
10:29:40	324	39	45	310	36	42
10:29:50	324	40	47	309	36	42
10:30:00	324	40	47	308	36	42
10:30:10	323	39	47	307	35	42
10:30:20	323	40	51	307	35	42
10:30:30	324	40	51	307	35	42
10:30:40	324	40	51	307	35	42
10:30:50	323	41	51	307	36	44
10:31:00	323	41	51	307	36	44
10:31:10	323	42	51	307	36	44
10:31:20	322	42	51	307	37	44
10:31:30	322	42	51	307	37	44
10:31:40	322	42	51	308	36	44
10:31:50	322	42	51	307	36	44

Two-minute mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R			RW 07R/25L		
	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:32:00	322	42	51	308	35	44
10:32:10	322	42	51	309	35	44
10:32:20	322	42	51	309	34	44
10:32:30	321	42	51	310	34	44
10:32:40	321	41	51	310	34	44
10:32:50	321	40	48	310	34	44
10:33:00	321	40	48	310	33	42
10:33:10	321	40	48	309	33	42
10:33:20	321	40	48	309	33	42
10:33:30	321	41	48	309	32	42
10:33:40	321	41	48	307	33	42
10:33:50	321	40	48	307	33	42
10:34:00	321	40	46	306	34	42
10:34:10	321	40	46	306	35	42
10:34:20	322	40	46	306	35	42
10:34:30	322	40	46	306	35	42
10:34:40	322	40	46	306	35	41
10:34:50	323	40	46	306	35	42
10:35:00	324	39	46	306	36	46
10:35:10	324	39	46	307	37	46
10:35:20	324	39	46	307	37	46
10:35:30	324	39	46	307	37	46
10:35:40	324	39	46	307	37	46
10:35:50	324	38	46	308	37	46
10:36:00	324	38	46	309	37	46
10:36:10	324	38	44	309	36	46
10:36:20	324	38	44	309	36	46
10:36:30	324	38	44	309	36	46
10:36:40	324	38	44	309	35	46
10:36:50	323	37	44	309	34	46
10:37:00	322	37	44	309	33	44
10:37:10	321	37	44	308	32	41
10:37:20	321	37	44	308	32	40
10:37:30	321	38	44	308	32	40
10:37:40	321	38	44	308	32	40
10:37:50	321	38	45	308	32	40
10:38:00	322	38	45	308	32	40
10:38:10	322	38	45	308	32	40
10:38:20	321	37	45	308	32	40
10:38:30	321	37	45	308	32	40
10:38:40	321	37	45	308	32	40
10:38:50	321	37	45	309	33	40

Two-minute mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R			RW 07R/25L		
	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:39:00	321	37	45	309	33	40
10:39:10	322	37	45	309	33	40
10:39:20	322	37	45	309	33	40
10:39:30	323	36	45	310	33	39
10:39:40	323	36	45	310	33	39
10:39:50	323	36	44	309	33	39
10:40:00	323	37	44	310	33	39
10:40:10	322	38	47	310	33	39
10:40:20	322	38	47	309	33	39
10:40:30	323	38	47	309	33	39
10:40:40	322	38	47	310	34	39
10:40:50	322	38	47	310	33	39
10:41:00	322	38	47	310	33	39
10:41:10	322	38	47	310	32	39
10:41:20	321	38	47	309	31	39
10:41:30	321	39	47	308	31	39
10:41:40	320	39	47	309	32	40
10:41:50	320	39	47	309	32	40
10:42:00	319	39	47	309	32	40
10:42:10	319	39	47	309	32	41
10:42:20	318	38	45	309	32	41
10:42:30	318	38	45	308	32	41
10:42:40	318	38	45	307	32	41
10:42:50	317	38	45	306	32	41
10:43:00	317	38	45	306	33	41
10:43:10	317	39	45	306	33	41
10:43:20	318	39	45	306	33	41
10:43:30	318	38	45	306	33	41
10:43:40	319	38	45	305	33	41
10:43:50	319	38	42	306	32	41
10:44:00	320	37	42	306	32	41
10:44:10	320	37	42	307	32	37
10:44:20	320	37	42	308	31	37
10:44:30	321	37	42	308	31	37
10:44:40	322	37	42	309	31	37
10:44:50	322	37	42	309	31	37
10:45:00	322	37	42	309	31	37

Two-minute mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	RW 25L			RW 25R		
	Direction (degrees)	Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	Gust (knots)
10:25:00	316	30	42	325	39	48
10:25:10	317	29	39	324	39	48
10:25:20	318	29	39	324	39	48
10:25:30	318	29	39	325	40	48
10:25:40	318	30	39	325	40	48
10:25:50	316	29	37	324	40	48
10:26:00	317	29	37	325	40	46
10:26:10	317	28	36	325	40	47
10:26:20	318	27	36	325	40	47
10:26:30	318	27	36	324	40	47
10:26:40	318	28	42	324	40	47
10:26:50	317	28	42	325	41	47
10:27:00	316	28	42	325	41	47
10:27:10	316	29	42	326	40	47
10:27:20	315	29	42	326	40	47
10:27:30	316	29	42	326	41	47
10:27:40	317	30	42	325	41	47
10:27:50	319	29	42	326	41	47
10:28:00	319	30	42	325	41	47
10:28:10	319	31	42	325	41	49
10:28:20	320	31	42	324	41	49
10:28:30	320	31	42	324	41	49
10:28:40	320	31	40	324	41	49
10:28:50	320	31	40	323	41	49
10:29:00	320	31	40	322	41	49
10:29:10	320	31	40	320	42	49
10:29:20	320	31	40	319	42	49
10:29:30	319	31	40	318	44	55
10:29:40	318	32	42	319	44	55
10:29:50	318	32	42	319	44	55
10:30:00	319	32	42	321	44	52
10:30:10	319	32	42	321	46	56
10:30:20	319	32	42	323	47	56
10:30:30	319	32	42	324	44	56
10:30:40	320	31	42	325	39	51
10:30:50	320	31	42	325	38	48
10:31:00	320	31	42	325	39	48
10:31:10	320	30	42	325	40	48
10:31:20	321	31	42	325	40	47
10:31:30	322	31	42	325	41	47
10:31:40	322	31	40	325	41	47
10:31:50	322	30	39	324	41	49

Two-minute mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	Direction (degrees)	RW 25L		RW 25R	
		Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)
10:32:00	322	30	39	322	41
10:32:10	322	30	39	321	42
10:32:20	322	29	39	322	42
10:32:30	322	29	39	322	42
10:32:40	322	29	39	322	41
10:32:50	321	29	39	321	39
10:33:00	321	29	39	320	40
10:33:10	321	28	39	320	41
10:33:20	321	28	39	320	41
10:33:30	320	27	35	320	41
10:33:40	320	27	36	320	41
10:33:50	319	27	36	320	41
10:34:00	319	27	36	320	41
10:34:10	318	28	44	320	41
10:34:20	317	29	44	320	41
10:34:30	317	29	44	320	41
10:34:40	317	29	44	320	40
10:34:50	318	29	44	320	39
10:35:00	318	29	44	320	39
10:35:10	319	29	44	321	39
10:35:20	319	29	44	321	38
10:35:30	320	29	44	321	38
10:35:40	320	29	44	320	37
10:35:50	320	29	44	320	36
10:36:00	321	29	44	320	36
10:36:10	321	29	39	320	37
10:36:20	321	29	39	321	37
10:36:30	321	29	39	321	37
10:36:40	320	29	42	321	37
10:36:50	320	30	42	321	37
10:37:00	321	30	42	321	37
10:37:10	320	30	42	321	38
10:37:20	319	30	42	320	39
10:37:30	319	29	42	320	39
10:37:40	319	29	42	321	40
10:37:50	319	29	42	321	40
10:38:00	319	29	42	321	39
10:38:10	320	29	42	321	39
10:38:20	319	29	42	321	39
10:38:30	320	28	42	321	39
10:38:40	320	27	36	321	39
10:38:50	319	26	36	321	39

Two-minute mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	Direction (degrees)	RW 25L		RW 25R		Gust (knots)
		Speed (knots)	Gust (knots)	Direction (degrees)	Speed (knots)	
10:39:00	318	26	36	321	39	46
10:39:10	318	26	36	322	38	46
10:39:20	318	26	36	322	37	44
10:39:30	318	26	36	322	37	45
10:39:40	318	26	36	322	37	45
10:39:50	318	26	35	322	37	45
10:40:00	319	25	34	322	38	45
10:40:10	318	24	32	322	38	45
10:40:20	318	23	32	322	38	45
10:40:30	318	23	32	322	38	45
10:40:40	318	24	32	322	39	45
10:40:50	318	24	32	322	39	45
10:41:00	318	25	33	321	39	45
10:41:10	319	25	33	322	39	45
10:41:20	319	25	33	322	39	45
10:41:30	319	25	33	321	39	45
10:41:40	319	25	33	321	38	45
10:41:50	319	25	33	321	38	45
10:42:00	317	26	36	321	38	45
10:42:10	318	26	36	320	38	45
10:42:20	318	27	36	320	37	45
10:42:30	318	27	36	320	36	44
10:42:40	317	28	36	320	36	42
10:42:50	317	28	36	319	35	41
10:43:00	317	27	36	318	36	41
10:43:10	316	26	36	318	36	42
10:43:20	317	26	36	318	36	43
10:43:30	316	25	36	318	37	43
10:43:40	317	24	36	318	37	43
10:43:50	317	25	36	318	37	43
10:44:00	318	24	35	318	37	43
10:44:10	318	24	35	318	37	43
10:44:20	318	25	39	318	37	43
10:44:30	319	25	39	318	38	43
10:44:40	319	25	39	318	38	43
10:44:50	319	26	39	319	38	43
10:45:00	320	26	39	319	38	43

Note : Gust figures evaluated from running 3 – second mean wind sequence

Ten-second mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	RW 07L		RW 07R	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:25:00	310	28	312	34
10:25:10	312	32	315	32
10:25:20	308	31	313	28
10:25:30	313	42	313	28
10:25:40	317	42	312	37
10:25:50	313	36	313	38
10:26:00	311	38	315	33
10:26:10	318	46	315	33
10:26:20	322	41	322	26
10:26:30	318	40	322	24
10:26:40	317	39	319	22
10:26:50	318	39	308	27
10:27:00	312	35	308	27
10:27:10	313	38	305	32
10:27:20	320	44	315	31
10:27:30	320	48	304	33
10:27:40	315	39	304	33
10:27:50	316	40	315	31
10:28:00	316	34	313	31
10:28:10	314	31	308	31
10:28:20	311	38	304	29
10:28:30	314	42	304	29
10:28:40	311	37	300	28
10:28:50	315	36	305	36
10:29:00	314	35	307	30
10:29:10	314	39	307	30
10:29:20	317	39	309	27
10:29:30	323	41	302	28
10:29:40	323	42	308	30
10:29:50	320	41	305	33
10:30:00	318	35	305	29
10:30:10	318	42	306	28
10:30:20	316	42	301	31
10:30:30	313	37	315	29
10:30:40	316	44	315	29
10:30:50	313	43	310	31
10:31:00	321	43	308	31
10:31:10	316	39	309	30
10:31:20	316	45	308	28
10:31:30	316	40	307	30
10:31:40	322	42	311	32
10:31:50	324	44	312	35

Ten-second mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	RW 07L		RW 07R	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:32:00	316	40	306	32
10:32:10	313	31	307	37
10:32:20	314	30	312	34
10:32:30	314	37	309	32
10:32:40	316	33	311	31
10:32:50	320	41	312	28
10:33:00	319	40	309	31
10:33:10	315	34	308	31
10:33:20	314	33	312	29
10:33:30	317	40	311	24
10:33:40	318	41	309	24
10:33:50	324	40	308	27
10:34:00	317	36	307	26
10:34:10	311	34	306	27
10:34:20	314	36	306	27
10:34:30	319	39	308	28
10:34:40	317	43	308	28
10:34:50	317	40	318	27
10:35:00	317	42	318	27
10:35:10	315	34	324	24
10:35:20	315	31	325	21
10:35:30	313	31	326	21
10:35:40	314	33	319	28
10:35:50	313	35	319	28
10:36:00	316	36	309	26
10:36:10	317	34	313	27
10:36:20	318	35	317	24
10:36:30	316	36	309	29
10:36:40	324	38	314	24
10:36:50	316	36	317	28
10:37:00	318	35	320	27
10:37:10	318	45	313	27
10:37:20	319	41	313	27
10:37:30	316	34	308	29
10:37:40	316	38	313	26
10:37:50	316	37	309	25
10:38:00	313	37	310	26
10:38:10	312	38	308	31
10:38:20	310	33	305	33
10:38:30	310	36	311	38
10:38:40	315	39	315	32
10:38:50	313	35	315	32

Ten-second mean wind data – RW 07L/07R touchdown zones

Ending-time (hh:mm:sec)	RW 07L		RW 07R	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:39:00	315	38	315	30
10:39:10	312	39	309	30
10:39:20	309	39	314	27
10:39:30	312	42	314	27
10:39:40	315	39	315	25
10:39:50	314	39	309	31
10:40:00	318	40	310	33
10:40:10	318	43	310	36
10:40:20	315	34	310	36
10:40:30	310	33	308	34
10:40:40	310	32	305	31
10:40:50	310	33	303	34
10:41:00	311	35	303	34
10:41:10	309	36	308	33
10:41:20	308	34	316	29
10:41:30	309	35	316	28
10:41:40	312	35	304	29
10:41:50	315	37	304	29
10:42:00	316	40	307	30
10:42:10	316	38	307	29
10:42:20	313	39	308	26
10:42:30	311	34	308	26
10:42:40	315	35	313	28
10:42:50	313	36	316	27
10:43:00	315	35	311	27
10:43:10	315	30	316	28
10:43:20	316	30	316	28
10:43:30	316	30	308	26
10:43:40	312	28	309	28
10:43:50	319	29	317	24
10:44:00	315	27	317	24
10:44:10	313	32	310	30
10:44:20	317	36	308	27
10:44:30	317	38	301	31
10:44:40	319	35	307	34
10:44:50	321	35	307	34
10:45:00	321	38	313	31

Ten-second mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R		RW 07R/25L	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:25:00	325	34	310	35
10:25:10	320	35	298	34
10:25:20	320	45	311	32
10:25:30	326	43	314	32
10:25:40	326	43	308	40
10:25:50	324	40	312	40
10:26:00	324	40	313	38
10:26:10	318	36	312	39
10:26:20	318	36	302	37
10:26:30	316	42	305	35
10:26:40	324	40	314	33
10:26:50	327	34	315	33
10:27:00	329	40	311	32
10:27:10	325	42	311	31
10:27:20	323	37	304	34
10:27:30	327	44	308	33
10:27:40	321	37	310	39
10:27:50	321	37	315	37
10:28:00	320	42	316	39
10:28:10	324	43	311	35
10:28:20	324	40	306	36
10:28:30	322	40	305	36
10:28:40	321	37	306	34
10:28:50	324	42	307	33
10:29:00	325	39	306	37
10:29:10	327	38	310	40
10:29:20	327	38	315	35
10:29:30	327	40	312	34
10:29:40	323	35	311	38
10:29:50	321	44	309	36
10:30:00	321	44	301	32
10:30:10	321	38	302	34
10:30:20	323	46	305	33
10:30:30	326	42	302	32
10:30:40	321	43	306	38
10:30:50	322	48	301	42
10:31:00	320	45	310	41
10:31:10	324	40	312	40
10:31:20	319	36	312	39
10:31:30	319	36	315	37
10:31:40	321	35	313	32
10:31:50	320	45	307	28

Ten-second mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R		RW 07R/25L	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:32:00	321	44	310	25
10:32:10	321	44	309	28
10:32:20	319	40	314	28
10:32:30	319	42	306	29
10:32:40	323	37	305	40
10:32:50	321	38	310	36
10:33:00	321	38	306	35
10:33:10	321	37	304	35
10:33:20	324	42	310	37
10:33:30	317	43	308	36
10:33:40	317	43	300	35
10:33:50	322	39	303	34
10:34:00	324	38	302	34
10:34:10	325	44	307	35
10:34:20	322	40	307	32
10:34:30	322	40	309	34
10:34:40	326	36	306	37
10:34:50	330	39	310	39
10:35:00	324	34	310	42
10:35:10	324	34	313	42
10:35:20	324	40	311	38
10:35:30	322	38	303	35
10:35:40	318	38	308	37
10:35:50	324	37	309	34
10:36:00	324	37	312	34
10:36:10	322	39	308	30
10:36:20	324	37	308	28
10:36:30	321	37	307	29
10:36:40	321	37	309	30
10:36:50	320	37	307	30
10:37:00	321	33	309	32
10:37:10	318	40	311	31
10:37:20	318	40	304	32
10:37:30	321	42	303	35
10:37:40	324	40	313	36
10:37:50	322	40	309	32
10:38:00	327	37	311	35
10:38:10	323	33	303	30
10:38:20	322	33	308	32
10:38:30	320	38	312	31
10:38:40	322	37	309	32
10:38:50	321	36	312	33

Ten-second mean wind data – RW 07L/25R and RW 07R/25L mid-points

Ending-time (hh:mm:sec)	RW 07L/25R		RW 07R/25L	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:39:00	320	36	309	33
10:39:10	325	36	312	37
10:39:20	323	35	313	35
10:39:30	324	39	313	35
10:39:40	324	39	306	29
10:39:50	320	42	305	34
10:40:00	327	42	313	31
10:40:10	325	45	306	30
10:40:20	325	45	302	33
10:40:30	320	37	312	36
10:40:40	319	34	313	35
10:40:50	323	34	314	28
10:41:00	318	36	310	27
10:41:10	318	36	309	29
10:41:20	315	39	305	30
10:41:30	323	42	308	33
10:41:40	319	43	312	38
10:41:50	319	43	311	35
10:42:00	315	39	305	31
10:42:10	315	40	303	33
10:42:20	314	37	303	33
10:42:30	319	35	302	35
10:42:40	319	35	299	32
10:42:50	315	33	305	32
10:43:00	320	39	309	32
10:43:10	321	39	307	34
10:43:20	324	40	303	31
10:43:30	325	38	311	31
10:43:40	322	37	307	30
10:43:50	321	38	319	29
10:44:00	320	36	309	31
10:44:10	320	36	312	29
10:44:20	318	33	309	29
10:44:30	323	35	308	32
10:44:40	320	38	306	35
10:44:50	320	38	306	35
10:45:00	321	37	312	32

Ten-second mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	RW 25R		RW 25L	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:25:00	325	41	328	30
10:25:10	322	42	324	26
10:25:20	325	39	323	28
10:25:30	326	37	319	26
10:25:40	326	40	309	25
10:25:50	321	40	300	28
10:26:00	325	40	315	28
10:26:10	325	44	318	23
10:26:20	323	42	319	23
10:26:30	324	41	317	31
10:26:40	329	40	318	36
10:26:50	328	41	310	36
10:27:00	331	41	319	32
10:27:10	323	36	320	31
10:27:20	327	43	317	29
10:27:30	326	41	329	30
10:27:40	323	40	327	30
10:27:50	322	41	319	26
10:28:00	321	39	312	29
10:28:10	319	47	326	35
10:28:20	320	44	326	30
10:28:30	320	41	315	31
10:28:40	322	39	318	32
10:28:50	319	45	314	31
10:29:00	322	42	320	32
10:29:10	321	44	320	36
10:29:20	321	46	317	31
10:29:30	317	45	314	27
10:29:40	320	41	313	38
10:29:50	320	45	322	34
10:30:00	322	49	320	29
10:30:10	323	52	326	33
10:30:20	327	38	327	25
10:30:30	323	35	319	31
10:30:40	324	37	326	28
10:30:50	324	42	320	31
10:31:00	325	41	320	27
10:31:10	326	40	321	31
10:31:20	323	42	322	33
10:31:30	331	41	323	36
10:31:40	323	40	323	32
10:31:50	320	44	320	31

Ten-second mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	RW 25R		RW 25L	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:32:00	322	42	320	29
10:32:10	324	42	325	23
10:32:20	321	43	320	24
10:32:30	323	39	319	28
10:32:40	322	42	327	31
10:32:50	322	36	311	24
10:33:00	321	40	317	28
10:33:10	318	37	322	25
10:33:20	319	39	322	27
10:33:30	320	39	314	29
10:33:40	326	43	320	33
10:33:50	323	41	315	28
10:34:00	316	39	311	28
10:34:10	319	39	312	35
10:34:20	319	40	317	34
10:34:30	320	38	320	31
10:34:40	321	38	326	29
10:34:50	318	37	325	25
10:35:00	321	36	315	27
10:35:10	325	35	331	26
10:35:20	322	33	328	26
10:35:30	320	35	314	30
10:35:40	318	33	323	31
10:35:50	322	37	321	32
10:36:00	319	35	314	28
10:36:10	323	43	317	31
10:36:20	323	40	324	28
10:36:30	319	40	316	30
10:36:40	320	41	318	34
10:36:50	322	40	325	33
10:37:00	322	37	320	31
10:37:10	319	40	323	25
10:37:20	320	43	316	24
10:37:30	318	42	319	19
10:37:40	326	38	318	28
10:37:50	321	36	320	33
10:38:00	321	33	314	34
10:38:10	322	37	324	32
10:38:20	322	40	317	24
10:38:30	323	41	325	21
10:38:40	321	41	313	21
10:38:50	323	35	321	24

Ten-second mean wind data – RW 25L/25R touchdown zones

Ending-time (hh:mm:sec)	RW 25R		RW 25L	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
10:39:00	321	37	311	24
10:39:10	322	31	319	29
10:39:20	322	33	313	22
10:39:30	324	43	322	26
10:39:40	326	39	315	27
10:39:50	322	38	323	26
10:40:00	320	37	328	20
10:40:10	321	38	316	21
10:40:20	319	44	314	19
10:40:30	321	45	317	22
10:40:40	319	42	322	24
10:40:50	322	40	318	26
10:41:00	319	35	314	31
10:41:10	323	33	324	29
10:41:20	324	38	317	27
10:41:30	321	36	321	29
10:41:40	317	30	320	29
10:41:50	320	38	316	24
10:42:00	320	38	307	29
10:42:10	319	38	325	28
10:42:20	316	37	315	25
10:42:30	317	31	319	26
10:42:40	318	37	310	31
10:42:50	314	36	319	27
10:43:00	312	37	311	19
10:43:10	317	40	317	21
10:43:20	319	41	321	22
10:43:30	322	39	319	21
10:43:40	320	35	322	22
10:43:50	318	37	321	27
10:44:00	321	36	317	21
10:44:10	319	38	323	28
10:44:20	318	39	320	35
10:44:30	320	39	325	29
10:44:40	317	36	312	32
10:44:50	321	38	323	33
10:45:00	317	41	319	24

1-second wind direction and speed recorded at 25L/25R TDZ anemometers

Date	Time	RW 25L		RW 25R	
		(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)
22-Aug-99	10:42:00	310	28	319	34
22-Aug-99	10:42:01	334	31	321	36
22-Aug-99	10:42:02	328	28	320	37
22-Aug-99	10:42:03	324	28	319	37
22-Aug-99	10:42:04	339	25	319	37
22-Aug-99	10:42:05	329	27	321	40
22-Aug-99	10:42:06	324	31	319	39
22-Aug-99	10:42:07	326	31	319	38
22-Aug-99	10:42:08	323	29	315	37
22-Aug-99	10:42:09	310	26	318	36
22-Aug-99	10:42:10	311	23	319	39
22-Aug-99	10:42:11	311	23	318	39
22-Aug-99	10:42:12	311	26	318	40
22-Aug-99	10:42:13	311	24	315	39
22-Aug-99	10:42:14	320	23	315	38
22-Aug-99	10:42:15	319	25	316	36
22-Aug-99	10:42:16	326	24	319	37
22-Aug-99	10:42:17	330	24	319	36
22-Aug-99	10:42:18	314	26	315	36
22-Aug-99	10:42:19	299	26	315	34
22-Aug-99	10:42:20	310	25	314	31
22-Aug-99	10:42:21	314	27	315	28
22-Aug-99	10:42:22	313	26	315	29
22-Aug-99	10:42:23	313	28	314	29
22-Aug-99	10:42:24	299	28	319	30
22-Aug-99	10:42:25	314	31	316	30
22-Aug-99	10:42:26	314	27	314	33
22-Aug-99	10:42:27	340	22	319	31
22-Aug-99	10:42:28	321	21	318	33
22-Aug-99	10:42:29	326	21	320	33
22-Aug-99	10:42:30	334	27	321	35
22-Aug-99	10:42:31	323	34	320	33
22-Aug-99	10:42:32	320	36	313	32
22-Aug-99	10:42:33	320	35	321	34
22-Aug-99	10:42:34	311	30	318	38
22-Aug-99	10:42:35	300	29	318	38
22-Aug-99	10:42:36	293	29	319	37
22-Aug-99	10:42:37	308	26	318	40
22-Aug-99	10:42:38	303	31	318	41
22-Aug-99	10:42:39	323	31	320	40
22-Aug-99	10:42:40	303	28	321	41
22-Aug-99	10:42:41	318	25	318	42
22-Aug-99	10:42:42	318	26	315	42
22-Aug-99	10:42:43	331	26	318	39

1-second wind direction and speed recorded at 25L/25R TDZ anemometers

Date	Time	RW 25L		RW 25R	
		(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)
22-Aug-99	10:42:44	326	29	318	36
22-Aug-99	10:42:45	318	29	315	39
22-Aug-99	10:42:46	313	29	314	37
22-Aug-99	10:42:47	311	28	313	30
22-Aug-99	10:42:48	314	27	309	29
22-Aug-99	10:42:49	324	24	314	30
22-Aug-99	10:42:50	316	23	309	33
22-Aug-99	10:42:51	314	23	304	31
22-Aug-99	10:42:52	319	21	299	30
22-Aug-99	10:42:53	318	20	318	35
22-Aug-99	10:42:54	309	19	310	40
22-Aug-99	10:42:55	311	18	313	38
22-Aug-99	10:42:56	310	19	314	37
22-Aug-99	10:42:57	309	18	318	38
22-Aug-99	10:42:58	299	18	314	37
22-Aug-99	10:42:59	301	18	313	40
22-Aug-99	10:43:00	323	20	316	39
22-Aug-99	10:43:01	320	21	314	40
22-Aug-99	10:43:02	320	23	320	41
22-Aug-99	10:43:03	321	23	314	38
22-Aug-99	10:43:04	319	20	321	39
22-Aug-99	10:43:05	324	20	318	35
22-Aug-99	10:43:06	308	19	314	37
22-Aug-99	10:43:07	283	19	318	41
22-Aug-99	10:43:08	320	18	321	43
22-Aug-99	10:43:09	345	22	316	43
22-Aug-99	10:43:10	306	20	319	41
22-Aug-99	10:43:11	335	20	314	41
22-Aug-99	10:43:12	339	17	318	39
22-Aug-99	10:43:13	294	14	320	42
22-Aug-99	10:43:14	303	15	321	43
22-Aug-99	10:43:15	311	21	319	42
22-Aug-99	10:43:16	320	24	318	41
22-Aug-99	10:43:17	331	28	321	40
22-Aug-99	10:43:18	324	28	320	39
22-Aug-99	10:43:19	325	26	316	39
22-Aug-99	10:43:20	325	24	319	41
22-Aug-99	10:43:21	319	25	320	39
22-Aug-99	10:43:22	323	24	326	40
22-Aug-99	10:43:23	309	22	324	39
22-Aug-99	10:43:24	328	22	320	39
22-Aug-99	10:43:25	325	21	325	39
22-Aug-99	10:43:26	314	22	320	40
22-Aug-99	10:43:27	321	21	320	41

1-second wind direction and speed recorded at 25L/25R TDZ anemometers

Date	Time	RW 25L		RW 25R	
		(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)
22-Aug-99	10:43:28	318	20	320	37
22-Aug-99	10:43:29	315	19	320	35
22-Aug-99	10:43:30	321	18	320	38
22-Aug-99	10:43:31	323	17	320	37
22-Aug-99	10:43:32	316	19	321	34
22-Aug-99	10:43:33	315	20	319	34
22-Aug-99	10:43:34	318	21	320	31
22-Aug-99	10:43:35	330	19	325	34
22-Aug-99	10:43:36	333	19	321	38
22-Aug-99	10:43:37	320	25	318	37
22-Aug-99	10:43:38	318	29	316	38
22-Aug-99	10:43:39	330	26	320	36
22-Aug-99	10:43:40	315	24	321	35
22-Aug-99	10:43:41	309	27	318	31
22-Aug-99	10:43:42	316	30	318	32
22-Aug-99	10:43:43	319	29	320	36
22-Aug-99	10:43:44	320	26	318	37
22-Aug-99	10:43:45	319	26	318	35
22-Aug-99	10:43:46	330	26	316	38
22-Aug-99	10:43:47	329	26	318	39
22-Aug-99	10:43:48	329	26	319	40
22-Aug-99	10:43:49	325	25	321	40
22-Aug-99	10:43:50	316	24	318	39
22-Aug-99	10:43:51	311	23	324	37
22-Aug-99	10:43:52	328	23	321	36
22-Aug-99	10:43:53	334	21	321	36
22-Aug-99	10:43:54	329	22	326	37
22-Aug-99	10:43:55	334	24	324	38
22-Aug-99	10:43:56	314	23	320	35
22-Aug-99	10:43:57	301	19	316	35
22-Aug-99	10:43:58	305	17	318	37
22-Aug-99	10:43:59	305	17	320	34
22-Aug-99	10:44:00	305	19	319	30

1-second wind direction and speed recorded at 07L/07R TDZ anemometers

Date	Time	RW 07L		RW 07R	
		(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)
22-Aug-99	10:42:00	315	43	304	31
22-Aug-99	10:42:01	316	43	310	31
22-Aug-99	10:42:02	324	42	310	30
22-Aug-99	10:42:03	316	43	303	31
22-Aug-99	10:42:04	316	38	308	31
22-Aug-99	10:42:05	311	37	313	31
22-Aug-99	10:42:06	319	37	309	29
22-Aug-99	10:42:07	316	35	303	27
22-Aug-99	10:42:08	309	32	301	28
22-Aug-99	10:42:09	320	33	308	27
22-Aug-99	10:42:10	314	36	303	27
22-Aug-99	10:42:11	314	36		
22-Aug-99	10:42:12	316	37		
22-Aug-99	10:42:13	313	36		
22-Aug-99	10:42:14	314	36		
22-Aug-99	10:42:15	318	41		
22-Aug-99	10:42:16	314	43		
22-Aug-99	10:42:17	315	45		
22-Aug-99	10:42:18	310	45		
22-Aug-99	10:42:19	310	38		
22-Aug-99	10:42:20	309	35		
22-Aug-99	10:42:21	315	35	305	28
22-Aug-99	10:42:22	311	38	308	26
22-Aug-99	10:42:23	313	34	303	24
22-Aug-99	10:42:24	313	34	300	26
22-Aug-99	10:42:25	313	36	310	25
22-Aug-99	10:42:26	306	33	314	25
22-Aug-99	10:42:27	304	33	309	27
22-Aug-99	10:42:28	310	32	309	27
22-Aug-99	10:42:29	313	31	308	29
22-Aug-99	10:42:30	316	31	313	27
22-Aug-99	10:42:31	323	32	305	26
22-Aug-99	10:42:32	313	29	311	27
22-Aug-99	10:42:33	313	30	309	27
22-Aug-99	10:42:34	310	28	311	28
22-Aug-99	10:42:35	309	33	313	29
22-Aug-99	10:42:36	315	37	310	29
22-Aug-99	10:42:37	320	37	315	27
22-Aug-99	10:42:38	316	40	318	30
22-Aug-99	10:42:39	320	42	316	31
22-Aug-99	10:42:40	315	44	319	28
22-Aug-99	10:42:41	319	43	329	29
22-Aug-99	10:42:42	313	40	309	29
22-Aug-99	10:42:43	316	39	304	27

1-second wind direction and speed recorded at 07L/07R TDZ anemometers

Date	Time	RW 07L		RW 07R	
		(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)
22-Aug-99	10:42:44	316	39	310	27
22-Aug-99	10:42:45	314	38	310	28
22-Aug-99	10:42:46	308	30	311	28
22-Aug-99	10:42:47	314	31	326	27
22-Aug-99	10:42:48	311	31	326	25
22-Aug-99	10:42:49	309	34	319	25
22-Aug-99	10:42:50	313	32	316	24
22-Aug-99	10:42:51	310	34	311	24
22-Aug-99	10:42:52	315	35	310	23
22-Aug-99	10:42:53	319	35	306	25
22-Aug-99	10:42:54	315	36	306	26
22-Aug-99	10:42:55	314	36	315	30
22-Aug-99	10:42:56	313	35	304	28
22-Aug-99	10:42:57	315	33	314	27
22-Aug-99	10:42:58	315	35	318	27
22-Aug-99	10:42:59	319	34	311	28
22-Aug-99	10:43:00	315	33	311	28
22-Aug-99	10:43:01	313	32		
22-Aug-99	10:43:02	311	33		
22-Aug-99	10:43:03	310	29		
22-Aug-99	10:43:04	316	31		
22-Aug-99	10:43:05	315	31		
22-Aug-99	10:43:06	321	30		
22-Aug-99	10:43:07	315	29		
22-Aug-99	10:43:08	316	27		
22-Aug-99	10:43:09	315	29		
22-Aug-99	10:43:10	319	33		
22-Aug-99	10:43:11	321	31	313	28
22-Aug-99	10:43:12	314	32	316	29
22-Aug-99	10:43:13	315	33	320	30
22-Aug-99	10:43:14	309	32	319	28
22-Aug-99	10:43:15	314	30	306	27
22-Aug-99	10:43:16	314	28	316	29
22-Aug-99	10:43:17	319	28	315	28
22-Aug-99	10:43:18	321	27	314	28
22-Aug-99	10:43:19	318	28	315	28
22-Aug-99	10:43:20	316	29	321	29
22-Aug-99	10:43:21	319	29	306	27
22-Aug-99	10:43:22	318	32	310	24
22-Aug-99	10:43:23	320	33	308	26
22-Aug-99	10:43:24	318	33	308	26
22-Aug-99	10:43:25	319	32	313	26
22-Aug-99	10:43:26	315	30	304	25
22-Aug-99	10:43:27	318	31	306	23

1-second wind direction and speed recorded at 07L/07R TDZ anemometers

Date	Time	RW 07L		RW 07R	
		(UTC)	Direction (degrees)	Speed (knots)	Direction (degrees)
22-Aug-99	10:43:28	309	30	301	25
22-Aug-99	10:43:29	310	27	306	29
22-Aug-99	10:43:30	311	26	314	29
22-Aug-99	10:43:31	313	28	303	29
22-Aug-99	10:43:32	314	28	305	29
22-Aug-99	10:43:33	311	26	305	31
22-Aug-99	10:43:34	311	26	316	30
22-Aug-99	10:43:35	314	27	304	28
22-Aug-99	10:43:36	310	28	308	30
22-Aug-99	10:43:37	314	28	309	27
22-Aug-99	10:43:38	311	31	313	26
22-Aug-99	10:43:39	311	31	313	26
22-Aug-99	10:43:40	311	29	315	25
22-Aug-99	10:43:41	314	31	305	28
22-Aug-99	10:43:42	320	31	315	27
22-Aug-99	10:43:43	319	30	311	25
22-Aug-99	10:43:44	324	30	324	26
22-Aug-99	10:43:45	320	29	318	25
22-Aug-99	10:43:46	318	29	324	24
22-Aug-99	10:43:47	320	28	320	23
22-Aug-99	10:43:48	315	28	319	21
22-Aug-99	10:43:49	318	27	311	22
22-Aug-99	10:43:50	319	28	320	24
22-Aug-99	10:43:51	320	26		
22-Aug-99	10:43:52	320	26		
22-Aug-99	10:43:53	316	24		
22-Aug-99	10:43:54	316	24		
22-Aug-99	10:43:55	310	24		
22-Aug-99	10:43:56	311	25		
22-Aug-99	10:43:57	315	28		
22-Aug-99	10:43:58	318	29		
22-Aug-99	10:43:59	315	29		
22-Aug-99	10:44:00	313	30		

One-minute mean cloud base heights

Ending-time (hh:mm:ss)	Cloud base (feet)
10:41:00	1300
10:41:10	1300
10:41:20	900
10:41:30	900
10:41:40	1200
10:41:50	800
10:42:00	900
10:42:10	900
10:42:20	1100
10:42:30	2300
10:42:40	2300
10:42:50	2300
10:43:00	1400
10:43:10	1400
10:43:20	1300
10:43:30	1200
10:43:40	1200
10:43:50	1400
10:44:00	1400

Notes : i) Cloud base height (feet above mean sea level) measured by ceilometer at meteorological enclosure

ii) Touchdown elevation of RW25L ≈ 27 feet

iii) Aerodrome elevation is 19 feet above mean sea level.

Five-minute cumulative rainfall data

Ending-time (hh:mm:ss)	Rainfall (mm)
10:41:00	0.2
10:41:10	0.2
10:41:20	0.2
10:41:30	0.2
10:41:40	0.2
10:41:50	0.2
10:42:00	0.2
10:42:10	0.2
10:42:20	0.1
10:42:30	0.1
10:42:40	0.1
10:42:50	0.1
10:43:00	0.1
10:43:10	0.1
10:43:20	0.1
10:43:30	0.1
10:43:40	0.1
10:43:50	0.1
10:44:00	0.1

Notes : i) Rainfall recorded by rain gauge at meteorological enclosure

WTWS Alerts

ISSUE TIME: 22/08/1999 10:05

07RA MOD TURB ARR
 07RD WSA 15K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 15K+ 3MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:06

07RA MOD TURB ARR
 07RD WSA 20K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 20K+ 3MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:07

07RA MOD TURB ARR
 07RD WSA 20K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 20K+ 3MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:08

07RA MOD TURB ARR
 07RD WSA 20K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 20K+ 3MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:09

07RA MOD TURB ARR
 07RD WSA 20K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 20K+ 2MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:10

07RA MOD TURB ARR
 07RD WSA 20K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 20K+ 2MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:11

07RA MOD TURB ARR
 07RD WSA 15K+ 1MD
 07LA MOD TURB ARR
 07LD SVR TURB DEP
 25RA SVR TURB ARR
 25RD MOD TURB DEP
 25LA WSA 15K+ 2MF
 25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:12

07RA MOD TURB ARR
 07RD WSA 20K+ 1MD
 07LA MOD TURB ARR
 07LD WSA 15K+ RWY
 25RA WSA 15K+ 3MF
 25RD MOD TURB DEP
 25LA WSA 20K+ 3MF
 25LD MOD TURB DEP

WTWS Alerts

ISSUE TIME: 22/08/1999 10:13

07RA MOD TURB ARR
07RD WSA 15K+ 1MD
07LA MOD TURB ARR
07LD WSA 15K+ RWY
25RA WSA 15K+ 2MF
25RD MOD TURB DEP
25LA WSA 15K+ 2MF
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:14

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD WSA 15K+ RWY
25RA WSA 15K+ 2MF
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:15

07RA MOD TURB ARR
07RD WSA 20K+ 1MD
07LA MOD TURB ARR
07LD SVR TURB DEP
25RA SVR TURB ARR
25RD MOD TURB DEP
25LA WSA 20K+ 2MF
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:16

07RA MOD TURB ARR
07RD WSA 15K+ 1MD
07LA MOD TURB ARR
07LD WSA 15K+ 1MD
25RA WSA 15K+ 1MF
25RD MOD TURB DEP
25LA WSA 15K+ 2MF
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:17

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD WSA 15K+ RWY
25RA WSA 15K+ 2MF
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:18

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD SVR TURB DEP
25RA SVR TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:19

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD SVR TURB DEP
25RA SVR TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:20

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:21

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD SVR TURB DEP
25RA SVR TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:22

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD SVR TURB DEP
25RA SVR TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:23

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:24

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:25

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:26

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:27

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:28

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD SVR TURB DEP
25RA SVR TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:29

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:30

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:31

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:32

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:33

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:34

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:35

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:36

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:37

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:38

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA MOD TURB ARR
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD MOD TURB DEP
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:39

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:40

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:41

07RA
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD

ISSUE TIME: 22/08/1999 10:42

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:43

07RA
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD

ISSUE TIME: 22/08/1999 10:44

07RA MOD TURB ARR
07RD MOD TURB DEP
07LA
07LD MOD TURB DEP
25RA MOD TURB ARR
25RD
25LA MOD TURB ARR
25LD MOD TURB DEP

ISSUE TIME: 22/08/1999 10:45

07RA MOD TURB ARR

07RD MOD TURB DEP

07LA

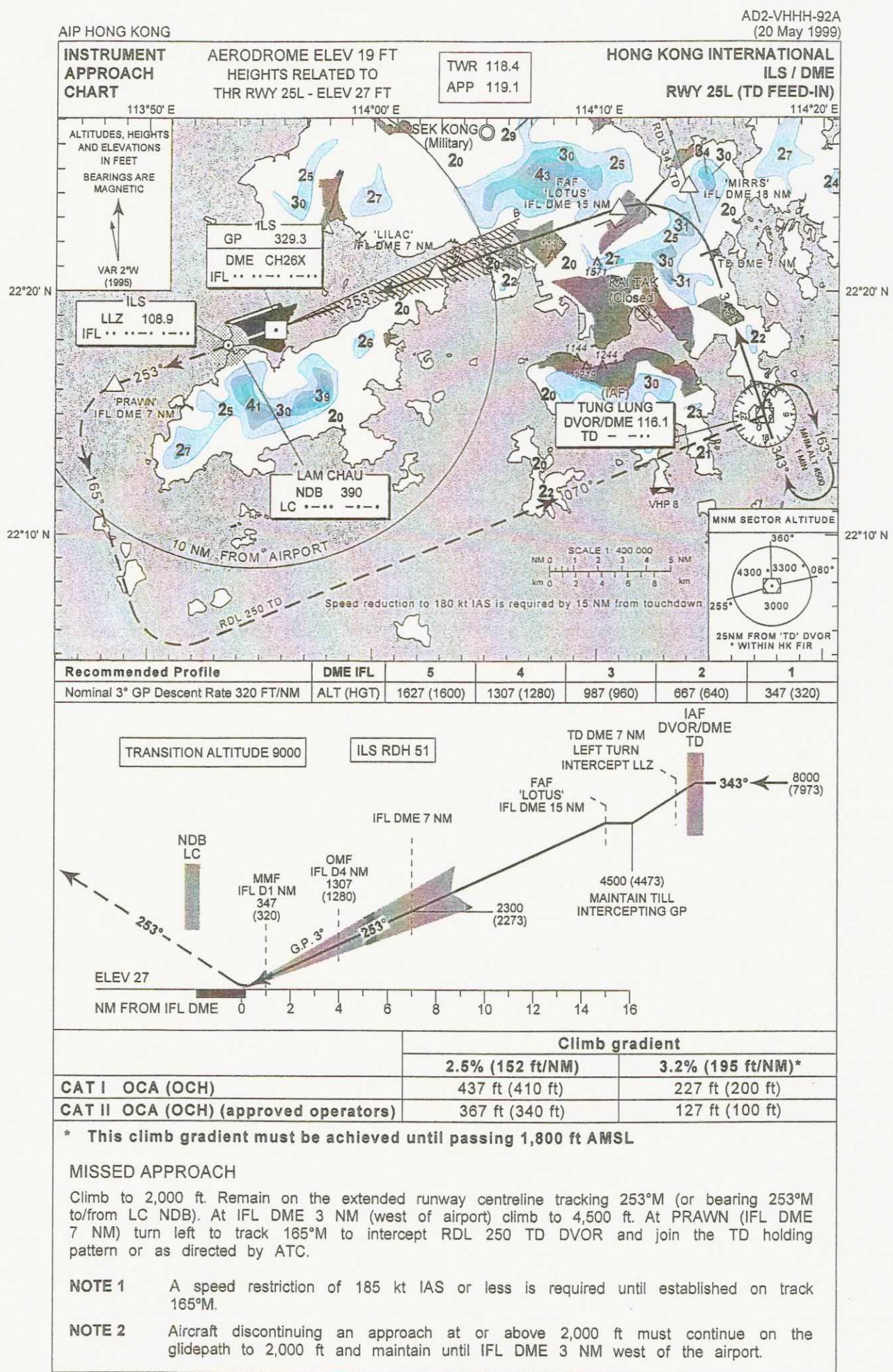
07LD MOD TURB DEP

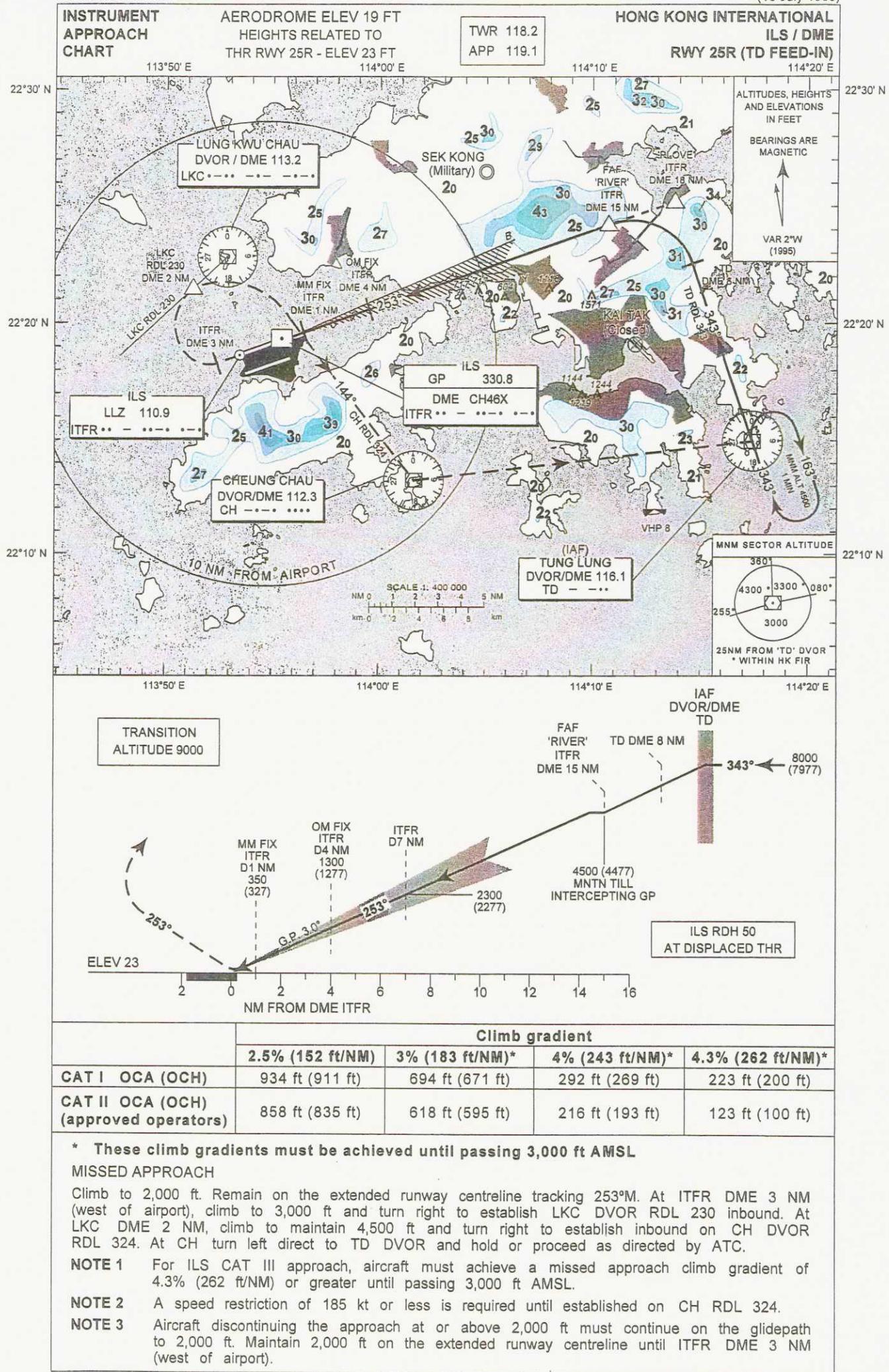
25RA MOD TURB ARR

25RD

25LA MOD TURB ARR

25LD MOD TURB DEP





**RELEVANT CVR TRANSCRIPTS
DESCENT AND FINAL APPROACH**

TIME UTC ATC	FDR	RTF COMMUNICATION			FLIGHT DECK COMMUNICATION ORIGIN	REMARKS
		FROM	TO			
10:13:08	10:14:03	Radar	CI642	DYNASTY 642, when ready descend to FL260.		
10:13:13	10:14:08	CI642	Radar	When ready descend FL260.		
10:13:28	10:14:23	Radar	CI642	DYNASTY 642, contact Radar 126.3.		
10:13:32	10:14:27	CI642	Radar	DYNASTY 642, contact Radar 126.3.		
10:13:33	10:14:28	Radar	CI642	Say again.		
10:13:38	10:14:33	CI642	Radar	DYNASTY 642, contact Radar 126.3.		
10:13:45	10:14:40	CI642	Radar	126.3, good day.		
10:13:50	10:14:45	Radar	CI642	Radar, DYNASTY 642 FL370.		
10:13:56	10:14:51	CI642	Radar	DYNASTY 642, Roger, when ready recleared FL130, reach by MANGO.		
10:14:06	10:15:01			Recleared FL130, reach by MANGO, 642.		
10:14:14	10:15:09				P1	<i>We go to BAKER and hold, what is the last weather?</i>
10:14:15	10:15:10	ATIS	-		P2	<i>Latest wind?</i>
						Remainder of ATIS broadcast overlayed by other RTF broadcasts but still audible at times.

TIME UTC		RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO			ORIGIN		
10:14:55	10:15:50					P2	<i>Are you avoiding weather? Shall we request?</i>	
10:15:03	10:15:58	CI642	Radar	<i>DYNASTY 642, request heading 360 due to weather.</i>		P1	<i>We can make it, wind 300, 35 at 255 is 45, 25 knots, 25 knots crosswind.</i>	
10:15:08	10:16:03	Radar	CI642	<i>360 DYNASTY 642 approved.</i>		P2	<i>Are we going down now?</i>	
10:15:11	10:16:06	CI642	Radar	<i>Thank you.</i>		P1	<i>Yes, you told the heading?</i>	
10:15:29	10:16:24					P2	<i>Yes</i>	
10:15:51	10:16:46					P1	<i>Let's go down, X-ray, we are only clear</i>	
10:15:52	10:16:47					P2		
10:15:55	10:16:50					P1		
10:15:57	10:16:52					P2		
10:16:01	10:16:56	CI642	Radar	<i>DYNASTY 642, leaving 370 for 130 now.</i>		P1	<i>OK, we try it.</i>	
10:16:06	10:17:01					P2	<i>Roger, DYNASTY 642, when clear weather, track direct to MANGO.</i>	
10:16:10	10:17:05	Radar	CI642	<i>When clear weather, direct to MANGO.</i>		P1	<i>Ah?</i>	
10:16:14	10:17:09	CI642	Radar			P2	<i>When clear weather, direct to MANGO.</i>	
10:16:19	10:17:14					P1		
10:16:21	10:17:16					P2	<i>When clear weather, direct to MANGO.</i>	
10:16:22	10:17:17					P1		
10:16:24	10:17:19					P2	<i>When clear weather, direct to MANGO.</i>	
						P1	<i>We are leaving for 130.</i>	

TIME UTC	RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:17:08	10:18:03				P1	OK. Which runway 25? Left, ILS25L, 8000, TD, to 4500, minimum for RW25L. 227, 227, go-around down 2000, or up 2000 until 3 miles, then PRAWN, maintain 165 to 4500 TD. If we are at 300, 35 that's OK.	Non-pertinent cockpit conversation
10:18:16	10:19:11				P1	We are, we are using runway 25, 25 Right? Minima is 223, minima 223.	
10:18:19	10:19:14				P2	223, 25L.	
10:18:30	10:19:25				P1	25 Right.	
10:18:36	10:19:31				P2	Who said 25R, the control?	
10:18:39	10:19:34				P1	Yes.	
10:18:42	10:19:37				P2	223.	
10:18:51	10:19:46				P1	Are we clear of weather?	
10:19:00	10:19:55				P2	MANGO.	
10:19:02	10:19:57				P1		
10:19:04	10:19:59	CI642	Radar	DYNASTY 642 clear of weather, now direct to MANGO.			
10:19:09	10:20:04	Radar	CI642	DYNASTY 642, thank you.			

RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
TIME UTC	ATC	FDR	FROM	TO	ORIGIN	
10:19:28	10:20:23				P1	OK. 227, from TD to 4500 then go down 2000 on glide, cross 7 miles, 2300, 4 miles 1300, minimum 223, go-around 2000, 3 miles then turning right, and leaving 3000 to 4500, intercept 270, turn to the right, 185, otherwise its too complicated, speed 185 eh, right?
10:20:27	10:21:22				P1	If you land, haven't, please be sure, people going out, very important.
10:21:16	10:22:11				P1	Is that correct 25L, recognise?
10:23:16	10:24:11				P2	We need visibility 800 metres or RVR 550.
10:23:38	10:24:33				P1	How much is now?
10:23:39	10:24:34				P2	Now is 800.
10:23:44	10:24:39				P1	Cat II, we have Cat II?
10:23:46	10:24:41				P2	No.
10:23:47	10:24:42				P1	We can make for the wind, we can make Cat II for the wind, we must take Cat I we need.
10:24:05	10:25:00				P2	Yes, Cat I, Cat I we need 800 metres.
10:24:12	10:25:07	Radar	CI642	DYNASTY 642, contact Approach 119.35.		
10:24:17	10:25:12	CI642	Radar	119.35, DYNASTY 642, good day.		
10:24:34	10:25:29	CI642	Appr	Hong Kong, DYNASTY 642 passing 150 for 130 and we have information X-ray.		
10:24:43	10:25:38	Appr	CI642	DYNASTY 642, good evening and Roger, descend 8000 feet, QNH 986		

RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
TIME UTC	ATC	FDR	FROM	TO	ORIGIN	
10:24:49	10:25:44	CI642	Appr	8000 feet and 896.	P1	986.
10:24:52	10:25:47					
10:24:54	10:25:49	CI642	Appr	986, DYNASTY 642.	P1	<i>Anti-ice for the water.</i>
10:24:58	10:25:53	CI642	Appr	That's correct, QNH 986 is current.	P1	<i>What speed be addable for landing?</i>
10:25:01	10:25:56	CI642	Appr	Roger.	P1	<i>157, we need 20 more that means 17, 170 correct?</i>
10:25:20	10:26:15					
10:25:46	10:26:41				P1	<i>And the medium for the braking action, eh?</i>
10:26:14	10:27:09				P1	<i>Now is clean, we need now is the spray for the water but the China Airline has no spray, very effective with the heavy rain.</i>
10:26:21	10:27:16				P2	<i>If we cannot see, we just go-around.</i>
10:26:35	10:27:30				P1	Yes, yes.
10:26:38	10:27:33				P1	<i>See the light at 400 feet.</i>
10:26:41	10:27:36	Appr			P1	<i>Why are they requesting 25L?</i>
					P1	<i>Should be a reason.</i>
					P2	<i>For us?</i>
					P1	<i>No, I mean Cathay requesting 25L.</i>
					P2	<i>Parking gate?</i>
					P1	<i>Ah, no.</i>
10:27:54	10:28:49					
10:27:55	10:28:50					
10:28:00	10:28:55					
10:28:01	10:28:56					
10:28:02	10:28:57	CI642	CI Ops	Operations, DYNASTY 642.		

TIME UTC	RTF COMMUNICATION				FLIGHT DECK COMMUNICATION	REMARKS
ATC	FDR	FROM	TO	ORIGIN		
10:28:06	10:29:01	CI Ops	CI642	642 go-ahead. Parking gate?		
10:28:08	10:29:03	CI642	CI Ops	Gate is S29.		
10:28:10	10:29:05	CI Ops	CI642	Our parking gate is 29.		
10:28:18	10:29:13	CI642	CI Ops			
10:29:01	10:29:56					1000 feet before assigned altitude.
10:29:55	10:30:50					
10:30:15	10:31:10	Appr	CI642	'Altitude': <i>Wind is pushing</i>	P1	
10:30:21	10:31:16	CI642	Appr	DYNASTY 642, turn right by the heading of 010, descend 6000 feet.		
10:30:42	10:31:37	Appr	CI642	Heading 010, descend 6000 feet, DYNASTY 642.		
10:30:47	10:31:42	CI642	Appr	DYNASTY 642, reduce speed 220 knots.	P1	
10:30:48	10:31:43	CI642	Appr	220 knots.		
10:31:35	10:32:30					
10:32:47	10:33:42	Appr	CI642	'Altitude': Speed 220 knots, DYNASTY 642.	Area	
10:32:53	10:33:48	CI642	Appr	DYNASTY 642, turn left heading 340, descend 4500 feet, DYNASTY 642.		
				Heading 340, descend 4500 feet, DYNASTY 642.		
10:34:20	10:35:15				P1	Non-pertinent cockpit conversation
10:34:22	10:35:17				P2	Slat extend. Slat extend.

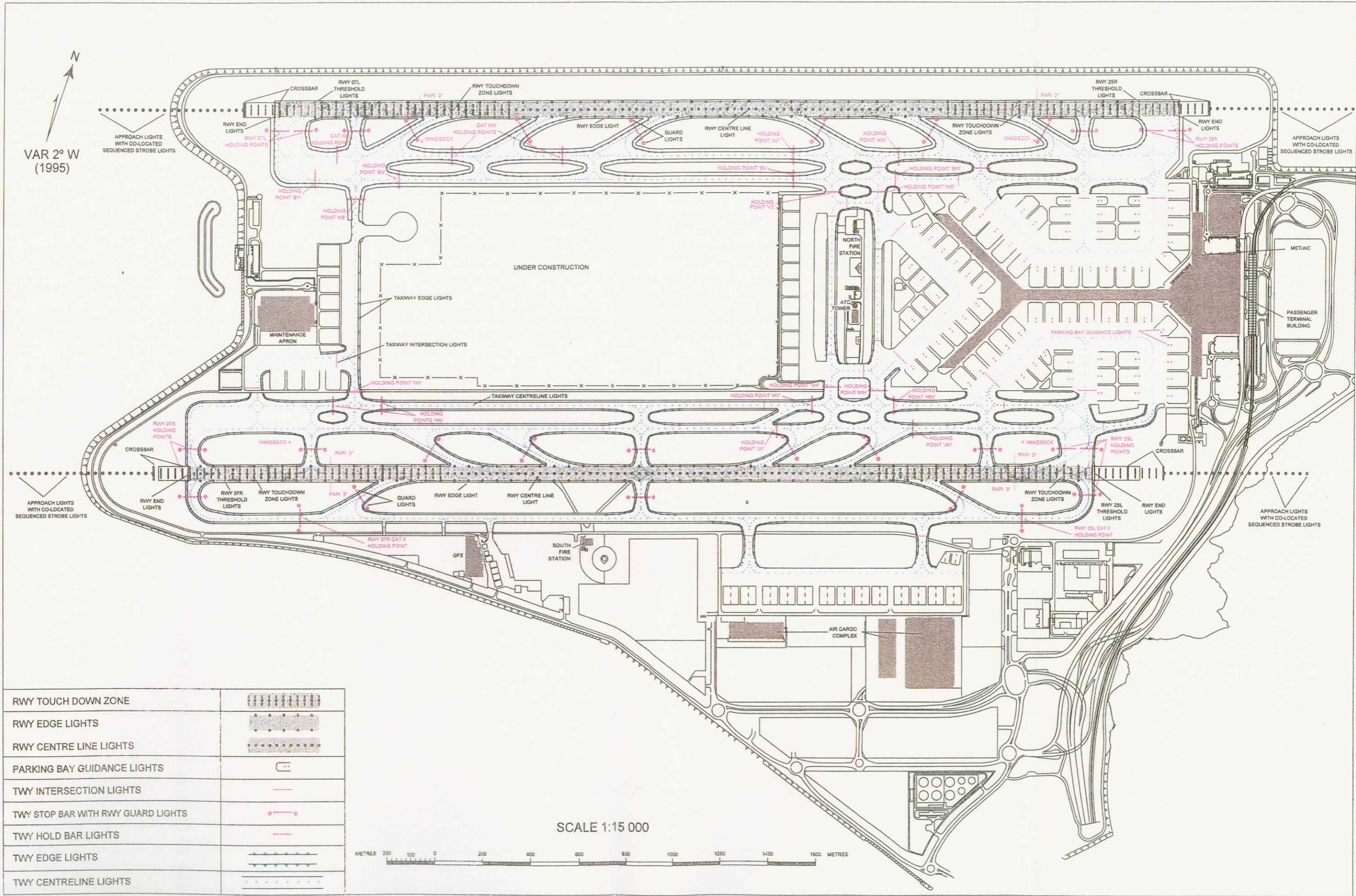
RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
TIME UTC	ATC	FDR	FROM	TO	ORIGIN	
10:34:31		10:35:26	Appr	CI642	DYNASTY 642, confirm your speed?	
10:34:34		10:35:29			P1	
10:34:34		10:35:29	CI642	Appr	220.	
10:34:35		10:35:30	Appr	CI642	Roger reduce to 180 knots, I will take your slightly through the localiser for spacing.	
10:34:41		10:35:36			P1	
10:34:44		10:35:39				Flap 15.
10:34:55		10:35:50				We are down to Foxtrot Romeo ILS.
10:35:00		10:35:55	Appr	CI642	DYNASTY 642, turn left on heading 230 to intercept the localiser from the right side, clear ILS approach runway 25L.	
10:35:09		10:36:04			P1	
10:35:13		10:36:08	Appr	CI642	Heading 230, confirm clear for ILS 25L?	
10:35:21		10:36:16				DYNASTY 642, heading 230 to intercept the localiser from the right side, clear ILS 25L.
10:35:26		10:36:21	Appr	CI642	Roger, heading 230, clear for ILS 25L, what RVR now?	
10:35:42		10:36:37			P2	RVR is showing on runway 25L at the touchdown point 1300, at the midpoint 1600, at the stop end 1700 metre.
10:35:44		10:36:39	Appr			Thank you sir.

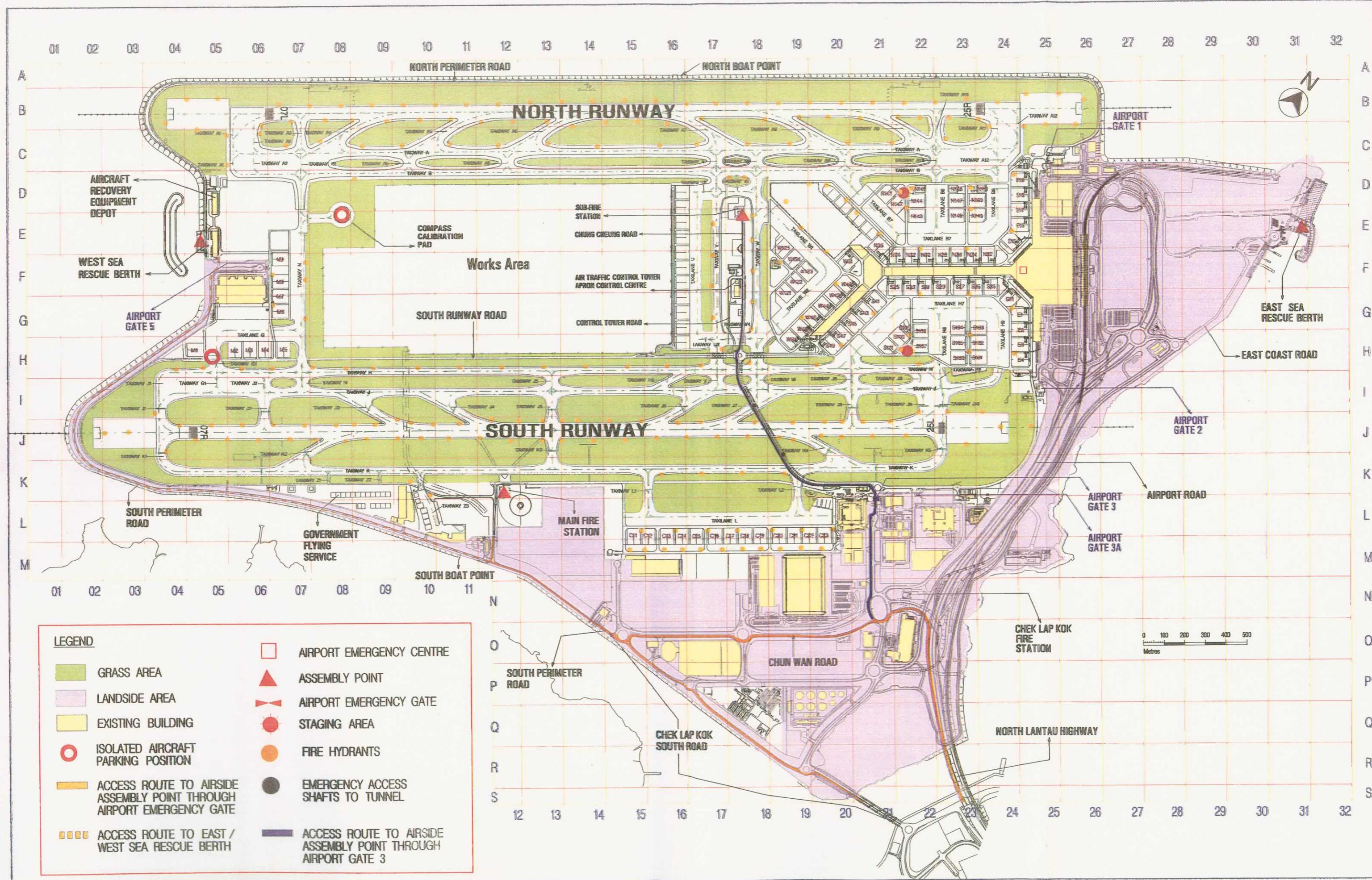
RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
TIME UTC	ATC	FDR	FROM	TO	ORIGIN	
10:35:55	10:36:50				P1	<i>IFL, 25L, APPROACH/LAND so then go-around in sequence.</i>
10:36:01	10:36:56				P2	<i>25L minimum is 22, 227 right? 25L minimum is 227.</i>
10:36:17	10:37:12				P1	<i>2000, then go to PRAWN, climb 4500, turn left 165.</i>
10:36:26	10:37:21				P1	<i>Speed is 185?</i>
10:36:29	10:37:24				P2	<i>Sorry 180 max 185 when establish on 165.</i>
10:36:31	10:37:26				P1	<i>LOC is alive, do we have the new yes 25R, we still have the 25R.....</i>
10:36:35	10:37:30				P1	<i>Remainder blotted out by incoming transmission at 10:37:07.</i>
10:36:46	10:37:41				P1	
10:37:07	10:38:02	Appr	CI642	<i>DYNASTY 642, you coming up the localiser now, maintain your speed 180 knots until 7 DME. Speed 180 knots until 7 DME, DYNASTY 642.</i>	P1	<i>For the go-around please Yes, standby.</i>
10:37:15	10:38:10	CI642	Appr		P2	<i>14 miles leaving 4500, correct.</i>
10:37:19	10:38:14				P1	
10:37:21	10:38:16					
10:38:23	10:39:18					
10:38:28	10:39:23	Appr	CI642	<i>DYNASTY 642, reduce speed now to 160 knots, contact Hong Kong Tower 118.4.</i>	P1	
10:38:35	10:39:30	CI642	Appr	<i>160 knots, 118.4, DYNASTY 642.</i>	P2	

RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
TIME UTC	ATC	FDR	FROM	TO	ORIGIN	
10:38:48	10:39:43	CI642	Tower	Tower, DYNASTY 642 with you on ILS 25L, 13 DME.		
10:38:56	10:39:51	Tower	CI642	DYNASTY 642, Hong Kong Tower, good evening, continue the approach 25L, number two, touchdown wind 230 degrees 26 knots gusting 36.		
10:39:04	10:39:59	CI642	Tower	Continue approach 25L, DYNASTY 642.		
10:39:36	10:40:31	Tower	CI642	Wind check acknowledge, 330 degrees 26 knots gusting 36 now.	P1	We can't do it, another wind check below 1000 feet.
10:39:59	10:40:54				P2	OK.
	10:40:04	10:40:59			P1	Gear down.
	10:40:07	10:41:02			P2	Gear down.
	10:40:08	10:41:03			P1	Go-around ready?
	10:40:22	10:41:17			P2	Yes.
	10:40:23	10:41:18			P1	2000.
	10:40:24	10:41:19			P2	Actually 4500.
	10:40:34	10:41:29			P1	2000 until 3 mile.
	10:40:36	10:41:31			P2	2000 until 3 mile.
	10:40:38	10:41:33			P1	Now is 330, OK flap 35.
	10:40:50	10:41:45			P2	Flap 35, medium.
	10:40:54	10:41:49			P1	Final checklist.
	10:41:10	10:42:05			P2	Final checklist, gear?
	10:41:12	10:42:07			P1	Negative.
	10:41:13	10:42:08	Tower	CI642		
	10:41:14	10:42:09	CI642	DYNASTY 642, copy?	P2	
	10:41:15	10:42:10	Tower	Negative.	P1	

RTF COMMUNICATION				FLIGHT DECK COMMUNICATION		REMARKS
TIME UTC	ATC	FDR	FROM	TO	ORIGIN	
10:41:17	10:42:12	Tower	CI642	DYNASTY 642, braking action is good. Thank you.	P2	Gear, 4 green, autobrake medium, Final word(s) blotted out by incoming RTF at 10:41:31.
10:41:20	10:42:15	CI642	Tower			
10:41:22	10:42:17					
10:41:31	10:42:26	Tower	CI642	DYNASTY 642, the visibility at touchdown 1600 metre, touchdown wind 320 degrees at 25 knots, gust 33 knots, run way 25L clear to land. Clear to land runway 25L, thank you.	P2	Dual land.
10:41:44	10:42:39	CI642	Tower		P1	Check list?
10:41:53	10:42:48				P2	Completed.
10:41:56	10:42:51				P2	Speed.
10:41:57	10:42:52				P2	'1,000'.
10:42:10	10:43:05				Area	
10:42:15	10:43:10					
10:42:18	10:43:13					
10:42:31	10:43:26					
10:42:37	10:43:32	CI 642	Tower	Approach light, approach light ahead, do you need the wind again?	P1	No, yes, wind check, wind check.
10:42:40	10:43:35	CI 642	Tower		P2	OK, now in sight 6
10:42:44	10:43:39	CI 642	Tower			
10:42:48	10:43:43	CI642	Tower	DYNASTY 642, wind check again?		
10:42:51	10:43:46			DYNASTY 642, just about to give you that, 320 degrees 28 knots gusting 36 knots.		
				Thank you and we have the runway in sight around 700 feet.	Area	'500'.

TIME UTC		RTF COMMUNICATION			FLIGHT DECK COMMUNICATION		REMARKS
ATC	FDR	FROM	TO		ORIGIN		
10:42:52	10:43:47	Tower	CI642	DYNASTY 642.	Area		Warning sound for autopilot disengage.
10:42:53	10:43:48						
10:42:57	10:43:52				P2		<i>Go-around speed 185.</i>
10:43:08	10:44:03				P2		<i>Left of course.</i>
10:43:15	10:44:10				P2		<i>Speed.</i>
10:43:19	10:44:14				'100'.		
10:43:23	10:44:18				Area		<i>50, 40, 30, 20, 10'.</i>
10:43:26	10:44:21				Area		
10:43:30	10:44:25				Area		
							Sound of touchdown.
							End of recording.



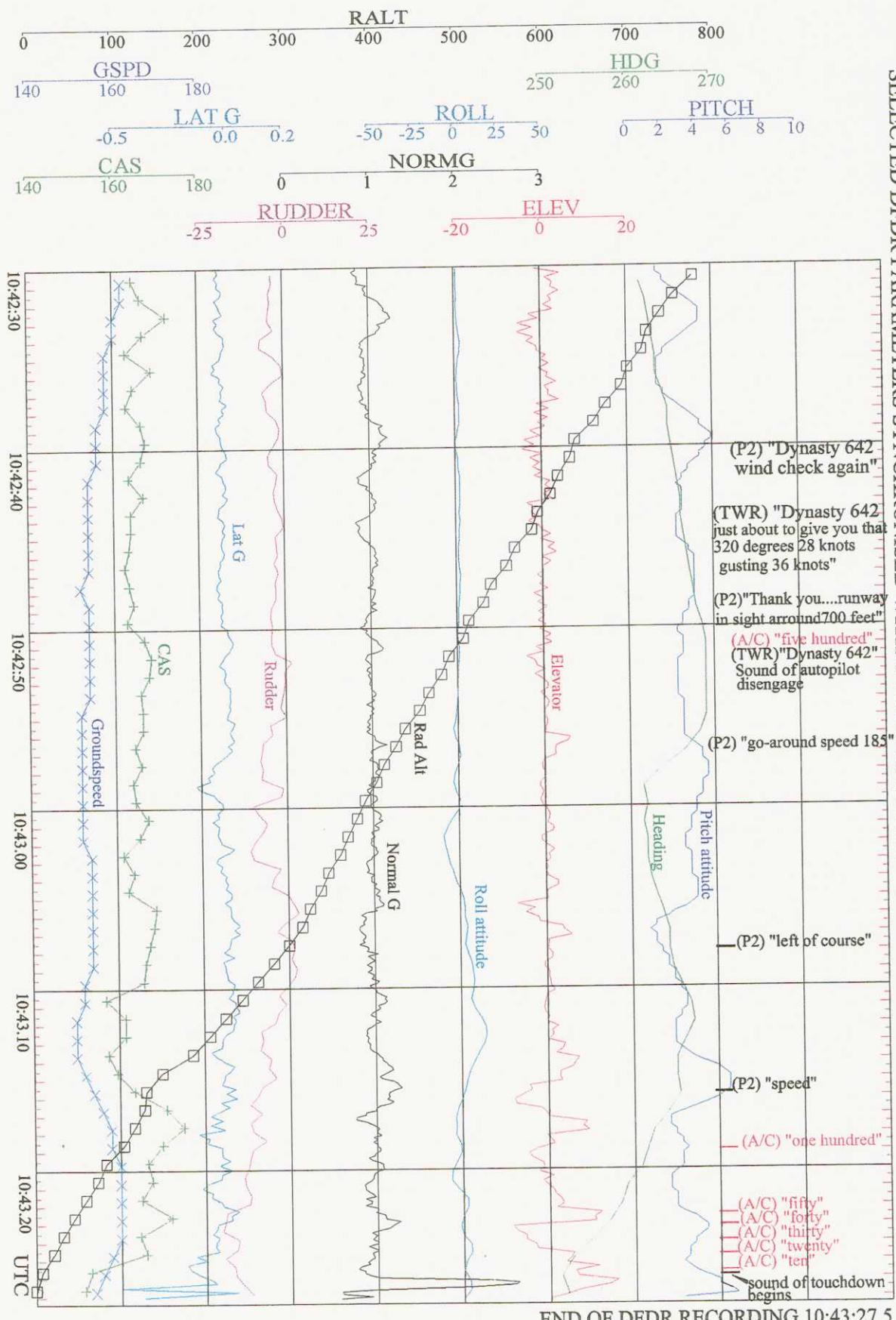


Tabulated FDR Data - 500 feet RA to Touchdown

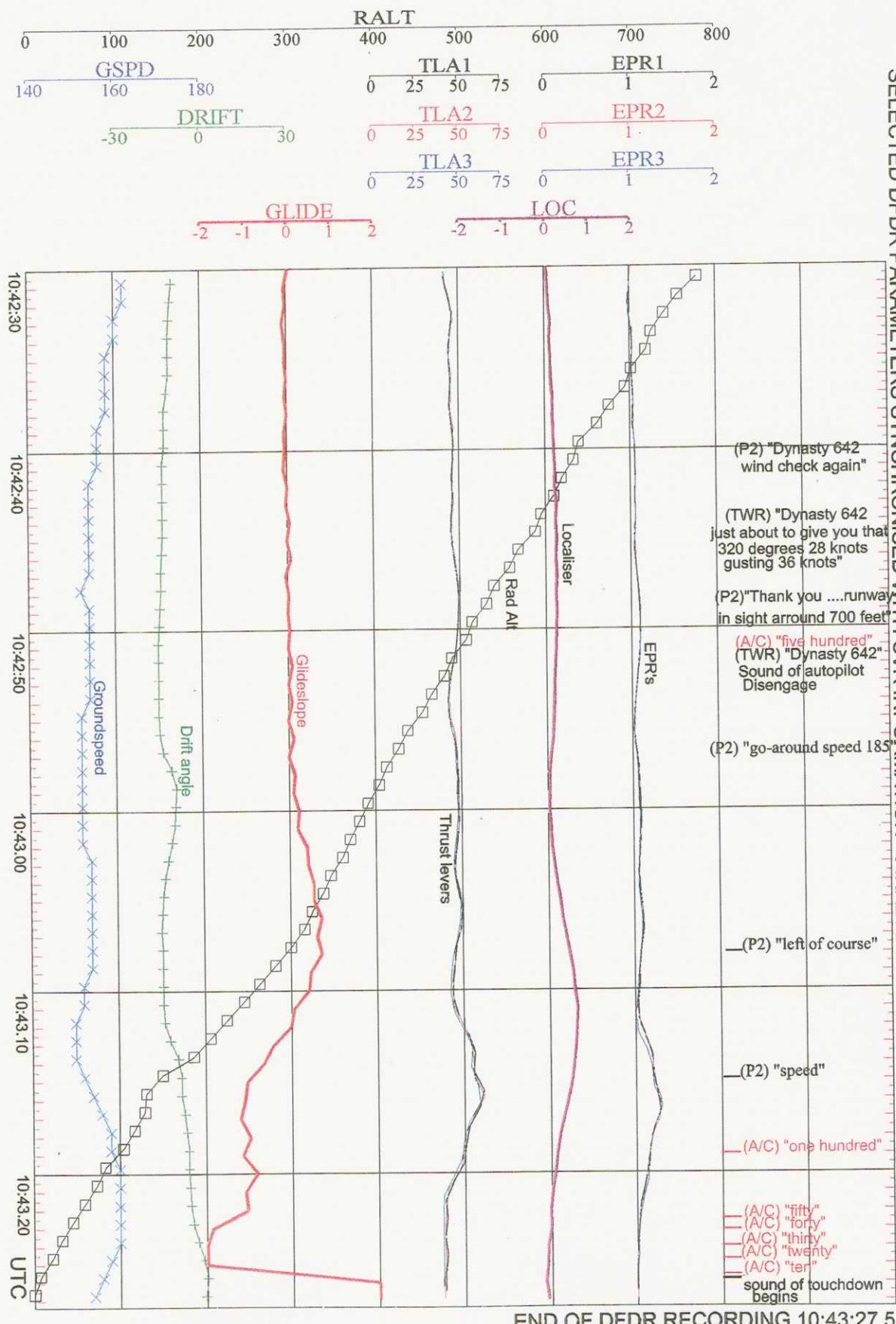
Line	Flight	Time	Alt	R	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AV	AW	AX	AY	AZ	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	B33	B34	B35	B36	B37	B38	B39	B40	B41	B42	B43	B44	B45	B46	B47	B48	B49	B50	B51	B52	B53	B54	B55	B56	B57	B58	B59	B60	B61	B62	B63	B64	B65	B66	B67	B68	B69	B70	B71	B72	B73	B74	B75	B76	B77	B78	B79	B80	B81	B82	B83	B84	B85	B86	B87	B88	B89	B90	B91	B92	B93	B94	B95	B96	B97	B98	B99	B100	B101	B102	B103	B104	B105	B106	B107	B108	B109	B110	B111	B112	B113	B114	B115	B116	B117	B118	B119	B120	B121	B122	B123	B124	B125	B126	B127	B128	B129	B130	B131	B132	B133	B134	B135	B136	B137	B138	B139	B140	B141	B142	B143	B144	B145	B146	B147	B148	B149	B150	B151	B152	B153	B154	B155	B156	B157	B158	B159	B160	B161	B162	B163	B164	B165	B166	B167	B168	B169	B170	B171	B172	B173	B174	B175	B176	B177	B178	B179	B180	B181	B182	B183	B184	B185	B186	B187	B188	B189	B190	B191	B192	B193	B194	B195	B196	B197	B198	B199	B200	B201	B202	B203	B204	B205	B206	B207	B208	B209	B210	B211	B212	B213	B214	B215	B216	B217	B218	B219	B220	B221	B222	B223	B224	B225	B226	B227	B228	B229	B230	B231	B232	B233	B234	B235	B236	B237	B238	B239	B240	B241	B242	B243	B244	B245	B246	B247	B248	B249	B250	B251	B252	B253	B254	B255	B256	B257	B258	B259	B260	B261	B262	B263	B264	B265	B266	B267	B268	B269	B270	B271	B272	B273	B274	B275	B276	B277	B278	B279	B280	B281	B282	B283	B284	B285	B286	B287	B288	B289	B290	B291	B292	B293	B294	B295	B296	B297	B298	B299	B300	B301	B302	B303	B304	B305	B306	B307	B308	B309	B310	B311	B312	B313	B314	B315	B316	B317	B318	B319	B320	B321	B322	B323	B324	B325	B326	B327	B328	B329	B330	B331	B332	B333	B334	B335	B336	B337	B338	B339	B340	B341	B342	B343	B344	B345	B346	B347	B348	B349	B350	B351	B352	B353	B354	B355	B356	B357	B358	B359	B360	B361	B362	B363	B364	B365	B366	B367	B368	B369	B370	B371	B372	B373	B374	B375	B376	B377	B378	B379	B380	B381	B382	B383	B384	B385	B386	B387	B388	B389	B390	B391	B392	B393	B394	B395	B396	B397	B398	B399	B400	B401	B402	B403	B404	B405	B406	B407	B408	B409	B410	B411	B412	B413	B414	B415	B416	B417	B418	B419	B420	B421	B422	B423	B424	B425	B426	B427	B428	B429	B430	B431	B432	B433	B434	B435	B436	B437	B438	B439	B440	B441	B442	B443	B444	B445	B446	B447	B448	B449	B450	B451	B452	B453	B454	B455	B456	B457	B458	B459	B460	B461	B462	B463	B464	B465	B466	B467	B468	B469	B470	B471	B472	B473	B474	B475	B476	B477	B478	B479	B480	B481	B482	B483	B484	B485	B486	B487	B488	B489	B490	B491	B492	B493	B494	B495	B496	B497	B498	B499	B500	B501	B502	B503	B504	B505	B506	B507	B508	B509	B510	B511	B512	B513	B514	B515	B516	B517	B518	B519	B520	B521	B522	B523	B524	B525	B526	B527	B528	B529	B530	B531	B532	B533	B534	B535	B536	B537	B538	B539	B540	B541	B542	B543	B544	B545	B546	B547	B548	B549	B550	B551	B552	B553	B554	B555	B556	B557	B558	B559	B560	B561	B562	B563	B564	B565	B566	B567	B568	B569	B570	B571	B572	B573	B574	B575	B576	B577	B578	B579	B580	B581	B582	B583	B584	B585	B586	B587	B588	B589	B590	B591	B592	B593	B594	B595	B596	B597	B598	B599	B600	B601	B602	B603	B604	B605	B606	B607	B608	B609	B610	B611	B612	

Tabulated FDR Data - 500 feet RA to Touchdown

SELECTED DFDR PARAMETERS SYNCHRONISED WITH CVR INFORMATION - FINAL APPROACH AND LANDING

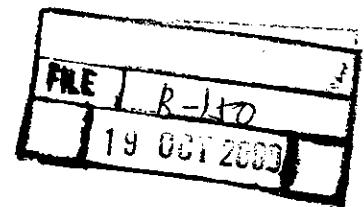


SELECTED DFDR PARAMETERS SYNCHRONISED WITH CVR INFORMATION - FINAL APPROACH AND LANDING



The Boeing Company
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13 October 2000
B-H200-17074-ASI



Mr. Y. K Leung
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10/F Commercial Building
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2 Chun Wan Road
Chek Lap Kok
Hong Kong


BOEING

Subject: Sink Rate Calculations - China Airlines MD11 B-150 Accident
Hong Kong – 23 September 1999

Reference: E-mail Jim Adams to Rick Howes, item ii, 25 September 2000

Dear Mr. Leung:

Per the reference request, the following provides the methodology used to calculate the sink rate of the subject airplane. The sink rate calculation uses an Adams-Bashforth 2-integration scheme, starting 35 seconds before the airplane contact with the runway. The initial sink rate is determined by using the change in radio altitude over one second. When the initial sink rate has been established, the vertical acceleration is integrated using the following equations from the Adams-Bashforth 2-integration scheme:

$$Vz(1) = \text{radalt}(2) - \text{radalt}(1)$$

$$Vz(i) = Vz(i-1) + (1.5 \cdot nz(i) \cdot g - 0.5 \cdot nz(i) \cdot g) \cdot dt$$

Where Vz is the sink rate, nz is the vertical acceleration – 1, g is the gravitational acceleration of 32.2 ft/s^2 , and dt is the time difference between samples.

A script was created to loop through these calculations to develop a time history of the sink rate for the final 35 seconds of the flight. Since the impact (right main landing gear contact with runway surface) sink rate is dependent on the value used for the starting sink rate, the starting point is moved forward by one second and the sink rate is recalculated using the new starting point.

To verify the calculated sink rate is accurate, it is integrated to calculate the radio altitude. This calculated radio altitude is then compared with the radio altitude recorded on the DFDR. Any difference in these values is corrected by adding a bias to the vertical acceleration and recalculating the sink rate and radio altitude.

Page 2
Y.K. Leung
B-H200-17074-ASI

A calculated sink rate of approximately 18 feet per second was determined using the above methods for this accident. The attached plots show the sink rate calculations for each of the starting points, which is approximately 18 feet per second. The second plot shows the radio altitude calculations with the recorded radio altitude (raw and adjusted for terrain height).


BOEING

If you have any further questions, please do not hesitate to contact me.

Very truly yours,



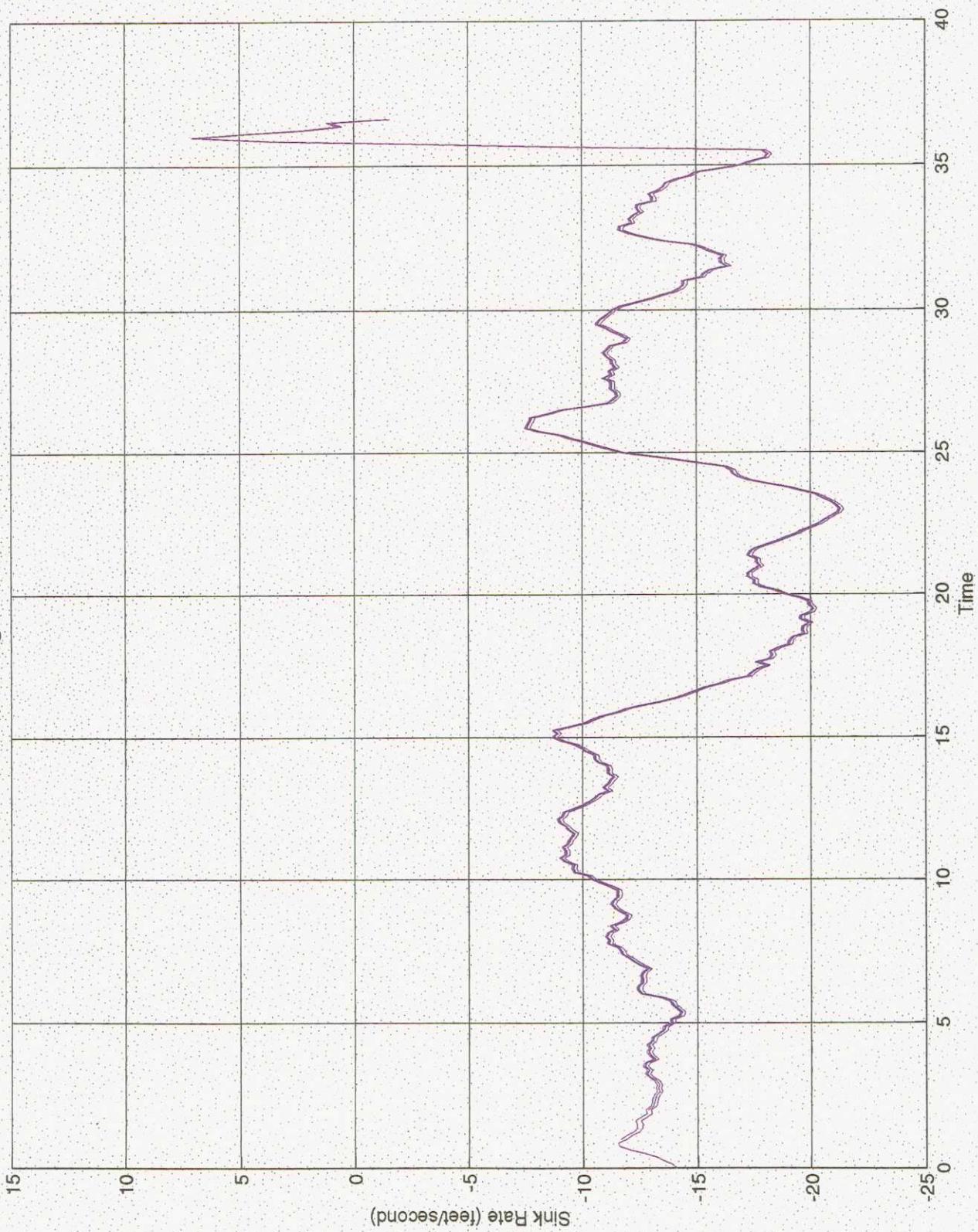
cc: Ronald J. Hinderberger
Director, Airplane Safety
Org. B-H200, MC 67-PR
Telex 32-9430, STA DIR AS
Phone (425) 237-8525
Fax (425) 237-8188

Encl:

- Boeing Figure 1, *CHI 642 Integrated Sink Rates*, and Figure 2, *CHI 642 Radio Altitude*

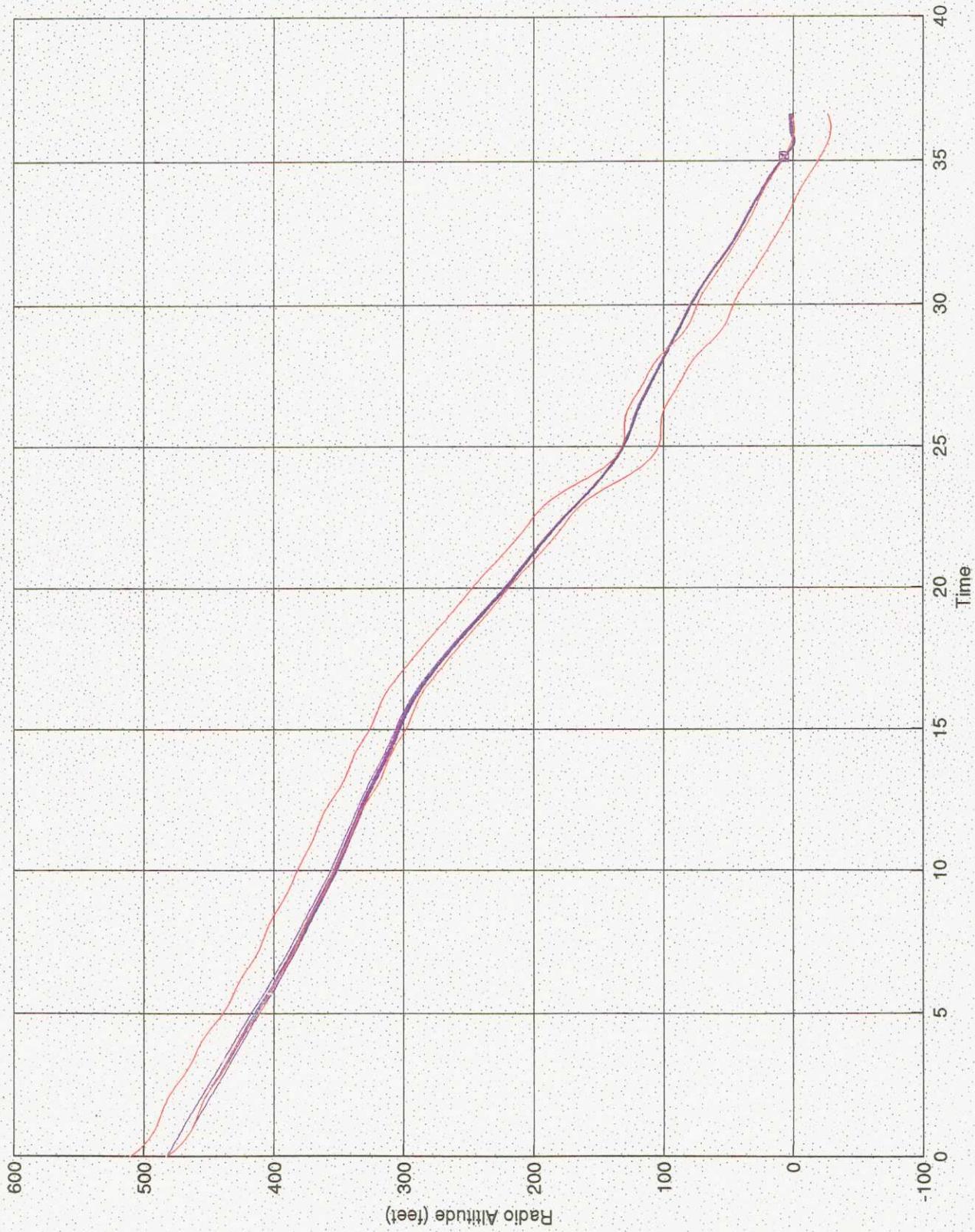
cc: Mr. Bob Benzon, NTSB, AS-10 (for Mr. John O'Callaghan)
Dr. Kay Yong, Taiwan ASC,
Captain Samson Yeh, China Airlines

CI 642 Integrated Sink Rates



A14-3

CI 642 Radio Altitude



WRECKAGE INFORMATION

1. Fuselage

The fuselage was found inverted at the main wreckage with severe impact damage and fire damage (Figure 1). The crown of the fuselage was crushed downward for the entire length (nose to tail). The pilot and co-pilot's windows were cracked and the side windows were pulled out and were lying outside the cockpit. There was no evidence of any bird strike or foreign object damage on the cockpit windows. The right side of the fuselage suffered slight impact damage just aft of the R1 entry door. The skin at this location was torn in the vertical direction (Figure 2).

The remaining fuselage on the right side was intact and suffered no impact damage. There was evidence of heavy external soot and fire damage on the skin and right wing fairing just forward of the right wing front spar. The lower wing fairing aft of the right main landing gear wheel well exhibited severe scrape/grind marks. These scrape marks were at 30 degrees angle (nose left orientation).

About a 10-feet section of the right wing upper and lower skins with front and rear spars remained attached to the fuselage (Figure 3). The trapezoid fitting which connects the fixed and folding retractable side brace of the right main landing gear remained attached to the fuselage. This fitting suffered no fire damage and was fractured in tension at the brace connection. The fractured surface exhibited overload features. This fracture surface area was cut from the fitting for detailed metallurgical examination. The right main landing gear had separated from the wing and fuselage point and was found near the aft right side of the fuselage under the right horizontal stabilizer (Figure 4).

The left fuselage suffered crushing damage just aft and forward of the L1 entry door. A large section of the fuselage common to L2 door from Station 735 to Station 1059 was pushed out (Figure 5). The remaining portion of the fuselage remained intact with minor impact damage. The aft section of fuselage suffered external fire damage and soot damage on left and right sides.

2. Wings

2.1. Left wing

The left wing remained attached to the fuselage and was found at the main wreckage (Figure 6). The inboard section of the wing exhibited evidence of sooting. There was evidence of scrape marks on the upper wing skin in a span-wise direction outboard of no.1 engine location. The leading edge at the inboard section was slightly damaged and suffered fire damage. The leading edge at the no.1 engine location was crushed aft and slightly upwards. The inboard slats remained attached to the wing and were found in extended position (approximately 30 degrees position). The leading edge outboard of the no.1 engine suffered severe impact and fire damage at various locations. The slats outboard of the no. 1 engine remained attached to the wing and were in the extended position. The outboard end of the slat suffered fire damage. The wing structure outboard from Station 855 suffered severe fire damage with the structure exhibiting melting. The front and the rear spars of the outboard section suffered severe fire damage and had sagged. The wing tip suffered severe fire damage. The outboard aileron and the wing-lets were consumed by fire. The spoilers remained intact with no apparent damage.

The inboard flap and the inboard aileron remained attached to the wing structure. There was evidence of slight scrape marks on the upper surface of the flap. The outboard flap remained attached with minimum damage. The left main landing gear remained attached to the attachment fitting on the wing. There was no damage to the attachment fitting.

2.2. Right Wing

The right wing fractured between the no. 3 engine nacelle and the right side fuselage at Station 163 on the leading edge and Station 197 at the rear spar (Figure 3). About a 15-feet section of the front spar and a six-feet section of the rear spar remained attached to the fuselage. The upper and the lower skins

between the front and the rear spar of the inboard section remained attached to the fuselage and exhibited upwards bending. About a six-feet section of the outboard front spar separated from the upper skin near the fractured end and the spar cap was cracked. The remaining nine-feet section remained attached to the upper skin and exhibited no bending. The stringers between the front and rear spar exhibited upward bending. The fractured surface exhibited overload features. There was evidence of slight fire damage and soot damage on the front spar and associated structure. Some of the fractured surfaces were sooted. The soot/fire damage was not very significant as compared to the outboard section of the wing.

The wing outboard from the fracture was in one section and was found about 300 feet from the nose of the airplane in the main wreckage (Figure 7). The upper skin exhibited sooting from the fracture to Station 772 and was consumed by fire from Station 772 to the tip. There was a crack of about 30 inches long at the middle of the upper skin in a span-wise direction. The fractured surface on this crack was sooted. The upper skin was bulged upward 12 inches forward of the rear spar on the upper skin and the side rib. The upper skin bulge was 38x46 inches in area and bulged up for about two inches. The leading edge suffered severe impact damage and fire damage. The inboard slat was detached and recovered at the site. The middle and outboard slats suffered severe fire damage and remained attached to the leading edge. The leading edge from the fracture to Station 538 suffered fire damage. The inboard end of the leading edge suffered severe impact damage and was dented at various locations. The leading edge outboard of Station 538 was consumed by fire. There was no evidence of heavy scrape marks on the upper skin. Only light scrape marks were observed at the inboard end on the upper skin in a fore and aft direction. The wing tip suffered severe fire damage on the upper skin. The strobe lens reflector and the case with the bulb remained intact and suffered fire damage. There was no evidence of any scrape marks on the wing tip structure on the lower skin. The right wing lower skin was intact from the inboard fracture location to the tip and suffered severe fire damage. There was no evidence of any heavy scrape marks on the lower skin.

The inboard fractured end of the lower skin exhibited severe scrape marks and grinding on the edge of the skin at a 45-degree angle.

The inboard flap was missing and was found on the left side of the runway in the vicinity of the main wreckage. The inboard aileron and the outboard flap suffered severe fire damage and were separated from the wing. These control surfaces were found at close proximity to the right wing. The outboard aileron was consumed by fire along with the outboard section of the wing.

The engine pylon forward attachment fitting (tombstone fitting) that attached to the engine pylon remained attached to the front spar and was fractured across the middle. The fractured end exhibited evidence of bending aft. The forward wing pylon mount fitting was pulled downward at the forward end and was slightly bent inboard. The aft pylon mount fitting remained attached to the lower skin with no bending. The aft pylon mount remained attached to the lower skin and was slightly bent aft. All the fasteners on the aft mount bulkhead sheared.

The forward and aft main landing gear attach fitting suffered severe damage. The aft lug of the forward mount fractured between 4 o'clock to 10 o'clock position (view looking forward - see Figure 8). The fractured surface exhibited soot accumulation and slight discoloration. The forward mount was cracked and exhibited impact damage in an upward direction. The forward mount shear pin was sheared off and a portion of the shear pin remained with the forward lug (Figure 9). The remaining piece was attached to the landing gear. The fractured surface on the shear pin was heavily sooted. The aft mount was fractured, and both the lugs along with a large piece of fitting remained attached to the landing gear including the shear pin (Figure 10). The entire area of the main landing gear fitting and fractured surfaces exhibited evidence of sooting. The piece of the head-end of the main landing gear actuator remained attached to the fitting.

3. Landing Gears

3.1. Right Main Landing Gear

The right main landing gear was separated from its mount. The forward shear pin was sheared off from the forward mount and half of the shear pin remained in the forward lug of the forward mount. This section of the shear pin was pushed out and exhibited severe soot damage on the fracture surface. The remaining portion of the shear pin remained on the forward lug of the landing gear and exhibited some bending. The fractured surface on this portion exhibited surface rust and the fractured surfaces could not be examined. The aft lug of the forward mount fractured between the 4 o'clock and 10 o'clock positions. This section of the lug fractured into two pieces and was found on the runway between the touchdown point and the main wreckage. The mating fractured surface on the wing forward mount aft lug exhibited some discoloration but the mating fractured surface of the lug that was found on the runway did not exhibit any discoloration. All surfaces on the aft lug exhibited evidence of overload features. There was no evidence of fire or soot on the pieces of lug found on the runway. The forward fitting that remained attached to the landing gear fitting suffered soot damage. The forward mount fractured in the middle and exhibited impact damage in an upward direction (Figure 8).

The landing gear fitting between the forward and aft mount fractured and a portion of the fitting was missing. This section was attached to the landing gear with the aft pin still in place. This piece also exhibited impact damage between the forward and aft mount. The landing gear fitting between the forward and aft mounts suffered severe soot damage and the soot was evident on the fracture surfaces.

The right main landing gear strut remained intact and was fully extended at the main wreckage site. The strut was deflated later for safe handling. The folding side brace remained attached to the gear. The upper rib of the folding side brace was fractured and twisted near the end that attached to the fuselage. A small

section of the fixed brace remained attached to the trapezoidal fitting along with the folding side brace (Figure 11). The trapezoidal fitting fractured from the trapezoidal panel that attached to the fuselage (Figure 12). The trapezoidal panel pillow block remained attached to the fixed and folding brace. The fractured surface exhibited evidence of overload features. There was no evidence of fire damage or soot damage to the right main landing gear.

The truck beam suffered impact damage and was cracked at the aft stop location on the upper surface. The forward stop exhibited severe impact damage on the upper surface. All four tyres remained attached to the truck beam. The outboard tyres remained inflated and the pressures in the tyres were 200 psi each. The inboard tyres were deflated. The inboard side-wall of the inboard tyres exhibited severe scuff marks generally in radial direction. There was no evidence of any fire damage to the landing gear tyres.

3.2. Centre Landing Gear

The centre landing gear fractured at the bottom of the cylinder (oleo) near the axle (Figure 13). The fractured surface exhibited overload features with a 45-degree shear lip and was severely rusted. The wheel truck with tyres was found on the runway near the main wreckage. There was evidence of heavy impact damage on the right hydraulic brake reservoir that attached on the wheel. The heavy impact mark was a 3/8-inch wide indentation and ranged up to 1/2 inch deep. There was no evidence of any fire damage or soot damage to the centre gear truck assembly. Only one tyre was inflated and did not exhibit any scuff mark on the inner or outer side. The other tyre was deflated and suffered severe sharp cuts on its side.

The strut remained attached to the fuselage with the inner cylinder (oleo) compressed all the way in. The lower end of the strut exhibited grinding consistent with runway contact. These grind marks was approximately at 45 degrees with respect to airplane centreline and about 30 degrees nose left. These grind marks covered about 50% of the circumferential surface. The body gear remained attached to the fuselage. There was no evidence of any damage to the

gear-to-fuselage attachment point. There was no evidence of any fire damage on the centre landing gear.

A small section of the base of the oleo (lower cylinder) of about five inches long with torque link was separated from the centre gear. The fractured surfaces on both sides exhibited overload and were rusted.

3.3. Left Main Landing Gear

The left main landing gear remained attached to the wing and fuselage with its attachment point. There was no evidence of any impact damage or fire damage to the left main landing gear. The gear cylinder was extended and the gear was in the lock position with the folding and fixed side braces intact. The tyres remained attached to the truck beam assembly and suffered no damage.

3.4. Nose Landing Gear

The nose landing gear remained attached to the nose fuselage with minimum structural damage. The strut was in an extended position. The right tyre separated from the hub and was found near the main wreckage. The tyre exhibited heavy cut damage in the bead area of the tyre. The hub fractured circumferentially. The left tyre remained attached to the axle and was scuffed on the inboard side-wall. There was no evidence of fire damage to the nose landing gear.

4. Engine Pylons

4.1. No. 1 Engine Pylon

The no. 1 engine remained attached to the left wing at its forward attachment point. The forward attachment point is the tombstone fitting and remained fully attached to the upper and lower spar of the pylon. This tombstone fitting was bent forward about 60 degrees. The pylon separated at the rear mount fitting. The fitting fractured in the middle of the lug. The fractured surface exhibited evidence

of overload failure. There was no evidence of any fire damage to the pylon-wing attachment structure.

4.2. No. 2 Engine Pylon

The no.2 engine pylon was separated from the empennage and was found intact. The front portion of the inlet duct was separated from the engine and the vertical stabilizer broke off at the manufacturing joint on the top of the pylon.

4.3. Engine No. 3 Pylon

The no. 3 engine separated from the wing at its pylon attachment points and was found in the grassy area near the right wing (Figure 14). The front (tombstone fitting) pylon mount fractured about 24 inches from the upper wing skin. This fitting suffered severe fire damage and the web and the cap was bent aft at the fractured end. The tombstone fitting was attached to the wing front spar and pulled out of the pylon about five inches below the pylon upper spar. The upper spar that the front links were attached, was broken out of the pylon and attached to the wing mount. A large section of the tombstone fitting remained with the engine pylon. The web and the cap were bent forward with slight twisting. The rear engine mount and bulkhead separated from the pylon in one piece and remained attached to the wing. The rear engine mount separated from the left and right pylon skin and all the fasteners were pulled out of the skin. The upper spar cap at the outboard side of the pylon was bent in a "U" shape and the web/ skin separated from the cap indicating that the pylon was experiencing loads in the inboard direction. The upper spar cap at the inboard side remained attached to the web with no noticeable bending. The inboard pylon skin was bent inboard.

5. Empennage

The right horizontal stabilizer remained attached to the empennage with severe impact damage (Figure 4). The section outboard of Station 292 was bent down. The inboard section remained attached to the empennage. The right stabilizer suffered soot damage on the leading edge, upper and lower skins. The leading edge and lower skin exhibited

severe scrape marks and these scrape marks were on top of the sooted leading edge and skin. The scrape marks were in three distinct directions. One set of scrape marks near the leading edge ran in span-wise direction. The second set was about 30 degrees anti-clockwise from the span-wise direction (view looking down), while the third one was about 70 degrees anti-clockwise from the span-wise direction (view looking down). There were other scrape marks in various directions. These scrape marks are indication of runway contact. The leading edge of the stabilizer was dented and crushed at various locations. The outboard end of the leading edge was crushed aft. The inboard and outboard elevators remained attached to the horizontal stabilizer and suffered severe fire damage.

The left horizontal stabilizer fractured at Station 290 (Figure 15). The inboard section remained attached to the empennage with upper skin. This section exhibited upward bending. The lower skin was fractured at the root in a jagged fracture pattern. The front spar and the associated structure at the fractured location were bent aft. The upper and lower skin suffered soot damage. The inboard elevator remained attached with no impact damage but exhibited severe soot damage. The outboard elevator fractured at Station 290. There was no scrape marks observed on the inboard section of the horizontal stabilizer.

The vertical stabilizer right skin fractured approximately at Station 525 and at Station 426 on the left side (Figure 16). The left skin and the associated structure were bent to the left. The front spar fractured at Station 525 and the lower section of the front spar web was missing. The front spar at the fracture was bent slightly to the left. The rear spar fractured at Station 525 and was bent aft. The second fracture on the rear spar was at Station 444. At this location the spar was bent aft. The left skin from Station 525 was still attached to the upper vertical stabilizer but the right skin was missing. The upper forward and aft rudders remained attached to the vertical. The lower forward and aft rudders fractured at approximately Station 426. The rudder section below this station suffered severe fire damage. A portion of the lower vertical stabilizer (lower from Station 426) remained with the lower rudder and suffered fire damage. The vertical stabilizer fractured at the base just above the no.2 engine. The rear spar and aft centre spar fractured about 10 inches above the base and was bent aft. The forward centre and

front spar attachment point fractured six inches above the base and exhibited no bending. All the fractured surfaces exhibited evidence of overload.

6. Powerplants

The accident aircraft was powered by three Pratt & Whitney model PW4460 engines. All three engines were found at the crash site. None of the engines displayed signs of engine fire or non-contained events. All of the engine cowling and nacelle hardware was found forward of the aircraft touchdown area. The Full Authority Digital Engine Control (FADEC) was removed from each engine for analysis of engine fault information by the FADEC manufacturer. No further engine disassembly was required for investigation.

6.1. No. 1 engine; s/n: 723907 (Figure 17)

After the accident, no. 1 engine remained attached to the pylon structure. The engine and pylon had separated from the left wing at the front and rear pylon mounts. The engine was inverted, along with the wing, with the 12 o'clock position of the fan case resting on the ground. The inlet structure was separated from the engine forward of A-flange. The fan rotor and fan blades were intact. Fifteen of the fan blades were slightly bent opposite the direction of rotation. The other 21 fan blades were not significantly bent while two fan blades were slightly bent in the direction of rotation. The fan case showed signs of fan blade tip contact with the fan case attrition material. The Low Pressure Compressor (LPC) inlet vanes were intact and did not show signs of distress. No significant damage was found to the LPC blades and vanes that could be seen from the LPC inlet. The fan exit guide vanes were intact. The fan cowl doors were separated from the nacelle. The thrust reverser doors were found in the stowed position. The rear stages of the low-pressure turbine were intact and showed no indication of distress. No indication of engine failure or debris was found in the turbine exhaust case. The exhaust nozzle and tail cone remained intact and were not significantly distressed. There were no indications of any scrape marks on the engine nacelle.

6.2. No. 2 engine; s/n: 723968 (Figure 18)

After the accident, no. 2 engine remained attached to the inlet and engine mounting structure. The engine, inlet, and mounting structure separated from the aircraft along the diverter structure of the vertical stabilizer. The inlet duct was breached radially inward and forward of the fan face. Debris was found in the inlet duct in front of the fan face. The fan rotor and fan blades were intact. Foreign object impact damage was observed on the fan blades in the form of nicks and local deformations of the fan blade leading edges. The inlet, fan section, LPC, and bypass air surfaces were thinly covered in soot, consistent with the external, post-accident fire. No damage beyond slight foreign object damage was observed on the LPC inlet vanes or blades. The fan exit guide vanes remained intact. The fan cowl doors were separated from the fan case, one of which was found on the side of the runway. The bypass and core cowl doors remained on the engine and showed impact damage from external directions. The thrust reverser doors were found in the stowed position. No indication of engine distress was found on the 6th stage LPC blades or in the turbine exhaust case. The exhaust tail cone and nozzle remained attached to the engine.

6.3. No. 3 engine; s/n: 723952 (Figure 19)

After the accident, no. 3 engine remained attached to the pylon structure. The engine and pylon structure was separated from the right wing at both the front and rear pylon mounts. The engine mounts did not exhibit any signs of distress. The inlet duct separated from the engine immediately forward of A-flange. The inlet exhibited abrasion marks at the 6 o'clock position. The fan case separated from the engine at C-flange, just behind the fan exit guide vane outer platform mounts. The separated fan case structure showed no signs of non-containment. Engine externals mounted near the 6 o'clock position of the fan case exhibited abrasion marks. The fan containment belt, yellow in color, displayed heavy fraying in the 6 o'clock region. Fragments of the belt material were found on the runway. The fan hub was intact and contained all 38 fan blade attachments. Three fan blades

were fractured at roughly 50% span while 25 fan blades were fractured at the part-span shroud location. The remaining 10 fan blades were of full length and bent opposite the direction of fan rotation. The LPC shroud was intact, with the 1st stage LPC stators showing signs of foreign object damage. Ground debris was found throughout the bypass ducts and the LPC.

The upper intermediate case struts were deformed rearward, while the lower struts were crushed into the engine core cowl. The outer structure of the bypass duct, including the thrust reverser, was collapsed radially inward on both the left and right sides of the nacelle. Scuff marks consisting of gray paint were found at the 10 & 11 o'clock positions. Two pieces were removed for further examination. The right thrust reverser door was in the stowed position. The left thrust reverser door was separated from the engine, along with the thrust reverser cascades. The thrust reverser cascades were in place on the right side of the engine. The lowest external region of the thrust reverser doors exhibited two distinct patterns of abrasion or grinding. One of the patterns of abrasion was oriented roughly along the engine centreline in the fore to aft direction. The second pattern of abrasion was oriented approximately 35 degrees right of engine centreline, also in the fore to aft direction. The 6th stage low-pressure turbine blades showed no signs of distress. The lower third of the turbine exhaust case was crushed radially inward at T-flange; however, P-flange was only slightly deformed. No engine debris was found in the turbine exhaust case. The exhaust nozzle was separated from T-flange. The exhaust tail cone suffered radial impact at the 6 o'clock position, but remained attached to the turbine exhaust case.

GENERAL COMMENTS

All station numbers are approximate

Conventional sign orientation with the aeroplane on gear

No evidence of any inflight collision or fire



Main Wreckage (Figure 1)



Right-hand Forward Fuselage (Figure 2)



Right Wing Root Section (Figure 3)



Right Main Landing Gear and Right Horizontal Stabilizer (Figure 4)



Left Forward Fuselage (Figure 5)



Left Wing (Figure 6)



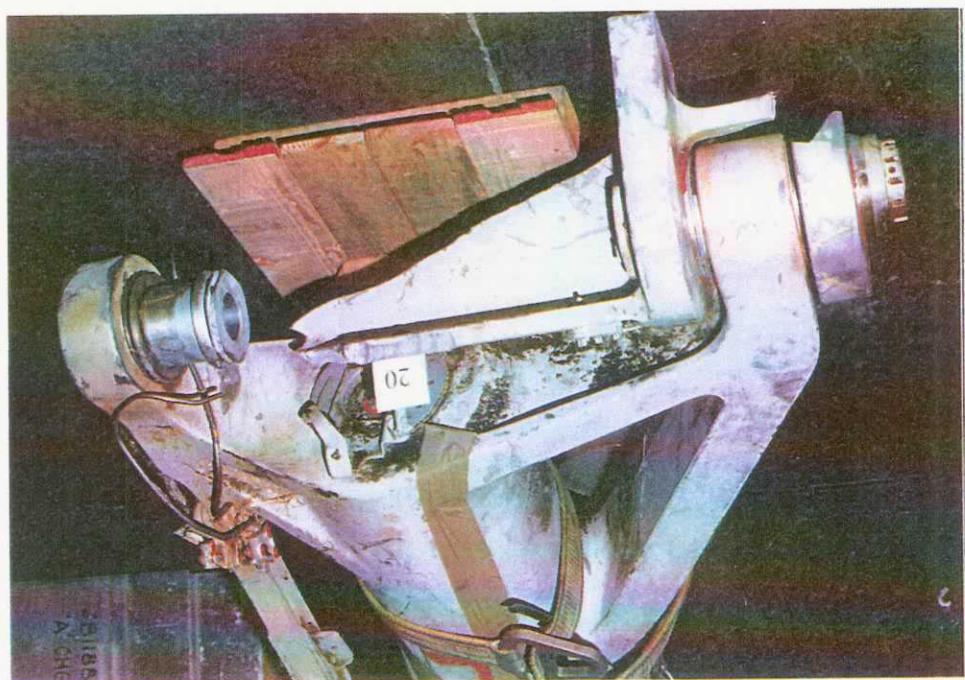
Right Wing Detached from Main Fuselage (Figure 7)



Right Main Landing Gear (RMLG) Forward Attachment Fitting (Figure 8)



Forward Shear Pin (Trunnion Bolt) (Figure 9)



**Fractured RMLG Aft Attachment Fitting with Aft Shear Pin (Trunnion Bolt)
(Figure 10)**



Fractured Fixed Side-Brace (Figure 11)



Fractured Trapezoidal Panel (Figure 12)



Fractured Center Landing Gear Oleo (Figure 13)



No. 3 Engine Pylon to Wing Forward Attachment Structure (Figure 14)



Left Horizontal Stabilizer (Figure 15)



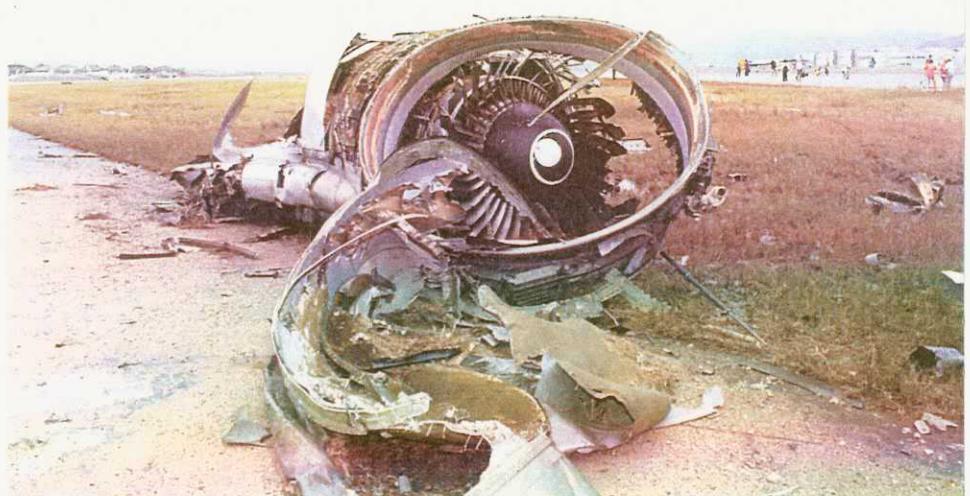
Vertical Stabilizer (Figure 16)



No.1 Engine (Figure 17)



No.2 Engine (Figure 18)



No.3 Engine (Figure 19)

SEAT LOCATIONS OF SERIOUSLY INJURED PERSONS

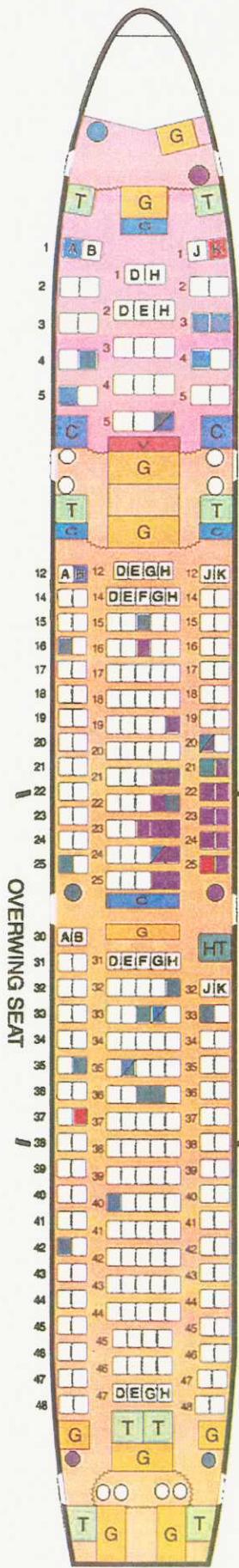
Appendix 16

圖示說明 KEY TO AMENITIES



LEGEND

-  — Dead (3 pax)
-  — Burn or Scald (21 pax, 3 F/A)
-  — Head Injury (10 pax, 1 F/A)
-  — Other Injuries (18 pax, 2 F/A)



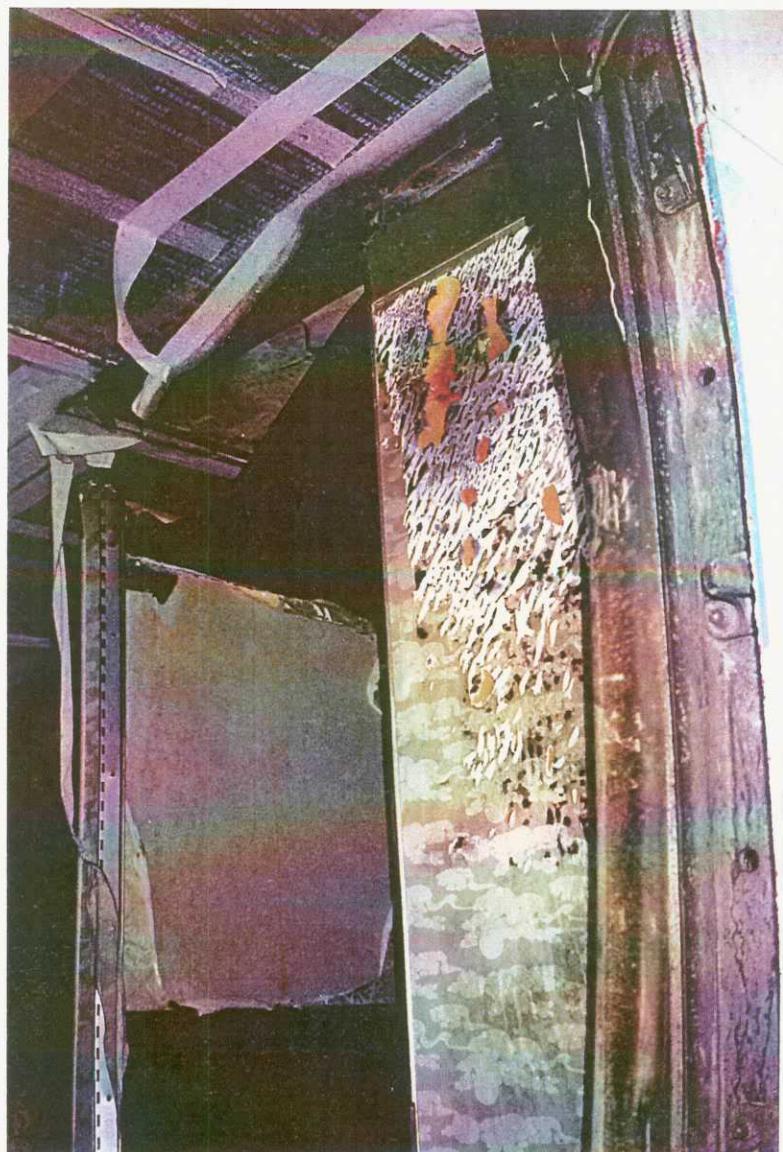
Photographs of Damaged Fuselage



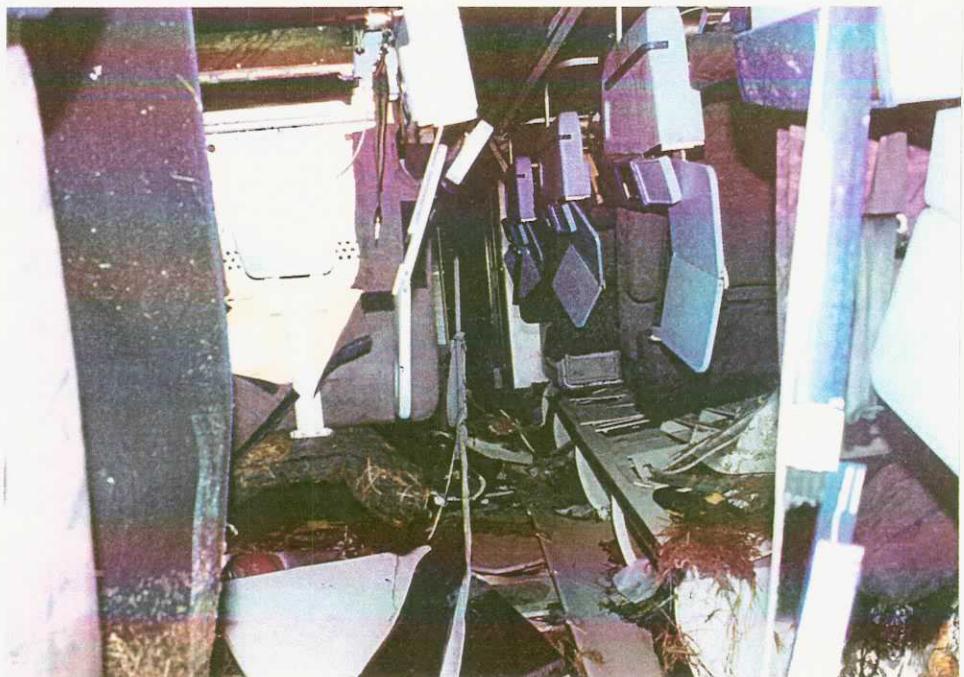
1. General view of main wreckage.



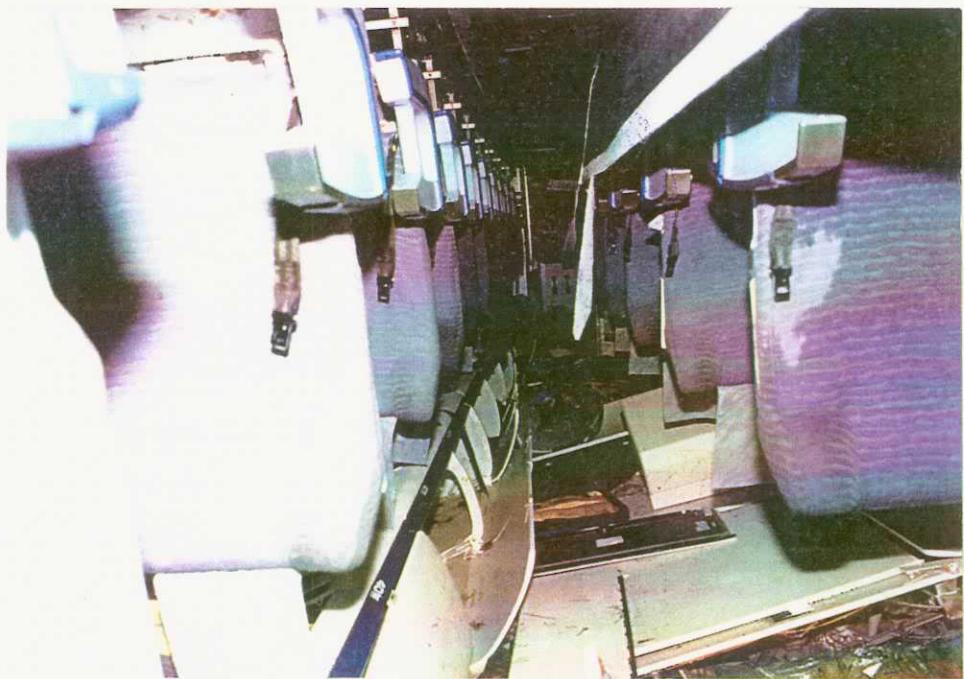
2. View of seats 1J and 1K.



3. View of the lavatory just inside Door 3R.



4. View of the Business Class section of the cabin.



5. View of the Economy Class section of the cabin.



6. View of right side of fuselage including Door 1R.



7. View of left side of fuselage including Door 3L.



8. View of crack in right fuselage (forward) including Door 2R.



9. View of crack in right fuselage (aft).

Enclosure to: B-H200-17041-ASI

MDC-00K1121

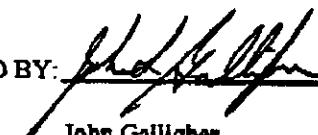
**Sequence and Characteristics of the Structural Failure of the Mandarin Airlines
(China Airlines) MD-11 Fuselage Number 518 – August 22, 1989 Accident at
Hong Kong International Airport**

REVISION: NEW

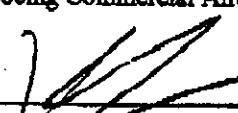
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TABLE OF CONTENTS

SECTION	PAGE NO.
TABLE OF CONTENTS	i
LIST OF FIGURES	ii
REFERENCES	iii
1.0 DESCRIPTION OF STRUCTURAL ARRANGEMENT	1
2.0 LANDING CONDITIONS	2
3.0 LANDING SIMULATION	2
4.0 STRUCTURAL FAILURE SEQUENCE	5
5.0 FORWARD TRUNNION BOLT FAILURE	5
6.0 DAMAGE TO THE MAIN-LANDING-GEAR-TO-WING ATTACH FITTING	7
7.0 REAR SPAR WEB FAILURE	7
8.0 INBOARD FLAP DEPARTURE	9
9.0 DAMAGE TO SIDE-BRACE-FITTING-TO-TRAP-PANEL JOINT AND TO THE FIXED AND FOLDING SIDE BRACES	13
10.0 DAMAGE TO THE MAIN LANDING GEAR TRUNNION ARMS AND ADDITIONAL DAMAGE TO THE MLG-TO-WING ATTACH FITTING	17
11.0 RIGHT HAND WING PYLON FAILURE MODE	19
12.0 SUMMARY	21

LIST OF FIGURES

FIGURE

PAGE NO.

1	MD-11 Structural Arrangement in the vicinity of the MLG-to-Wing attachment	1
2	MD-11 Dynamic Landing FE Model	2
3	Case 4.010 Landing Gear Loads for China Airlines Crash Scenario	4
4	Case 4.010 Key Loads for China Airlines Crash Scenario	4
5	Main-Landing-Gear-to-Wing Attach Arrangement	6
6	Damage to MLG-to-Wing Attach Fitting at the forward lugs	7
7	Right Wing Rear Spar Web Fracture from Ship 553 (FedEx - Newark)	8
8	Right Wing Rear Spar Web Fracture from Ship 518 (China Airlines)	8
9	Inboard Flap (Location relative to MLG)	9
10	Inboard Flap inboard support	9
11	Inboard Flap outboard support	9
12	Inboard Flap track and rollers	10
13	Inboard Flap rollers (flap removed)	10
14	Inboard Flap track and side rollers	10
15	Right Inboard Flap from Ship 518 (China Airlines)	11
16	Right Inboard Flap from Ship 553 (FedEx - Newark)	11
17	Right Inboard Flap track from Ship 518 (China Airlines)	12
18	Right Inboard Flap track from Ship 553 (FedEx-Newark)	12
19	Location of the side-brace-fitting-to-trap-panel joint	13
20	Side-brace-fitting-to-trap-panel joint (from inside the right wheel well)	13
21	Underside of the right trapezoidal panel	14
22	Side-brace-fitting-to-trap-panel joint (from aft and outside the right wheel well)	15
23	Evidence of contact between the fixed brace and the side brace fitting	15
24	Outboard end of the fixed brace from Ship 518 (China Airlines)	16
25	Outboard end of the fixed brace from Ship 553 (FedEx-Newark)	16
26	Outboard trap panel failure at the S-B-F-T-T-P joint	17
27	Right main landing gear strut from Ship 553 (FedEx-Newark)	17
28	Right MLG-to-wing attach fitting from Ship 553 (FedEx-Newark)	17
29	Wing fitting lugs that support the MLG forward trunnion	18
30	Separated pieces of the aft wing fitting lugs that support the MLG forward trunnion	18
31	Right main landing gear assembly	18
32	Aft trunnion arm of the right main landing gear strut	19
33	Right MLG-to-wing attach fitting from Ship 518 (China Airlines)	19
34	Inboard aft tire from the right main landing gear	19
35	Pylon-to-wing attachment details	20
36	Wing pylon "fusing" mechanism	20
37	Right engine pylon aft-attach bulkhead still attached to the right wing	21
38	Right engine pylon	21

REFERENCES

Reference 1 China Air Accident "Performance Group Report"
Reference 2 MDC-00K1008, "Materials and Process Engineering Report on Mandarin Airlines (China Airlines) MD-11 Fuselage Number 518 Accident at Hong Kong International Airport, Hong Kong, China"

1.0 DESCRIPTION OF STRUCTURAL ARRANGEMENT

A rendering of the MD-11 structural arrangement in the vicinity of the main landing gear is included as Figure 1. Note that the rendering is “artistic” in character and incorrectly shows some structure which should (from the view depicted) be hidden.

The MD-11 main landing gear is cantilevered off the rear spar of the wing. Two trunnion bolts attach the main landing gear strut (blue) to the wing fitting (green). The wing fitting attaches to the rear spar (yellow). Vertical, drag and side loads applied to the landing gear are reacted through the trunnion bolts into the wing fitting and from there into the main torque box of the wing.

The forward of the two main landing gear trunnion bolts is a designed “fuse”. For very high drag loads (as might be encountered during an off-runway excursion, or if the landing gear struck an obstruction) the forward bolt is designed to shear as the forward main landing gear trunnion moves downward.

Loads about the main landing gear pivot axis (gear sideloads) are reacted via a trusslike structure made up of the folding side brace (magenta), the fixed brace (light blue), and the strut. This arrangement results in loads which are primarily up and down (vertical) at the joint where the truss attaches to the fuselage. The loads at this joint are primarily up when an inboard acting sideload is applied to the landing gear, and down when the sideload is outboard.

The fuselage attach point for the truss is on a machined beam referred to as the “trap panel” because of its trapezoidal shape. The trap panel is shown in red in Figure 1.

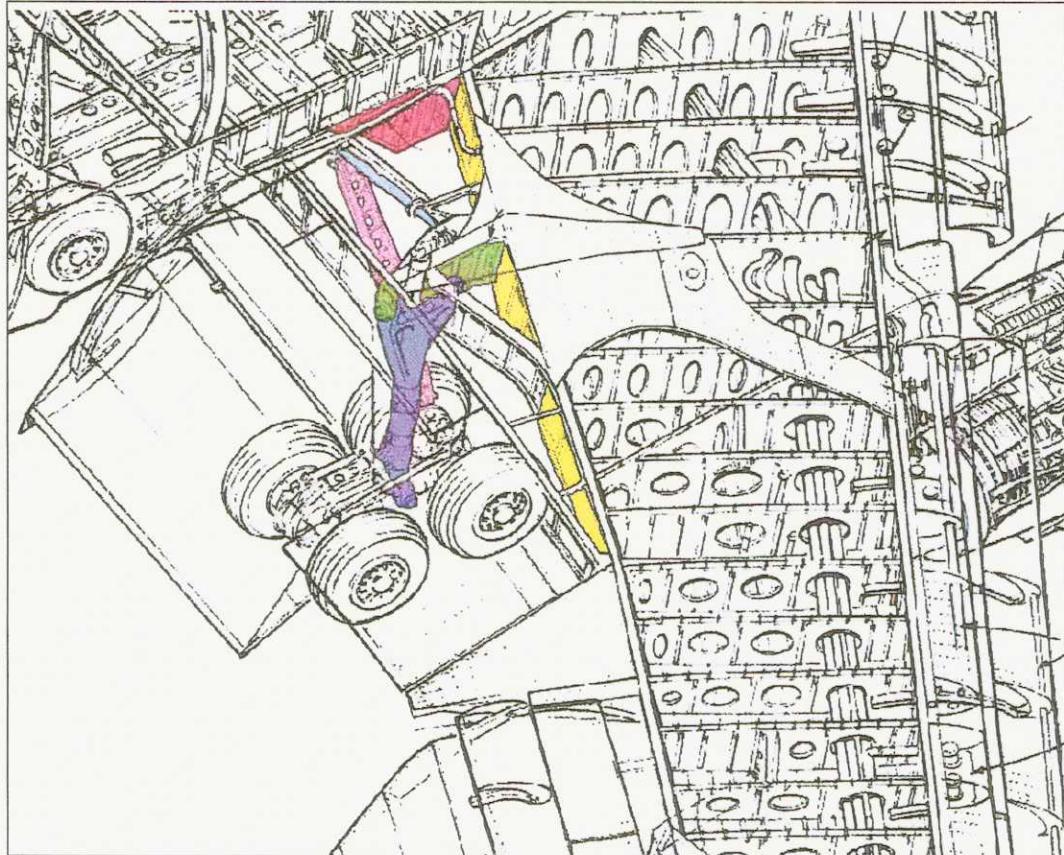


Figure 1. MD-11 Structural Arrangement in the vicinity of the MLG-to-Wing attachment

2.0 LANDING CONDITIONS

The attitude of the accident aircraft, along with the velocity and acceleration components were estimated from data obtained from the flight data recorder. More detail is available in the report published by the Performance Group of the accident investigation team (Reference 1). From a structural loads perspective the most significant of these parameters is the sink rate (velocity towards the ground) which has been estimated to be in the vicinity of 18-20 feet-per-second. The next most significant parameter is the roll attitude (approximately 3 degrees right-wing-down).

It should be noted that the design sink rate for a symmetric landing (zero degrees roll) is 10 feet-per-second. Recognizing that the kinetic energy which must be absorbed to decelerate an aircraft moving towards the ground is a function of the velocity *squared*, it is observed that the energy from a 20 foot-per-second sink rate is four times (not double) that from a 10 foot-per-second sink rate. And since the aircraft was rolled right at touchdown, most of the load was taken by the right-hand main landing gear.

3.0 LANDING SIMULATION

MD-11 crash landing simulation analyses were run using initial conditions consistent with the accident aircraft at touchdown. The aircraft was rolled right-wing-down 3 degrees, pitched nose-up 4.5 degrees, and was descending at nearly 20 feet-per-second. There was no perceptible roll rate and the lift on the airplane was roughly equal to its weight. The high sink rate combined with the rolled attitude caused

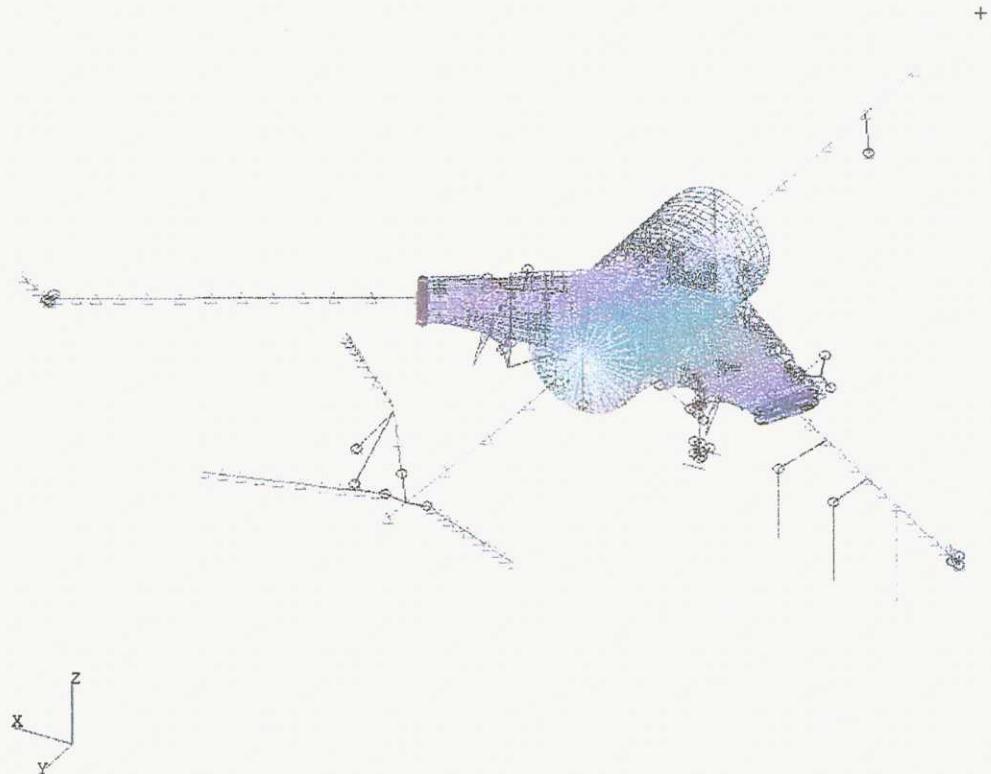


Figure 2. MD-11 Dynamic Landing FE Model

bottoming of the right main landing gear strut and generated a vertical load "spike" which failed structure in the area where the right main landing gear attaches to the right wing.

The structural failures (of the right wing rear spar in particular) which were observed in this accident bore notable similarities to those that were observed for a FedEx MD-11 that was involved in a crash landing at Newark, New Jersey on July 31st, 1997. A significant amount of analysis was conducted to simulate the FedEx accident and estimate structural loads on the right main landing gear, the right MLG-to-wing attach fitting, the right wing rear spar, and the right landing-gear-side-brace-fitting-to-trap-panel joint. These analyses were conducted using an in-house aircraft dynamic landing program (B7DC), a commercially available finite element program (MSC NASTRAN), and a commercially available nonlinear kinematics code (ADAMS).

Based on knowledge and experience gained in analyzing the FedEx accident a simplified analysis technique was developed for studying the effects of very high sink rate landings on aircraft structure. The crash landing analyses performed for this accident utilized MSC NASTRAN. A transient nonlinear solution was run using a detailed finite element model of the MD-11 inboard wing and center fuselage, combined with a coarser idealization of the remaining structure. (See Figure 2). The main landing gear was idealized using the BUSH1D element, which allowed the gear nonlinear spring and damping characteristics to be input in table form. The results from this model were compared and correlated with certification analyses (for cases within the design limits of the aircraft) and with the FedEx ADAMS analysis and were shown to be satisfactory.

The most significant differences in the structural loads applied to the aircraft during the FedEx and the China Airlines accidents lay in the drag loads applied to the right main landing gear. Landing gear drag loads were not significant for the FedEx accident. This is because the aircraft touched down, bounced, then landed a second time at a high sink rate and sink acceleration, and at a significantly rolled attitude. Since the high vertical loads occurred on the second touchdown, the wheels were already spinning and drag loads were minimal. The high vertical loads for the China Air accident occurred at the initial touchdown so "spin-up" and "spring-back" (plus and minus drag) loads were significant.

The existence of significant drag loads for the China Air accident required an adjustment to the simplified NASTRAN analysis technique. Spin-up and spring-back loads (essentially a time history of the main landing gear drag loads) were estimated using B7DC (the certification landing gear loads analysis program) and the time history was manually input into the NASTRAN solution. The peak load from the B7DC time history was phased to correspond with the peak right main landing gear vertical load.

Figure 3 displays the landing gear strut and tire loads for the China Airlines baseline case (Case 4.010). The structure responds linearly for this case and it is assumed that all of the lift on the right-hand wing is lost when the right main landing gear load reaches 600,000 lbs. (This assumption is consistent with analyses that were run for the FedEx crash simulations, which used ADAMS to dynamically calculate wing lift as a function of local angle of twist). For the China Airlines analysis, both the left main landing gear and the center landing gear pick up load well before the right main landing gear reaches its peak load.

The strut and total-tire load time histories should be equal for a given gear (note that the right main landing gear strut load oscillates near its peak and separates after the peak due to NASTRAN convergence problems). These convergence problems do not have a significant effect on the time history of the other gear loads or the peak value of the right main landing gear total-tire load.

Time histories of key loads from Case 4.010 are plotted in Figure 4. From the figure, the right main landing gear strut load peaks at 1.4 million pounds, the peak rear spar shear flow is 35,000 lbs/in, and the peak load on the right main landing gear forward trunnion bolt is 1.2 million pounds. The rear spar shear flow is well in excess of what is required to fail the rear spar shear web and the forward trunnion bolt load is roughly that which is required to fail it.

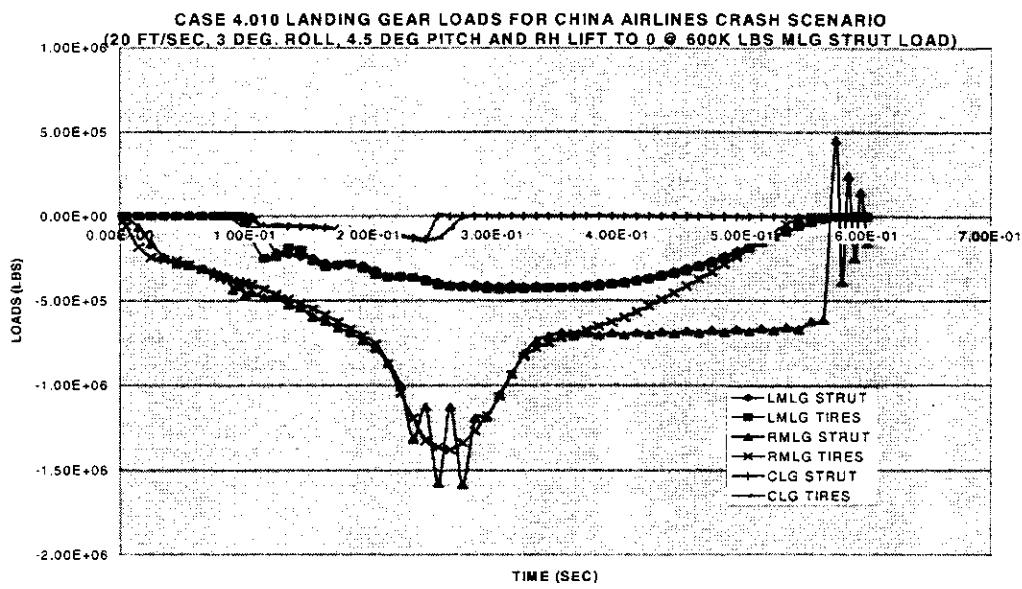


Figure 3. Case 4.010 Landing Gear Loads for China Airlines Crash Scenario

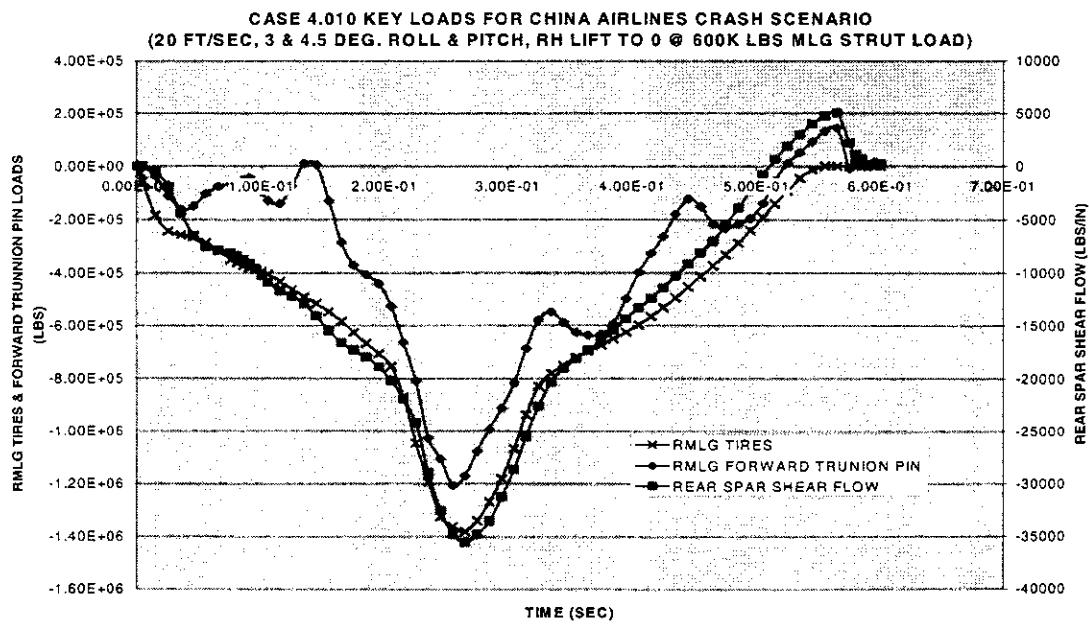


Figure 4. Case 4.010 Landing Gear Loads for China Airlines Crash Scenario

The results of this analysis, although not rigorous, confirm that loads high enough to fail the forward trunnion bolt and the rear spar shear web are feasible, and that the failure sequence described in the following sections is reasonable.

4.0 STRUCTURAL FAILURE SEQUENCE

The most likely sequence of structural failures is summarized below. Details and supporting evidence are included in the Sections 5.0 through 11.0.

- Due to the combination of a high sink rate and a right-wing-low rolled attitude, the right main landing gear shock strut bottomed and the vertical load on the right main gear “spiked”.
- The forward trunnion bolt on the right main landing gear sheared upwards as a result of a very high vertical gear load combined with a large “springback” moment.
- The forward trunnion of the right main landing gear was driven upwards and contacted the MLG-to-wing attach fitting, damaging the fitting.
- The rear spar web and caps of the right wing fractured, inboard of the MLG-to-wing attach fitting.
- The inboard upper wing panel of the right wing began to collapse from back to front.
- The outboard (right) wing twisted significantly nose down which caused the MLG-to-wing attach fitting to move up, and the main landing gear tires to move aft and outboard.
- The track attached to the inboard flap on the right wing was pried off the rollers that support it at the fuselage side-of-body.
- The inboard flap on the right wing twisted off its outboard hinge support fitting and separated from the aircraft.
- Excessive movement of the right main landing gear and its wing attach fitting imparted large “prying” loads on the side-brace-fitting-to-trapezoidal-panel (S-B-F-T-T-P) joint.
- The right main landing gear fixed brace failed near the S-B-F-T-T-P joint.
- With the side brace failed, large sideloads were introduced to the S-B-F-T-T-P joint by the folding side brace.
- The S-B-F-T-T-P joint failed; first the inboard attach bolt fractured, then an outboard section of the outboard trapezoidal panel “split off” releasing the outboard attach bolt and its barrel nut.
- The right main landing gear strut, now released from the fuselage (trap panel), pivoted outboard; the trunnion arms contacted the MLG-to-wing attach fitting. The resulting “short couple” (prying) loads finished separating the landing gear from the attach fitting.
- The right nacelle contacted the runway (at about the same time as the inboard flap was separating the S-B-F-T-T-P joint was failing) and the right wing engine/pylon assembly was twisted off. (The pylon-wing separation appears to have been dominated by side loads applied to the nacelle rather than vertical loads).
- The aircraft began to roll clockwise having lost the integrity of the right wing, yet still carrying enough speed to generate meaningful lift on the left hand wing.
- Failures beyond this point were consequent, are not considered particularly relevant, and were not studied in detail.

5.0 FORWARD TRUNNION BOLT FAILURE

The first structural element thought to have failed in this accident is the forward trunnion bolt, also known as the “zero margin trunnion pin”. This bolt is designed to reliably shear at a predetermined load (approximately 1.2 million lbs) and acts as a “fuse” when the main landing gear is subjected to excessive drag loads. Figure 5 shows the location of the zero margin trunnion pin.

When acting as a fuse against excessive drag load the zero margin trunnion pin fails by shearing downwards (i.e. the forward trunnion of the main landing gear moves downward relative to the wing attach fitting). In this accident this bolt failed in the *upwards* direction due to a combination of high landing gear vertical load, and a high “springback” moment. Both the high vertical load and the high “springback” moment were a result of the excessive (18-20 ft/sec) sink rate.

“Spin-up” and “springback” loads occur when an aircraft touches down and the tires are not yet spinning (a normal occurrence). First the runway exerts a drag force (“spin-up”) on the tires which starts them spinning and bends the strut aft. As the tires spin up the drag force disappears and the strut “springs

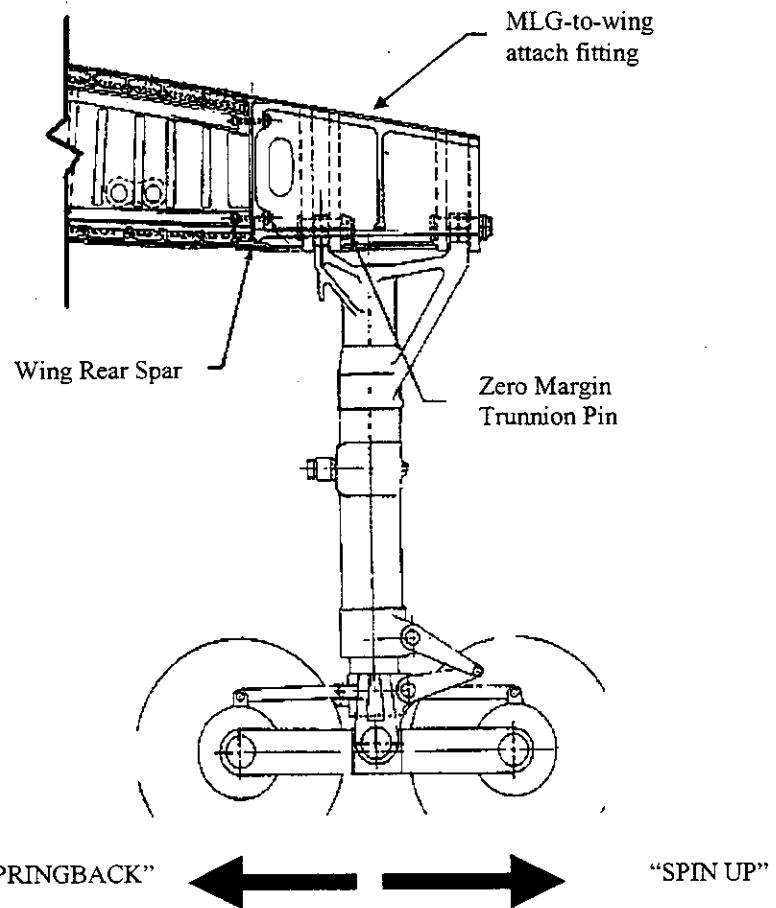


Figure 5. Main-Landing-Gear-to-Wing Attach Arrangement

back" (bending the strut forward). For conditions within the aircraft design range this phenomenon is well known and understood, and analytical tools are available to calculate the associated loads.

As described in Section 3 the spin-up and springback loads for this accident were estimated using B7DC (an in-house aircraft dynamic landing program). When the estimated springback loads were combined with the vertical loads predicted for a 20 ft/sec touchdown, it was shown that a 1.2 million lb load on the forward trunnion bolt was within the feasible range.

It should be noted that the structural loads presented in Section 3 are estimates and are based on analytical extrapolation into a regime for which we have little or no data to establish correlation. In fact we believe the springback moment obtained from B7DC is probably underestimated.

The results of the metallurgical examination of the forward trunnion bolt are presented in the Boeing Materials and Process Engineering Report (Reference 2) in Section 4.5.2. The findings are consistent with the theory that the forward trunnion bolt failed as the forward trunnion of the main landing gear was moving upwards relative to the wing attach fitting. This relative motion is most evident in Figure 38 of Reference 2, which shows how the aft portion of the bolt is bent down.

Note that the bolt failed at the forward zero-margin groove. The bolt is loaded in double-shear; there are zero-margin grooves at both shear interfaces.

6.0 DAMAGE TO THE MAIN-LANDING-GEAR-TO-WING ATTACH FITTING

After shearing the forward trunnion bolt at the forward zero-margin groove, the forward trunnion of the right main landing gear was driven upwards and contacted the wing attach fitting, damaging the fitting. This is clearly evident in a photograph taken at the crash site (Figure 6) and in Figures 34 and 35 of the Materials and Process Engineering Report (Reference 2).

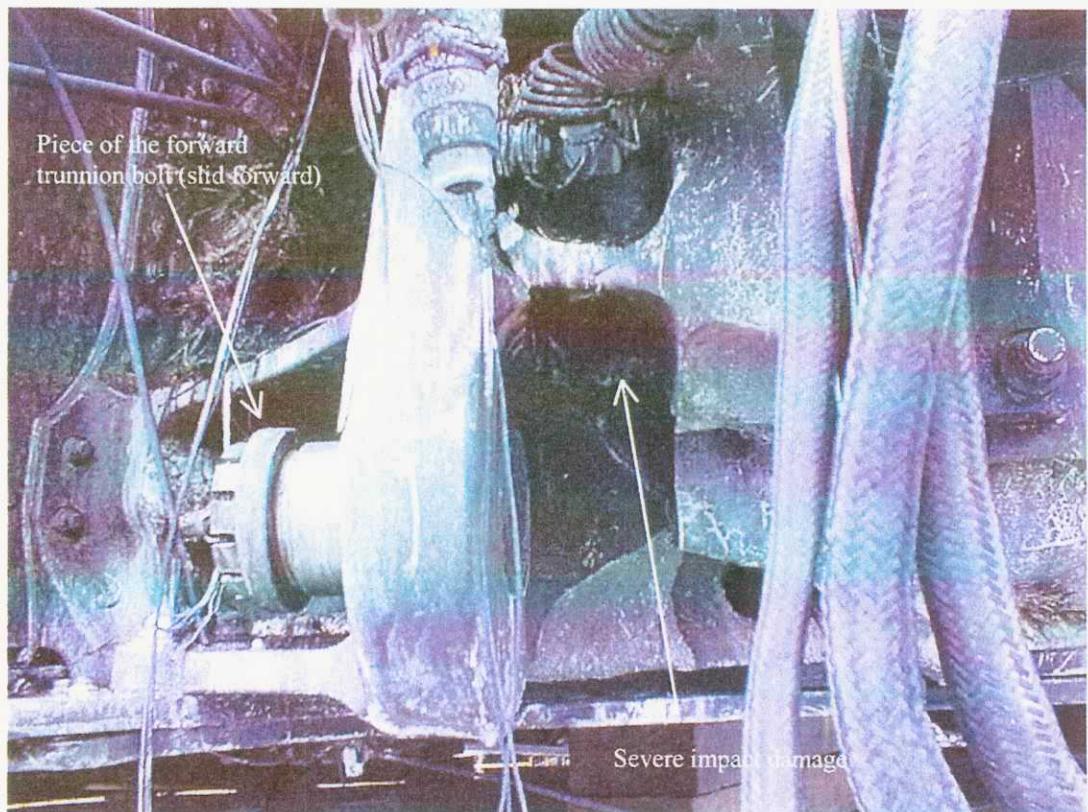


Figure 6. Damage to MLG-to-Wing Attach Fitting at the forward lugs

7.0 REAR SPAR FAILURE

With the forward trunnion bolt sheared, and the forward trunnion of the right main landing gear jammed upwards into the wing attach fitting, the vertical load on the gear was driven into the wing rear spar. Both rear spar webs fractured (in this area the web is doubled for failsafe reasons), along with the upper and lower rear spar caps. The rear spar web fractures were oriented roughly 45 degrees relative to the spar caps, as is typical of shear overload of a beam web.

The rear spar web was identified as the first structural element thought to have failed in the FedEx accident that occurred in Newark, New Jersey on August 31st, 1997. A significant amount of analysis was conducted to validate the FedEx failure sequence, so this failure mode was quickly recognized when the wreckage of the China Airlines aircraft was examined.

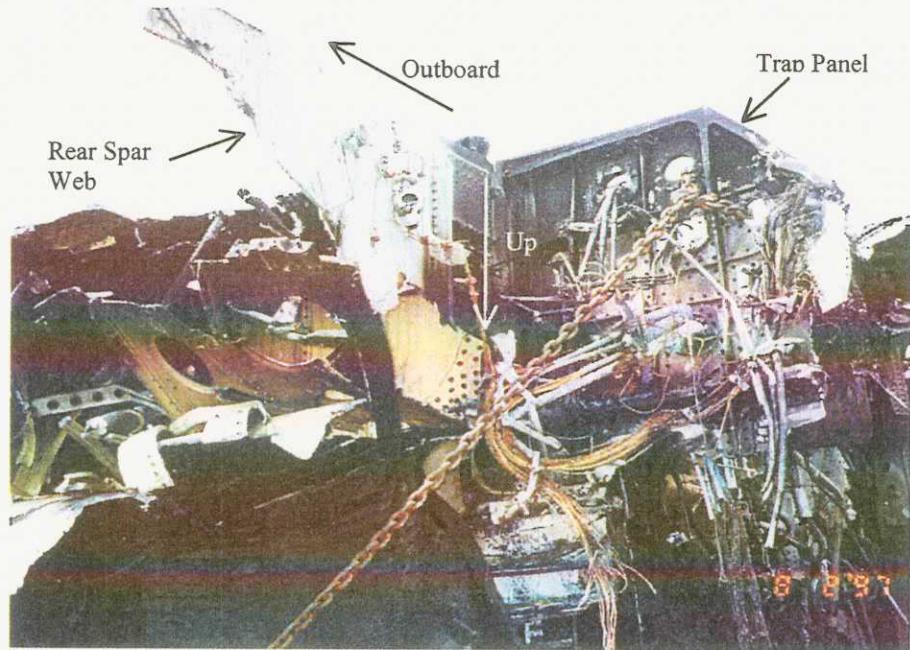


Figure 7. Right Wing Rear Spar Web Fracture from Ship 553 (FedEx - Newark)

A photograph of the FedEx aircraft showing the right wing rear spar web fracture is included as Figure 7. Note that the aircraft is inverted in this photograph.

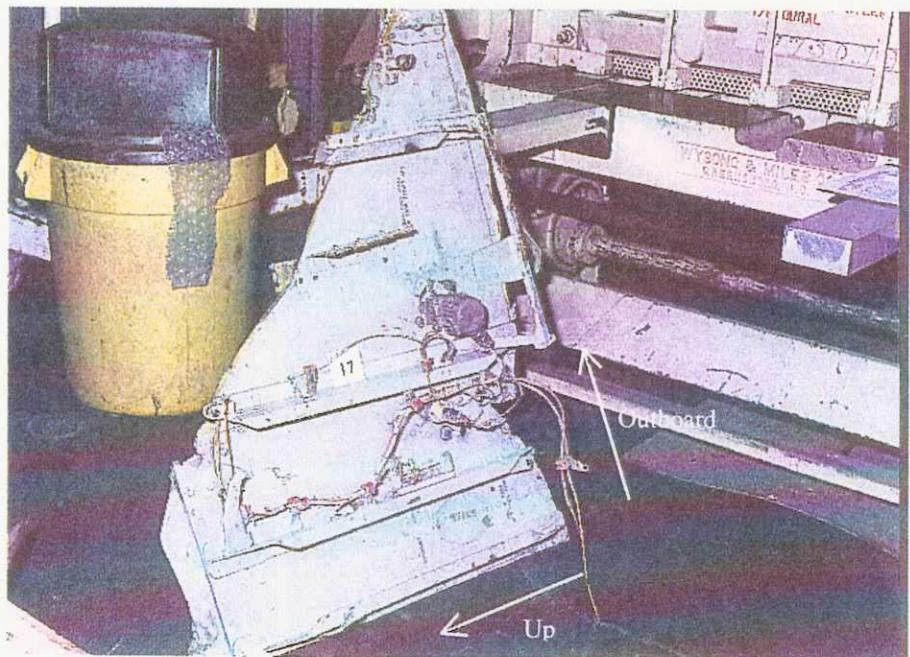


Figure 8. Right Wing Rear Spar Web Fracture from Ship 518 (China Airlines)

A lab photograph of the right wing rear spar web which was cut from the China Airlines aircraft is included as Figure 8. When examined closely it was observed that the rear spar web fractures from the two accidents occurred at almost identical locations.

8.0 INBOARD FLAP DEPARTURE

The inboard flap is located just aft of the main landing gear (Figure 9) and is supported at its inboard end by a track/roller arrangement (Figure 10) and at its outboard end by a simple hinge (Figure 11). The track is mounted on the flap and the rollers on the fuselage (Figures 12 and 13). The outboard hinge is supported off the wing rear spar.



Figure 9. Inboard Flap (Location relative to MLG)



Figure 10. Inboard Flap inboard support

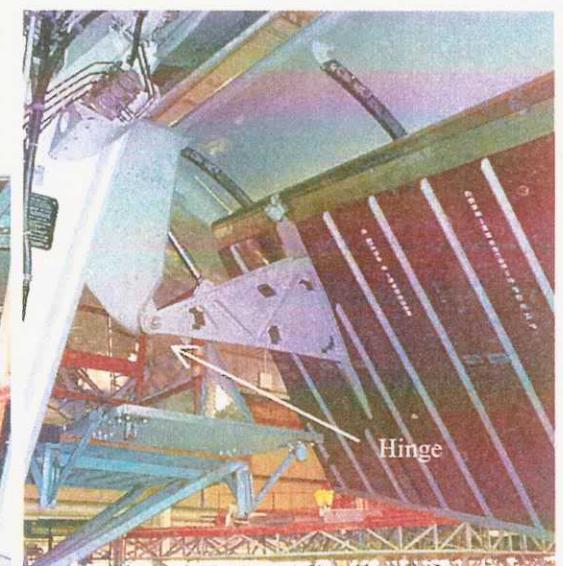


Figure 11. Inboard Flap outboard support

The flap track is an I-beam with return lips on the inboard legs of the two caps. The upper "lip" is captured by three side rollers which limit the outboard motion of the flap track (Figures 13 and 14).

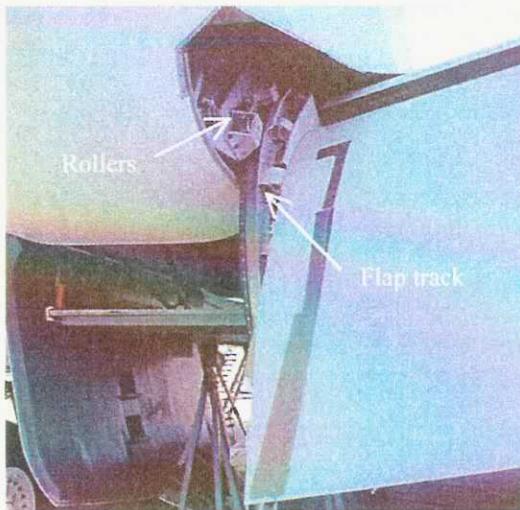


Figure 12. Inboard Flap track and rollers

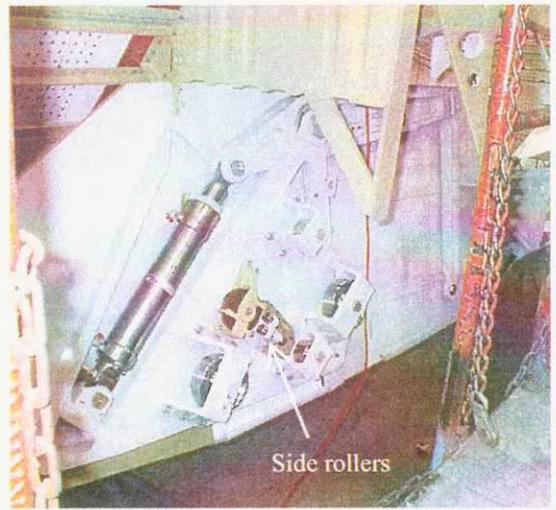


Figure 13. Inboard Flap rollers (flap removed)

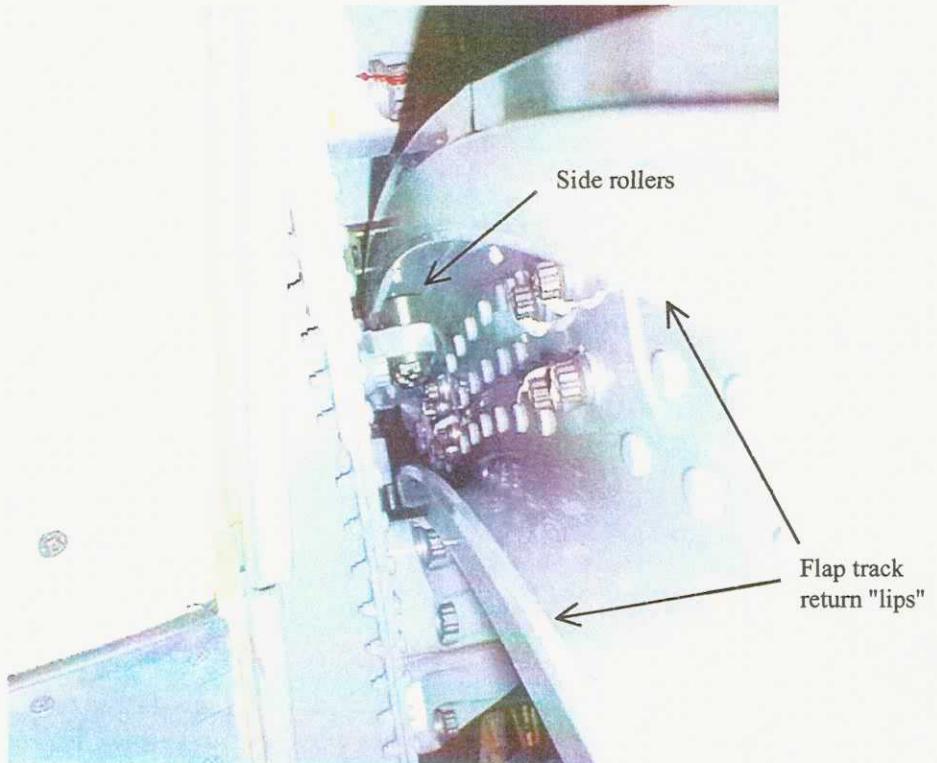


Figure 14. Inboard flap track and side rollers

With the aircraft structurally intact the nominal side loads (inboard-outboard) are small as is evident by the relative size of the side rollers.

Continuing the failure sequence of the China Airlines accident, fractures of the wing rear spar webs, and of the upper and lower spar caps destroyed the integrity of the right wing as a "box structure" resulting in very large relative displacements between the inboard flap's inboard support (mounted to the fuselage) and its outboard support (mounted to the wing, outboard of the landing gear). This relative movement effectively pried the flap track off its roller support system. Once the inboard end became unsupported,

the flap easily twisted off its outboard hinge, separating at the tension bolts where the aft hinge attaches to the flap box.

As was the case for the wing rear spar failure mode, there are some observed similarities in the FedEx and China Airlines inboard flap failures. Both inboard flaps were found near the beginning of the debris field, were relatively intact (having almost no lower surface damage), and evidenced local shear-out failures of the flap track lips at the side roller locations.

The China Airlines inboard flap was found off to the left of the runway and is thought to have been carried there by the crosswind (which was blowing right-to-left) after it departed the aircraft. The flap, as it was found, is pictured in Figure 15. The FedEx inboard flap was found on a taxiway to the right of the runway (Figure 16); note there was little or no crosswind present when the FedEx accident occurred.



Figure 15. Right Inboard Flap from Ship 518 (China Airlines)

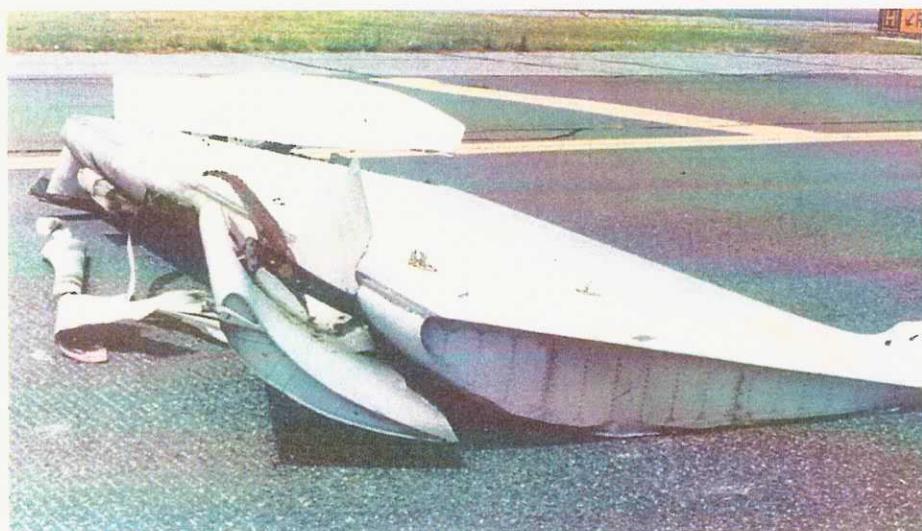


Figure 16. Right Inboard Flap from Ship 553 (FedEx - Newark)

It is viewed as significant that the lower surfaces of these flaps suffered no significant damage. The inboard flap would have been directly in the path of the main landing gear had the gear separated before the flap and would have been badly damaged. It is clear then, that the main landing gear did *not* "knock" the inboard flap off the aircraft.

The local shear-out failure of the flap track is evident in a photograph taken at the accident site (Figure 17). The location of this failure is consistent with the position of the side rollers for the reported flap setting of 35 degrees. The same type of failure is observed in the photograph of the inboard flap from the FedEx-Newark aircraft (Figure 18); in this case the failure location is consistent with the reported flap setting of 50 degrees.

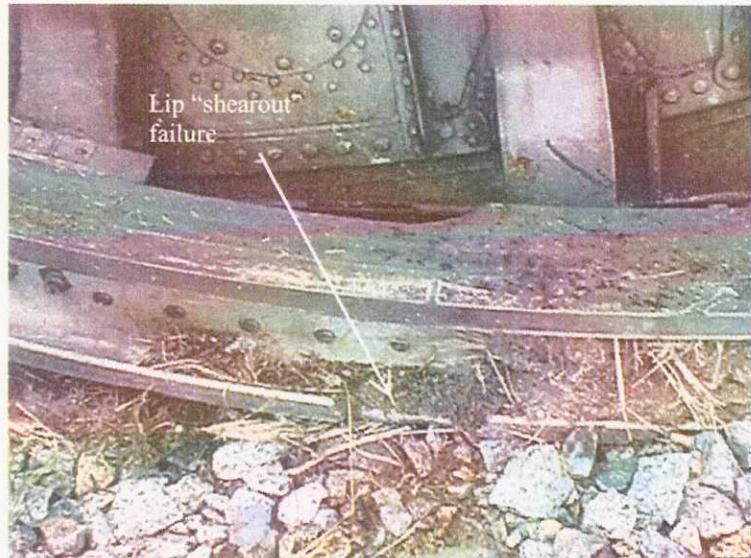


Figure 17. Right Inboard Flap track from Ship 518 (China Airlines)

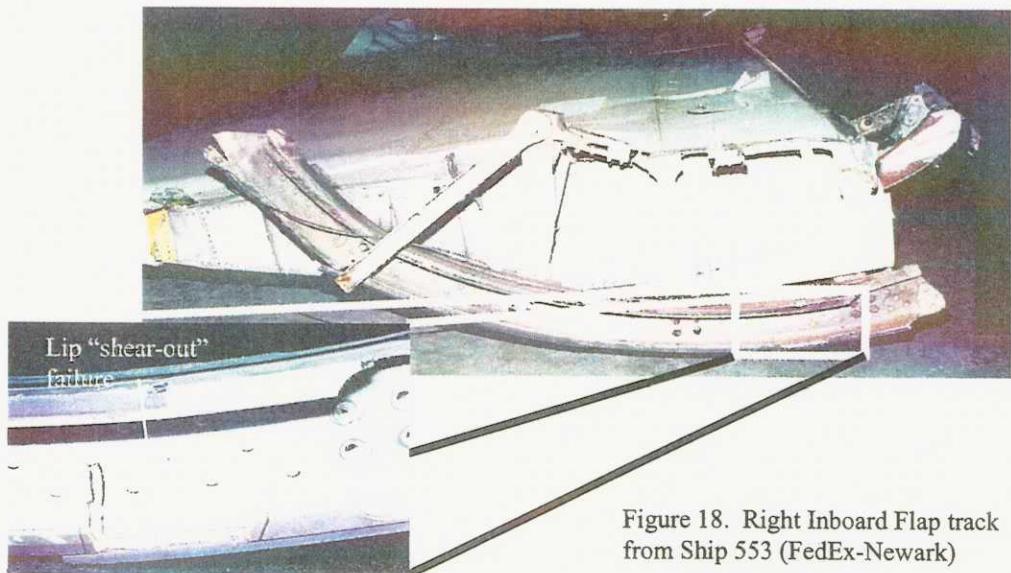


Figure 18. Right Inboard Flap track from Ship 553 (FedEx-Newark)

9.0 DAMAGE TO SIDE-BRACE-FITTING-TO-TRAP-PANEL JOINT AND TO THE FIXED AND FOLDING SIDE BRACES

The location of the side-brace-fitting-to-trap-panel (S-B-F-T-T-P) joint is highlighted in Figure 19. A photograph of this area (taken from inside the landing gear wheel well) is included as Figure 20 along with a sketch of the joint (with the fixed and folding side braces removed).

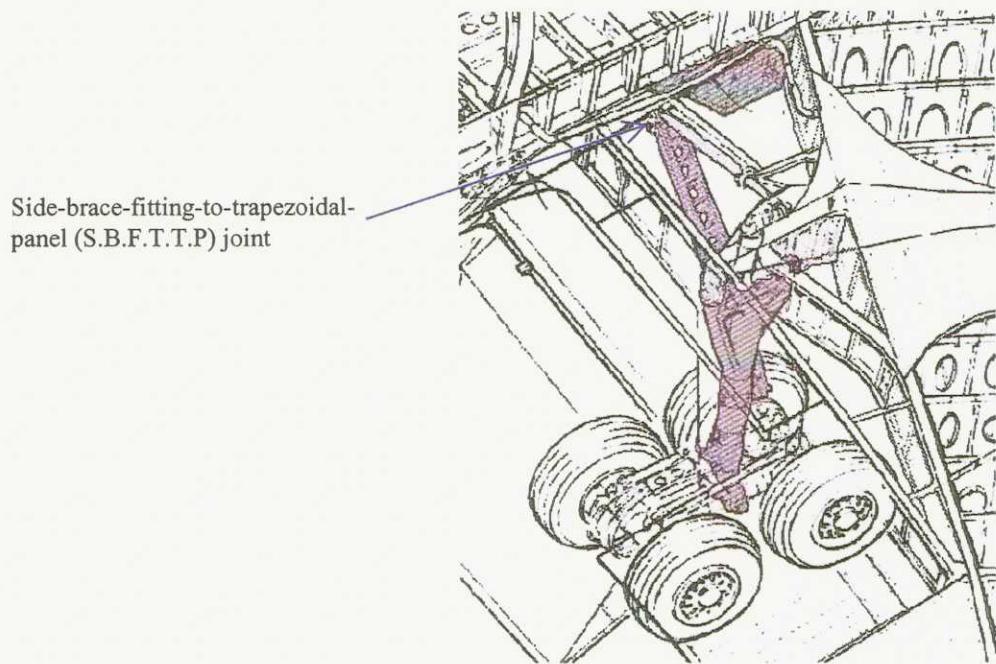


Figure 19. Location of the side-brace-fitting-to-trap-panel joint

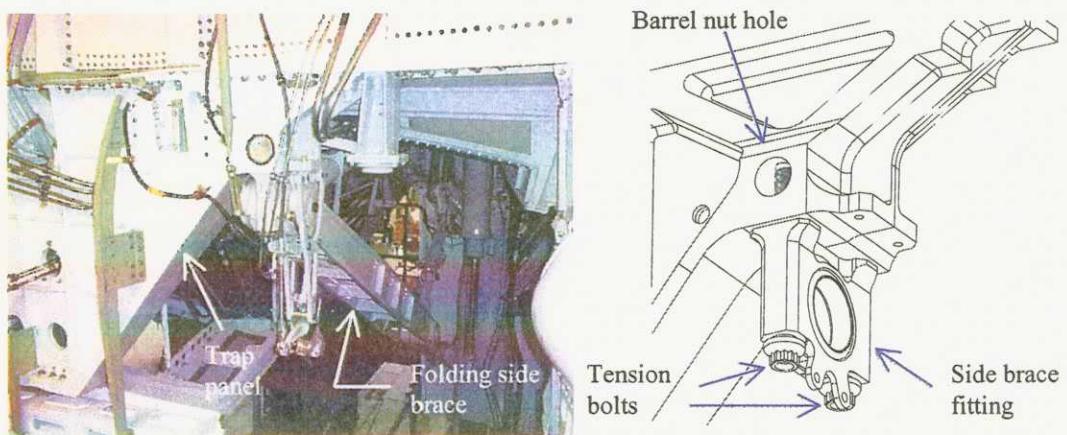


Figure 20. Side-brace-fitting-to-trap-panel joint (from inside the right wheel well)

The fixed brace and folding side brace are connected to one another and to the side brace fitting via a large pin. The side brace fitting is attached to the trap panel with two long tension bolts and mating barrel nuts. As discussed in Section 1.0 this joint is designed to take primarily vertical loads; the fore-and-aft and inboard/outboard loads are nominally small.

As was the case for the inboard flap's departure, the damage to the S-B-F-T-T-P joint was the result of large relative displacements between attach points on the wing and on the fuselage. After the right wing rear spar failed, the MLG-to-wing attach fitting moved up (relative to the fuselage) and the outboard wing twisted severely nose-down. This motion effectively tilted the truss formed by the MLG strut, and the fixed and folding side braces, and applied a nose-down twist to the S-B-F-T-T-P joint. This applied twist rocked the side brace fitting (bottom-end-aft) and resulted in "impressions" on the lower surface of the trap panel (Figure 21). Similar impressions were observed on the underside of the trap panel from the FedEx-Newark accident aircraft.

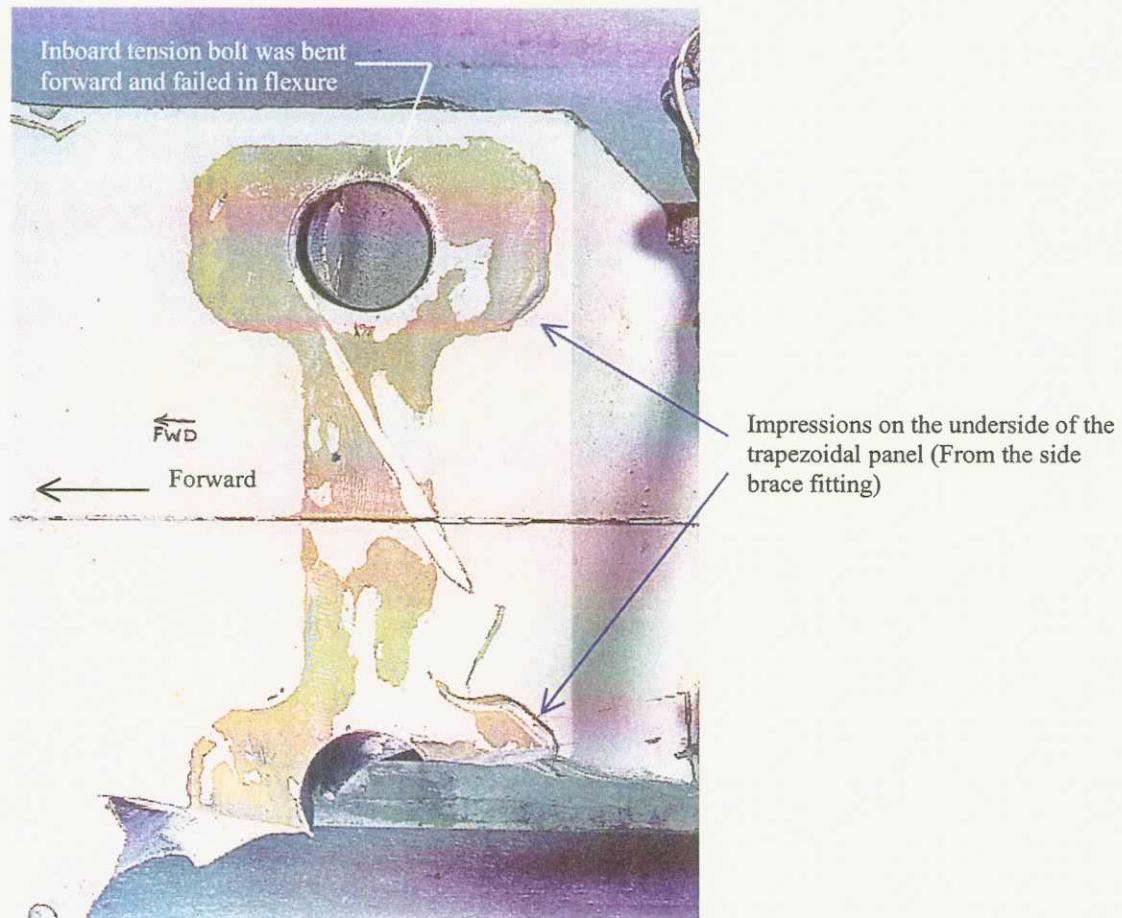


Figure 21. Underside of the right trapezoidal panel

Figure 22 is another photograph of the S-B-F-T-T-P joint area. The photograph is annotated to point out the limited clearance between the clevis end of the fixed brace and the side brace fitting. Excessive upward motion of the outboard end of the fixed brace (which is connected to the MLG-to-wing attach fitting) results in contact in the noted area, and creates a "short couple" prying load at the joint. Evidence of contact in this area for parts taken from the China Airlines accident aircraft is seen in Figure 23. Similar evidence was also noted for the FedEx-Newark accident aircraft.

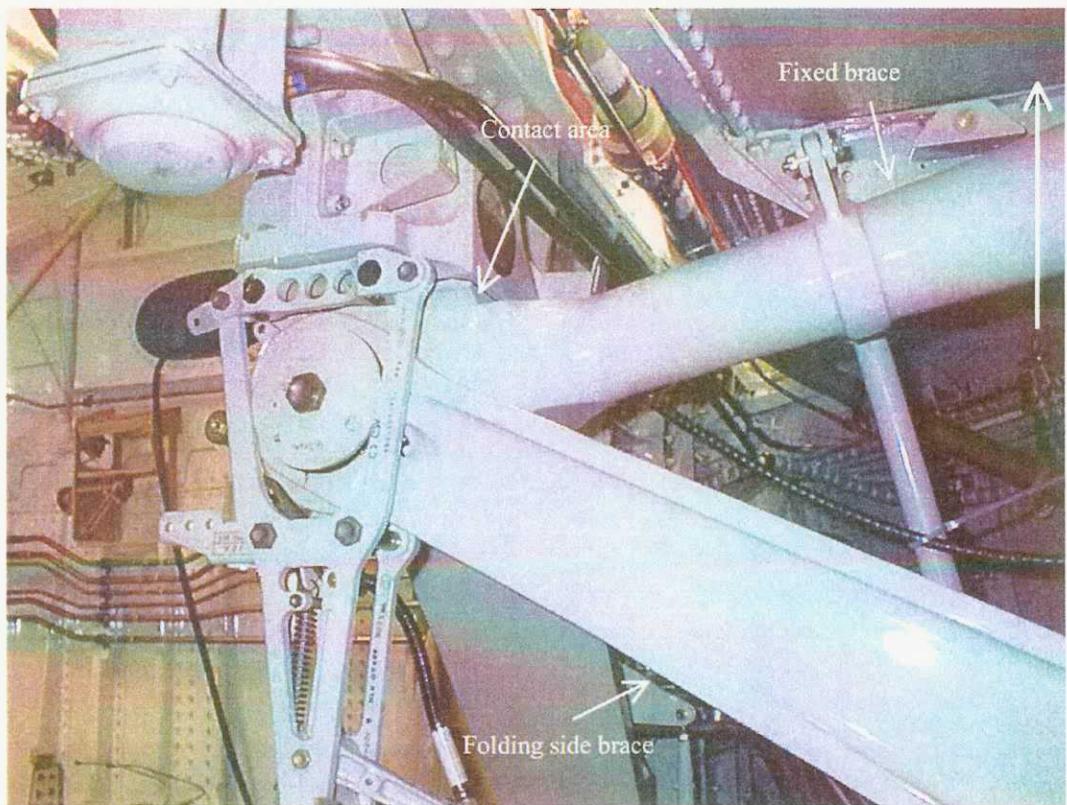


Figure 22. Side-brace-fitting-to-trap-panel joint (from aft and outside the right wheel well)



Figure 23. Evidence of contact between the fixed brace and the side brace fitting

The presence of a large prying load at the S-B-F-T-T-P joint results in severe distress to this joint. This manifests itself as localized high bending (flexure) at the outboard end of the fixed brace, and a large tension load on the inboard of the two tension bolts attaching the side brace fitting to the trap panel. Evidence of flexural distress of the fixed brace was observed in parts taken from both the China Airlines and FedEx-Newark accident aircraft. The fixed brace from the China Airlines aircraft failed completely (Figure 24). The fixed brace from the FedEx-Newark aircraft was bent and suffered a stress corrosion fracture (Figure 25). The stress corrosion fracture is attributed to residual stress resulting from a high flexural load. Note also in Figure 25 the evidence of local contact with the side brace fitting.

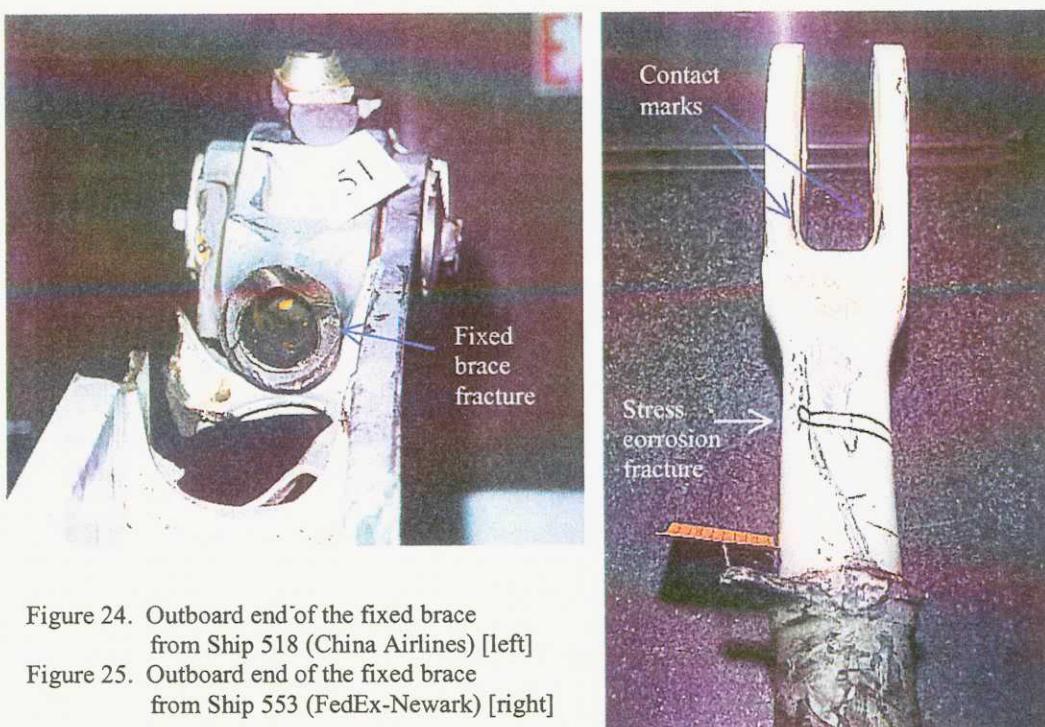


Figure 24 also shows damage to the upper folding side brace. The upper folding side brace is an I-section "laid on its side" with lightening holes in the web (Figure 19). The fixed brace after it failed in flexure, appears to have dropped down into the upward facing "channel" of the I. Relative motion between the outboard wing and the fuselage then appears to have "punched" the inboard end of the fixed brace through the web and aft cap of the upper folding side brace.

The final two failures at the S-B-F-T-T-P joint involve the two tension bolts that attach the side brace fitting to the trap panel, and the trap panel itself. The inboard of the two tension bolts failed in flexure and was bent lower-end-forward (Figure 21 and also Figure 15 of Reference 2). This is thought to have been a consequence of the fixed brace having previously failed, coupled with the lower end of the main landing gear strut moving aft. The folding side brace, acting as a lever, would then apply a twist about the vertical axis of the S-B-F-T-T-P joint. Presuming the outboard tension bolt is acting as a pivot, this would tend to bend the inboard bolt forward.

The outboard tension bolt did not fail. Instead a portion of the outboard face of the trap panel appears to have "split off", releasing the outboard barrel nut and tension bolt (Figure 26). This is thought to have occurred *after* the inboard bolt had failed and appears to have been the result of a prying load applied by the outboard tension bolt, the prying load resulting from the folding side brace pulling outboard on the side brace fitting. (Note the photograph is upside-down relative to the normal position in the aircraft).

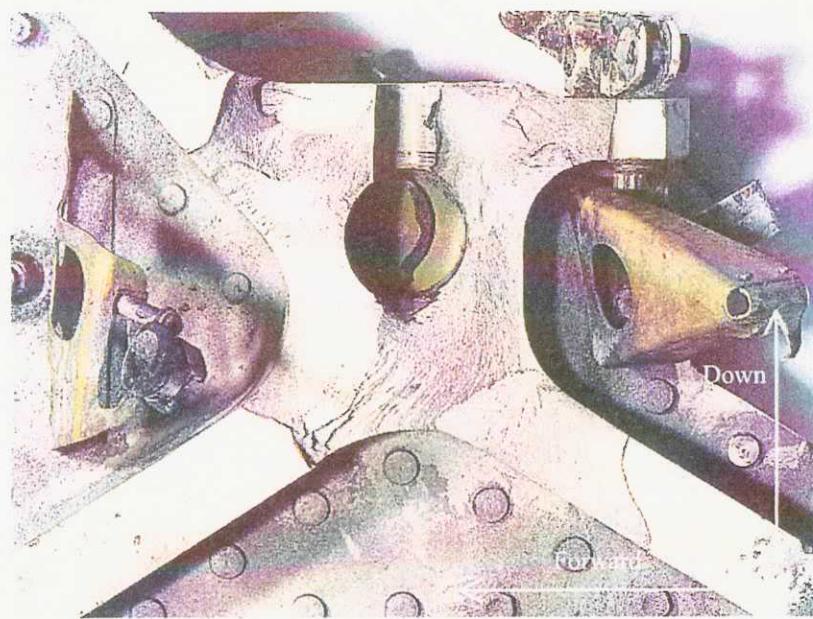


Figure 26. Outboard trap panel failure at the S-B-F-T-T-P joint

10.0 DAMAGE TO THE MAIN LANDING GEAR TRUNNION ARMS AND ADDITIONAL DAMAGE TO THE MLG-TO-WING ATTACH FITTING

There is clear evidence that the right main landing gear strut, once released at the S-B-F-T-T-P joint, rotated outboard and contacted its wing attach fitting. Similar observations were made for the parts from the FedEx-Newark accident aircraft (see Figures 27 and 28). This type of contact creates a "short couple" prying action that easily breaks the gear loose from the fitting.

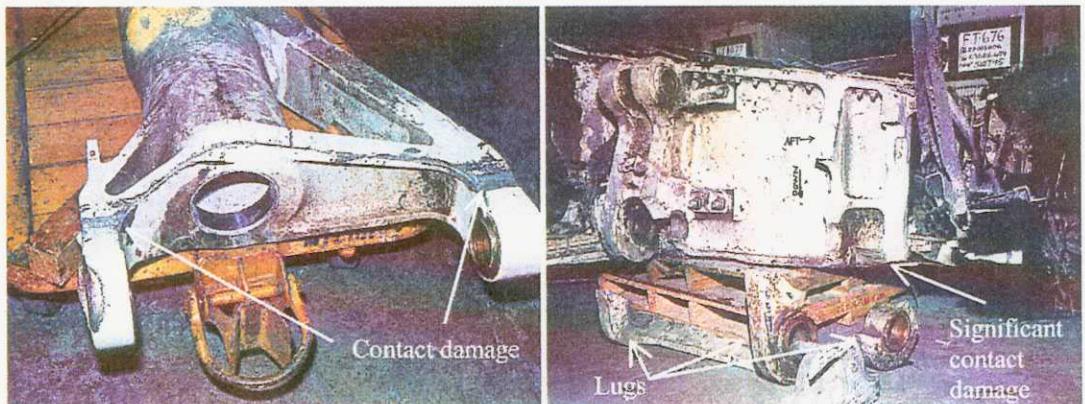


Figure 27. Right main landing gear strut from Ship 553 (FedEx-Newark) [left]
 Figure 28. Right MLG-to-wing attach fitting from Ship 553 (FedEx-Newark) [right]

In the case of the China Airlines accident the markings indicating contact between the right main landing gear strut and the wing attach fitting are slightly different (and not quite as clear). This is primarily due to the fact that the forward trunnion connection was partially failed (See Section 5.0) before the strut rotated outboard. The contact area for the forward trunnion was therefore very localized, and quickly resulted in the fracture of the remaining connection (the aft lug). See Figures 29 and 30. The two lugs that support the *aft* trunnion, the forwardmost still connected to a large piece of the wing fitting, also

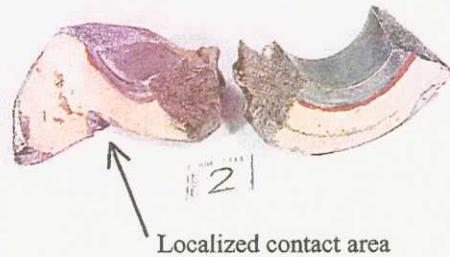


Figure 29. Wing fitting lugs that support the MLG forward trunnion [left]

Figure 30. Separated pieces of the aft wing fitting lugs that support the MLG forward trunnion [right]

cracked off as a result of the gear rotating outboard (Figure 31). This separated the right main landing gear from the aircraft. The contact area on the aft trunnion arm is shown in Figure 32. A photograph of the wing fitting, showing the mating area for the two aft trunnion support lugs, is included as Figure 33.



Figure 31. Right main landing gear assembly

Substantial sidewall abrasion was noted on the inboard sidewall of the aft inboard tire on the right main landing gear truck (Figure 34). This evidence further supports the theory that the gear rotated outboard putting the inboard sidewalls of the inboard tires in contact with the ground.



Figure 32. Aft trunnion arm of the right main landing gear strut [left]
 Figure 33. Right MLG-to-wing attach fitting from Ship 518 (China Airlines) [right]

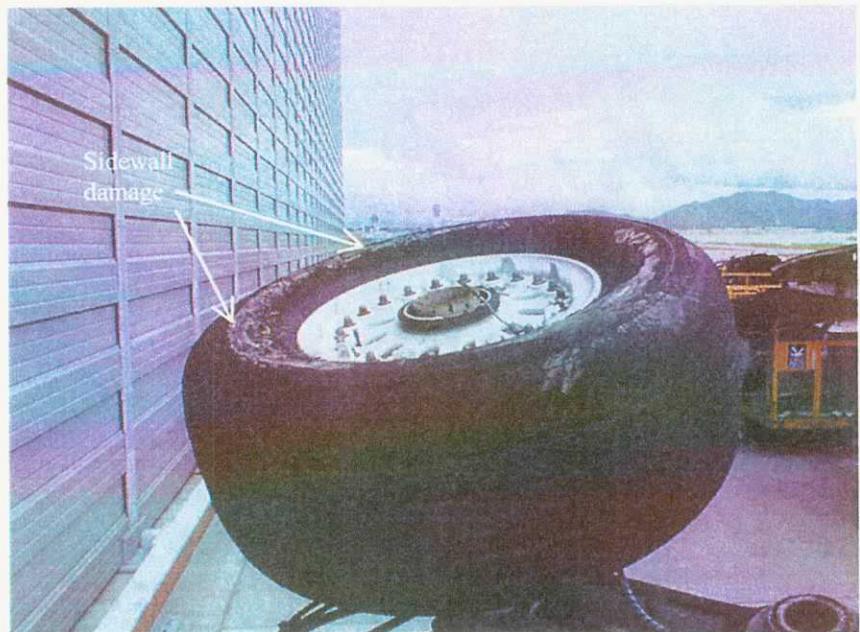


Figure 34. Inboard aft tire from the right main landing gear

11.0 RIGHT HAND WING PYLON FAILURE MODE

Figure 35 illustrates and describes the key elements of the attachment of the engine pylon to the wing. Figure 36 shows how the wing engine pylons are designed to “fuse” in the event of a wheels up landing to protect against rupture of the wing fuel tanks.

If the loads acting on the nacelle are primarily upwards, the engine pylon’s aft attach bulkhead is designed to break at the top of the monoball housing, freeing the back end of the pylon and allowing the engine/nacelle to tilt up and act as a “ski”. This failure mode has been verified by testing and validated in a number of in-service incidents. (As a point of reference, this *was* the observed failure mode for the right engine pylon from the FedEx-Newark accident).

Figure 37 shows that the right pylon failure mode was different for the China Airlines accident aircraft; the right engine pylon aft-attach bulkhead is still attached to the right wing. Figure 38 shows the right engine pylon. The observed failures suggest that the loads on the nacelle included a significant sideways

component. This is thought to have occurred because the outboard wing, as the failure progressed, began to sweep further and further aft.

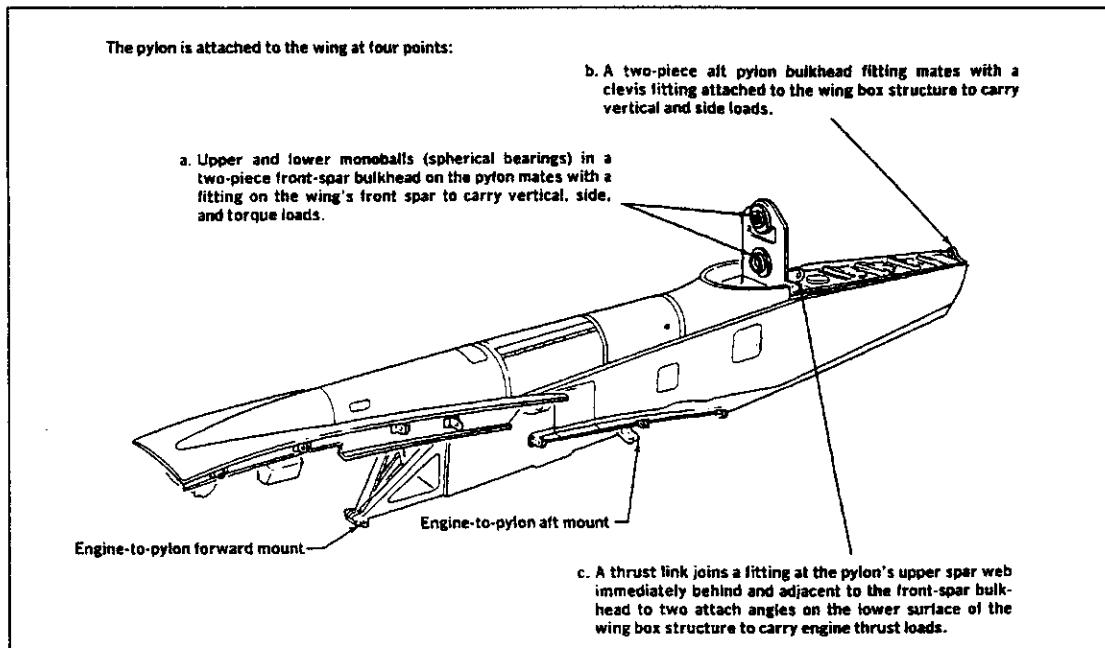


Figure 35. Pylon-to-wing attachment details

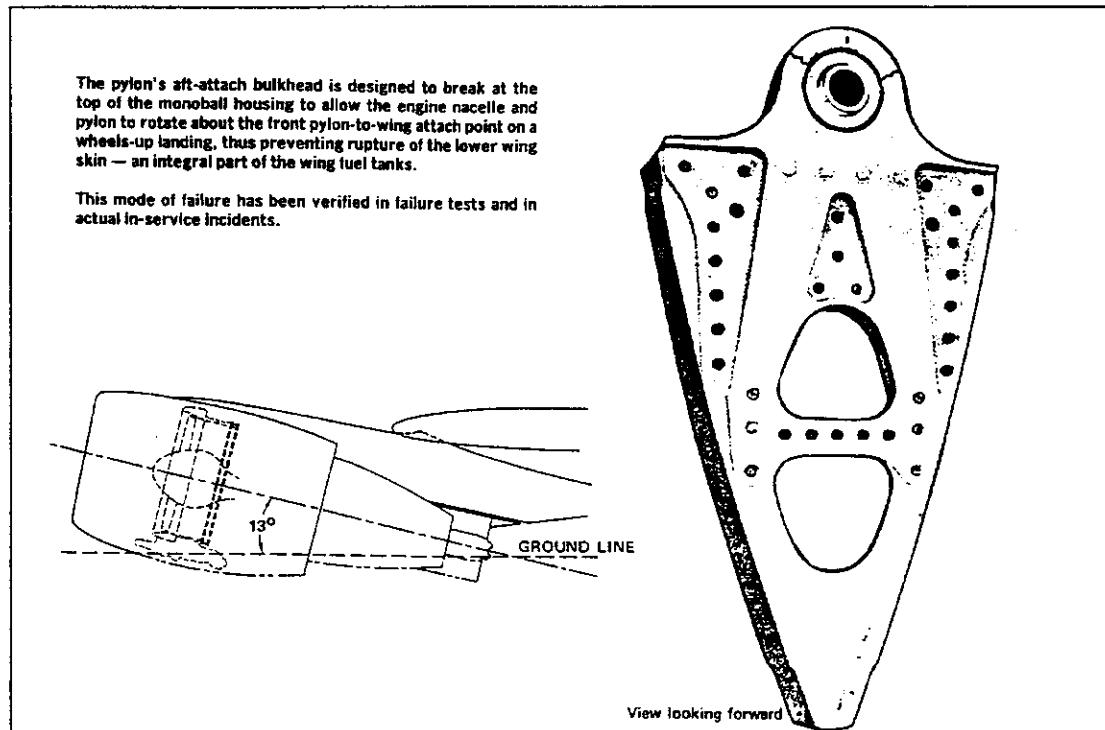


Figure 36. Wing pylon "fusing" mechanism

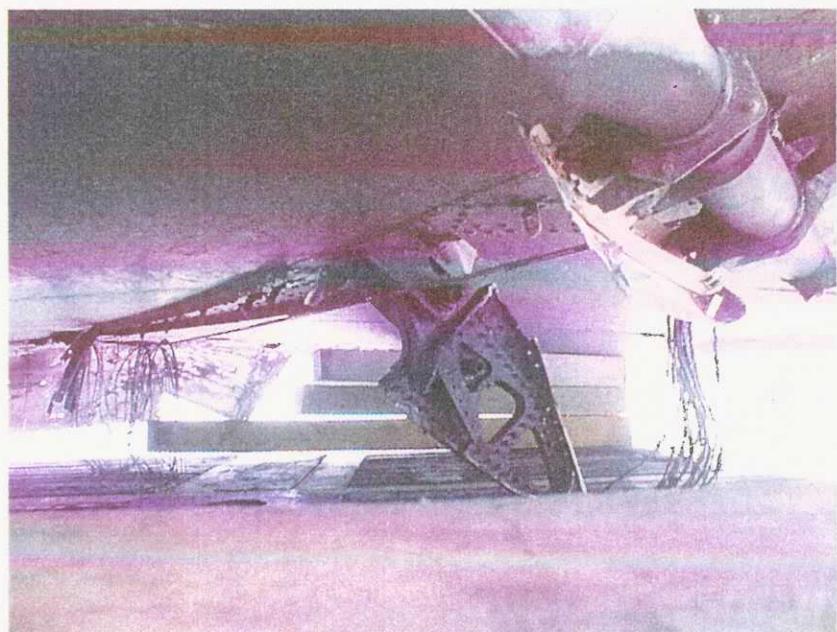


Figure 37. Right engine pylon aft-attach bulkhead still attached to the right wing



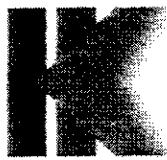
Figure 38. Right engine pylon

12.0 SUMMARY

Analysis was conducted to attempt to understand the structural failure sequence, failure modes, and failure characteristics of the accident aircraft. The analysis included primarily the review and examination of failed parts and photographs from the accident site, along with a limited amount of dynamic loads analysis using parameters taken from the Flight Data Recorder.

The analysis has produced a definition of a failure sequence that is reasonable and appears to have no significant inconsistencies with the accident observations.

The failure appears to have initiated with the forward trunnion bolt of the right hand landing gear (the trunnion shearing upwards) closely followed by failures of the inboard right wing rear spar webs and caps. These failures were the result of an extremely high vertical load and an associated "springback moment" applied to the right main landing gear. Both the high vertical load and the high "springback moment" were a result of the excessive (18-20 ft/sec) sink rate, and the slightly rolled (3 degrees right-wing-down) touchdown attitude.



民航處 Civil Aviation Department

飛行標準及適航部

Flight Standards and Airworthiness Division

香港赤鱲角駿運路 2 號機場空運中心商業大樓十樓

10/F Comm Bldg Airport Freight Forwarding Centre 2 Chun Wan Road Lantau Hong Kong

INVESTIGATION OF CAL 642 ACCIDENT ON 22 AUGUST 1999

TEST REPORT ON CAPTAIN'S WIPER MOTOR & ELECTRICAL CIRCUIT COMPONENTS

Test Requirement:- Minutes of Accident Investigation Team Meeting dated 11 January 2000 Meeting Note item 6. a.

Location of Test:- Electrical Workshop 2110 at the HAECO Component Overhaul Facility at Tseung Kwan O (TKO)

Date of Test:- 17th February 2000

Test Witnesses:- C M Lee – Inspector of Accident, HKCAD
K W Lau – HAECO QA Head of Section, TKO

Items Tested:- Wiper Motor and Drive Assembly (Captains Position)
Vendor - Rosemount Aerospace Inc, USA
P/N 2313M-537
S/N 00097

15 AMP Main Power Supply Circuit Breaker (Captains wiper)
Vendor – Jackson Inc, USA
P/N 700-030-15, (700-066-15) (76374-9137)
S/N None visible

5 AMP Wiper Control Power Supply Circuit Breaker (Captains wiper)
Vendor – Jackson Inc, USE
P/N 8500-005-5 (76374-9151)
S/N None visible

Captain's Wiper Control Switch
Vendor – Cole, USA
P/N 200-3061
S/N None visible

1. Testing Method and Considerations

All components were checked for any obvious damage prior to testing, none was evident. All components had been removed from the subject aircraft by HAECO. The wiper motor had been removed intact, together with attachment hardware. However, the circuit breakers (CBs) and control switch had been removed by the release of the attachment feature and the cutting of the associated circuit wiring. Therefore, the testing which was possible was applied to each separate unit/item, and not the physical circuit installed upon the subject aircraft. Although HAECO was nominated and willing to accomplish the testing, they do not hold specific maintenance approval for the MD-11 Wiper Motor, which being classified as a rotatable component, would normally be tested and serviced in accordance with an approved Component Maintenance Manual (CMM). On the other hand, the CBs and Control Switch being of a consumable design, would not normally be the subject of overhaul and repair. Therefore, the scope of the testing was done on the basis that HAECO were not approved for these components, but possessed enough experience and knowledge to apply basic testing techniques. In addition to this, consideration must be given to the fact that unit specifications or CMM's were not to hand. On this basis, best practice was applied to the rudimentary scope of the testing that was possible. All test power was applied in accordance with MD-11 wiring diagrams, reference 30-43-01 supplied by China Airlines.

2 Unit Testing and Results

2.1 Wiper Motor Assembly

2.1.1 This unit was tested to establish the correct operation of the following features:

- i) Operation of the drive motor.
- ii) Operation of drive brake.
- iii) Functioning of parking switch circuit.

2.1.2 Witnessed operation of main drive motor:

- i) The unit ran smoothly without undue noise or vibration.
- ii) No load current draw at low speed was 5 amps.
- iii) No load current draw at high speed was 7.5 amps.
- iv) The output shaft to the wiper arm was witnessed to rotate back and forth in an arc of approximately 30 degrees.
- v) The unit brake released when power was applied, and had a circuit resistance of 60 ohms.
- vi) The wiper parking system interrupter switch was tested during motor operation and found to make and break as would be expected.

It was not possible to apply any representative working load to this unit while running due to the fact that no test bench is available at HAECO. Furthermore, the power and size of this unit is such that any additional testing could only be accomplished on a suitable test stand, or alternatively by the unit being temporarily installation upon another MD-11 aircraft. As no CMMs, or unit design specifications were available, we are unable to determine how this unit conforms to such data.

2.2 15 AMP Main Power Circuit Breaker

2.2.1 This unit was tested to establish the correct operation of the following features:

- i) Ability to sustain a continuously applied current of 15 amps without tripping.
- ii) Test the current overload protection of the unit.

2.2.2 Witnessed operation of the 15 amp CB:

- i) This unit was able to carry a load of 15 amps for over 2 minutes without tripping.
- ii) When tested in overload, a circuit trip occurred after 22 seconds with a load of 30 amps applied.

2.3 5 AMP Control System Power Circuit Breaker

2.3.1 This unit was tested to establish the correct operation of the following features:

- i) Ability to sustain a continuously applied current of 5 amps without tripping.
- ii) Test the current overload protection of the unit.

2.3.2 Witnessed operation of the 5 amp CB:

- i) This unit was able to carry a load of 5 amps for over 2 minutes without tripping.
- ii) When tested in overload, a circuit trip occurred after an average elapsed time of 6 to 8 seconds with a load of 10 amps applied.

2.4 Captains Wiper Control Switch

2.4.1 This unit was tested to establish the correct operation of the following features:

- i) The switch rotated to all three detented positions.
- ii) Basic circuit electrical resistance and continuity test across all six contact positions.
- iii) Basic electrical insulation/leakage test of all terminal to switch the body (aircraft electrical grounding plane).

2.4.2 Witnessed results of the above switch tests:

- i) The switch rotated with positive detents at three positions corresponding to OFF, LOW and HIGH.
- ii) The resistance check applied to all switch contact positions produced the following results:

Across the "A" Contacts

C-1 = 1.2 ohms, C-2 = 2.2 ohms and C-3 = 1.5 ohms

Across the "B" Contacts

C-1 = 2.2 ohms, C-2 = 2.8 ohms and C-3 = 1.6 ohms

- iii) The insulation tests applied to all of the "A" and "B" contacts to the unit body, resulted in an infinity ohmic resistance being achieved, indicating no circuit electrical breakdown.

3. Conclusion

In view of the limited amount of test and specification data to hand for these units, it is not possible to make comprehensive operation statements. However, from the witnessed rudimentary test results, and the condition of the subject components, there is nothing to suggest that they would not be able to operate and function, as designed.

This witness test report was raised and presented by:

C M Lee - Inspector of Accident

Signed:-

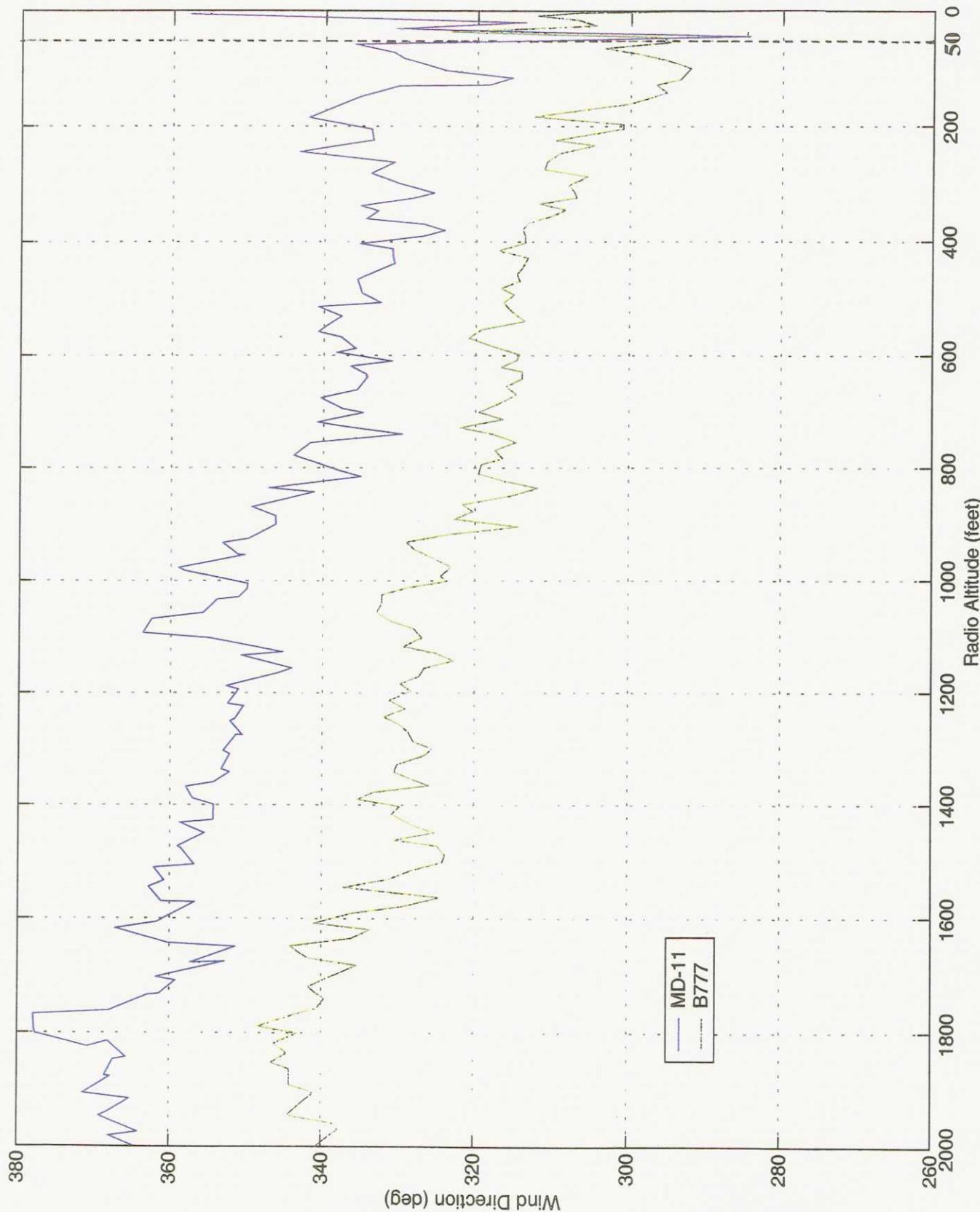


Dated:- 18 February 2000

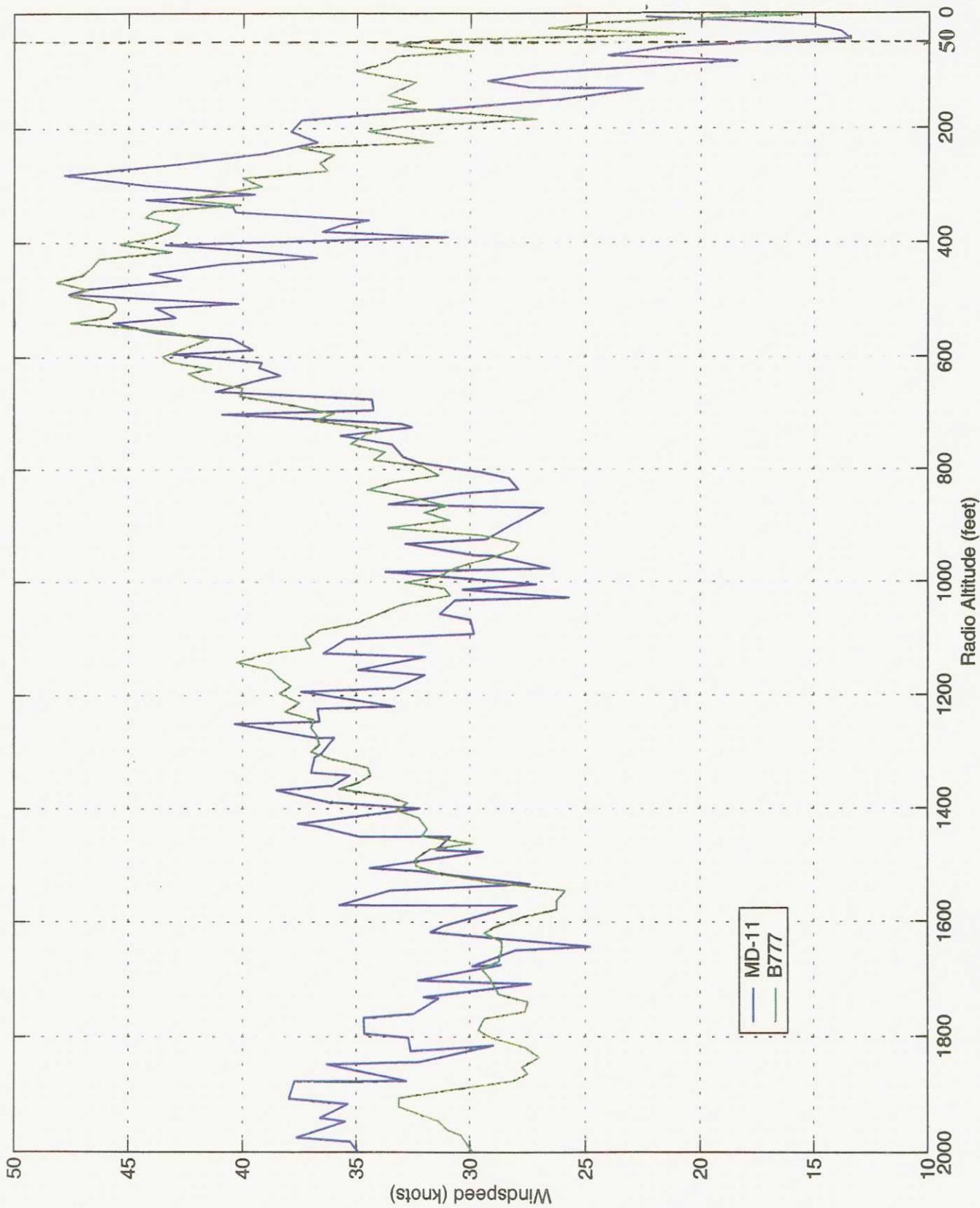
SUMMARY OF APPROACHES
HONG KONG INTERNATIONAL AIRPORT
0657 – 1044 Hours UTC, 22 August 1999

Aircraft type	Landed	Go-around	Comments
Runway in use 07R			
A330		0657	2 nd go-around @ 0727
A330	0700		
MD82	0710		
MD11	0716		
A320	0721		
A330		0727	Diverted
A330		0735	Diverted
A330		0742	Diverted
Runway change to 25L			
A340		0818	Diverted
B742		0830	Diverted
B744	0849		
A340		0859	Diverted
B773	0915		
B744		0940	Diverted
A330		0945	2 nd approach, landed 1019
B773	0947		
B772	0953		
A330	1002		
A330	1019		
B744	1024		
A340	1029		
B763	1031		
A330		1034	Diverted - airport closed due later accident
B744	1036		
B773	1040		
MD11	1043		Accident flight

COMPARATIVE WIND DATA – MD11 / B777 AIRCRAFT



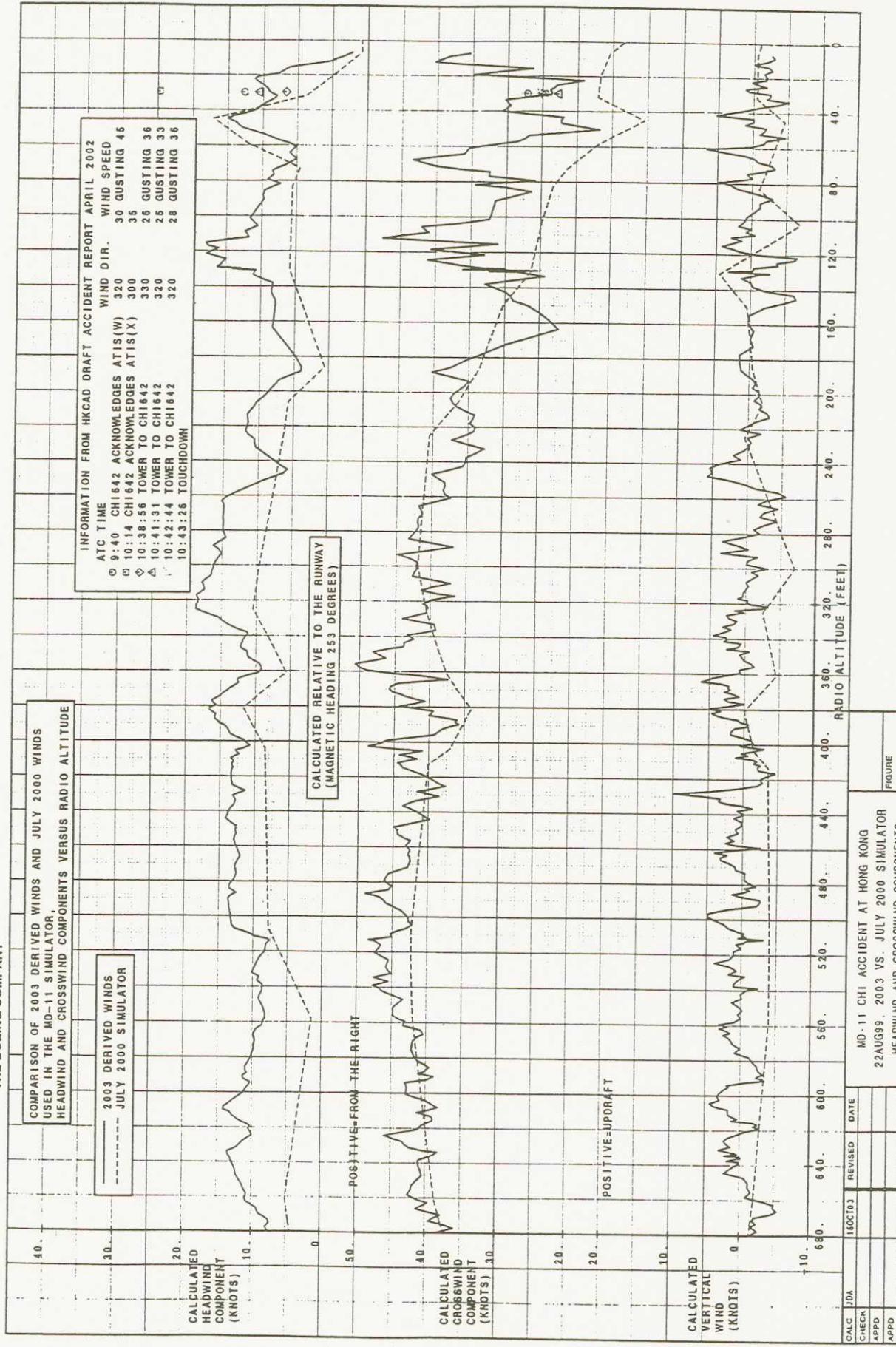
Note : See qualification at Paragraph 1.18.4 of the report regarding accuracy of MD11 wind data below 50 feet RA



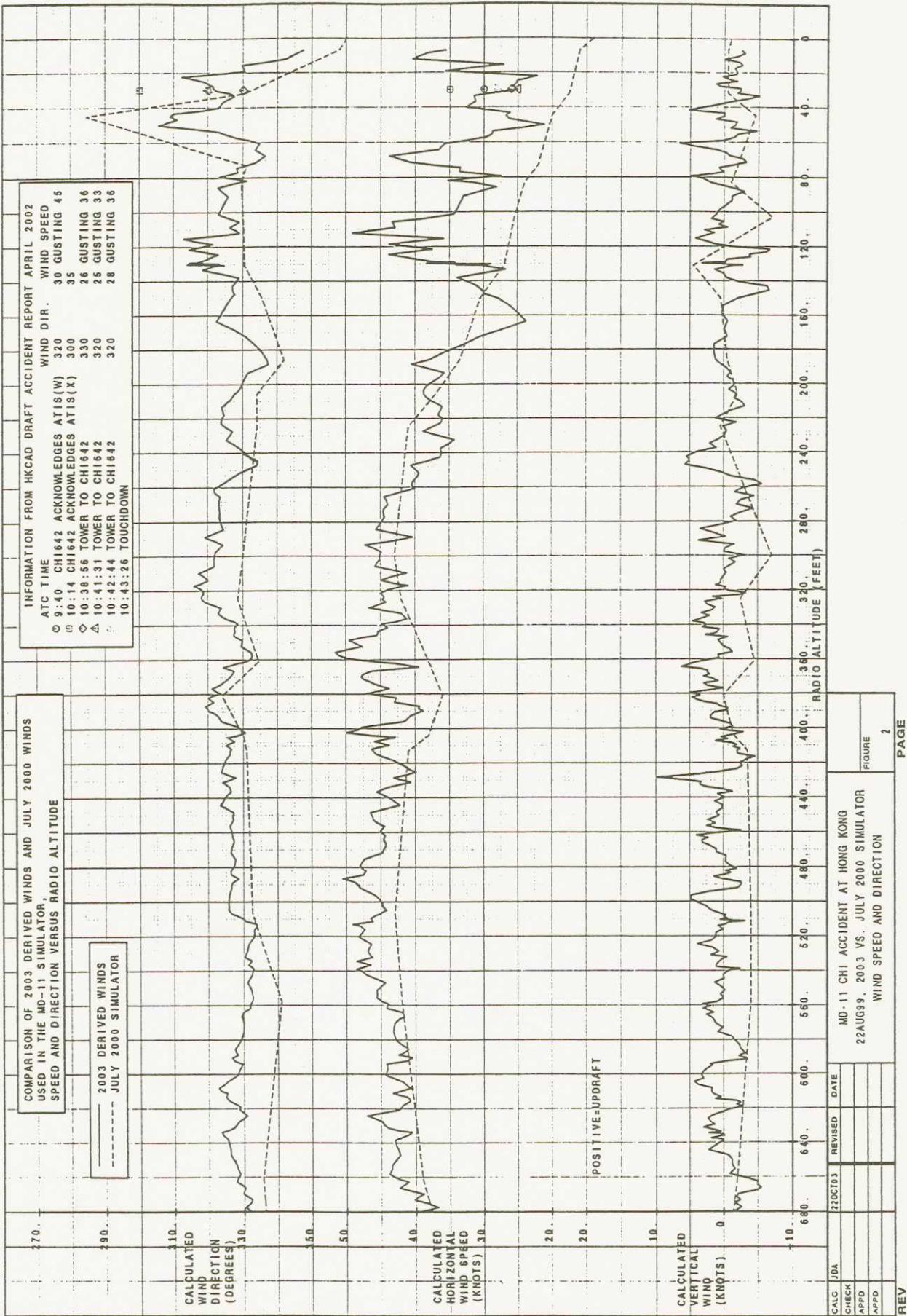
A21-2

Note : See qualification at Paragraph 1.18.4 of the report regarding accuracy of MD11 wind data below 50 feet RA

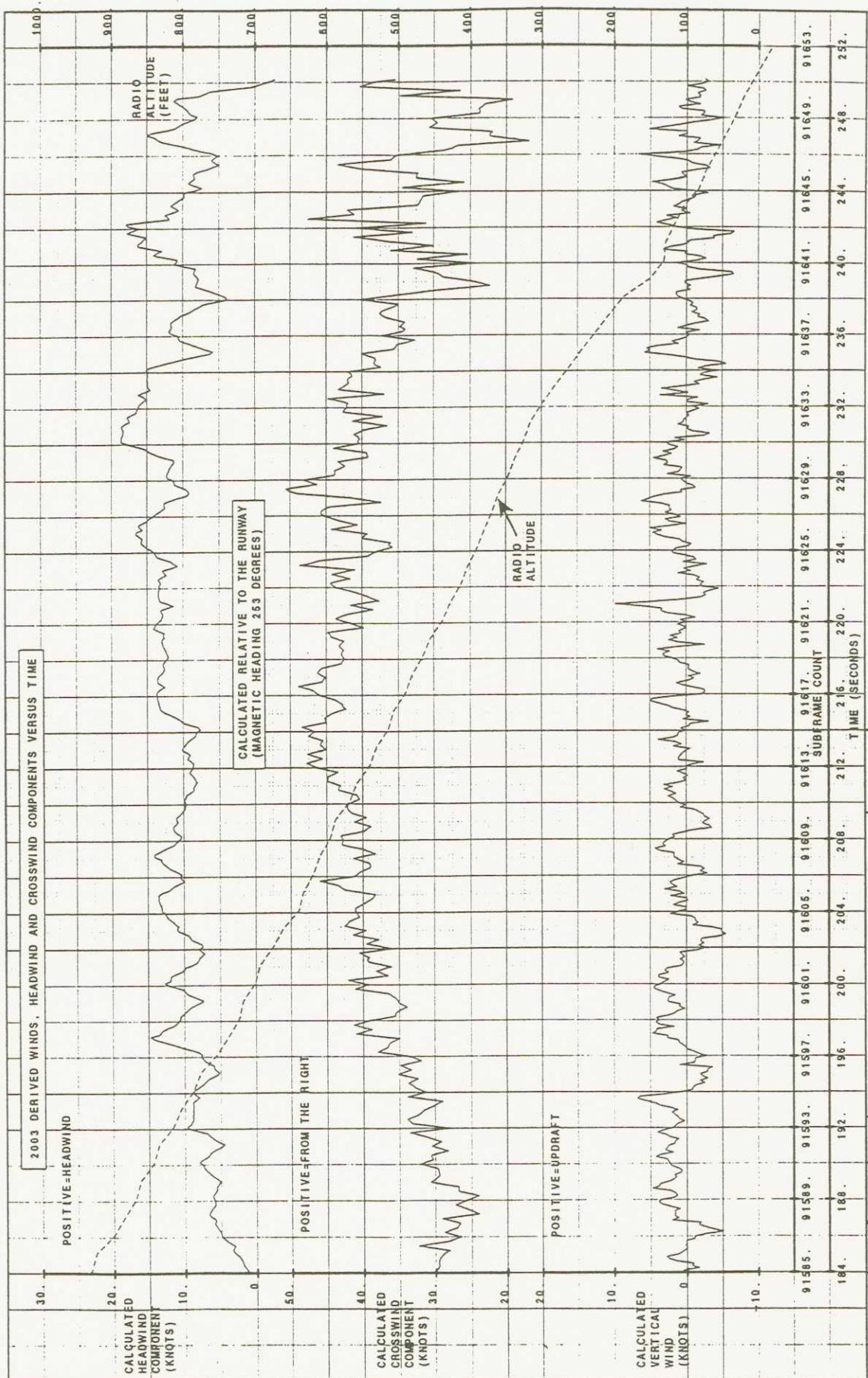
THE BOEING COMPANY



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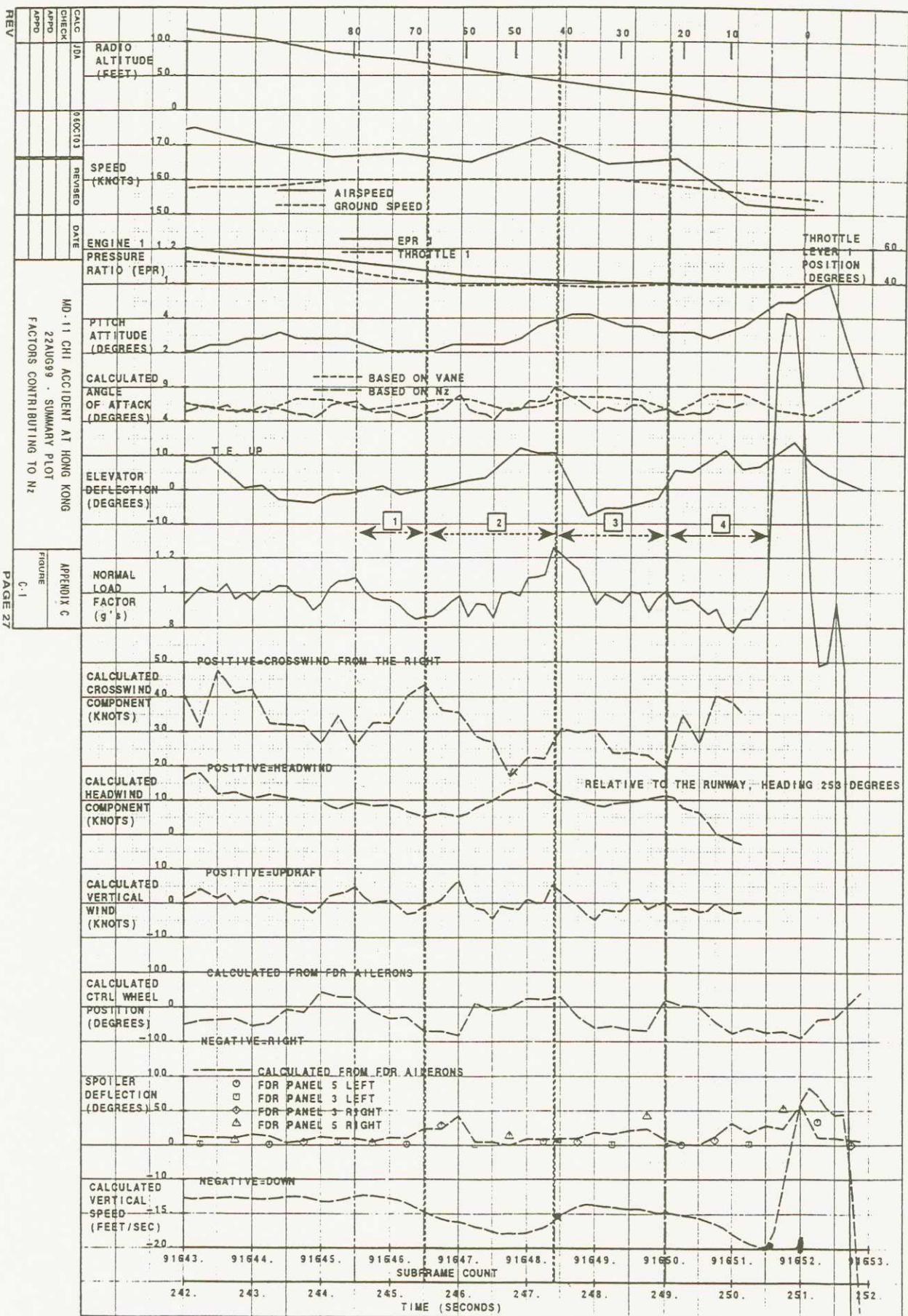


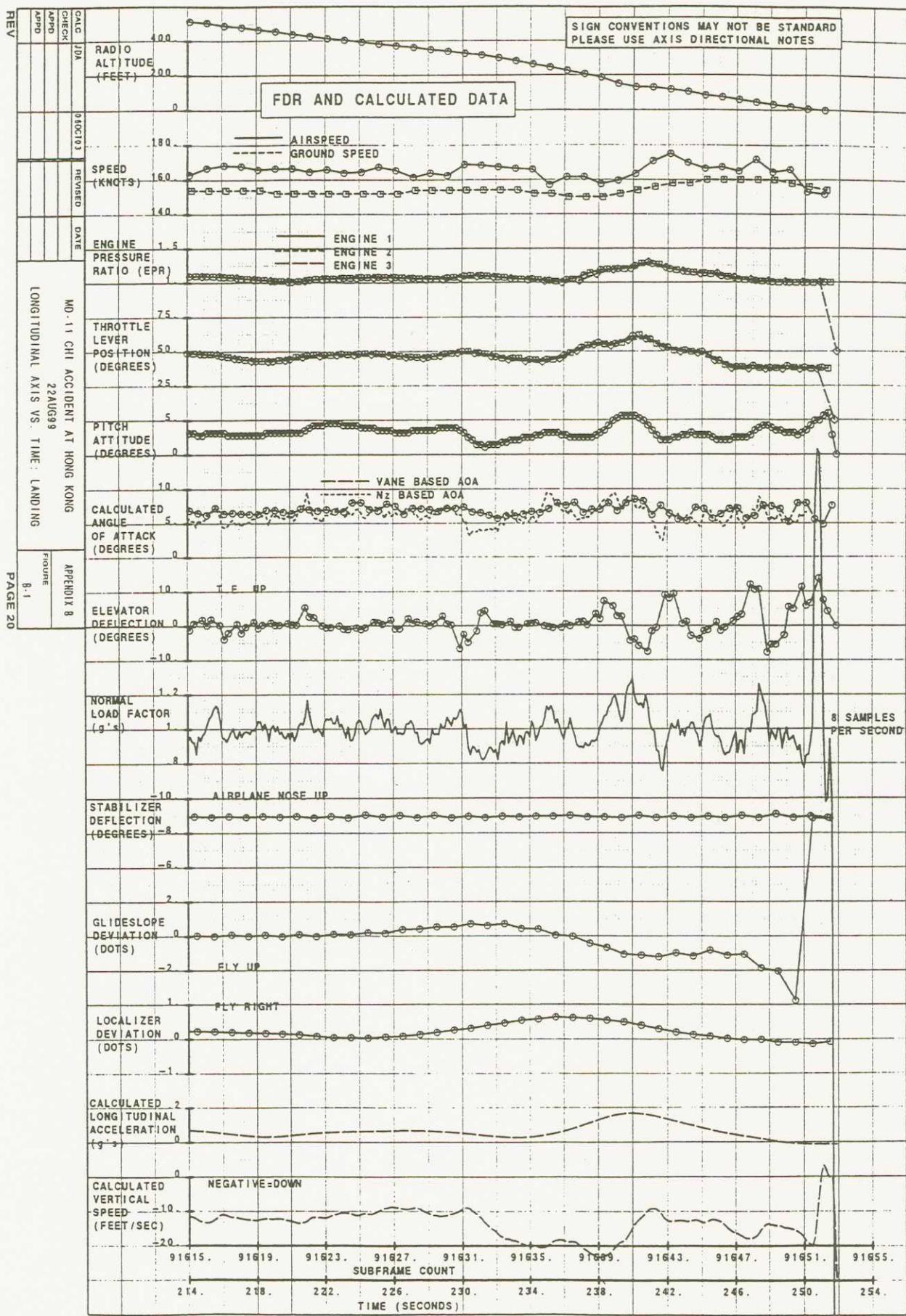
THE BOEING COMPANY

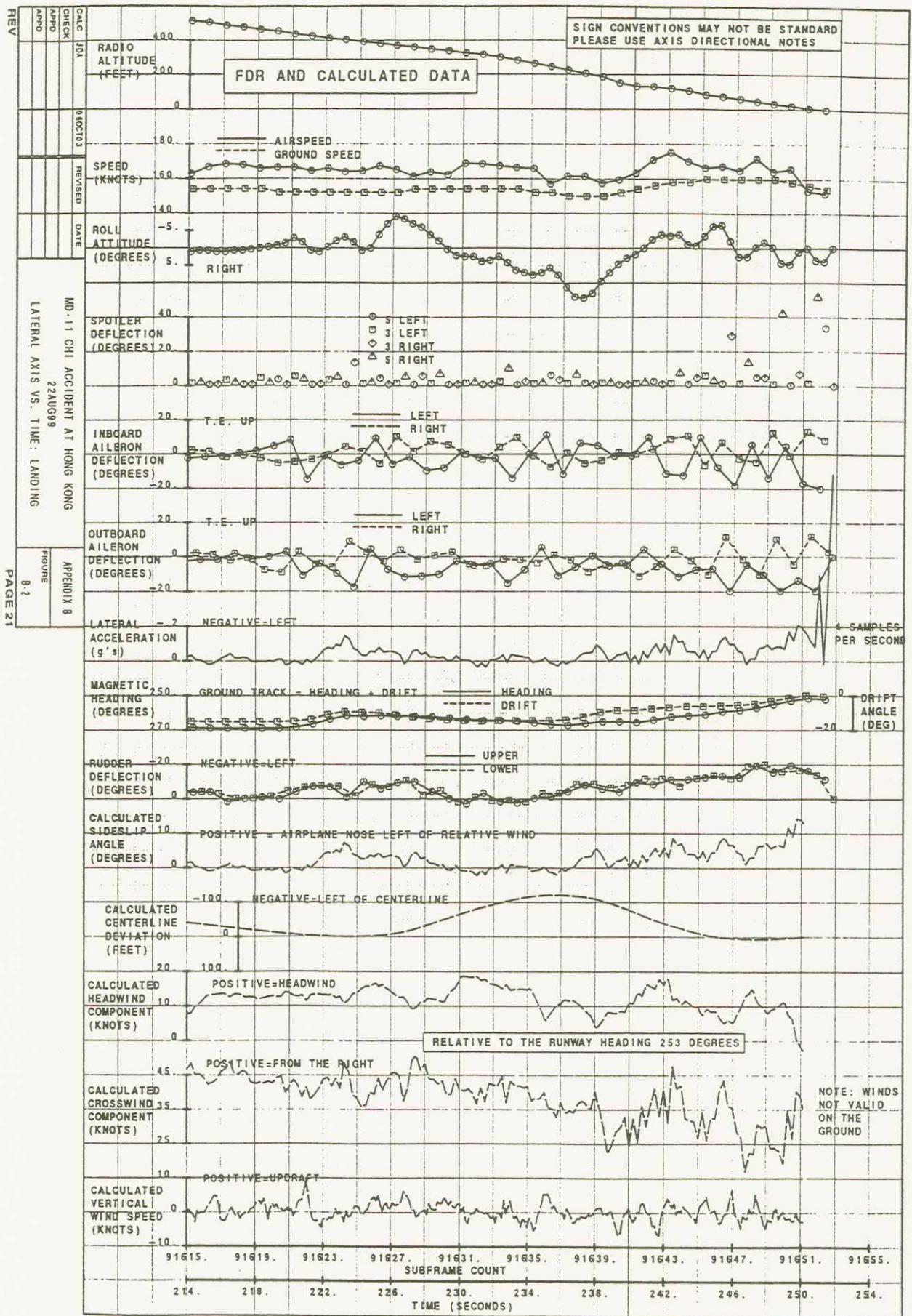


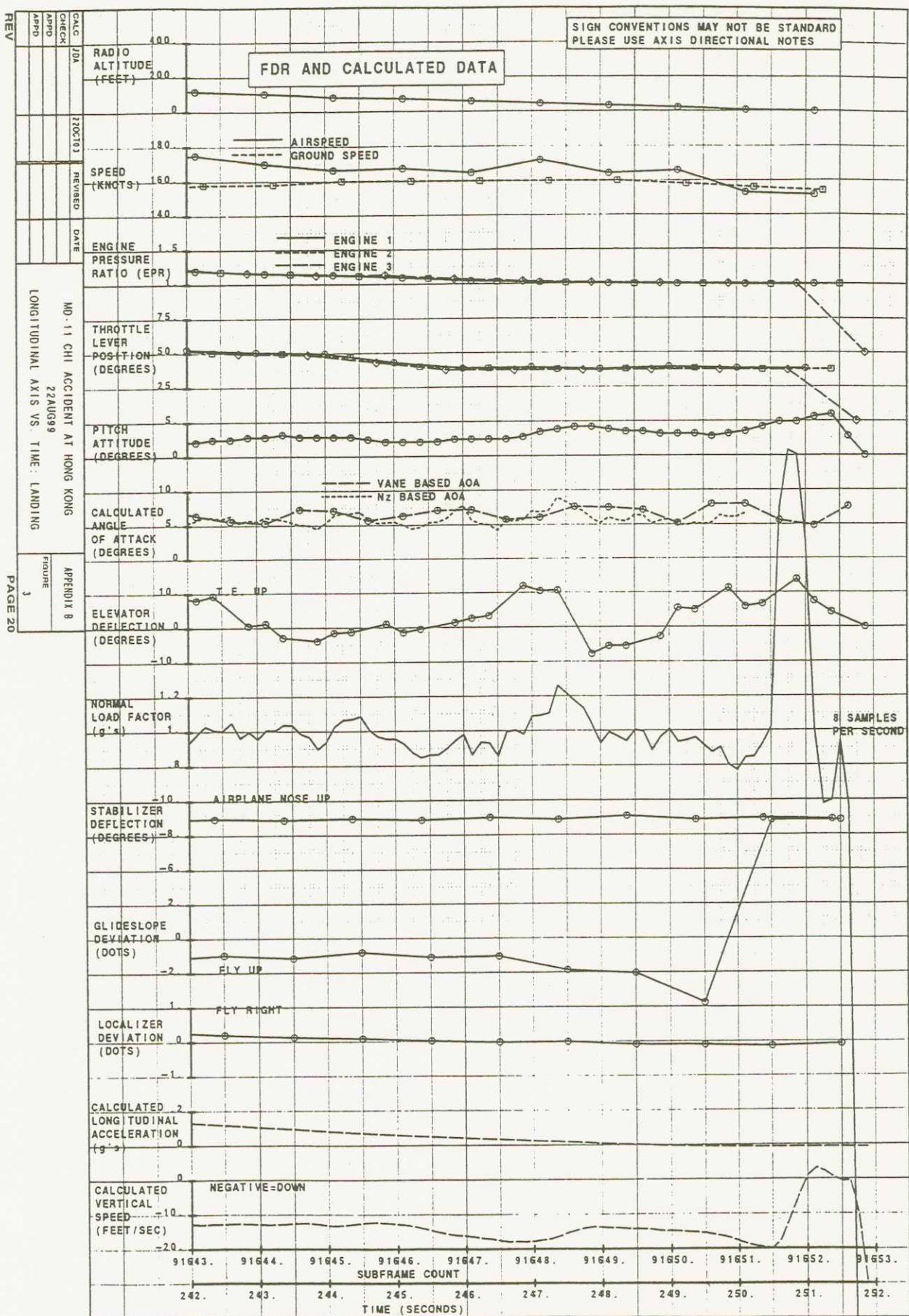
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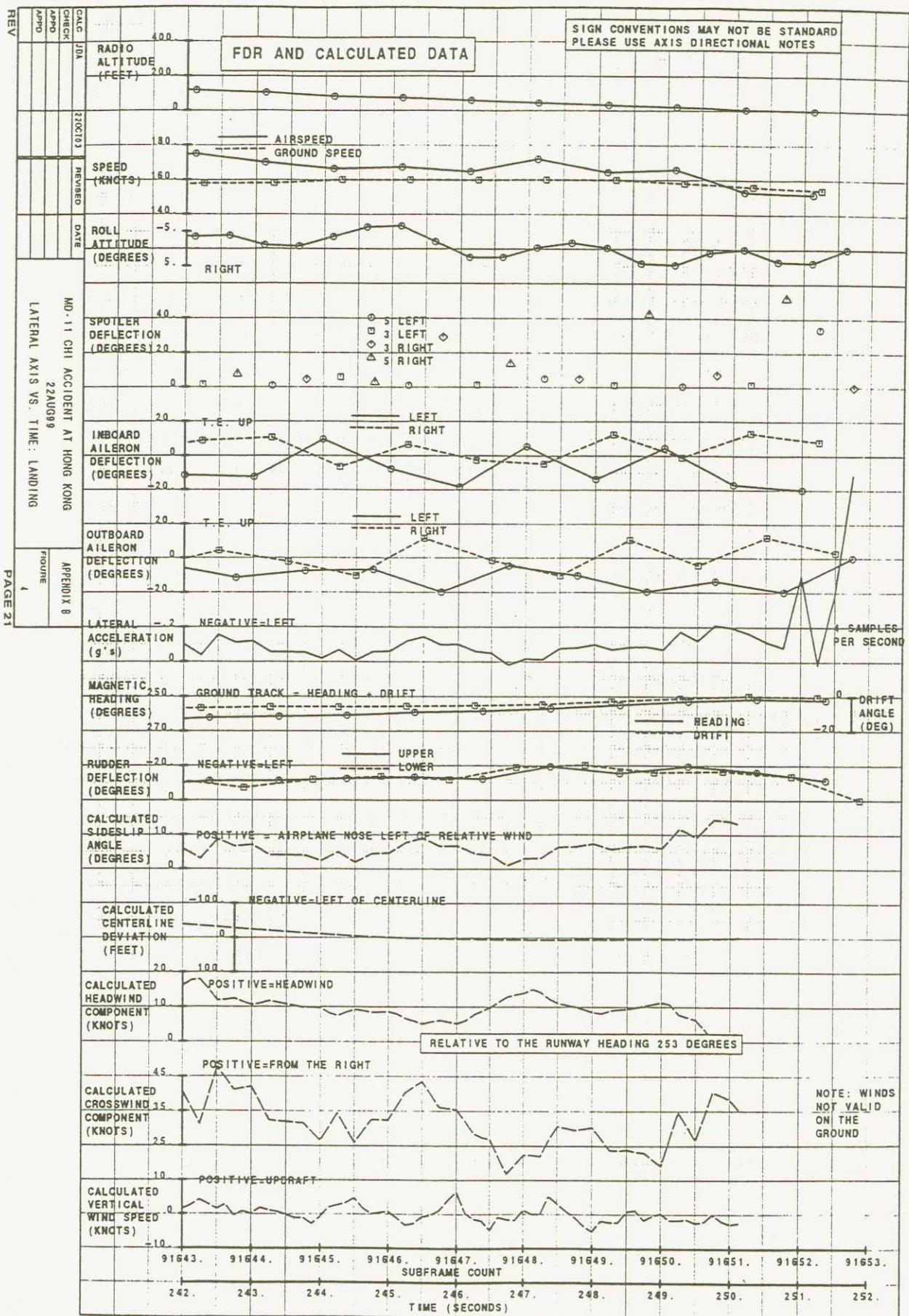
CAIC	IBA	REvised DATE	MD-11 CHI ACCIDENT AT HONG KONG	APPENDIX A
CHECK			22AUG99, 2003 DERIVED WINDS	FIGURE
APPD			HEADWIND AND CROSSWIND VS. TIME	A-1
APPD				
REV				PAGE 16











MD-11 S.O.P.	NORMAL PROCEDURE	REV. 01-01-95	PAGE 93
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PREPARATION FOR DESCENT PROCEDURE

1. ATIS

Acquire the destination weather information from destination ATIS or other appropriate source.

2. MCDU ACT F-PLN PAGE

(1) Select the ACT F-PLN page by pushing the F-PLN key. Page up with the ↑ key on the MCDU until the arrival airport is in view.

(2) Pushing the LS key adjacent to the waypoint prior to the destination selects the LAT REV page.

(3) To select the STAR page push LS key 1R.

(4) On the STAR page select the appropriate approach and landing runway on the right then select the appropriate STAR (if applicable) with the left LS keys. To return to the ACT F-PLN page push " * INSERT" (LS key 6L).

(5) If the approach selected has a transition option the MCDU will automatically display the options for pilot selection.

(6) After picking the appropriate transition push " * INSERT" line select key 6L or "ACT F-PLN" line select key 6R to return to the ACT F-PLN page.

3. MCDU APPROACH PAGE

Select the Approach Page, verify the landing field LENGTH H and ELEV, select the desired flap setting for landing and crosscheck MCDUs for correct VREF speed.

NOTE

Landing field altitude is normally entered into the

MD-11 S.O.P.	NORMAL PROCEDURE	REV. 01-01-95	PAGE 94
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pressurization controller by the FMS. In the event of an emergency return after climbing through 5000 feet above takeoff field altitude or diverting to an airport other than planned. Landing field altitude must be inserted by turning the MANUAL, LDG ALT knob on the Cabin Pressurization Panel.

4. WINDSHIELD ANTI-ICE

Use of windshield anti-ice when descending into high humidity conditions will prevent window fogging.

5. GLARESHIELD

On the EIS Control Panel rotate the RA/BARO Selector to RA or BARO as required and rotate the Minimums Control Knob to the correct Decision Height or Minimum Descent Altitude as appropriate for the approach being flown.

6. CREW BRIEFING

Please refer L/D briefing formats as followed:

FLIGHT CREW BEFORE L/D BRIEFING

(1) WX:

LANDING A/P
ALTERNATE A/P

(2) TIME OF DESCENT

MSA

(3) TRANSITION LEVEL

MSA

(4) RUNWAY IN USE

FIELD ELEVATION

(5) STAR & MISS APPROACH PROCEDURE

(6) GO-AROUND PROCEDURE

MD-11 S.O.P.	NORMAL PROCEDURE	REV. 1	PAGE 95 12-31-95
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PREPARATION FOR DESCENT PROCEDURE (CONT'D)

PUSH G/A BUTTON, ADVANCE THROTTLES
 FLAPS 28, POSITIVE RATE, GEAR-UP.
 ALT _____ LEVEL CHANGE
 ALT _____ SPEED SELECT
 THEN FLAPS SKJ & CONTINUE CLIMB.
 (7) FMS & NAV RADIO SET UP
 (8) REMARK:

MD11 FLIGHT CREW CAT II APPROACH BRIEFING

- WX :
 1. LANDING AIRPORT ATIS _____
 ALTERNATE AIRPORT _____
 2. TIME OF DESCENT _____
 3. TRANSITION LEVEL _____
 MSA _____
- RUNWAY IN USE _____
 FIELD ELEVATION _____
 ILS FRQ & CRS _____
 LANDING CAT II OR III. DH OR AH _____
 AUTOLAND OR MANUAL LAND.
- STAR & MISS APPROACH PROCEDURE.
- MINIMUM DIVERSION FUEL.
- GO-AROUND PROCEDURE.
 PUSH G/A BUTTON, ADVANCE THROTTLES.
 FLAPS 28, POSITIVE RATE, GEAR-UP.
 LEVEL CHANGE PROFILE
 HEADING SELECT OR NAV
 SPEED SELECT MAP
 MAP
- THEN FLAPS SKJ & CONTINUE CLIMB.
- FMS & NAV RADIO SET-UP.
- REMARK :

MD-11 S.O.P.	NORMAL PROCEDURE	REV. 1	PAGE 95 01-01-95
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PREPARATION FOR DESCENT PROCEDURE (CONT'D)

7. SEAT BELTS SWITCHES PF
 Move SEAT BELTS switch to ON when beginning the descent from cruise altitude.

8. SHOULDER HARNESS PF/PNF
 PF and PNF should fasten their shoulder harness before descend.

9. DESCENT/APPROACH CHECKLIST PNF
 Begin the DESCENT/APPROACH checklist by accomplishing the check list through SEAT BELTS.

NOTE

Refer to supplemental procedures and procedures and techniques sections of the FCOM for operation of AUTO FLIGHT and MCDUs during descent phase of flight.

DESCENT TECHNIQUES

• STANDARD DESCENT PROCEDURE

- The FMS will consider the optimum point to begin an unrestricted descent to a landing, however, in actual operations, when it is necessary to compute a TOD point, use the following rule-of-thumb:
 - Determine the altitude difference.
 - Drop the last three digits.
 - Multiply by three.
 - For an unrestricted descent to a landing, add 10 n.m.
 - For a descent to an intermediate altitude above 10000 feet, no additive required.
 - Adjust TOD point for wind (tailwind-earlier TOD headwind-later TOD);

China Airlines

MD-11 Accident, August 22,1999

At Hong Kong International Airport,

Hong Kong

Comments on the draft final report

By the

Aviation Safety Council

Taiwan

Submitted June 2002

TABLE OF CONTENTS

- Part 1** - Overview of the ASC's Comments
- Part 2** - Comments on Section 1, Factual Information
- Part 3** - Comments on Section 2, Analysis
- Part 4** - Comments on Section 3, Conclusions
- Part 5** - Comments on Section 4, Safety Recommendations

REFERENCES

- Reference A** - CAD Aircraft Accident Report 1/2002 (Final Draft) dated April 2002.
- Reference B** - ICAO ISRPs Annex 13 to the Convention on International Civil Aviation - Aircraft Accident and Incident Investigation Section 6.3.
- Reference C** - ICAO ISRPs Annex 3 to the Convention on International Civil Aviation – Meteorological Service for International Air Navigation, Section 5.6.
- Reference D** -CAD Aircraft Accident Report 1/2001 dated June 2001
- Reference E** -Fujita, T.T. Manual of downburst identification for project NIMROD”, University of Chicago, SMRP research Paper No.156, 104pp.dated 1978
- Reference F** –Technical Note No.102, Hong Kong Observatory

Part 1

An Overview of the Comments from the ASC to the CAD on the Confidential Draft Final report Concerning the China Airlines Boeing MD-11 Accident at Hong Kong Airport, August 22nd 1999

ASC Comments

The ASC, Accredited Representative team on CI642 accident investigation has carefully studied and reviewed the CAD draft Final Report.

The sole purpose of the ASC's comments is to provide constructive feedback to Hong Kong on the draft Final Report. Our aim is to achieve a Final Report of the highest possible quality, and one that will make a significant contribution to the enhancement of international aviation safety.

The Guiding Principles of the ASC's review of the Hong Kong Draft Final Report

In accordance with the principles and spirit of Annex 13, our aim is to ensure that the Draft Final Report of the CI-642 investigation is accurate, objective and balanced, and does not apportion blame or liability.

We have considered the Hong Kong draft Final Report in the light of established and proven air safety investigation methodology. We have considered whether all of the relevant factual material gathered in the investigation has been included in the Hong Kong draft Final Report. We have also assessed the degree to which the analysis and conclusions are based upon sound investigation procedures and factual evidence.

Both CAD, Hong Kong and ASC, Taiwan share the common goal of pursuing excellence in aviation safety. Notwithstanding the difficulties that have been encountered, ASC hopes that the valuable lessons learned by both Hong Kong and Taiwan from the experience of the CI-642 investigation will enhance aviation safety.

The Hong Kong draft Final Report

The ASC considers that:

- a) The Hong Kong draft Final Report minimizes the significance of the absence of high capability wind shear warning detection system at Chap-Lap-Kok Airport. The improvement of wind shear detecting system is a major challenge confronting the world aviation industry.
- b) The Hong Kong draft Final Report also minimizes the finding of the three very valuable simulator lessons tested at Boeing facility, Long Beach, California.
- c) The Hong Kong draft Final Report does not adequately address the RWY 25L and 25R wind difference analysis attributed from passenger terminal building. It should be considered in that context. See Figure 1 below.

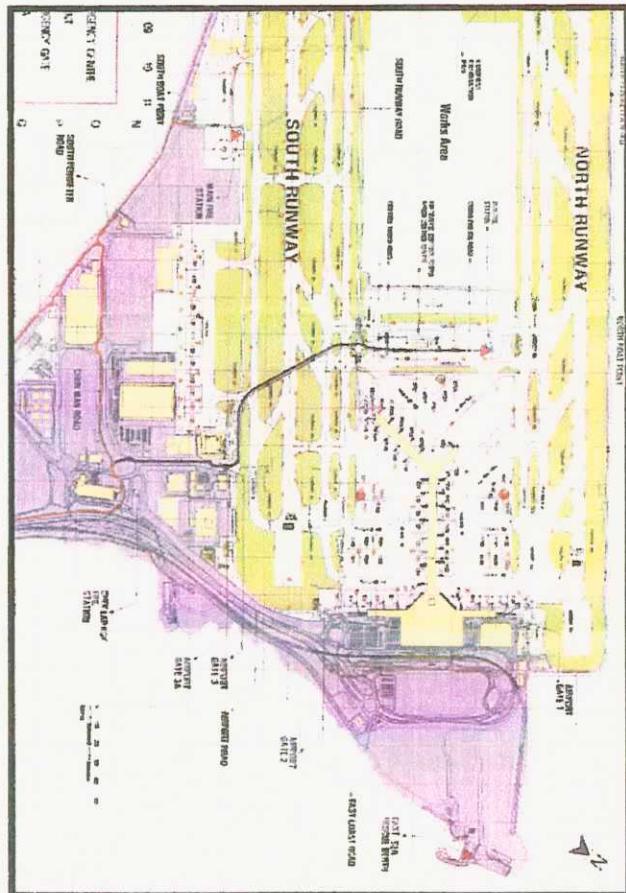


Figure 1. Runway 25L approach area in the lee of the Passenger Terminal Building

Part 2

Comments on Section 1, Factual Information

Reference A, Section 1.1. History of the flight Pg. 6 Para 3

ASC issues and Discussion

This paragraph contains: "...and exited through L1 door and began..." which does not reflect the actual fact, since the crew exited through a hole in the fuselage.

ASC proposed changes

Change Page 6, Para 3 of Ref. A Section 1.1 to read: "...and exited through a hole in the fuselage and began..."

Part 3

Comments on Section 2, Analysis

ASC proposes the following paragraphs and figures to support the findings as a result of analysis that based on recorded data and known aircraft characteristics.

(A) Wind derived from FDR data

According to FDR parameters, ASC interpolated the horizontal wind direction, wind speed, vertical wind speed and derived the following data as shown in Table 1.

UTC Time	CAS	BALT (DRA)	sink rate VG	airkrate VG	MDHEading	ROLL	FITCH	GSPD	DRIFT	AOA1L	AOA2L	ELEV RIB	ELEV RCB	flight path angle	WNPD (Easting)	WINDIR (Easting)	Vert.WNPD (Easting)
(hh:mm:ss) (knot)	(deg)	(ft/s)	(ft/s)	(deg)	(deg)	(deg)	(deg)	(ft/sec)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)	(Km)	(deg)	(Km)
10:44:01.0	169.0	225	-13	-8.89	264	2.46	3.16	154	-14.42	6.86	5.45	-4.83	-1.76	-3.7	46.15	323.23	4.82
10:44:02.0	165.5	316	-9	-11.68	264	3.87	1.41	154	-14.77	5.27	4.57	4.31	5.89	-3.86	42.85	317.70	6.13
10:44:03.0	167.5	268	-16	-16.20	264	2.46	1.41	154	-14.42	3.69	4.39	0.85	1.22	-2.28	46.35	322.89	4.16
10:44:04.0	166.5	292	-18	-18.29	265	6.33	2.11	154	-14.42	4.39	4.92	-0.53	0.44	-2.28	47.95	326.10	1.89
10:44:05.0	166.0	268	-19	-19.91	266	7.74	2.46	152	-14.42	5.62	5.37	0.79	1.76	-3.16	48.37	329.80	8.26
10:44:06.0	157.0	245	-18	-19.21	267	5.63	3.16	152	-14.42	6.33	7.91	-0.62	-0.70	-2.17	39.65	322.10	0.52
10:44:07.0	161.5	225	-20	-17.76	267	11.25	2.81	150	-14.06	7.21	8.89	-0.09	2.37	-4.4	37.33	321.89	2.11
10:44:08.0	161.5	206	-19	-18.82	266	14.42	2.46	150	-12.31	5.27	6.15	0.18	4.13	-2.81	26.70	317.93	3.03
10:44:09.0	157.5	186	-20	-21.33	265	9.49	3.16	150	-9.49	6.15	7.91	7.21	6.33	-2.99	25.74	325.08	8.96
10:44:10.0	129.5	150	-36	-17.89	265	4.57	5.27	152	-12.84	5.80	7.91	2.72	3.34	-0.53	27.07	315.40	4.81
10:44:11.0	163.5	131	-19	-12.47	265	1.76	5.63	154	-8.44	8.96	8.44	-5.89	-1.82	-3.33	26.56	308.30	1.51
10:44:12.0	171.0	129	-2	-7.88	264	-1.46	3.52	156	-7.39	4.73	7.21	-0.53	0.18	-1.23	33.30	304.00	2.76
10:44:13.0	172.0	117	-12	-11.98	262	-3.52	2.11	158	-6.88	5.10	3.52	9.32	-0.44	-2.99	26.42	301.89	7.22
10:44:14.0	170.0	104	-13	-11.58	262	-1.05	2.81	158	-5.98	2.99	6.68	-2.90	-4.73	-0.18	31.85	307.68	8.59
10:44:15.0	166.5	89	-21	-12.06	261	-3.52	2.81	160	-5.98	6.33	3.69	-1.23	-2.31	-3.52	24.48	307.40	4.78
10:44:16.0	167.5	73	-10	-11.45	259	-6.68	2.11	160	-5.63	4.97	6.33	-0.44	0.88	-2.81	29.15	314.90	1.72
10:44:17.0	165.0	59	-14	-14.65	258	2.46	2.46	160	-5.27	6.58	3.87	3.34	1.58	-4.04	21.85	315.16	5.29
10:44:18.0	172.0	45	-14	-16.07	257	-0.35	3.32	160	-4.37	4.39	7.21	10.63	-8.53	-0.87	28.50	271.40	8.79
10:44:19.0	164.5	22	-13	-12.30	255	-0.35	3.87	160	-2.81	7.03	6.33	-5.45	3.43	-2.16	17.81	301.10	0.46
10:44:20.0	165.0	21	-11	-13.27	253	4.57	3.16	160	-1.89	2.91	7.91	5.01	3.69	0.38	18.49	308.00	4.22
10:44:21.0	153.0	7	-14	-16.82	251	0.00	3.52	156	0.26	7.91	2.52	6.68	15.73	-4.39	20.87	341.60	4.14
10:44:22.0	161.5	1.1	-8	-4.45	252	3.87	5.63	154	-0.38	2.11	-4.57	4.72	-10.37	3.52	20.87	343.96	6.21

Table 1. FDR Parameters and Derived Wind Data

From table 1 ASC identified the following information:

- (1) At altitude of 325 ft ~ 150 ft RA, the wind speed varied from 46.2 knots to 27.7 knots, and wind direction varied from 315 degree to 326 degree. This wind condition is consistent with the data of ground measurement.
- (2) Sinking rate was integrated from vertical acceleration and found varied with parameters of the vertical acceleration and angle of attack.
- (3) The vertical wind was found varied at different altitude till touch down.
- (4) This high sinking rate was found affected by wind. At 117 ft RA and 32 ft the wind speed indicated 36 knots and 17.8 knots,

(B) Downdraft Analysis

Professor Fujita of University of Chicago stated the wind change in convective mode, with wind speed over 34 knots, is called downdraft. Fujita also pointed out that the over 12 ft/sec wind change rate could also be defined as a downdraft. (Reference E)

Wind shear refers to a change in the headwind or tailwind for more than a few seconds, resulting in changes in the lift to an aircraft. A decreased lift will cause the aircraft to go below the intended flight path. In the presence of significant windshear, a pilot has to take corrective action in a very short time. Turbulence is caused by rapid irregular motion of air. It brings about bumps or jolts. In severe cases, the aircraft might go momentarily out of control. (1.1 pp1 , Reference F)

Refer to Table 1; there are two major findings as below:

(1) The significant delta CAS or unsteady horizontal wind:

Between 300 ft ~ 186 ft, the CAS varied from 167.5 to 157.5kts (-10.0 kts) .

Between 186 ft ~ 117 ft, the CAS varied from 157.5 to 175 (+17.5 kts) .

Between 117 ft ~ 7 ft, the CAS varied from 175.0 to 153.7 (-21.3 kts) .

(2) The significant vertical wind changed:

During passing 316 ft ~ 245 ft, the vertical wind speed varied from +8.13 to -0.53

During passing 206 ft ~ 150 ft, the vertical wind speed varied from +3.01 to -4.81.

During passing 59 ft ~ 21 ft, the vertical wind speed varied from +5.29 to -0.22.

Below 50 ft RA, according to Table 2, the sinking rate of CI642 varied from 16.1 ft/sec to 12.0 ft/sec. There were significant vertical accelerations data recorded in FDR. During this period, the ground speed indication was stable at 158 knots and the angle of attack (AOA) varied. ASC believes that below 50 ft RA, the aircraft encountered a downdraft that affected the descent rate.

UTC Time	CAS	RALT	sink rate (DRA)	sinkrate VG	Meaning	ROLL	PITCH	OSPD	DRIFT	AOA	flight path angle	WSPD (Boeing)	WINDIR (Boeing)	VERT ACC	ELEV LIB	ELEV RIB	ELEV ROB	ELEV LOB
(hh:mm:ss)	(knots)	(feet)	(ft/s)	(ft/s)	(deg)	(deg)	(deg)	(ft/sec)	(deg)	(deg)	(deg)	(Kts)	(deg)	(g)	(deg)	(deg)	(deg)	(deg)
10:44:18.0	172	45	-14	-16.1	257.02	-0.35	3.52	160	-4.57	4.39	-0.87	20.38	271.60	1.083	10.55			
10:44:18.1				-15.7											1.087			
10:44:18.2				-15.3			3.87								1.101		10.63	
10:44:18.4				-14.2											1.261			
10:44:18.5				-13.4		-1.76	4.22				7.21	-2.89			1.215			8.53
10:44:18.6				-12.7											1.170			
10:44:18.7				-12.2			4.22								1.128			-1.73
10:44:18.9				-12.0											1.035			
10:44:19.0	164.5	32	-13	-12.3	254.91	-0.35	3.87	160	-2.31	7.03	-3.16	17.81	301.10	0.927	-5.45			
10:44:19.1				-12.3											0.991			
10:44:19.2				-12.3			3.52								0.956		-5.45	
10:44:19.4				-12.7											0.938			
10:44:19.5				-12.7		4.22	3.52			6.33	-2.81				1.003			3.43
10:44:19.6				-12.7											0.993			
10:44:19.7				-13.2			3.16								0.986			-2.72
10:44:19.9				-13.3											0.954			
10:44:20.0	166	21	-11	-13.3	252.8	4.5	3.16	150	-1.05	2.81	0.35	18.49	290.00	1.007	5.54			
10:44:20.1				-13.5											0.984			
10:44:20.2				-13.7			3.16								0.943		5.01	
10:44:20.4				-13.9											0.959			
10:44:20.5				-14.2		1.0	2.81			7.91	-5.1				0.916			3.69
10:44:20.6				-14.7											0.874			
10:44:20.7				-15.1			3.16								0.904			11.34
10:44:20.9				-15.9											0.803			
10:44:21.0	153	7	-14	-16.8	251.39	0	3.52	156	0.28	7.91	-4.39	21.87	341.60	0.771	5.39			
10:44:21.1				-17.4											0.849			
10:44:21.2				-18.0			4.22								0.849		6.68	
10:44:21.4				-18.3											0.925			
10:44:21.5				-16.3		3.52	4.93			3.52	1.4				1.019		15.73	
10:44:21.6				-13.0											2.294			
10:44:21.7				-6.5			4.93								2.630			13.8
10:44:21.9				0.0											2.026			
10:44:22.0	151.5	-1	-8	4.4	252.1	3.87	5.63	154	-0.28	2.11	3.52	20.87	343.90	2.104	7.47			
10:44:22.1						4.5									1.005			
10:44:22.2						2.8		5.98							0.877		4.22	
10:44:22.4						1.1									0.997			
10:44:22.5															0.938			-10.37
10:44:22.6															0.403			
10:44:22.7															0.385			-9.49
10:44:22.9															0.316			

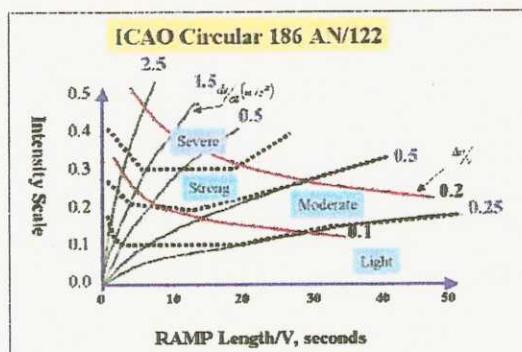
Down draft

T/D

Table 2 Vertical Acceleration Variations Below 50 ft RA

(C) Wind Shear Identification from Flight Data Record

In 1987, ICAO proposed a method to measure the wind shear hazard (ICAO, 1987). This method categorizes the wind shear into four levels: light, moderate, strong and severe. The wind shear identification depends on two parameters, i.e. the air speed change and the proportion of air speed, as shown in Figure 3.



Wind Shear identification method - airspeed variation, published by ICAO.
Source: Prof. Fujita, Univ. of Chicago, USA, 1985

Figure 3: Wind Shear Intensity classification

CI642 FDR Analysis
[Wind Shear Intensity Vs. CAS/TLA/Wind speed]

UFC Time	CAS	delta CAS	alt	Dt/s	ms/dt	windstructure	delta YWSPD	delta WSPP	TLA	AOA	Vert Wind	WSPD	WINDIR	GSPPD	TLA1	TLA2	TLA3	HEADING	PITCH
hrs	kts						(hrs)	(hrs)		deg	(kts)	(kts)	(deg)	KTIS	(deg)	(deg)	(deg)	Deg	deg
18:43:46	167.0								507.0	5.10				154.0	48.2	48.2	47.6	268.9	3.2
18:43:47	168.5								490.0	5.10	4.1	50.4	317	154.0	46.8	46.1	45.0	268.9	3.2
18:43:48	168.0								481.0	4.80	4.7	48.9	323	154.0	44.6	43.9	43.2	268.9	3.2
18:43:49	166.0	-1.6	3.0	0.61	0.17	below light	-0.1	-4.7	466.0	4.80	3.9	45.8	326	154.0	43.2	43.2	42.9	268.9	3.2
18:43:50	166.5								455.0	5.10	4.3	47.0	316	152.0	42.9	43.6	43.6	268.9	3.2
18:43:51	166.5								438.0	5.10	3.3	44.4	320	152.0	44.3	46.1	46.1	268.2	3.2
18:43:52	164.5								427.0	6.20	4.6	40.4	313	152.0	47.1	47.5	46.8	266.5	3.9
18:43:53	166.0	-0.5	3.0	0.61	0.16	below light	-2.3	-3.6	415.0	6.20	2.0	43.1	325	152.0	47.5	47.5	46.7	263.7	4.6
18:43:54	164.0								404.0	6.10	-0.4	46.0	316	152.0	48.2	47.8	47.5	261.6	4.2
18:43:55	164.5								391.0	8.10	4.1	34.5	320	152.0	48.2	48.5	47.8	261.9	3.9
18:43:56	167.5	1.5	3.0	0.61	0.26	below light	1.3	-4.0	381.0	7.00	3.2	39.4	316	152.0	48.5	48.2	47.1	261.6	3.5
18:43:57	165.5								370.0	7.00	6.0	41.7	318	152.0	47.5	46.8	46.8	261.9	3.2
18:43:58	161.5								361.0	6.20	6.0	39.0	325	154.0	46.1	45.7	45.0	261.9	3.5
18:43:59	164.0								347.0	6.20	4.1	43.2	325	154.0	45.7	46.4	46.8	262.3	3.5
18:44:00	162.5								338.0	6.90	2.4	42.4	325	154.0	48.2	48.5	48.9	263.0	3.9
18:44:01	169.0	7.5	3.0	0.61	1.29	below light	-2.0	7.2	325.0	6.90	4.0	46.2	313	154.0	49.9	49.9	48.5	263.7	3.2
18:44:02	168.5								316.0	3.70	8.1	42.1	318	154.0	48.9	48.2	46.4	264.4	1.4
18:44:03	167.5								300.0	3.70	4.2	46.2	313	154.0	46.1	45.0	43.9	264.4	1.4
18:44:04	166.5								282.0	5.60	1.0	47.9	326	154.0	45.0	45.0	42.9	264.7	2.1
18:44:05	166.0								265.0	5.60	0.4	43.3	321	152.0	43.9	43.6	42.5	265.0	2.5
18:44:06	157.0	-11.5	4.0	0.61	1.38	moderate	-8.7	-2.4	245.0	7.20	-0.5	39.7	312	152.0	43.9	43.9	44.6	266.8	3.2
18:44:07	161.5								225.0	7.20	2.1	37.5	321	150.0	47.1	48.9	50.3	267.2	2.8
18:44:08	161.5								206.0	6.20	3.0	36.8	311	150.0	52.7	54.5	54.8	266.1	2.5
18:44:09	157.5	-10.0	6.0	0.61	0.88	light	-3.2	-10.6	186.0	6.20	1.0	35.7	325	150.0	56.2	55.2	54.1	265.1	3.2
18:44:10	159.5								150.0	9.00	-4.8	27.7	312	152.0	55.5	56.2	58.0	265.1	5.3
18:44:11	163.5								131.0	9.00	1.5	26.6	308	154.0	61.2	61.9	59.1	265.4	5.6
18:44:12	171.0								129.0	5.10	2.7	33.3	311	156.0	58.7	55.5	52.7	264.0	3.5
18:44:13	175.0	17.5	4.0	0.10	2.25	strong	6.3	0.7	117.0	5.10	7.2	36.4	301	156.0	52.7	50.6	49.6	262.3	2.1
18:44:14	170.0								104.0	6.30	1.0	31.8	308	158.0	50.6	49.6	48.5	261.0	2.8
18:44:15	166.5								83.0	6.30	4.8	24.5	307	160.0	49.6	47.1	43.2	260.9	2.3
18:44:16	167.5								73.0	6.50	1.	29.1	312	160.0	49.2	49.1	37.6	259.1	2.1
18:44:17	165.0	-10.0	4.0	0.06	1.29	moderate	-1.9	-14.6	59.0	6.50	5.3	21.9	317	160.0	38.7	38.7	37.3	258.4	2.8
18:44:18	172.0								45.0	7.00	0.8	20.4	277	160.0	39.4	39.0	37.3	257.0	3.5
18:44:19	164.5								32	7.00	0.5	17.8	301	160.0	38.6	38.3	37.3	254.9	3.9
18:44:20	166								21	7.00	-0.2	18.5	287	158.0	39.4	38.3	37.3	252.8	3.2
18:44:21	133								7	7.00	4.1	20.9	341	156.0	38.7	37.6	37.3	251.4	3.5
18:44:22	151.5	-20.5	4.0	0.14	2.64	severe	5.3	0.5	-1	0.00	6.0	20.9	344	154.0	38.3	37.6	36.0	252.1	5.6

Table 3.Wind Shear Intensity in a,b,c,d,e zone at different altitude.

Based on table 3 data for calculating wind shear intensity, the result showed CI642 encountered a strong to severe wind shear below 200 feet. The intensity of wind shear varied with radio altitude is plotted in figure 3.

- (1) a zone: 300 ft~ 245ft: Light to moderate wind shear [25 ~ 19sec. Prior to touch down]
- (2) b zone: 245 ft~ 186ft: Moderate to Light wind shear [19 ~ 13sec. Prior to touch down]
- (3) c zone: 186 ft~ 117 ft: Light to Strong wind shear [13 ~ 9sec. Prior to touch down]
- (4) d zone :117 ft~ 59 ft: Strong to Moderate wind shear [9 ~ 6sec. Prior to touch down]
- (5) e zone: 45 ft ~ -1 ft: Moderate to Severe wind shear [6 ~ 1sec. Prior to touch down]

(D) Summarized Comments of ASC's Analysis

1. During the final landing phase, the aircraft encountered unsteady airflow as downwash that was exacerbated to have a high descent rate at the 6 seconds and 2 seconds before touch down.
2. At the time of the six seconds and the two seconds before touchdown, the elevator position indicated increasing from +2 to +11 degrees and +5.1 deg to +15.7 deg max respectively. ASC believes that the commander was working on the recovery to the high descent rate and provided large control column input. The pilots responded and recovered the first downdraft to have less descent rate. It took three seconds to recover the first downdraft.
3. The second downdraft happened at two seconds before touch down. The pilot did make his effort by pulling the column back and the elevators were moving up to a higher degree but no enough time for the pilot to recover.
4. The ASC believes that AOA is a significant parameter to the analysis in this accident. Angle of Attack in conjunction with normal acceleration and elevator deflection are of vital importance to differentiate between external forces acting on the aircraft and pilot-generated responses, was mentioned only in factual (paragraph 1.11.6.): "...fluctuated with increasing divergence between 3° and 8°..." and was not mentioned in the "Analysis" (Section 2. of Reference A).
5. Appendix A5-3-2 in Reference A shows a variation in TDZ wind direction of between 314° and 326° with speeds from 39kt to 43kt (Runway 25R) in comparison to a variation in TDZ wind direction of between 283° and 339° at 14kt to 28kt (Runway 25L) in the lee of the Passenger Terminal Building. This kind of wind change will affect the landing to a great extent.

Part 4 (continued)

Comments on Section 3, Conclusions

Cause Factors

Reference A, Section 3.2. Causal factor 3.2.1.

ASC issues and Discussion

According to the FDR data and ASC's analysis, the elevator was changed by the pilot's effort during final seconds of landing while the aircraft was encountering a downdraft and pouring rain on Runway 25L. It is in contrast with the statement that the pilot did not arrest the high sinking rate during landing.

ASC proposed changes

Change Causal Factor 3.2.1 to reflect the derivation from analysis of the data (Part 3, above), as follows:

3.2.1 During the final two seconds before touchdown the aircraft encountered atmospheric conditions, which caused an increasing rate of descent, culminating in touchdown at a rate in excess of 18 fps. The existence of a downdraft condition at a point where landing aircraft normally flare for runway 25L was involved in this accident.

Contributing factors to the downdraft condition were:

- 3.2.1.1 Rapidly changing strong wind and downdraft conditions resulting from an approaching tropical storm.
- 3.2.1.2 Large differences in wind velocity and direction between the approach path to runway 25L and that of runway 25R at Chep Lap Kok Airport, Hong Kong. (See Ref A appendix 5.3)

Reference A, Section 3.2. Causal factor 3.2.2.

ASC issues and Discussion

This Causal factor should be deleted in its entirety, for the following reasons:

(1) The FDR data show that the pilot flew the aircraft after passing the altitude of 21ft_{RA} fully configured for landing, on centerline, corrected for cross-wind and with a kinetic energy margin in excess of 15% for that gross weight and configuration. Additionally, the aircraft descent rate at that point (less than 2 seconds from touchdown) was less than that for a nominal 3° glide path (see Figure 4). Given the aircraft's excess energy at that time, the thrust was (and should have been) automatically retarding to idle, as designed by the manufacturer.

(2) The training manual contains no instructions or procedure for arresting rate of descent by adding thrust.

ASC proposed changes

Change Causal Factor 3.2.2 to reflect the derivation from analysis of the data (Part 3, above), as follows:

3.2.2.1 Reduced visibility in heavy rain and dusk conditions which prevented visual detection of the increasing rate of descent until less than 1 second before touchdown, due to obscured peripheral vision and partially obscured forward vision in heavy rain.

Reference A, Section 3.2. Causal factor 3.2.3.

ASC issues and Discussion

This conclusion is invalid and is included as cause factor 3.2.2.4, above; it may therefore be replaced.

ASC proposed changes

For completeness, in the interest of identifying all causes, which can pass the test of links of the accident chain, the following factors need to be included in the accident report.

3.2.3 The time critical location of the sudden onset of the severe downdraft, at a position and altitude less than two seconds prior to touchdown, which prevented pilot awareness of the phenomenon in sufficient time to effect corrective action prior to ground contact, was a contributing factor of the accident.

3.2.3.1 Elevator control forces required achieving the large deflections necessary to arrest the descent rate in time, which were well in need of large input from the pilot (with one hand on the control wheel, See Figure.4 below).

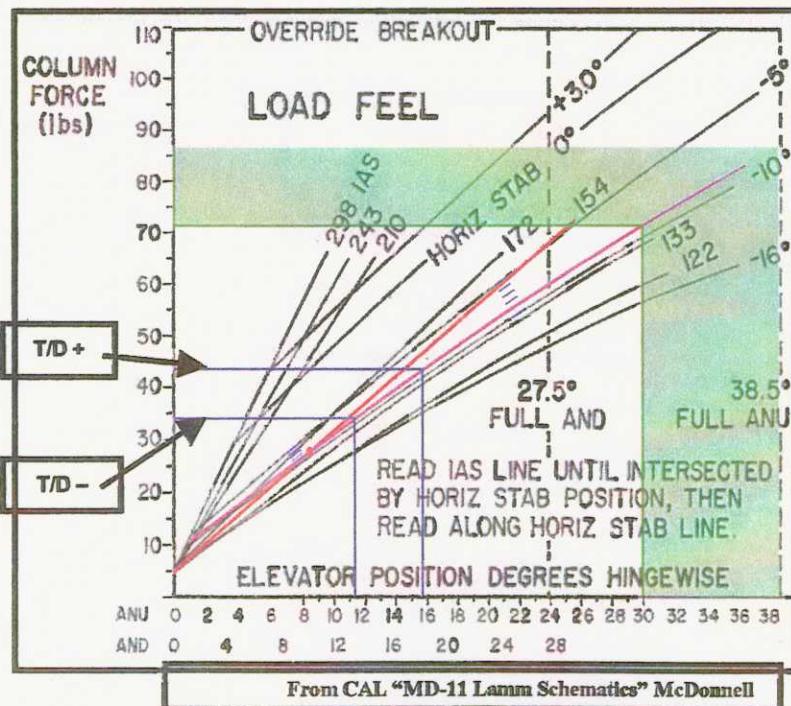


Figure 4. MD-11 Elevator Load Feel force Gradient

3.2.4 Structural failure of the right main landing gear in such a fashion that fracture of the wing main spar rear web occurred, resulting in separation of the right wing followed by inversion of the fuselage was an important factor to this accident.

Contributing causes to the structural failure were:

3.2.4.1 Crosswind conditions that required asymmetric touch down.

3.2.4.2 Touch down sink rate in excess of design limit loads.

Design limit loads (12fps) such that a normal approach at maximum landing weight involves descent rates 40 to 50% in excess of limit loads. (13.9 to 15.2fps).

3.2.4.3 The absence of an energy absorbing landing gear structure which would dissipate excessive touch down loads without compromising the integrity of the wing main spar

Findings

General

Some of the Findings of Reference A exhibit in the absence of detailed analysis of the data of Flight Recorder.

Specific

Reference A, Section 3.1. Finding 3.1.16.

ASC issues and Discussion

It is normal for an aircraft to land at gross weights up to and including its published maximum landing weight, and since normal landing procedures require the choice of an approach speed (with additives as required for environmental conditions) predicated on landing weight, in no event can a loss of airspeed be attributed to the gross weight.

ASC proposed changes

Delete Finding 3.1.16.

Reference A, Section 3.1. Missing/Deleted Finding

ASC issues and Discussion

Finding 3.1.28, of the Reference D (Initial Draft Report dated June 2001):

3.1.28 During the final two seconds before touchdown the aircraft encountered atmospheric conditions, which caused an increasing rate of descent, culminating in touchdown at a rate in excess of 18fps.

was omitted from Reference A. Since analysis of the data shows that this Finding accurately describes the primary causal factor of this accident, it should be included again.

ASC proposed changes

Re-instate the Finding contained in paragraph 3.1.28 of Reference D (the Initial Draft report) into the final report.

Part 5

Comments on Section 4, Safety Recommendations

ASC considers Safety Recommendations 4.9 and 4.10 of Reference A to be of merit, and would like to add the following safety recommendations:

To Hong Kong International Airport

1. Enhance the capability of the WTWS system to enable detection of both vertical and horizontal components of wind shear on approach.
2. Enhance its emergency response planning in accordance with ICAO Document 9137 Part 7 Section 1.2 to provide a timely emergency shelter capability for survivors of an accident. (Reference A, Finding 3.1.28)