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

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
- Autolanding
- 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. EVERS (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. EVERS (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. EVERS (for CAL)

5.1 Captain EVERS, 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS, 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 10º, resulting in a pitch angle of just over 4º up and a decreasing ROD to about 12 fps. At this critical point, a down elevator deflection of 8º was commanded. According to Captain EVERS 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 10º 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 4º to nearly 3º, 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 EVERS' 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS 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 320º. 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 EVERS, *"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 EVERS 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 EVERS 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 EVERS was taken through the FDR Data traces at Appendix A13 of the Report and commented as follows:-

a. Glideslope

The 3º 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 EVERS 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 20º shortly before touchdown. Captain EVERS 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 10º or more both left and right. Captain EVERS 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 3º glideslope translates to a descent rate of approx. 12-14 fps (720-840 fpm). Captain EVERS 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 EVERS 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 EVERS 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 EVERS' 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 253º) until touchdown. Hence, it is clear that the recommended crosswind landing technique as described by Captain EVERS 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 EVERS Report. In tabular form it reads –

Height (feet)	ROD (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 EVERS accepted that this increasing ROD was at least partly caused by the pilot reversing the elevator deflection from 10º up to 8º 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 EVERS 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 10º nose up on landing, whereas this particular aircraft had never achieved more than 4º nose up at any stage during the landing.

Captain EVERS 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 EVERS insisted that the subsequent hard landing was entirely due to factors outside the commander's control.

5.24 In short, Captain EVERS 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 283º-345º and wind speeds at 18-23 knots on Runway 25L whereas 25R showed fluctuations of 314º-321º 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: -

Height	Headwind	Crosswind
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 18º-20º, right control wheel from zero to about 70º 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 70º 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. <u>The Evidence of Mr. SHUN Chi-ming (for HKO)</u>

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 350º 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 345º and 339º were immediately followed one second later by the figures of 306º and 294º.

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 310º-320º 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 310º, 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:

25R mid-point (10:42:40)		25LTouchdown(10:43:20)
Direction	318º	317º
Speed	38 knots	26 knots
Gusts	45 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 EVERS' 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 EVERS 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 10º up to 8º down (i.e. a total of 18º). 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 EVERS 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 EVERS. 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 EVERS' 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^{o} pitch up and the chance of a tailstrike (which only occurs at a pitch angle of 10^{o}) 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 266º, the alignment maneuver started and the pilot commanded variable amounts of rudder, eventually to a maximum of about 20º. 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 EVERS (recalled)

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

12.2 Captain EVERS 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 EVERS 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 EVERS' 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 EVERS' 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 EVERS 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 EVERS went on to suggest that the unusually large 10º-12º up-elevator input at about 50 feet produced a larger than expected lift because of an *"assist"* (or headwind increase). Captain EVERS then calculated that if that 10º elevator input was maintained for another 3-4 seconds, the aircraft pitch up would have increased from 4º to about 10º, which would have been within tailstrike range. Therefore, he reasoned, the pilot commanded 8º down elevator to correct this, which reduced the aircraft pitch to about 3º. 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 10º up-elevator slightly, but certainly not so far as to go 8º down, Captain EVERS 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 EVERS 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 EVERS 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 EVERS 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 EVERS' 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 EVERS (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. <u>Costs</u>

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