ANALYSIS

of

ACCIDENT MARTINAIR DC-10-30F, MP495

FARO, 21 DEC. 1992

Limited supplemental analysis
including comments on the investigation

Undertaken at the request of

Qualimax B.V.

and

Mr. J.W. Koeleman, lawyer

on behalf of

Mr. and Mrs. Vroombout

17 December 2012

Harry Horlings

Avio*Consult*
Independent aircraft expert and consultant

Limited Supplemental Analysis Of The Accident With Martinair DC-10-30F, MP495

FARO, 21 DEC. 1992

Including comments on the Accident Investigation Report and the response by the Dutch Safety Board.

This is the translation of the original Dutch version, for the most parts translated by a non-aviator.

Avio*Consult* is an independent aircraft expert and consultant. Refer to www.avioconsult.com.
The author is a retired Lieutenant Colonel of the Royal Netherlands Air Force, graduate of the USAF Test Pilot School at Edwards Air Force Base, CA, USA (1985) and an experienced private pilot.

The general terms and conditions, filed with the Chamber of Commerce, apply to this analysis.

First issue: 26 May 2010 Last revision: 2017

TABLE OF CONTENTS

LIST OF REFERENCES

1 – Accident Report, DC-10-30F Martinair Holland NV, DGAC, No. 22/ACCID/GPI/92, 31-10-1994.
2 – DFDR Factual Report, NTSB, DCA 93-RA-011, February 12, 1993.
3 – Letter NTSB to Portuguese Committee of Inquiry, October 26, 1994.
4 – Martinair DC-10 Flight Crew Operating Manual, Volume II, Sep 1/91.
5 – Comments Dutch Safety Board on the Draft Final Report, version RVDL 3, d.d. 6 sept. '94.
6 – NLR Contract Report CR 94238 C, included as Annex 4 in het RvO (Ref. 1).
7 – ICAO Doc 4444 ATM/50, Procedures for Air Navigation Services, Air Traffic Management, page A1-4.
8 – National Archive, access number 2.16.107, various inventory numbers.
9 – MD-11 accident report, 31 Jul 1997, PB2000-910402, NTSB/AAR-00/02, DCA97MA055.

LIST OF ABBREVIATIONS

Abbreviation	Meaning
A/T of ATS	Auto throttle (System)
ACN	Aircraft Classification Number
ACT	Actual
AIDS	Airborne Integrated Data System – aircraft data recording system for maintenance purp.
AINS	Area Inertial Navigation System
ALT	Altitude
ANA	Aeroportos e Navegação Aérea, E.P. – Operator of Airport Faro
AOM	Airplane Operating Manual
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service transmitted by VOR Station
CAP	Capture – autopilot mode to reach a preset altitude (ALT)
Cb	Cumulonimbus
CoI	Committee of Inquiry (accident investigation committee
CVR	Cockpit Voice Recorder
CWS	Control Wheel Steering – manual airplane control via autopilot
DFDR	Digital Flight Data Recorder – black box
DGAC	Direcção-General da Aviação Civil – Portugese aviation authority
DME	Distance Measuring Equipment
DSB	Dutch (Aviation) Safety Board
F.O.	First Officer
FCOM	Martinair DC-10 Flight Crew Operating Manual
FE	Flight Engineer
ft	foot or feet (1 ft = 0,3048 m)
FWD	Forward
g	acceleration of gravity (9,81 m/s^2)
HDG	Heading
HLD	Hold – autopilot mode , e.g. for maintaining altitude (ALT)
ICAO	International Civil Aviation Organization
kt	knot(s) – nautical mile per hour
lb	pound(s), English pound (0,454 kg)
LW	Landing weight
METAR	Meteorological Aerodrome Report
MP	Company code Martinair Holland NV
N1	Engine compressor RPM
NLR	Netherlands National Aerospace Laboratories, Amsterdam
nm	Nautical Mile
NTSB	National Transportation Safety Board
PAPI	Precise Approach Path Indicator
PCN	Pavement Classification Number
RA	Radio Altitude, Radar Altitude
RoA	Report of Accident (Ref. 1)
SEL	Select – autopilot mode
SIO	Sistema Integrado de Observação Meteorológica – Portuguese meteo observation system
TAF	Terminal Area Forecast
UTC	Universal Time Coordinated (formerly Greenwich Mean Time)
VERT	Vertical
VOR	VHF Omni Directional Ranging

SUMMARY

1. **Introduction**. Following the catastrophic accident with Martinair DC-10-30F at Faro airport, Portugal, on 21 December 1992, the accident was investigated by a Portuguese Committee of Inquiry (CoI), in cooperation with Dutch, American and other investigators. The Dutch Safety Board (DSB) read out and reported on the Cockpit Voice Recorder (CVR), the American National Transportation Safety Board (NTSB) read out and reported on the flight data recorded by the Digital Flight Data Recorder (DFDR - the "black box").

2. The draft accident investigation report of 21 July 1993 was submitted for comments to, among others, the NTSB and the DSB who translated the report into English, or arranged for this to be done. Both boards issued comments, after which the final version of the Accident Investigation Report was published (6 September 1994).

3. At the request of a few victims this supplemental analysis was made to find the real cause of the accident, using the report of the Portuguese CoI, the letters from the NTSB (included in the appendices to the report) and the flight data recorded by the DFDR, transcripts of the CVR, a report by the Netherlands National Aerospace Laboratory (NLR) and the comments by the DSB.

4. **Conclusions of the Committee of Inquiry.** The main conclusions of the Accident Report (RvO) can be summarised as follows. An (✖) means that the conclusion is not agreed with.

(1) During approach the aircraft passed a turbulent zone associated with microburst and downburst phenomena which caused longitudinal instability of the aircraft (✖);

(2) The crew was informed twice by Approach Control that the runway was covered with water (flooded), but the term "flooded" was not associated with poor braking conditions, although its meaning, given a statement by the captain to the police, was known and defined in ICAO Doc 4444 (PANS-RAC). Despite the available information about the instability and temporary worsening of visibility during the final phase of the approach and because of the incorrect interpretation of the information provided to them about the state of the runway (flooded), the crew did not decide to abort the approach;

(3) At an altitude of 150 ft, power was reduced to "flight idle", probably by the copilot. Under normal conditions the Auto Throttle System (ATS) starts the reduction at 50 ft. A premature reduction in power probably worsened the rate of descent which reached values exceeding the operational limits of the aircraft (✖). There was no significant change in the wind speed and wind direction in the final 20 seconds, according to the values recorded by the meteorological service;

(4) The collapse of the right-hand main landing gear was due to a combination of the high rate of descent and the alignment correction at the time of contacting the runway (✖).

5. **Conclusions of the DSB**. The sudden variation in wind direction and speed during the final approach caused a crosswind component which exceeded the aircraft limits in the Airplane Operating Manual (✖). Due to the premature major and sustained power reduction and tailwind component during the final phase of the landing the rate of descent of the aircraft reached approximately 1000 ft/min (*). The collapse of the right-hand landing gear was caused by the combination of landing on the right-hand aft wheel, the crab angle and the high rate of descent (✖).

6. **Conclusions of this supplemental analysis.** Despite the fact that important data had been left out of, or was deleted from the Accident Report, it could be concluded, provisionally and objectively, based on both the information about the final phase of the flight presented in words, numbers and graphs by the NTSB in their DFDR Factual Report and the factual information in the Accident Report, that:

(1) at least four minutes before the landing the crew were informed that the runway was "flooded" (covered with water), which would result in "braking action poor". The captain was aware of the meaning of the term "flooded". The runway length required under these conditions would, according to the Landing Data Card calculated and drawn up by the crew themselves, be approximately 600 m (!) longer than the actual length of the runway. If the aircraft had landed correctly then the aircraft would not have come to a full stop in time on the flooded runway;

(2) the crosswind limit for the actual condition of the runway ("flooded") was exceeded by 15 kt;

(3) the approach at an altitude of 500 ft was not stable in terms of altitude, approach angle, speed and engine power, as specified in the Flight Crew Operating Manual (FCOM);

(4) the deviation in the angle between the approach path followed by the aircraft and the prescribed approach radial in the horizontal plane was too large. No attempt was made to correct this, although time for this was available. The aircraft approached the runway at an excessive angle, not steering enough into the crosswind, and therefore did not reach the runway;

(5) the throttles of the three engines were pulled back or held back prematurely as a result of which the engine speed and airspeed reduced too early and way too much during the last part of the approach, and the go-around initiated by the captain at the very last moment before the landing failed.

(6) the standard manoeuvre to align the longitudinal axis of the aircraft up with the runway heading, to prevent a traversing landing, was initiated with significant hesitation too high and too early and the roll angle required for alignment with the runway was not attained and maintained, as a result of which the aircraft was not aligned with the runway and landed with a crab angle;

(7) the aircraft landed half next to the runway and for a DC-10 approach using the PAPI too far beyond the touchdown zone and almost certainly with braked wheels as a result of which the forces on the landing gear increased enormously and resulted in its collapse;

(8) the graphs of the DFDR data and discussions recorded on the CVR did not provide any indication that during the approach the aircraft passed through a windshear area. It was also found that the rate of descent was normal and that the landing was not hard, but it was traversing. According to the ICAO definition the turbulence experienced was only light;

(9) the crew did not act in accordance with the procedures for flying during or recovering from experienced windshear, and hence neither expected nor experienced windshear;

(10) from an altitude of 500 ft there were several reasons, based on the procudures in manuals, to make a go-around, which was not done;

(11) the throttles were operated incorrectly and not in accordance with the procedures and the autopilot was used inappropriately;

(12) the crew did not make the approach in accordance with the prescribed Martinair procedures and also not in accordance with the approach procedure and route prescribed by the Portuguese authorities;

(13) the calculation of the approach speed in the Martinair FCOM is incorrect when the autothrottle is used.

7. **Causes according to the Committee of Inquiry.** The most likely causes of the accident were:

(1) the high rate of descent during the final phase of the approach and the landing on the right-hand main landing gear, because of which structural limitations of the aircraft were exceeded (×);

(2) the crosswind, which exceeded aircraft limits, experienced during the final phase of the approach and the landing.

(3) Due to the combination of these two factors the structural limitations of the aircraft were exceeded (×).

(4) Contributing factors to the accident: The instability of the approach, the premature engine reduction and maintaining this condition, probably due to crew action, the incorrect information about the wind from approach control, the incorrect assessment of the runway condition, the go-around attempt which was undertaken too late, and the reduction in wing lift due to the heavy rain.

8. **Causes according to the RVDL**. A sudden and unexpected change in wind direction and speed (windshear) during the final phase of the approach (×). This was followed by a high rate of descent and an extreme lateral displacement, which caused a hard landing on the right-hand main landing gear which, together with the significant crab angle, exceeded the structural limitations of the aircraft (×).

9. **Causes according to this supplemental analysis.** The accident was caused because the crew:

(1) ignored the current wind data communicated to them and read out in the aircraft and ignored the condition of the runway and did not respond to these by making a timely go-around as prescribed and diverting to an alternative airport. The crosswind limit was exceeded;

(2) during the final approach, deviated too much from the approach path (Approach Chart) prescribed by the Portuguese authorities and were still not flying stably on the approach path at the altitude defined in the FCOM and, despite this, continued the approach and did not make the prescribed go-around;

(3) pulled the engine throttles back too early or held them back, as a result of which the go-around initiated at a very low altitude failed;

(4) made serious, even fatal operating errors, both during the final approach and during landing, as a result of which the aircraft touched down partly to the side of the runway, most likely with braked wheels, due to which structural limits were exceeded;

(5) handled the autopilot, autothrottle system and crosswind landing incompetently.■

1. Introduction

1.1. On 21 December 1992 a Martinair Holland NV DC-10-30F departed, as charter flight MP495, at 04:52 Universal Time Coordinated (UTC), carrying 327 passengers and 13 crew on board, from Amsterdam with destination Faro in Portugal. Departure had been delayed by 40 minutes, for remedying a fault affecting the thrust reverser of the centre engine. Two hours and 41 minutes later the DC-10 crashed at Faro airport. Of the 340 on board, 56 were killed, 106 were seriously injured and 178 were lightly injured or not injured.
The accident investigation was undertaken by the Office for Aviation Prevention and Safety of the Portuguese Direcção-General da Aviação Civil (DGAC - Directorate General for Civil Aviation), which arranged for the Digital Flight Data Recorder (DFDR, "black box") of the aircraft to be read out by the American National Transportation Safety Board (NTSB). The draft Accident Report (RvO), was submitted to the Netherlands Aviation Safety Board [Raad voor de Luchtvaart] (RVDL) on 21 July 1994 and on 10 August 1994 to the NTSB, and comments were requested. The report was translated in English. Some of the additions and the comments by both the RVDL (dated 6 September 1994) and the NTSB (dated 26 October 1994) were incorporated in the final version of the Portuguese RvO. Both documents were included as appendices to the Portuguese RvO (ref. 1).

1.2. This limited supplementary analysis of the accident was undertaken at the request of Qualimax BV, Dr. C Spaans and personal injury lawyer J.W. Koeleman, on behalf of Mr and Mrs Vroombout. A file with various documents was made available, including the RvO (ref. 1) and an non-official translation into English of part of it, as well as appendices to the RvO with transcripts of the Cockpit Voice Recorder (CVR) and two letters from the NTSB (ref. 2 and 3) including, among other things, graphs of data from the DFDR, the "black box" (ref. 1).

1.3. Avio*Consult* is an independent engineering consultancy and aircraft expert and advises on aviation operations, such as assessing and testing aircraft, including their use, and flying characteristics and on-board systems. On request, AvioConsult also assesses accident investigations and aircraft handbooks and training manuals for crews. Engineer H. Horlings, retired Lieutenant Colonel of the Royal Netherlands Air Force and founder of AvioConsult, was trained as test flight engineer at the USAF Test Pilot School for the qualification to prepare, undertake and assess experimental flight tests with all types of fixed wing aircraft and has over 15 years' experience in this field with the Royal Netherlands Air force, the last 5 years of which as Head of the Operational Research and Assessment Department (experimental flight test).

1.4. In this supplementary analysis, which was limited to the information provided, the RvO is critically assessed, relevant information in the RvO is compared with the information provided by the NTSB, the runway and wind data used by the crew and the landing approach to Faro airport are analysed, and the comments by the RVDL (ref. 5) are critically considered. Finally, based on the information made available, a supplementary analysis and the causes of the accident, different from those stated in the RvO, are presented.

2. Comments on the information used in the Accident Report

2.1. The English translation of the Accident Report by the Portuguese DGAC, marked as non-official and dated November 1994, was used for this analysis. Some paragraphs were verified, using the original RvO in the Portuguese language which could be downloaded over the Internet from the web site of the Portuguese DGAC.

2.2. Clock times

2.2.1. The RvO (ref. 1) uses no fewer than five time scales/clocks. The table in Annex 5 to the RvO contains three columns with times using the following clock times: Radar, standard (Padrão) and CVR. The three columns are headed UTC, although there are differences between the times in the three columns for the same event, see Figure 1 below. Annex 9, at the x-axis of the graphs (see e.g. Appendix 6) there are the radar times - calculated on the basis of the elapsed time recorded by the DFDR - and finally a clock of the meteorological service (SIO, Sistema Integrado de Observação Meteorológica) is mentioned.

	Hora UTC			
C10 D min	RADAR	Padrão	CVR	O
	06:48:04	06:48:35	06:46:15	
		06:48:36	06:46:17	

Fig. 1. Three "UTC' times" in RvO Annex 5.

According to § 1 of the RvO the times mentioned in the RvO refer to the "ATC Communications" clock, which is elsewhere referred to as the "ATC system" clock. This appeared to correspond with the standard Padrão clock (the actual UTC). RvO § 1.11.3 and 1.11.4 describe the correlation between clocks and clock times. However, this does lead to some questions, specifically about the "adjustments" made and what clock time the "adjusted time" actually refers to. Many different terms are used, which can lead to confusion. Some of the clocks used are described below.

2.2.2. *CVR time.* In the CVR transcript in Annex 6 of the RvO the UTC times are listed for the sounds and spoken words recorded in the cockpit. However, these cannot be original UTC times, as a CVR does not record time. The recording length of a CVR is limited to a maximum period which depends on the storage medium used (for MP495: approx. 40 minutes); the oldest recordings on the endless tape are overwritten. At the start of a flight, the UTC is not set on the CVR. The times specified in the RvO for the sounds recorded by the CVR are therefore the times calculated by the Committee of Inquiry (CvO), generally indisputable synchronisation moments are used for this, such as sounds of switches in the cockpit which are also on the DFDR or times of communications with traffic control, after which the recording speed of the CVR can be calculated and interpolation is used to be able to determine the correct time of the other sounds recorded, see also RvO § 1.11.1.
The CVR transcripts in Annex 6 are included in the table in Annex 5, including the times inappropriately described as UTC. However, in Annex 5 the CVR times from Annex 6 are not given as UTC times but in a separate column as CVR times. The synchronisation of the CVR recordings with UTC is clearly shown by that column with CVR times. The difference between the UTC and CVR clock times on the first line of the table in Annex 5 (see figure in the preceding paragraph) is two minutes 20 seconds and decreases to 31 seconds at the end of the recording (see Figure 2 below). According to the table in Annex 5 of the RvO, in almost three-quarters of an hour, the CVR time ran no less than 108 seconds faster than the UTC time. That really is a very large difference.

	Registo das Comunicações ATS e CVR				
	Hora UTC			Factos	
C10 D min	RADAR	Padrão	CVR	Origem	Relato ATS - CVR
200	07:32:49	07:33:20	07:32:49	C1-2-3-4-	TOUCHDOWN 4 = 31 sec. [illegible] 2' 19''
		07:33:21	07:32:50		

Fig. 2. Three "UTC" times at the landing (touchdown), RvO Annex 5 page 117.

2.2.3. It is also unclear why the extensive table in Annex 5 lists times in the CVR column for the period that the CVR recordings had already been overwritten(from 06:48:35 to 06:54:55 UTC). It might be concluded from this that a linear comparison was used to convert the CVR times to UTC which was calculated with only two synchronisation moments and not with several indisputable moments, e.g. communications with traffic control during the last 40 minutes of the flight. As a cassette tape always stretches a bit during recording and replaying, it could be that a recording on the CVR did not occur exactly at the UTC time stated in the RvO Annex 5, but many seconds earlier or later. The observed difference between the clocks affects the reliability of the analysis of key events recorded on the CVR at certain times during the last 40 minutes of the flight.

2.2.4. *Radar time*. The difference between radar time and UTC was between 29 and 31 seconds (due to rounding?). It is not clear from the RvO if the radar time was corrected to the actual UTC for the analysis or if this was possibly the only clock running correctly. However, in the RvO Annex 9, from which four graphs are included as figures in this analysis (from Appendix 6), the radar time is referred to as UTC on the x-axis of the graphs. According to these graphs, the landing occurred at 07:32:50 UTC, while the RvO mentions a landing time of 07:33:20 UTC. It may be concluded that UTC was used incorrectly.

2.2.5. *Meteo time.* The SIO meteo clock was supposed to have a deviation of 1.5 minutes relative to UTC (RvO § 1.7.4.3.1, page 111). The RvO always refers to "a deviation" but not if the deviation amounted to a clock running fast or slow. Only in RvO § 3.1, page 127, is it mentioned in a list of established facts that the meteo clock was 1.5 minutes behind the ATC clock. It is not made clear if the correction required by this was always made correctly; it is also unclear why reference is made to the ATC clock rather than to UTC.

2.2.6. *Elapsed time.* The DFDR has an internal clock which runs continuously; the elapsed time. To use the data recorded by the DFDR this time has to be converted to UTC. The conversion of the DFDR elapsed time to standard UTC was not always correct, as will be shown below.

2.2.7. *Clock differences and time inaccuracies.* Some examples, for illustration. In RvO § 1.1, History of flight, at UTC time 06:57:50 it is indicated that the captain advises the copilot to make a landing with a "positive touchdown". This sentence is also included in the CVR transcript in Annex 6, but at UTC time 06:55:54, a difference of 1 minute 56 seconds. In the RvO Annex 5, page 23 this time is mentioned again as a CVR time in the CVR column. In the same row under UTC time (Padrão): 06:57:50 and under radar time: 06:57:19. Unacceptable differences.
On the last page (118) of RvO Annex 5 it is stated that the touchdown (first contact with the ground) occurred at radar time 07:32:49. The same row states UTC 07:33:20 and CVR 07:32:49. The meteo time is not included in this appendix. The x-axis of all 18 graphs in Annex 9 states "UTC", however this turns out to be "radar time" and not the "ATC communication" time mentioned in § 1 of the RvO. The difference between radar time and UTC was no less than 30 seconds.

2.2.8. According to RvO § 1.11.2, between 07:26:50 and 07:39:18 the "Command Altitude Hold" of the autopilot was selected. After conversion, the DFDR indicated 07:27:25 for this or 07:30:13, a difference of no less than 9 minutes with the final value in the RvO (07:39:18). The accident occurred at 07:33:20. A typing error?

2.2.9. According to RvO § 1.1, the copilot, referred to as pilot flying in the rest of the document, says at 07:32:34 "PAPI[1] hè". But in the RvO Annex 5, page 116 it is stated that this comment was made at 07:32:45 "standard" UTC, which according to this annex corresponds with CVR time 07:32:15 and with radar time 07:32:14. An inexplicably large difference.

2.2.10. Allegedly, 30 seconds before the landing, the captain, at 07:32:50 (= 07:32:19 in the graphs in the RvO/Annex 9) warned that the speed was somewhat low. According to the graph, at that time the speed was indeed falling, but was still 147 kt, higher than required. Only 4 seconds later the speed was 138 kt, only one knot lower than the set approach speed. This also leads to doubt about the correctness of the stated times and therefore the synchronisation of the various clocks.

2.2.11. At 07:33:10 (= 07:32:39 radar/graph time) the captain warned that the wind was 190° /20 kt. It is also stated in the RvO in § 1.1 that at this time the autopilot changed over from "Control Wheel Steering" (CWS) to "manual" (=autopilot off). However, in the graphs of RvO Annex 9, see e.g. Appendix 6, it is stated that the CWS changed to Off at 07:32:44. An inexplicably large difference of 5 seconds.

2.2.12. ***Sub-conclusion - clock times in the RvO***. Three of the times used in the RvO, between which there were differences, were referred to as UTC; however, there is only one UTC, a clock time formerly known as Greenwich Mean Time. It must be concluded that, apparently, the CvO did not understand exactly what UTC is. UTC in the report was Padrão (Fig. 1 and 2).

2.2.13. The CVR times in the RvO showed an inexplicable, increasing deviation from the UTC clock. The synchronisation moments used were not stated and could therefore not be verified. It was concluded that either the UTC in the RvO, or the CVR times in Annex 5 and 6 of the RvO were incorrect in some cases and that the analysis undertaken on the basis of the CVR and/or UTC clock times was not accurate enough. It was also unclear if the radar and meteo times mentioned in relation to the facts and in the analysis in the RvO were corrected to UTC (incorrectly referred to as communications UTC) in the right way, for an accurate and correct analysis. In some cases, the deviation between the clocks was excessive. It may be concluded that the times used in the RvO

[1] [1] PAPI is a "Precision Approach Path Indicator", a combination of 4 lamps placed on each side of the runway which shows approaching pilots if the correct glide path is being followed (as many white as red lamps: ●●○○), or if the approach angle is too high (more white than red lamps: ●○○○) or if the approach angle is too low (more red than white lamps: ●●●○).

are not reliable enough for a thorough analysis of the accident. This conclusion is also supported by the altitude and distance reports by the captain plotted in Appendix 2 and recorded on the CVR, which were found not to correspond with the altitudes the CvO used in the RvO. The use of at least five different clocks in a single RvO is highly confusing and is likely to contribute to errors in the analysis.

2.3. Meteo

2.3.1. Apparently, the crew received the available meteo information from Faro from the meteo desk at Schiphol (RvO § 1.1). It is suggested that the captain and the copilot (who is mentioned in the Portuguese report, but not in the English translation) studied satellite photographs showing a low pressure area near the south coast of Portugal. The weather forecast also mentioned isolated (single) thunderstorms and rain.
However, a member of the meteo staff later stated (RvO § 1.7.2.1) that neither the captain nor the copilot of flight MP495 had been to the desk. Two Martinair crew members were said to have been seen, but they might have been the crew of Martinair flight MP461, a Boeing 767, which arrived at Faro 10 minutes before MP495. The RvO does not provide definite information about this. This could mean that the MP495 crew only used the flight folder they received and the weather information from the Flight Information Centers received during the flight, and had not prepared themselves appropriately.

2.3.2. RvO § 1.7.2.2 should include the information about the weather at the time of the accident. The weather is described during a period extending to 12:00 UTC, 4.5 hours after the accident. The wind direction is mentioned, among other things, but the specified wind direction at the time of the accident (180°) differs from the direction given elsewhere in the RvO (160°). Furthermore, the specified wind speed (35 - 40 kt) does not correspond with the values recorded in the SIO (24, max. 35 kt).

2.3.3. According to the RvO § 1.7.2.4 page 39, the SIO prints the wind data every 10 minutes. Next the wind at 07:40 meteo time is given (= 07:41:30 UTC): 170°/24 kt max. 220°/35 kt. This was the wind 8 minutes and 10 seconds after the accident. The wind at 07:30 (07:31:30 UTC), 1 minute and 50 seconds before the accident was not included among the facts listed by the committee. However, it was stated that the wind speed might have been higher than 20 - 25 kt during the passage of a Cumulonimbus (Cb - a thundercloud). According to the weather information the Cb covered 1/8-part of the sky and was at an altitude of 2,500 ft. Apparently at 07:30 UTC a heavy rainstorm was approaching and according to the Portuguese RvO heavy rain fell from it. The Portuguese RvO mentions "violent down pour" (heavy precipitation), the English translation by the RVDL states that "a violent storm arose"; however that is rather exaggerated. The weather will have been bad, but in the RvO everything is done to give the impression that it was very bad. If that was indeed the case then the pilots made a gross error by continuing the approach. Elsewhere in this analysis, DFDR data will show that the aircraft did not experience major accelerations and was therefore not subjected to a "violent storm". Similarly, there are no comments on the CVR about very bad weather during the approach.

2.3.4. In § 1.7.2.4 it is stated that a "detailed analysis" indicated that the wind started turning and increased in strength. § 1.7.4.4 contains a table with the wind information communicated to aircraft, but the numbers given do not correspond with the table in the same chapter with the average and maximum wind, as recorded every half minute by the SIO. Hence the source of these "facts" in the "detailed" analysis is therefore unclear. The chapter should only provide factual information, but the authors of the RvO were seduced into adding analyses and their own interpretations.

2.3.5. According to RvO § 1.7.4.5 between 07:34:00 and 07:35:30 UTC the meteo system generated a windshear warning, and that this was not sent to the aircraft. This would not have been useful anyway, as the aircraft had already crashed (at 07:33:20 or 07:32:50, depending on which "UTC time" is used ...).

2.3.6. RvO § 1.7.4.6 contains a table with the maximum wind speeds every 30 seconds recorded between particular times. Above the table it is indicated that the table contains the wind values between 07:33:00 and 08:10:00 UTC, but the first line of the table indicates that the recorded maximum wind in the period from 07:32:30 UTC to 07:43:00 UTC was 35 kt. These times are incorrect; it is likely that meteo time and UTC have been mixed up. It may be concluded that the correction to (or from) UTC was done carelessly, hence the accuracy of the wind in the table at the stated times is in doubt. Furthermore, on line 5 of the table for runway 11 it is stated that at a later time the wind was "between 27 and 22 kt"; if this was a maximum wind table this should have been 27 kt and not "between". A carelessly drawn up table which is not appropriate for a thorough accident analysis. The question also remains if the major meteo clock deviation of one minute and a half was appropriately used to correct the meteo time to UTC (§ 2.2.5).

2.3.7. In the final version of the RvO the CvO added the established fact that during the last 20 seconds of the flight where was no significant change in the wind speed and direction according to the values recorded by the SIO (See the list of the concluded facts in Appendix 10, § 27).

2.3.8. *Meteo information known to the crew.* At 06:54:56, more than 38 minutes before the landing, the CVR recorded that the copilot, while reading out the airport details, mentioned that the runway would be wet ("wet runway"). At 07:09:58 UTC, half an hour before the landing, the crew were informed by air traffic control of the weather conditions at Faro, including a thunderstorm, 3/8 cloud cover at 500 ft, 7/8 at 2300 ft and 1/8 Cb (cumulonimbus - high thundercloud) at 2500 ft and wind of 150°/ 18 kt. At 7:30:47 UTC, two and a half minutes before the landing, the MP495 captain mentioned wind from the right, 30 kt and a drift of 12° so that the approach heading would have to be 123° (= 111° for the runway + 12° drift). The source of this was not mentioned, but it was probably read out from the aircraft inertial navigation system (AINS), a standard procedure during approach to recognise any windshear early (see also § 4.5.2); this was a local wind at that time, but higher than the landing limits. This local wind speed of 30 kt, a drift of 12°, a ground track of 111° and an airspeed of 139 kt lead to a wind direction of 185°.
Apparently, the crew only assumed a "wet runway" despite the fact that two minutes earlier, at 07:28:56 UTC, according to the CVR traffic control had informed MP495: "runway surface conditions are flooded". So there was water on the runway. According to the RvO (§ 2.2.3) the maximum permitted crosswind component for "braking action medium" (a "wet runway") was 15 kt and for "braking action poor" (a "flooded runway") it was only 5 kt. The last wind information, provided together the permission to land, was 150°/ 15 max. 20 kt (at 07:32:15 UTC). The crosswind component of this was $15 \cdot \sin(150° - 106°) = 10.4$ kt max. 13.9 kt, so within the limits for a "wet" runway but most certainly not for a "flooded" runway. The wind read out by the captain from the AINS 10 seconds before the landing was 190°/ 20 kt, with a crosswind component $20 \cdot \sin(190°-106°) = 19.9$ kt, therefore much higher than the limit (15 kt) for a "wet runway" and very much higher than the 5 kt limit for a "flooded" runway. Although the wind specified by traffic control is always used, rather than the wind read out from the AINS, the higher wind direction and speed read out on board should at least have made them think. The difference was too large.

2.3.9. ***Sub-conclusions - Meteo in the RvO***. The weather and wind information presented in Chapter 1 (Factual information) of the RvO are not limited to purely factual information; it is therefore difficult, or even impossible, to reconstruct what happened, in meteorological terms, shortly before the accident. Sometimes the average wind is given, but at times when it is more convenient (in terms of attributing blame) a peak wind is given and then it is unclear if these are instantaneous values or averages during a particular time period, and what the source is. The meteo clock was lagging 1.5 minute behind UTC. It is not clear whether time-corrections were applied. Incidentally, most of the meteo information presented concerns the period after the accident.

2.3.10. It may be concluded that the meteorological "facts" presented in the RvO, whose source is sometimes inexplicable, cannot adequately contribute to correctly understanding the weather conditions shortly before and during the accident. The Chapter Meteorological information of the RvO (§ 1.7) is a chaotic collection of comments which was probably produced by several investigators.

2.3.11. Although the wind which traffic control informed the aircraft of was within the limits for the runway condition assumed by the crew ("wet runway"), the wind read out by the captain from his AINS, in accordance with the instructions, was far above that limit, which did not lead to the only appropriate action, i.e. a go-around. Despite the fact that traffic control twice informed MP495 that the runway was "flooded", a term which the captain was familiar with, this did not lead to the go-around required in this case. The wind was stronger than permitted for landing at Faro given the runway conditions. The runway would be much too short.

2.3.12. The CvO also concluded that the required runway length for landing MP495 not only on a flooded runway but even on a wet runway would be greater than the available length. The CvO also concluded that in the last 20 seconds of the flight no significant changes in the wind speed and direction were recorded by the SIO.

2.4. Airport and aircraft information

2.4.1. In RvO § 1.6.1, under aircraft details, the Aircraft Classification Number (ACN), used to determine if the runway met the requirements defined for a DC-10-30, is missing. Similarly, the actual and maximum landing weights are not stated (the maximum is probably 192,322 kg). Without this information it is not possible to calculate the maximum descent rate for an actual aircraft weight lower than the maximum.

2.4.2. According to RvO § 1.6.3 three operational thrust reversers are required for landing at Amsterdam. That is incorrect. Further down, in RvO § 1.17.1.4, it is stated that an aircraft should not depart with a faulty thrust reverser from an airport where repair can be undertaken. This is a company rule, and does not affect airworthiness and safety, as the regulations were complied with; before the flight the faulty thrust reverser was mechanically blocked by the Maintenance Department.

2.4.3. According to RvO § 1.6.5 the weight and centre of gravity were within the limits, but also that "weight and balance automatic system unserviceable". This system had not been used for a long period as manual calculations were found to be more reliable. This fault did not affect the accident. This paragraph too fails to state the landing weight of the aircraft.

2.4.4. In RvO § 1.10.2 the length of the runway is given as 2490 m, while according to the Landing Data Card (Appendix 1) the available landing distance was 2445 m. This discrepancy is not explained in the RvO. Here, the length of the touchdown zone is given as 268 m. This length will be used later in this analysis.

2.4.5. The airport data included in RvO § 1.10.2 contain some other minor errors which indicate the thoroughness, or lack thereof, with which the report was written. For example "magnetic deviation": 06° (JAN 90) is used, while this should be "magnetic variation". Similarly, the direction of the "deviation", East or West, is not given. Deviation is an error in the reading due to the place where the compass is installed (in the aircraft). Variation is the angle between the true (geographic) North and the magnetic North Pole, apparently this was 6° West at Faro.

2.4.6. In RvO § 1.10.2 no reference is made to the note, which is highly relevant when approaching runway 11, that the specified magnetic approach course of 111° has an offset of 5° from the magnetic runway course 106°, see the note on the Approach Chart in Appendix 2. At 1 nm before the runway, at an altitude of approximately 300 ft this requires a coordinated turn for a course correction of this 5° to the left. The consequence of an approach course which differs from the runway course is that the part of the approach until the last mile is not aligned with the (illuminated) runway. It is inexplicable that this information which is relevant to the analysis of the accident is not included in the RvO. However, the pilots were aware of this given their comment on the CVR at 07:01:00 UTC, more than 32 minutes before the accident.

2.4.7. In the same paragraph it is stated that the width of the "hardened area" was 150 m. However, the Pavement Classification Number (PCN) is not given. This is relevant because the aircraft allegedly landed half off the runway (§ 3.1.15) and therefore might have sunk into the hardened area with the left and centre main landing gear. The photographs (ref. 8) show that the rim of the center landing gear scored a long, near straight deep groove on the left-hand side of the runway.

2.4.8. According to RvO § 1.11.5 there was no data recorded by the Airborne Integrated Data System (AIDS) from an altitude of 47 ft due to damage to the recorder tape, probably caused by the shock of the landing However, data recording by the DFDR continued normally, given the DFDR Factual Report (ref. 2, see Appendix 3 to Appendix 5). Possibly deliberately, the DFDR data were not included in the graphs in RvO Annex 9 (see Appendix 6 to Appendix 9, although their heading does identify the AIDS / DFDR as the source of the parameters.

2.4.9. *Sub-conclusion - airport and aircraft information in the RvO.* The 45 m difference in available landing distance of runway 11 is not explained in the RvO. Apart from the magnetic variation, for which an incorrect term is used, no reference is made to the 5° deviation in the approach course (offset) prescribed by the Portuguese authorities. Information about the classification of the hardened area, the strip of land besides the runway, and of the aircraft is missing. It may be concluded that much of the data recorded on the DFDR about the last 50 ft of altitude was not included and presented in the graphs in Annex 9 of the RvO and was not used when analysing the events.

2.5. Comparison of data in the NTSB's DFDR Factual Report and the RvO

2.5.1. The graphs in the NTSB's DFDR Factual Report, included in RvO Annex 14, have been reduced and are difficult to read. However, in the accompanying letter (ref. 2), the NTSB analysts described some data which is significant to this analysis.
Below, the data provided and described in the letter accompanying the NTSB's DFDR Factual Report is used, and was found to be sufficient to formulate conclusions and a cause of the accident which are different from those in the RvO. The original DFDR report was requested from Portugal, but only slightly better copies of the NTSB graphs were received, included here as Appendix 3 and Appendix 4.

2.5.2. During the analysis of the provided document, differences were found between the graphs in the NTSB's DFDR Factual Report (ref. 2, see Appendix 3 and Appendix 4) and the graphs in Annex 9 of the RvO (ref. 1), some of which have been included in Appendix 6 and beyond. Table 1 below provides a comparison of the data provided by the NTSB in ref. 2 and the data in the RvO. The second column lists the data described in the letter accompanying the NTSB's DFDR Factual Report (ref. 2), obtained from the DFDR. The third column lists the data derived at the corresponding times from the graphs in Annex 9 of the RvO (ref. 1). The data was compared; The fourth column indicates if the difference was acceptable (√) or unacceptable (*). Some of the graphs in RvO Annex 9 are included in Appendix 6 to Appendix 9.
As discussed in § 2.2, the RvO referred to several clocks. The table below lists the Elapsed time from the DFDR report and the third column shows the radar time which was also used for the x-axes of the graphs in Annex 9 (where it is incorrectly referred to as UTC).

Table 1. Comparison of data in the NTSB's DFDR Factual Report and the RvO

Compared data	**NTSB data (ref. 2, Factual Report DFDR)** ***Elapsed time*** *(mm:ss)*	**RvO data (ref. 1 Annex 9) Martinair PH-MBN - AIDS / DFDR** ***Radar times*** *(hh:mm:ss)*	**Difference acceptable?**
Time synchronisation, touchdown The NTSB time (elapsed time) has to be incremented by 07:25:48 for comparison with data in the graphs in the RvO (radar time).	*07:02 (mm:ss)*	*07:32:50 (hh:mm:ss)*	
At time: Pressure altitude Magnetic heading Speed	*05:40 (mm:ss)* 995 ft 125° 140 kt	*07:31:28 (hh:mm:ss)* graph missing graph missing 143 kt (Appendix 9)	 X X X
At time: Pressure altitude Vertical acceleration variations	*05:52 (mm:ss)* 815 ft 0.75 - 1.25 g	*07:31:40 (hh:mm:ss)* graph missing 0.8 - 1.25 g (Appendix 9)	 X ✓
At time: Radio altitude Rudder position Roll angle	*06:52 (mm:ss)* 104.3 ft -22.5° (left) -1.76° (left)	*07:32:40 (hh:mm:ss)* 150 ft (Appendix 6) 21° left (Appendix 6) 0° (= wings horizontal) (Appendix 6)	 X ✓ ✓
2 sec later, at time: Max. roll angle Radio altitude	*06:54 (mm:ss)* -14.41° (left) 82.8 ft	*07:32:42 (hh:mm:ss)* 1° left (peak 2 sec. later = 15° left) 105 ft (Appendix 6)	 X X
1 sec later, at time: Radio altitude Left-hand inner aileron Right-hand outboard aileron	*06:55 (mm:ss)* 70.6 ft -11.612° (right) +7.11° right)	*07:32:43 (hh:mm:ss)* 96 ft (Appendix 6) 4.5° left = opposite (graph 11) 2.5° right (graph 11)	 X X X
One sec. before landing: Right-hand no. 3 spoiler Left-hand no. 5 spoiler	*07:01 (mm:ss)* 6.7 and 7.0° 0.0 and 0.4°	*07:32:49 (hh:mm:ss)* 1.5° (graph 12) 7° (graph 12)	 X X
During landing: Radio altitude Speed Magnetic heading Pitch	*07:02 (mm:ss)* 1.2 ft 126.0 kt 116.72° +8.79° nose up	*07:32:50 (hh:mm:ss)* the last part of the graph is missing (Appendix 6) the last part of the graph is missing (Appendix 9) graph missing from the RvO 9° (Appendix 9)	 X X X ✓

Compared data	**NTSB data (ref. 2, Factual Report DFDR)** ***Elapsed time*** *(mm:ss)*	**RvO data (ref. 1 Annex 9) Martinair PH-MBN - AIDS / DFDR** ***Radar times*** *(hh:mm:ss)*	**Difference acceptable?**
Roll angle	+5.62° right	during the last sec. from 0 to 5.62° right (Appendix 9)	√ ✓
Vertical g	1.9533	peaks at 1.96 (Appendix 3)	✓
Elevator position	max. up	20° up (= max.?) (Appendix 7)	
Autopilot modes Autopilot #2 was in: - Roll mode: HDG-SEL	*01:00 - 06:0x (mm:ss) =* 07:26:48 - 07:31:4x	07:26:13 - 07:31:55	x
- Pitch mode: ALT-CAP between	*01:00 - 01:06 (mm:ss) =* 07:26:48 - 07:26:54	07:26:13 - 07:26:19	x
ALT-HOLD between	*01:07 - 03:55 (mm:ss) =* 07:26:55 - 07:29:43	07:26:20 - 07:38:48 (accident occurred at 07:32:50!)	x
then to VERT-SPEED	*03:56 -* = 07:29:42 -	07:38:49 -	x
Autopilot disengaged, CWS engaged	*06:09 (mm:ss)* = 07:31:57 -	07:31:56	✓

2.5.3. The fourth column of Table 1 above shows that there are unacceptable differences between the DFDR data described in the NTSB's DFDR Factual Report (ref. 2) and the graph in Annex 9 of the RvO (ref. 1). It was concluded that the data about the airspeed, radio altitude and longitudinal axis control (ailerons and spoilers) exhibit major and inexplicable differences. Some data which is significant to the analysis of the last stage of the flight, including pressure altitude and magnetic heading, are missing in the RvO graphs, while they are included in the NTSB's DFDR Factual Report (see also ref. 3). In some graphs data on the last 3 seconds before touchdown is missing, i.e. from a radio altitude of approx. 50 ft, again, while again this is included in the NTSB's DFDR Factual Report.

2.5.4. In the appendix to the RvO containing graphs, the NTSB's DFDR Factual Report does not include any graphs with the pilots' control inputs; however, it is not certain if this data was recorded by the DFDR; The RvO does not include a list of the data recorded by the DFDR. The raster discontinuities in the appendix containing the NTSB report (Appendix 3 and Appendix 4) show that it was likely that there was cutting and pasting. Hence, key information may have been left out.
In the graphs in Annex 9 to the RvO (some of which are included in Appendix 6 and beyond) control inputs are given, but again end 3 seconds before touchdown, at an altitude of approximately 50 ft. Furthermore, the graphs in the RvO are not particularly clear and it is suspected that they may not be as accurate as the source data. Only once the source data has been made available will it be possible to undertake a better analysis of the last stage of the flight, if required.

2.5.5. The graph title states "AIDS/DFDR parameters". It is unclear which data was obtained from the AIDS and which from the DFDR. Neither is it indicated which data was measured objectively, and which was calculated and on what basis (e.g. the descent rate in Appendix 9). In some cases, the scales of the vertical axes (y-axes) are unrealistically extended, which may gave an incorrect representation of the actual information (which may be intentional). In any case, the available DFDR was not used to supplement the graphs (from an altitude of 50 ft).

2.5.6. ***Sub-conclusion - Comparison of data in the DFDR Factual Report NTSB and the RvO***. The above comparison shows that much data is missing from the RvO, although it was included in the original NTSB DFDR Factual Report, and that there are excessively large differences in the radio altitude and control surface (ailerons and spoilers) positions a few seconds before the landing. It appears that the NTSB graphs have been cut and pasted. Furthermore, the representation of data about the control inputs by the pilots, which is extremely important to the analysis, in the graphs stops shortly before the time of landing. It is most likely that the copy of the DFDR Factual Report of the NTSB is not the original version with all relevant data which the NTSB provided to the investigators. Extremely important data is missing from the RvO (or was deleted) and data which was available was not used to supplement the graphs in the RvO.

3. Comments on the reconstruction of the accident in the Accident Report

3.1. Approach

3.1.1. RvO § 1.11.2 includes data from NTSB's DFDR Factual Report. Apart from two minor discrepancies relating to the stated radio altitudes at 07:33:12 (104.3 ft) and at 07:33:15 (70.6 ft), both of which were reached 2 seconds earlier according to the NTSB, this paragraph of the RvO fails to include the spoiler data (information about the position of the spoilers on the wings), and the note that the roll angle continued to fluctuate. As already stated al in § 2.2.6 the conversion of the elapsed time of the DFDR clock to standard UTC times, used in this chapter of the RvO, was not always correct.

3.1.2. Before descending below 500 ft, the autopilot must be switched from command mode (Vertical Speed) to CWS. According to the NTSB, this occurred at 07:31:57 Radar time, at a pressure altitude of 597 ft. This altitude does not correspond with the radio altitude included in the graphs in RvO Annex 9, which was 560 ft one second earlier, see the altitude graph in, for example, Appendix 6. According to the DFDR (Appendices 3 and 4) the radio altimeter constantly indicated 245 ft for any height above 245 ft. Hence, the altitude graphs in Appendices 6 - 9, the AIDS graphs, are the pressure altitude graphs.

3.1.3. The rest of this paragraph of the RvO includes an analysis of the last stage of the flight. Reference is made to minor variations in the nose attitude, around an average of 4° 'nose-up'. These variations are so small that they are irrelevant and need not be mentioned. Next it is stated that major variations between 0 and 8° started which were not damped, and also increasing turbulence between them. The longitudinal pitch graph (see Appendix 7) does indeed show variations. However, 8 degrees is not that much, furthermore the two highest nose attitudes occurred exactly when the pilot flying was apparently flying slightly too low, below the prescribed approach glide path and pulled the nose up slightly to return to the right glide path and to see the same number of white and red PAPI lamps. As an apology, after this first glide path correction he says "PAPI, eh". The table in Appendix 2 with the CVR altitude report shows that the aircraft flew below the prescribed glide path during almost the full final approach. To draw the pilot flying's attention to another low altitude, at radar time 07:32:34 the captain says "a bit low bit low bit low", after which the pilot flying pulls the nose up slightly to return to the correct glide path. Three seconds later the captain says "OK OK OK", apparently because he has seen that the correction was done appropriately. Elsewhere in the RvO, these glide path corrections, from which nothing unusual can be concluded, are explained as the effects of windshear. However, in the cockpit windshear or any other external influence on the glide path was never mentioned; nothing about this was recorded on the CVR.

3.1.4. According to the RvO the movement around the longitudinal axis of the aircraft (the roll angle) indicated that the stability reduced, primarily from 07:33:20 UTC. That is quite correct, at that time the aircraft hit the ground and rolled around the longitudinal axis. (...) Presumably an earlier time is meant, as movement around the longitudinal axis during the last minute of the flight is shown in the graphs. However, this was fairly limited, apart from two peaks of 9° and 10° degrees. Nothing unusual given the crosswind at the time. According to the graphs there was hardly any counter aileron needed to correct the roll movements (Appendix 8).

3.1.5. The RvO continues with the descent rate (vertical speed) which from 07:31:51 UTC started to vary from +130 to -1300 ft/minute. Obviously these signs should have been the other way round (descent rate) but that is just a side remark. During landing the descent rate was supposed to have been 900 ft/minute. It is important to know the source of this data, as it is not recorded by the DFDR, it was probably calculated by differentiating the aircraft altitude (dh/dt). However, the DFDR does not record continuously, but records sampled data. This causes discontinuities in the graphs which when differentiated lead to a lot of noise and high values which apparently were not filtered out. However, the radio altitude graphs show that there were absolutely no large vertical movements which could have resulted in such large variations in the descent rate. The calculation appears to be quite careless; it is even worse that the result is used to demonstrate that the aircraft was exposed to major vertical movements (due to windshear). It would have been better simply to state that the vertical, the normal, acceleration only ranged from 0.9 to 1.22 g. The aircraft did move, but according to the relevant definition in Doc. 4444 of the International Civil Aviation Organisation (ICAO, ref. 7) it was only slightly turbulent. It really was not that bad; the aircraft limit was much higher. Hence, nothing is recorded on the CVR about large variations in descent rate.

3.1.6. Next it is stated that the groundspeed did not show abnormal features. The only noteworthy item was that around 07:31:31 UTC there is claimed to be a reduction in groundspeed, which later returned to normal. The groundspeed is the airspeed minus the frontal headwind component. The time was before that shown on the graphs, therefore more than two minutes before the accident. It is not explained how this conclusion was arrived at, and it is indeed unclear. However, it does indicate that at that time the wind strength was not high and varying, or abnormal.

3.1.7. According to the RvO the vertical approach profile referred both to the pressure altitude and to the radio altitude. The radio altitude exhibited an "oscillating" character with a level off at 400 ft at 07:32:10. Now, suddenly, this RvO paragraph does not refer to the standard UTC time but to the Radar time. According to the DFDR graphs (Appendix 3) there are indeed two different altitude graphs: the pressure altitude (based on air pressure measurements in the aircraft) and the radio altitude (height above ground). It appears that, as shown by the graph, that the radio altitude is limited to at most 250 ft above ground. Hence the 400 ft mentioned must be based on the pressure altitude, and not on the radio altitude as stated in this paragraph. However, it is indicated near the graphs in Annex 5 that the altitude shown is the radio altitude, which is therefore incorrect. Although there are minor variations in the altitude graph, this cannot be called "oscillating". The level off occurred exactly at the time the pilot flying noticed that he was slightly below glide path and briefly flies straight ahead to return to that glide path, as described above in § 3.1.3 .

3.1.8. The changes in the magnetic heading and the path followed by the aircraft (over the ground) do not show anything unusual according to the RvO, taking into consideration the wind at the time, the specified approach course of 111° and the fact that the last turn was too large (overshoot). However, the magnetic heading in the NTSB's DFDR Factual Report (ref. 2) was not included in the graphs in Annex 9 of the RvO. Might this have been done on purpose? Later in this supplementary analysis, the large horizontal deviation between the flown approach path and the specified approach path will be described. This is considered to be abnormal.

3.1.9. This paragraph also states that after 07:32:10 the wind correction angle started "oscillating" significantly, and at 07:33:17 reached a magnitude of 9°. The wind correction angle is not included in the graphs, as it cannot be measured. It is likely that the magnetic heading in the NTSB report was read out and that the difference between the magnetic heading and the runway heading was referred to as the wind correction angle. However, this does not include the drift due to the crosswind at the time, but that was actually a significant factor.
However, the graph of the magnetic heading in the NTSB report (Appendix 3) did not show any "oscillations" but only the heading change due to the early attempt by the pilot flying to align the longitudinal axis of aircraft with the runway heading by using the rudder. This movement was not successful, as discussed later in this analysis, so that landing was done with a crab angle which was not approved for a DC-10 on a wet runway.
Time 07:32:10 is probably the radar or graph time again as that is when the pilot flying operated the rudder. Earlier he had unnecessarily operated the brake pedal a few times, see Appendix 6. Although the movement includes variations (not "oscillations" as those are periodical), these are not apparent in the heading graph, possibly due to the mass inertia of the large, heavy aircraft (Appendix 3). The "oscillations" were certainly not significant.

3.1.10. According to the RvO, until 07:32:00 the engine speeds (rpm) were maintained within the limits, but after that unusual oscillations started as a result of the reaction of the autothrottle system to the longitudinal pitch oscillations (that is, variations). It is unclear what "within the limits" refers to. An autothrottle system reacts quickly to changes in parameters such as pitch, longitudinal acceleration and obviously the airspeed. Appendix 9 clearly shows that at 07:31:42 the nose of the aircraft went from 4° up to 0° (due to the autopilot which was still engaged to maintain the set vertical speed). The speed increased to approximately 153 kt so apparently for a brief time less engine power was needed; the autothrottle responded by pulling the throttles back slightly. The speed briefly remained constant and then reduced, as it had to as the pilot flying had set 139 kt as the approach speed, see § 3.3.6. At 07:31:50 radar time the nose was at the horizon and it appeared that the autothrottle calculated that if it remained like that, the speed would fall below the setpoint. Hence the autothrottle increased the throttle setting a bit. The speed increased after which the throttle was pulled back somewhat. However, the pilot flying noticed that he was getting below the glide path and pulled the nose up a bit, the only correct response. The autothrottle responded im-

mediately to the higher nose attitude, as that always reduces the speed and more throttle is needed. The nose attitude increased to 6° and hence also the N1 engine speed, up to as much as 98%. Once the aircraft was back on the glide path the pilot flying said: "PAPI hè" and pushed the elevator control forwards again to approx. 2.5° to stay on the glide path. The speed varied a bit and at 07:32:30 graph time the pilot flying pulled the nose up a bit to 8° because apparently he was below the specified glide path again. Three seconds before that the captain had called out "a bit low bit low bit low". The autothrottle responded immediately to the higher nose attitude and increased rpm to 102%. After the aircraft was back on the specified glide path the nose was pushed forward again and the rpm decreased quickly as less engine power was required. After that, over 9 seconds time the rpm dropped from 102% to 40% or lower (graph 10 in the RvO ends at this point) Appendix 9. In the NTSB's DFDR Factual Report the N1 data continued for some time, over two seconds after the landing. After some small pitch movements the landing followed.
Hence, there were no "remarkable oscillations" but variations needed to stay on the specified glide path; so perfectly normal. However, it would appear that the three throttles, the three power handles of a DC-10, were pulled back or held back by the pilot flying, from an altitude of 150 ft, at 102% rpm. An autothrottle system would only close the throttles slowly and according to a given pattern, after passing a radio altitude of 50 ft. The probable reason for the throttles being closed by the pilot flying is given below, in § 3.1.12.

3.1.11. The RvO stated that the vertical accelerations indicated the turbulent nature of the approach as did the pitch oscillations. The approach was indeed somewhat turbulent, the vertical acceleration was between 0.8 and 1.22 g. However, according to Doc. 4444 of the International Civil Aviation Organisation (ICAO, ref. 7) turbulence leading to such g-variations is only specified as light (0.75 - 1.25 g). About the so-called pitch oscillations we can state that these were the result of minor pitch corrections needed to follow the specified glide path, as explained in the preceding paragraph and earlier in § 3.1.3.

3.1.12. According to the RvO, the reduction in engine power at 150 ft altitude to 40% resulted in a "sinking". However, this sinking is not apparent in the radio altitude graph of the DFDR (Appendix 3) and also not in the graphs in the RvO Annex 9 until an altitude of 50 ft was reached; the last part of the radio altitude graphs is left out in this. When landing, after reducing the engine power, to prevent an aircraft going down too far, the nose of the aircraft is almost always pulled up slightly just before touchdown, as a result of which the angle of attack, and therefore the lift produced by the wings, increases, the descent rate therefore decreases and the landing is not too hard. This flare does reduce the speed, but when landing that is not a disadvantage if the aircraft is close to the ground; indeed, it is the intention. In English, this manoeuvre is known as flare. However the engine power was reduced at an altitude (150 ft) which was too high. As the engines, because the throttles were held closed, could not respond to the pitch increase, as happened earlier during the approach, speed was lost. The last part of the speed graph was also left out from Annex 9 of the RvO (Appendix 9), but it could be read and was also described in the NTSB's DFDR Factual Report (ref. 2): when passing 50 ft altitude the airspeed had already reduced to 134 kt, 5 kt below the required threshold speed of 139 kt. The landing speed, the airspeed at "touchdown", was 126 kt.
A reason for closing the throttles prematurely could also have been that the pilot flying realised that the aircraft would land too far down the runway if the speed was not reduced quickly. On a runway which is already short this can have disastrous consequences, unless a go-around is initiated. The go-around was initiated, but it took too long to develop sufficient engine power; the aircraft kept descending and landed. At touchdown the N1 speed of the engines had increased to 100% on average and after that increased further to above 100%.

3.1.13. The reconstruction in the RvO concludes with the finding that the extreme values of the vertical acceleration were between 1.29 and 0.8 g but were within the limits of the aircraft. The 1.29 g cannot be found in the DFDR graphs (Appendix 3). Only two short peaks are visible one up to 1.22 g and one up to 1.2 g; the average was only approximately 1.05 g, so not at all extreme. As mentioned above, according to the ICAO definition in Doc. 4444 (ref. 7) it was only slightly turbulent, with variations of at most 0.5 g, even including the two peaks.

3.1.14. According to RvO § 1.11.5 the data recorded on the AIDS ended at an altitude of 47 ft. It is stated that the recorder tape was damaged, presumably due to the impact of the landing. The RvO then states that using a combination of AIDS and DFDR data in Annex 9, the flight profile of the last stage of the flight could be determined, but many graphs required for a thorough analysis stop at that altitude. It could be that there was no AIDS data, but all the DFDR graphs continued below 47 ft, in fact, for at least 7 seconds after the landing. For inexplicable reasons this data was not included in the graphs in Annex 9 although the headings of the graphs ('AIDS / DFDR parameters') indicate that it was. Hence, these graphs are not as complete as they could be.

3.1.15. According to RvO § 1.12.1 the aircraft landed on the left-hand side of runway 11. However, the sketch in RvO Annex 11 which shows the location is illegible because it has been reduced and copied. In § 2.3.1 of the report by the Nationaal Lucht- en Ruimtevaart Laboratorium (NLR) in Amsterdam (ref. 6) the landing site is described in words: the aircraft landed at a distance of 392 m from the runway threshold, 124 m beyond the 268 m long touchdown zone, at 22 m to the left of the centre of the 45 m wide runway, with the centre landing gear (in the centre of the fuselage, between the two main landing gear) on the edge between the runway lights and the site. According to the NLR the left-hand main landing gear landed completely off the runway; only the right-hand main landing gear was on the tarmac of the runway. It was unclear if the site next to the runway was higher or lower than the tarmac and if the left-hand landing gear may have sunk into it, which would also explain the collapse of the right-hand landing gear. See Figure 3 below and also § 2.4.7.

Fig. 3. Landing area (touchdown) on the first part of the runway.

3.1.16. According to RvO § 1.16.1 the collapse of the right-hand main landing gear was purely due to the impact of the landing; the possibility that the wheels may have been locked at the time of the landing because the brakes were engaged too early is not mentioned. This will be discussed in the supplementary analysis in § 4 below.

3.1.17. *Chapter 2 of the RvO* has the title Analysis, but in fact it only includes repetitions of partly incorrect analyses and conclusions already presented in Chapter 1 of the RvO. Hence Chapter 2 of the RvO will not be discussed here.

3.1.18. ***Sub-conclusions - approach in the RvO***. The reconstruction of the accident was partly included in Chapter 1, which should only have contained factual information, and partly in Chapter 2, Analysis, however this does not contain a proper analysis but more of a list of conclusions. Differences were observed between the data in the DFDR Factual Report and the RvO. Altitude corrections to stay on the specified approach glide path and changes in engine speed were incorrectly explained as being the effects of windshear. According to the ICAO definitions, the aircraft was only subjected to light turbulence. The origin of the high descent rate is doubtful; this data cannot be correct. The altitude indicated as "radio altitude" in the graphs is not just the radio altitude; according to the NTSB report the available radio altitude was limited to 250 ft. The approach was abnormal, not along the specified course. The pilot flying started aligning the aircraft with the runway, in preparation for landing, too early. This alignment was not completed, hence there was a sideways movement (crabbing) during the landing. In many RvO graphs the last part is missing, from an altitude of 50 ft, although the NTSB graphs do continue. According to an NLR report the aircraft landed too far and half off the runway. The collapse of right-hand landing gear could also have been caused by landing with braked wheels.

3.2. Consideration of windshear in the RvO

3.2.1. RvO § 1.16.4 considers the presence of windshear conditions. The NLR was asked to provide two reports, only the second one (ref. 6) of which was included in the RvO, as Annex 4. The study concluded that it was turbulent, but also that the aircraft was supposed to have flown through a downburst during the last part of the approach, which it left at 700 ft altitude without adverse effects apart from this being the beginning of the "oscillations" in the flight parameters. In the following paragraphs of the RvO everything is done to convince the reader that there was windshear and that a windshear warning would certainly have been given if the aircraft had been fitted with a windshear warning system. But the graphs in the NTSB report, the graphs in Annex 9 of the RvO (Figures 2 - 10) and the CVR transcripts do not suggest windshear at all. The radio altitude graph (in Appendix 6 and elsewhere) does level off a few times, but that was because the aircraft had very gradually moved to below the glide path after which a correct and perfectly normal correction followed, as discussed above in § 3.1.10. Additionally, the CVR transcripts did not include any comments by the crew about windshear. The graphs with the positions of the aerodynamic control surfaces do not indicated that their limits were even approached. There was light turbulence and there was a crosswind component, but nothing to suggest that the aircraft was subjected to large, unavoidable weather effects, let alone windshear.

3.2.2. It appears that the NLR concluded that the windshear reached values which temporarily exceeded the aircraft performance limits and that the throttle response during the last 10 seconds was normal. In the introduction to the NLR report (ref. 7) the NLR states: "In summary it was concluded that a windshear (a downburst) had been present, however, it was not a hazardous factor in itself during the approach of the aircraft". However, the NLR did assume that the throttles were closed while the autothrottle was engaged. None of the graphs indicate that the aircraft limits were exceeded during the last part of the flight. The throttles can only have been pulled back and held back by the pilot flying and that is neither normal nor in accordance with the defined procedures.

3.2.3. Next, in § 1.16.4 item 6 the RvO states that several conclusions may be drawn from the behaviour of the autothrottle system. According to the RvO the instability in the longitudinal direction, speed and engine power started when the autopilot was still in the vertical speed mode and was triggered by the vertical upburst associated with the first downburst. This stability got worse when the autopilot was switched from CMD to CWS. However, the graph in Appendix 6 shows that at that time the pilot flying was already using his feet to give directional steering inputs to the left, as if he wanted to line up with the runway. Rudder movements result in rotation around the centre of gravity and therefore an increase in the drag of the aircraft resulting in a speed decrease and increase in the descent angle which the autopilot and autothrottle then respond to, if they are engaged. During the rest of the flight we can see that the pilot flying is giving more and more steering inputs, which therefore led to greater instability which he caused himself. It must be concluded that, apparently, the pilot flying did not know how to handle the CWS mode of the autopilot. This is also confirmed by the US Accredited Representative of the NTSB in his letter of 26 October 1994 (ref. 3) in which he writes: "CWS and autothrottle functions were inappropriately used by the flight crew". Initially, the captain did not intervene, although his rudder controls are mechanically linked to the rudder controls of the copilot and he could therefore have felt his steering inputs. This will be discussed in greater detail further on in this analysis.

3.2.4. According to RvO, § 1.16.4 item 6.3, just before the landing the crosswind exceeded the specified aircraft limit. The wind was not only above the limit "just" before the landing, but was already like that when traffic control informed the crew of the wind data and the "flooded" condition of the runway, well before the landing, see § 2.3.8. The crosswind limit, according to the RvO 5 kt when landing on a runway with "braking action poor" (flooded), was exceeded.

3.2.5. The RvO also states (in § 1.16.4 item 6.4) that changing over from CWS mode to off (manual flight) just before the landing must have contributed to the abrupt flare, followed by a hard landing because of the fact that the landing technique with CWS is significantly differently from that with a manual landing. CWS disengaged due to simultaneous and conflicting aileron steering forces by the pilot flying and the captain; before this the captain had not said "My controls" as prescribed in the AOM (RvO § 1.17.1.3), so that the copilot would release the controls. Under CWS the autopilot is still controlling the aircraft, but it "listens" to the control forces applied by the pilot(s) on the elevator and aileron controls and then determines the required position of the aerodynamic control surfaces to meet the demands of the pilot(s). If a small deviation from the required course is observed then under CWS the pilot flying only needs to apply a small steering force in the required direction; the autopilot will then set the required control surface positions. But if the pilot flying keeps applying large and changing forces to the controls, as in manual flight, then the CWS mode of the autopilot will respond to this and it will get even worse.
The landing technique with CWS is not significantly different than when landing manually and certainly did not lead to an abrupt flare and hard landing, as shown by DFDR and AIDS data. This is extremely far-fetched. The graphs (Appendix 7 for the elevator and Appendix 8 for the aileron)

indicate that the pilot flying gave large and changing steering inputs, as if the CWS was not engaged. He used the CWS function of the autopilot inappropriately, again you are referred to the NTSB's comment in § 3.2.3 above. A summary description of CWS is given in § 4.1.2 and the landing is also described in detail later in this analysis (§ 4.6).

3.2.6. In § 1.16.4 item 6.6 the RvO stated that the crosswind data from the inertial navigation system was affected by the slip angle, which was significant. The slip angle cannot be measured, but if the rudder is used then there is a slip angle. Shortly before reading out, the rudder was moved left a few times with peaks up to 30%, as a result of which the course shrank by approximately 10°. This had hardly any effect on the speed and engine power so we cannot say there was a significant slip angle. The CVR transcript indicates that the captain read the wind, not the crosswind, from the system display. That was done at graph time 07:32:39, 3 - 4 seconds after the pilot flying gave left rudder to align the longitudinal axis of the aircraft with the runway. Hence it was likely that there was no significant slip angle at the time the wind was read out. So, the wind information from the inertial navigation system (AINS) should have been considered as relevant.

3.2.7. According to § 3.3.5-08 of the AOM (included in RvO § 1.17.1.4) the minimum altitude at which the autopilot may be disengaged fully from CWS is 150 ft. Here, it was disengaged automatically at approximately 80 feet after the conflicting steering forces of the pilot flying and the captain mentioned above. If the disengagement of the CWS at this altitude was dangerous and could have contributed to an abrupt flare followed by a hard landing then at least visible and audible warnings would be generated; otherwise the autopilot should not have been certified by the authorities.

3.2.8. As stated above, the captain intervened and gave different steering force inputs than the pilot flying without first saying "My controls", as required; in that case the pilot flying (copilot) should have released the control wheel. The autopilot CWS mode responded to the differing control force inputs by disengaging. The captain caused the disengagement of the CWS mode at low altitude; perhaps he was not fully familiar with the operation of the CWS which could indicate a lack of training.

3.2.9. ***Sub-conclusions - windshear in the RvO***. As far as the effects of the weather are concerned, the reconstruction of the final part of the flight was incorrect. There is absolutely no evidence of windshear. There was light turbulence but the movements were never extreme and also explicable. The RvO strongly veers towards windshear, while it cannot be concluded from the objective DFDR data that the aircraft made movements which approached the standards for windshear. The instability was explained as crossing through areas with upbursts and downbursts, while they were normal glide path corrections. The pilot flying caused the instability by unnecessary rudder actuation and he did not use the autopilot CWS mode appropriately. The captain caused the disengagement of the CWS by not taking over control appropriately.

3.2.10. The crew ignored the information about the runway conditions and landed on a runway with a crosswind component which was far too high for DC-10 under the weather conditions at the time; the crosswind limit was exceeded.

3.2.11. It may be concluded that nature was to be blamed for the accident. It is inexplicable that this reconstruction was accepted by the RVDL.

3.3. Landing Data Card

3.3.1. Well before the landing, a Landing Data Card is filled in, normally by the Flight Engineer, with the required landing distance and the speeds to be used by the pilots during the approach and the landing for the expected weather conditions and the expected aircraft weight at the time of landing. The Landing Data Card filled in for the landing of MP495 is included in Appendix 1. This is always placed or fixed in a position in the direct line of sight of the pilots as a reminder.

3.3.2. *Wind data.* According to RvO § 1.17.4, the crew filled the Landing Data Card in with the wind information from Approach Control (the approach traffic control at Faro) and the wind information from the aircraft's inertial navigation system. However, this is incorrect.
The approach and landing speeds on the Landing Data Card were read out aloud by the Flight Engineer at 06:56:09 UTC, 37 minutes before the landing (transcript CVR). This was the oldest recording on the CVR's endless tape, hence it is unknown what the source was of the 140°/14 kt wind entered on the Landing Data Card. This could be the Automatic Terminal Information Ser-

vice (ATIS) information which is regularly updated and continuously transmitted at the frequency of Faro's VOR beacon and which approaching aircraft normally listen to. However, in the wind tables in the RvO § 1.7.4.4 this wind is only listed later, at 07:09:00 UTC.
At the time of the reading out aloud there had not been radio contact with Approach Control, as [they] only switched over to the Faro Approach frequency (119.4 MHz) at 07:09:42. The CVR did record the communications between Martinair flight MP461 and Approach. The wind information which MP461 received at 07:04:27 from Approach was 150°/15 kt and the statement "thunderstorm". At 07:05:30 MP461 again requested wind information, which was 150°/ 16 - 18 kt. Hence the crew of DC-10 MP495 was already listening to the Faro Approach frequency but did not use the wind information. The wind information used in MP495 (140°/14 kt) was not communicated to MP495 by Approach. Hence, old and superseded wind information was used to plan the landing.

3.3.3. *Landing flaps*. Flaps are large surfaces at the trailing end of the wings which provide adequate lift at low speeds, at the cost of some drag. According to the Martinair DC-10 Flight Crew Operating Manual (FCOM, 03-50-08) the normal flap position for a landing is 35°. A flap position of 50° should be used at short runways and when the runway is wet, or contaminated by snow, ice or slush, or if in the view of the captain there is an adverse influence on the required landing distance. The choice of flap position 50° for the landing at Faro was therefore in accordance with the FCOM, both given the limited length of the runway and its condition.

3.3.4. ***Required landing distance***. The Landing Data Card in the RvO (Appendix 1) shows that the available runway length was 2445 m, while the pilots mentioned 2490 m (CVR).
The Flight Engineer filled in the required actual required runway length for three different braking actions: good (1905 m), medium (2400 m) and poor (3055 m). This clearly shows that the available landing distance of runway 11 at Faro with braking action poor (flooded) would be 600 m too short to bring the aircraft to a stop before reaching the end of the runway. Apparently, when planning the landing it was assumed that there was a wet runway with the braking action no worse than medium. Hence, a landing at Faro with braking action poor would not have been possible. It is odd that on the Landing Data Card the landing distance (3055 m) for braking action poor was filled in while that length was not available and that there was no cross to indicate that with braking action poor it would not be possible to land; just like the cross drawn through the threshold speed at 35°/ LAND (see Appendix 1).

3.3.5. ***Approach speeds***. These speeds depend on a number of factors, such as the flap position, wind conditions and aircraft weight, and are specified in the FCOM 0350-03 and 07-97-15). A distinction is made between the "threshold speed", the speed which the aircraft needs to have during approach above the runway threshold (at an altitude of approximately 50 ft) and the "approach speed", the approach speed to be maintained during the final stage of the approach. The approach speed should be reached at altitudes below 2000 ft and should be maintained.

3.3.6. When choosing the approach speeds, the threshold speed is used. The FCOM (ref. 4) presents the minimum threshold speeds in a table, with weight/mass steps of 10,000 lb, approximately 4,000 kg, see the relevant part of the table in Table 2 below. According to the Landing Data Card (Appendix 1) found after the accident, the estimated mass (weight) of the aircraft at the landing was 162,000 kg, the actual weight (mass) was supposed to have been 161,400 kg. Apparently, the Flight Engineer interpolated between two columns in the FCOM (159,000 and 163,000 kg) with the exception of the speed (139 kt) for a landing with 50° flaps (as was indeed done); he choose the safest value and wrote that on the Landing Data Card.

Table 2. Approach speeds in the DC-10 instructions

Flaps/slats	Minimum Threshold Speeds (kt) for Landing Weight		
	159.000 kg	163.000 kg	Landing Data Card
35º / extended	141	144	143
50º / extended	137	139	139
NOTE: For 35º and 50º approach speeds, add 5 kt or wind additives to threshold speeds			

3.3.7. According to the NOTE in the table above, to obtain the approach speed the threshold speed should be increased by 5 kt or by a "wind additive" an addition or wind correction. A NOTE on FCOM page 03-50-03 gives guidelines for the wind additive to be added to the threshold speed. In the first line of that it is stated that a minimum addition of 5 kt should be applied on top of the threshold speed for all approaches in the normal configuration. Normal configuration means that during the approach all aircraft systems are working and that the wing flaps, landing gear, etc. are operational, i.e. that there are no technical problems. Hence the approach speed should always be at least 5 kt higher than the threshold speed.

3.3.8. The wind additive has to be calculated by the pilots and according to FCOM (0350-03) it is the highest of the total wind gusts or half of the constant wind above 20 kt, with a maximum total additive of 20 kt. The wind filled in on the Landing Data Card was 140°/ 14 kt (Appendix 1), incidentally this does not correspond with the METAR and TAF on page 35 of the RvO. At that time, no gusts had been reported and the wind speed was below 20 kt, so the standard 5 kt additive would apply to MP495. The approach speed for a landing with 50° flaps should therefore have been 139 + 5 = 144 kt. However, there was no space for this approach speed on the Landing Data Card, apparently Martinair pilots had to calculate and apply it mentally.
A traffic control radio message (at 07:32:15) mentioned gusts (150°/ 15 - 20 kt, § 2.3.8) together with the permission to land, but this did not change the approach speed (144 kt) as the gusts were 20 kt - 15 kt = 5 kt, the same as the standard additive.

3.3.9. However, on the next page of the FCOM (page 03-50-04) a NOTE states that the autothrottle system, if engaged, during weather conditions with gusts, provides an automatic gust protection amounting to 5 kt above the set approach speed. The FCOM states that hence during weather conditions with gusts a speed 5 kt lower than the approach speed calculated on the basis of the current wind and gusts has to be set on the autothrottle control panel as the landing speed, so in this case 144 - 5 = 139 kt. The autothrottle was supposed to automatically maintain the approach speed at a value 5 kt higher, but that did not happen, as shown by the graphs. Consequently on several occasions the speed fell to the threshold speed of 139 kt, which was unsafe for the approach, possibly because the autothrottle did not notice any gusts at those occasions. This NOTE in the FCOM cannot have had the intention [of specifying] an approach speed which falls to the threshold speed due to the autothrottle system. The minimum additive above the threshold speed should always be at least 5 kt, as specified above in § 3.3.7 . Hence the calculation of the approach speed in the Martinair FCOM is incorrect when the autothrottle is used.

3.3.10. According to RvO § 1.17.4 the choice of 139 kt as the threshold speed (indicated as Vref landing reference speed) was correct and there was no obligation to add the wind corrections mentioned in the AOM. The CvO may have copied the text in the FCOM literally and not have realised that an approach speed around the threshold speed was simply too low and unsafe, especially if there was also light turbulence. The Martinair FCOM was unclear and incorrect with respect to this point, as also discussed in the preceding paragraph. If the autothrottle is not engaged, or disengages, then an approach speed of at least 139 + 5 = 144 kt should be maintained manually under the same wind conditions.

3.3.11. The calculation of a DC-10 approach speed, as specified in the FCOM is not straightforward. The variables are a minimum additive of 5 kt above the threshold speed, the strength of the gusts and a proportion of the constant wind above 20 kt. This calculation was supposed to be done by the Flight Engineer and then be filled in on a dedicated part of the Landing Data Card instead of just the threshold speed, to prevent mistakes. The pilots then had to set the approach speed on the autothrottle. This speed will be discussed further in the supplementary analysis (§ 4.3.2).

3.3.12. ***Sub-conclusion - Landing Data Card in the RvO***. The Landing Data Card included old wind information which had been superseded. The available landing distance at Faro with a wet runway would have been just sufficient for a DC-10; landing on a flooded runway would not have been possible. The application of the wind correction calculation method described in the Martinair FCOM leads to an approach speed which is too low when the autothrottle is used. The pilots did not add the minimum required 5 kt wind correction to the threshold speed provided by the Flight Engineer. The correct approach speed was not included on the Landing Data Card. The calculation of the approach speed in the Martinair FCOM is incorrect when the autothrottle is used.

4. Supplementary analysis of the approach and landing

4.1. Introduction

4.1.1. In chapter 3 above several paragraphs of the RvO were discussed in detail, with comments and explanations. This chapter presents the supplementary analysis. Comments from the preceding chapter are repeated and references are made where necessary to explain the analysis. Various aspects which affected the final part of the flight will be discussed in turn. The supplementary analysis is preceded by a short explanation of the CWS and the radar observations used.

4.1.2. *Control Wheel Steering (CWS).* The final part of the approach was still flown with the autopilot (in command mode). From a radio altitude of approximately 560 ft the CWS mode of the autopilot was engaged, in accordance with the instructions. CWS is a mode of the autopilot system where the autopilot, without the pilot flying giving steering input, operates the elevator and ailerons, to maintain a set flight path as soon as there are changes due to external circumstances, such as the effects of crosswind or turbulence. CWS does not use the steering inputs of e.g. the navigation system, but the forces applied to the aileron and elevator controls of both pilots.
If the path of the aircraft due to CWS differs from the path the pilot flying wants the aircraft to follow, then a small force can be applied to the elevator and/or aileron controls which the CWS will translate in the position of these aerodynamic control surfaces required for the current speed and other circumstances. If the pilot flying does not do anything, then the aircraft will continue on the flight path set earlier. The inputs of the pilots are added to the inputs of the sensors of the autopilot system to maintain the set attitude. The autopilot provides autonomous (and additional) corrections for turbulence and other external influences. The elevator and aileron controls of the two pilots reflect the movements of the aerodynamic control surfaces so that the pilots can see and feel what the autopilot is doing. CWS does not actuate the rudder; directional stability is provided by a yaw damper.
If the CWS is disengaged, or if it disengages, then the pilot flying not only has to give steering inputs for the desired flight path but also to compensate the external influences. This increases the workload but the question is if the pilot flying, in a busy stage of the flight such as the landing, will actually notice if the CWS has disengaged, as they will be very much in the loop, especially at low altitudes; see also § 3.2.7.

4.1.3. *Radar observations.* According to RvO § 1.17.5 the path followed by MP495 could be determined through to the landing. In Appendix 2 the last part of the approach path is drawn on the Approach Chart, in both the horizontal and vertical plane. It also states that using the radar data recording at Lisbon it could be determined that the rate of descent, at the time of the landing, was 1000 ft/minute (RvO § 2.2.3; incidentally the report in the Portuguese language states 900 ft/minute...). It is claimed there was not significant difference with the position and altitude data from the AIDS and DFDR.
A normal traffic control radar, especially one located in Lisbon at a great distance from Faro, simply cannot be used to determine the rate of descent of an aircraft at Faro. This could only be done using a Precision Approach Radar at the airport, but Faro did not have such a radar. The traffic control radar rotates at a relatively low speed and only receives a few echoes of an aircraft once every revolution. The height resolution of a traffic control radar at a long distance, with a slowly rotating antenna, is not fine enough to provide reliable altitude data from which the rate of descent can be calculated. Furthermore, the verbal altitude reports recorded on the CVR during the approach do not correspond with the altitude profile drawn on the Approach Chart, see the table in Appendix 2. Hence, the source of the aircraft altitude drawn on the Approach Chart is therefore unclear. It is also unclear if the range resolution of the radar (approximately 500 ft per microsecond pulse width) was sufficient for an accurate representation of the path followed in horizontal plane as drawn by the CvO in Appendix 2.

4.2. Approach heading

4.2.1. The approach to runway 11 specified by the Portuguese authorities is indicated on an Approach Chart, see Appendix 2, part of which is included in the figure below. The approach of the MP495 was drawn in on this by the CvO. After passing the airport VOR/DME beacon from the north at an altitude of 4000 ft a Cat. C/D aircraft (approach speed 121 - 140 kt / 141 - 165 kt), which includes a DC-10, should follow radial C/D 269° from the VOR/DME beacon until the distance to it is at least 8 nm.

4.2.2. The approach path of the aircraft plotted in Appendix 2 and Figure 4 below shows that the turn towards the approach heading was already started at approximately 8 nm from the VOR beacon; this is too early according to the procedure and the permission given by traffic control, but it is sometimes left up to the pilot flying (if there is no other traffic). It was recorded on the CVR (07:26:43 UTC) that the captain gave permission to start the turn at 8 nm; nothing was mentioned about bad weather as a possible reason for the early turn. The approach radial of 111° was set at 07:28:36 UTC on the autopilot. Shortly afterwards the copilot says he wants a heading of 080° which the captain confirmed. A difference of 30° is normally used to intercept the approach radial (111°). When the approach radial is almost reached, the HSI indicates this and the heading has to be changed 30° to the approach radial. In this case the autopilot started the turn and reached the set heading of 080 exactly, as shown by the approach path drawn by the CvO. Whether or not the 111° approach radial was then set was not recorded on the CVR. Due to the approach radial not being set on the HSI, and an apparently late response when reaching the 111° radial the last turn on the radar plot in Appendix 2 looks rather affected by the wind as apparently the effect of the southerly wind was not considered.
The pilots must have been very aware of this major deviation from the approach radial as this must have been displayed very clearly on the two Horizontal Situation Indicators (and probably also on the two Attitude Director Indicators (ADI) in the cockpit). The corrective action, easing the heading to reach the correct approach ground course (VOR beacon radial), was not taken. It is possible that the pilots set a heading/ radial directly to the VOR beacon.

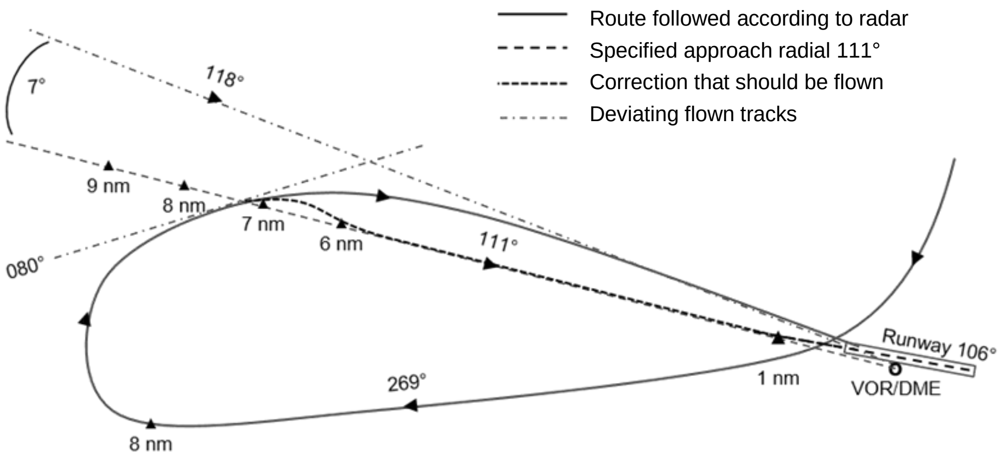


Fig. 4. Approach to Faro airport, based on the Approach Chart in Appendix 2.

4.2.3. At a distance of approximately 5 nm the captain (CVR 07:30:47 UTC) suggested to make the approach at a heading of approximately 123°, to offset the southerly crosswind, the local direction of which must have been 185°, see § 2.3.8. The NTSB report (ref. 2) mentioned a followed heading of 125° read out from the DFDR (Table 1, page 7, see also Appendix 5); this heading graph is not included among the graphs in the RvO. To intercept the approach radial again at an angle of 30°, given the wind, a heading between 140° and 151° would have been required. This was not recorded.
According to the radar data in the RvO (which, for now, will be assumed to be correct) the deviation of the approach path followed relative to the specified approach path was still no less than approximately 1 km (!) at a distance of approximately 5 nm from the VOR/DME beacon at the airport (see Appendix 2). With a correctly set approach radial (of 111°) the needle of the VOR indicator must have been almost all the way to the right (3.5 dots, corresponding with a deviation of approximately 7°), as an instruction to change the ground track to the right, i.e. to steer more against the crosswind at the time, unless a direct approach heading was set in which case this would have been 118° according to the radar. The flight path drawn on the radar plot (Appendix 2) indicates that no effort was made to get to the correct and specified approach radial. When passing 500 ft altitude the horizontal distance to the specified approach path was still approximately 400 m. This must have been clearly visible as the runway lighting was on and it was still twilight. Additionally, traffic control had asked MP495 if they could see the runway lights, which was confirmed (07:32:14 UTC, 66 seconds before the landing). Thirty seconds earlier the captain had ac-

tually said "yes, you can see the runway" (07:31:46 UTC). According to the FCOM (RvO § 2.2.3) a visual approach should be stable from an altitude of 500 ft, i.e. the approach path is lined up with the runway centre line within certain margins (<2.5°), the airspeed is the specified approach speed and the engine thrust is stable to maintain that speed and to follow the correct glide path (descent rate). Hence the approach of the DC-10 was not stable and should have been aborted at that time. By delaying the go-around to an altitude below 500 ft the problems were only made worse.

4.2.4. An additional problem when approaching runway 11 at Faro is the difference in angle (offset) of 5° between the runway heading (106°) and the specified approach heading (111°) which is due to the location of the VOR/DME halfway down and 240 m south of the runway axis at the airport, see the NOTE about the offset in Appendix 2. This offset makes it necessary to correct the heading by 5° to the left at a distance of 1 nm before the runway (approximately 25 seconds remaining flight time and at an altitude of approximately 300 feet). The pilots were aware of this, given the comments on the CVR (07:01:00), half an hour before the landing. The DFDR heading graph and the steering graphs do not show this heading correction being made, which also is an indication that they did not fly the specified offset ground track (111°), see Appendix 2.

4.2.5. According to the radar, the ground track of the followed angled approach path was approximately 118°. The required wind correction angle for 190°/20 kt wind was 8°, see Figure 5 below, hence the heading must have been 126°. That correspond with the heading of 125° recorded by the DFDR; a difference of 1°, a rounding error. Even from the start of the approach, after the last turn, there was insufficient wind correction into the direction of the crosswind at the time and, as shown by the radar plot (Appendix 2), the DFDR data (Appendix 3), summarised in Figure 4 above, no attempt at correction was made to fly to the approach radial. The approach path drawn by the Portuguese CvO (Appendix 2) shows that the aircraft never reached the extended centre line of the runway but approached the runway from the side. Hence the approach path was not within the required angle (2.5°) for a stable approach. The approach was not flown accurately and not according to the Approach Chart and can therefore definitely not be considered as a stable approach in accordance with the requirements of the FCOM (§ 4.2.3 above). This is another reason why the approach should have been aborted.

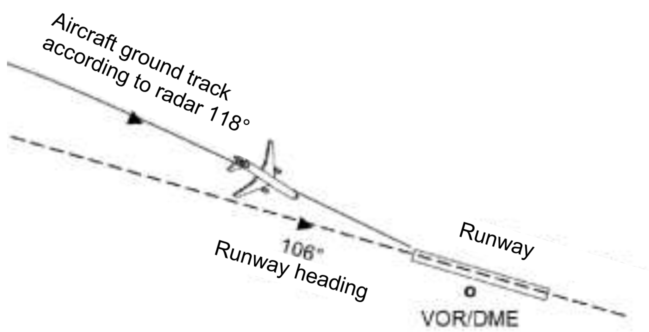


Fig. 5. Wind correction for wind from 190° at 20 kt, and at an airspeed of 139 kt is 8° to the right. Therefore the heading must have been 126° (consistent with the DFDR).

4.2.6. From 42 seconds before the landing, probably to line up the longitudinal axis of the aircraft with the runway, left rudder pedal was regularly applied to no less than 30% of the maximum possible movement, which is quite a lot and also far too early and too high (approximately 450 ft). Yawing movements (around the vertical axis of the aircraft) due to external influences, such as fluctuating crosswind, are automatically compensated by the yaw damper, without intervention by the pilot flying. If the aircraft starts yawing due to external influences the damper will give an opposite control signal to the upper and lower rudders. If the pilot flying also gives inputs using the rudder pedals then these are added to the yaw damper inputs. The graphs in the RvO (Appendix 6) show that from approximately 42 seconds before the landing the pilot flying used the rudder pedals to add large inputs to the other inputs of the yaw damper. Normally there is no need for these steering inputs, only when lining up just before the landing. These undesirable steering actions had side effects such as heading and roll angle changes and additional a slipping flight affecting drag and therefore the airspeed, angle of descent and engine power (due to the autothrottle). Roll angle changes are a side-effect of yaw; the outer wing gains speed and therefore generates more lift which has to be offset with the ailerons. This caused more unsettled movement of the aircraft than just those due to light turbulence, which were therefore caused by the pilot flying himself. Instead of correcting the approach heading with the ailerons, as one should do, the pilot flying used the rudder (with the rudder pedals), a beginner's error and a serious training shortcoming. The combined graph in Appendix 5 illustrates the use of the rudder with text boxes.

4.2.7. ***Sub-conclusions - approach heading***. The last turn before the landing was too close to the runway and was too wide, thus it was not flown in accordance with the specified procedures. No corrections were made. At and below 500 ft altitude the aircraft was still not flying the specified approach radial, the deviation from the specified approach heading was far too large and the corrections for the crosswind at the time were not in time and were insufficient. The pilot flying caused variations in the direction and roll angle through unnecessary steering inputs which also resulted in speed variations and engine speed variations; this suggests a training deficiency. Thus, the approach was most certainly not stable, as specified for altitudes below 500 ft and should have been aborted for various reasons. The approach was not flown correctly and not corrected in time by the captain..

4.3. Approach speed

4.3.1. The selected flap position and related approach and threshold speeds were discussed in § 3.3.5 . The Landing Data Card filled in by the Flight Engineer and given to the pilots (Appendix 1) included a threshold speed of 139 kt. The pilots should add at least 5 kt to that and, in this case, set 144 kt on the autothrottle control panel. In the event of gusts or steady wind exceeding 20 kt the pilots have to calculate and apply the addition themselves. If there are gusts the autothrottle automatically adds 5 k as gust protection (§ 3.3.9). According to the FCOM these 5 kt may be deducted from the approach speed if the autothrottle is used, but as explained earlier, this cannot be correct (§ 3.3.9). The pilots stated (RvO § 1.17.4) that they had set 144 kt, but in the wreck the investigators found a setting of 139 kt, 5 kt too low. According to the NTSB's DFDR Factual Report (ref. 2, see Table 1 on page 7) the airspeed 90 seconds before touchdown was 140 kt, 1 kt above the 139 kt which was set, but in effect 4 kt too low. According to the speed graph in the RvO the speed at that time was 143 kt; the difference with the speed stated in the NTSB's DFDR Factual Report is too large. It is unclear what the origin of this difference is. Based on the DFDR speed it may be stated that apparently there were no gusts, as a result of which the autothrottle system did not increase the approach speed with the gust protection, as a result of which the speed was too low. It is unclear why the addition was not checked and corrected and why the approach speed was not monitored.

4.3.2. The data in graph 18 in Annex 9 of RvO (see also Appendix 9) indicates that from 54 seconds before touchdown the airspeed varied between 138 and 150 kt, probably due to the light turbulence (yaw damper and gust additive in ATS) and later also due to the unnecessary rudder inputs mentioned in § 3.2.3 and the drag variation these caused.
According to the RvO, until the autopilot was changed over to the CWS mode, the speed remained above 144 kt, the set 139 kt plus - probably - the automatic gust addition of the autothrottle system of 5 kt. After changing over to CWS there were three speed dips, down to approximately 140, 138 and 139 kt (Appendix 9) while there was also light turbulence, but probably no gusts; it is not known how the autothrottle system determines this. An approach speed amounting to the threshold speed is too low; the approach speed should always be at least 5 kt higher than the threshold speed. If the wind is above 20 kt, or if there are gusts, then the approach speed may even be up to 20 kt higher than the threshold speed. However, during the approach the speed was too low on several occasions which could mean that either the automatic gust addition of the autothrottle did not operate correctly, or that the pilot flying was also operating the throttles himself, or even that the observed error [difference] between the speeds in the DFDR and the RvO graphs continued.
Another possibility is that the FCOM procedure concerning the 5 kt reduction with the autothrottle engaged is incorrect (§ 4.3.1). If it is assumed that the pilot flying did not operate the throttles (until the last 15 seconds of the flight) and that the autothrottle system controlled the engine power then it has to be concluded that something was wrong. The approach speed, which is constantly shown on the speed indicator for the two pilots, was too low. The Martinair Landing Data Card included a space for the required threshold speed, but not for the approach speed, which may be up to 20 kt higher than the threshold speed. This must be considered as a shortcoming (§ 3.3.8) as the calculated approach speed, essential to safety, cannot be monitored effectively, with the autothrot-

tle engaged or not, which is actually the purpose of the Landing Data Card which is placed in a position visible to both pilots. Partly given the light turbulence, which should have led to greater alertness, the captain did not monitor the approach speed enough during the entire approach and he did not take corrective action.

4.3.3. From 15 seconds before touchdown, at a radio altitude of 150 ft, the throttles were closed to 40% N1 (Appendix 9). Normally, the autothrottle system, which according to the NTSB (ref. 2) was still engaged at that time, only changes over to a "programmed rate to bleed off speed for flare and landing" (a preprogrammed engine power reduction scheme) when the radio altitude is less than 50 ft (ref. 3). As soon as the wheels of the main landing gear touch the runway and start rotating the throttles are quickly closed fully. It therefore appears that the throttles were closed or held closed too early by the pilot flying. This is against the instructions for flying in windshear and turbulence (FCOM, ref. 3). In those circumstances the pilot flying actually has to prevent the engaged autothrottle system reducing the engine speed too much by placing a hand on the throttles to feel the throttle operation by the autothrottle and to intervene when the autothrottle closes the throttles too far at the wrong time, e.g. during a short increase in speed or altitude, because increasing the thrust of a turbofan engine from a low rpm takes so long (6 - 8 seconds) that the increase might not happen quickly enough to maintain the required angle of descent (flight path) or to initiate a go-around. Hence the rpm required for the desired angle of descent should be maintained to an altitude of 50 ft above the runway. Maintaining the rpm is also one of the conditions for a stable approach, as explained in § 4.2.3. The pilot flying did not prevent major throttle variations by the autothrottle and therefore did not operate the throttles in accordance with the instructions; the captain monitored and corrected this too late. At 50 ft altitude the rpm had dropped so much that the engines could not develop enough power quickly for the go-around which was initiated.

4.3.4. In serious turbulence or heavy rain the autothrottle system should be switched off (FCOM 04.85.07). Obviously the pilots were aware of this, but it was not done, hence it may be assumed that they did not consider the turbulence to be serious and that there was no heavy rain.

4.3.5. From 10 seconds before touchdown the airspeed reduced to 141 kt and, after the CWS was off, linearly to 134 kt, which was too low, after which the presentation of this speed in this Annex ended for unknown reasons 3 seconds before touchdown and from an altitude of 50 ft. It appears that this altitude data was deliberately left out of the RvO, as the NTSB writes about it in the DFDR Factual Report (ref. 2). According to this report, the threshold speed was approximately 134 kt, 5 kt below the specified threshold speed of 139 kt; this is also indicated in Appendix 3. Due to this lower speed, the lift generated by the wings, which is proportional to the square of the speed, reduced, which during flight stages other than the landing would be compensated by increasing the angle of attack (nose up) and with engine power, but the latter was not possible, or not possible quickly enough, in this case as the throttles had already been closed.

4.3.6. Approximately three seconds before touchdown the throttles were pushed forward. The engine rpm did increase, but too late to build up enough power in time for a go-around. The increase in the N1 rpm (the fans which provide 75% of power) is illustrated in the NTSB graphs till after touchdown (Appendix 3); the graphs of the fuel flow, exhaust gas temperature (EGT) and N2 (turbine rpm) in the RvO also stopped at a radio altitude of 50 ft, three seconds before touchdown, or were deleted.

4.3.7. ***Sub-conclusions - approach speed.*** Differences were observed between the speed data provided by the NTSB and the speed data in the RvO graphs. During the first part of the approach the speed was already too low according to the NTSB. The approach speed set on the autothrottle was 139 kt, 5 kt too low, see also Appendix 5. Later the approach speed fluctuated, probably due to the automatic gust correction by the autothrottle system or due to the light turbulence, but also due to unnecessary rudder inputs by the pilot flying, and even fell to close to and below the threshold speed. The FCOM procedure is unclear with regard to the calculation of the approach speed with the autothrottle engaged. The captain did not intervene.

4.3.8. At 50 ft radio altitude (at Faro still before the runway threshold) the speed had fallen to 134 kt. Hence the speed was 10 kt below the specified approach speed and 5 kt below the specified threshold speed, too low for a safe approach under the conditions at the time. The Martinair Landing Data Card did not include a space for the approach speed, only for the threshold speed. This made it more difficult to monitor the correct operation of the autothrottle and maintaining the correct, safe approach speed.

4.3.9. During the last part of the approach the engine throttles were already closed by the pilot flying at an altitude of 150 ft, against the instructions. The attempted go-around initiated by the captain 2.5 seconds before the landing was too late.

4.4. Glidepath

4.4.1. According to the radar plot in the bottom part of Appendix 2, the approach in the vertical plane, the glide path, was not flown accurately. The path drawn in shows that the aircraft was always flying above the glide path. However, that does correspond with the altitude readings by the captain during the approach, at 6, 5, 4 and 3 nm from the VOR/DME navigation beacon at the airport which were recorded on the CVR. These altitudes are also included in the plot and table in Appendix 2; they were flying up to 110 ft below the specified glide path. At 3 nm distance the altitude was still 70 ft too low, lower than the glide path drawn in the CvO. It could be that the source of the altitude data used by the CvO (a radar at a long distance) was not that accurate, see also § 4.1.3. It is also possible that the differences between the clocks used affected this (§ 2.2.3). The glide path indicated by the PAPI next to the runway was 5.2% (see Appendix 2), corresponding with a descent angle of almost 3°. When the correct PAPI glide path is followed (see footnote on page 3) the pilots see an equal number of red and white lamps; if the altitude is too low they see more red than white lamps. In any case, a correction was applied (§ 3.1.10). Differences were observed between the altitude data in the RvO and that in the NTSB's DFDR Factual Report (ref. 2, see also Table 1 on page 7). A better analysis would require the original DFDR graphs provided by the NTSB.

4.4.2. ***Sub-conclusion - glide path***. With respect to the flown glide path altitude, there were differences between the DFDR data and the glide path drawn in the graphs in the RvO. According to the CVR transcript, the approach in the vertical plane was lower than that shown in the RvO and at 3 nm it was still 70 ft too low. The quality of the graphs and information about the source of the glide path altitude date in the RvO left something to be desired.

4.5. Wind at the time and condition of the runway

4.5.1. The meteo information known to the crew was discussed in § 2.3.8 . At approximately 13 minutes before the landing traffic control informed departing flight TP120 that the wind was 150°/ 24 kt. The crosswind component of this (16.7 kt) was higher than permitted for a DC-10 on a wet runway. At over 10 minutes before the landing, when the altitude was still 4000 ft, departing flight TP120 reported that they were "in the middle of a thunderstorm", at 8000 ft. The exact location of TP120 could not be determined, but a warned pilot ... [translator's note: this is a variation on the first half of the Dutch expression "een gewaarschuwd mens telt voor twee" which is equivalent to "forewarned is forearmed", i.e. if you are warned about something you are extra careful]. At 7 minutes before the landing traffic control informed Martinair flight MP461, which landed before flight MP495, of a wind of 150°/20 kt (crosswind component 13 kt), see also Figure 6 below, and also mentioned that the runway was flooded. The pilots were listening to the same frequency and must have heard all these messages; indeed they were recorded by the MP495's CVR
At 4.5 minutes before the landing, traffic control also informed MP495 that the runway was flooded. The captain told the Portuguese police: "If the runway is actually flooded, that means "standing water" to me. In that case, the breaking action is "poor" and the crosswind limit is reduced to 5 kt."

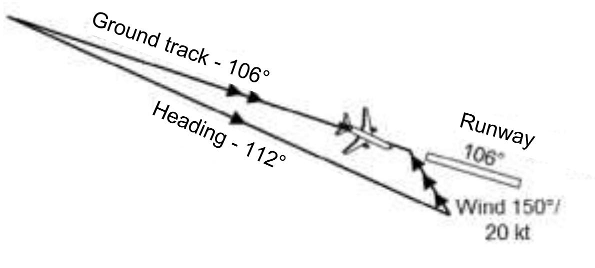


Fig. 6. The wind correction for wind from 150° at 20 kt, and at an airspeed of 139 kt is 8° to the right.

According to the Landing Data Card (Appendix 1) filled in by the Flight Engineer, the available landing distance on Faro's flooded runway (with "braking action poor") would have been far too short for the aircraft to come to a stop before reaching the end of the runway. Given the information provided, a go-around and waiting for better conditions or diverting to another airport should have been considered.

4.5.2. Together with the clearance to land, 64 seconds before touchdown, at a radio altitude of approximately 700 ft, the crew also received wind information from the traffic control tower: 150°/ 15, max. 20 kt. This is illustrated in the wind triangle in Figure 6 above.
Hence the maximum crosswind component was 20·sin (150° - 106°) = 13.9 kt, only 1.1 kt below the limit of 15 kt specified for the "braking action medium" associated with a wet runway. At 150 ft radio altitude, 10 seconds before touchdown, the captain read the actual wind conditions out from the display, as calculated by the inertial navigation system (AINS) of his aircraft: 190°/ 20 kt, see Figure 7 below. The crosswind component of this amounted to 20·sin (190° - 106°) = 19.9 kt, which is much higher than the specified limit (15 kt) for a wet runway, and very much higher than the 5 kt limit for a flooded runway. Their own observation of the wind conditions at the time and the light turbulence at the time did not ring any alarm bells in the heads of the pilots and to aborting the approach, which would still have been possible at that altitude and with the engine power selected at the time. Reading out the wind conditions from the AINS is a standard procedure in the Martinair Flight Ops Manual (BIM) § 3.1.7, which states, among other things, that "Inertial data should be monitored to recognize shear at an early stage"; this cannot refer to anything other than the wind calculated by the AINS. Hence the crew were aware that the current wind was always close to the crosswind limit of the aircraft for landing on a wet runway, and had in fact already exceeded it once. Furthermore, the wind they observed themselves on the AINS display was well above the limit. Something could and should have been done with the wind as read out, even if there was side slip due to rudder movement. A go-around should also have been initiated on the basis of the excessive wind read out.

4.5.3. *Effect of crosswind on the approach.* Data not included in the RvO but would be desirable

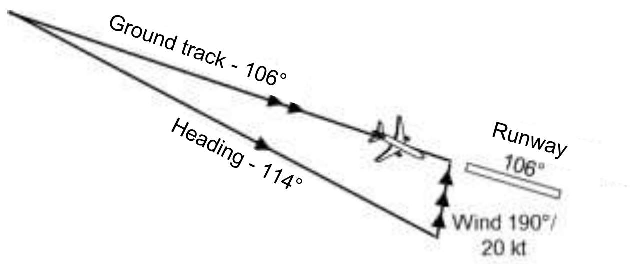


Fig. 7. The wind correction for wind from 190 at 20 kt, and at an airspeed of 139 kt is 8.5° to the right..

for an effective analysis also include the magnetic compass heading and pressure altitude. The NTSB's DFDR Factual Report (ref. 2) covered these items (see Appendix 3) but for unclear reasons this data is not included in the RvO. The magnetic heading could also be used to determine if the aircraft was affected by a sudden crosswind. This is because the lateral area behind the centre of gravity is larger than the area ahead of it, so that the weathervane effect (of the vertical tailplane) at the heading and suddenly increasing southerly wind could have resulted in a brief change [translator's note: "ruimen van de koers" unclear] in heading, obviously taking the inertia into consideration. The heading graph provided by the NTSB in Appendix 3 (or Appendix 5) shows that two seconds before touchdown the heading did indeed by almost 5° but this may also have resulted from the rudder position which at the same time changed from left to centre (§ 4.3.3) and due to the ailerons to the right (Appendix 4). The last part of the rudder graph was not included in the RvO graph (Appendix 6).

4.5.4. *Sub-conclusion - wind at the time.* The wind read out in the aircraft 10 seconds before the landing (190°/ 20 kt) was higher than the specified limit. Additionally, the flooded runway would have been far too short to come to a halt in time. For these reasons too, the landing should not have been undertaken. The data required for this part of the analysis had also been "left out" of the RvO.

4.6. Landing

4.6.1. Lining up. To avoid a traversing landing it was attempted, shortly before the landing, to line up the longitudinal axis of the aircraft with the direction of the runway (106°) using the rudder pedals. During this manoeuvre, the lining up, also known as decrabbing, for which the rudder of DC-10 was moved to the left using the rudder pedals (RvO, graph 6, see also Appendix 6), the aircraft not only yawed to the left around the centre of gravity, but the aircraft also rolled to the left because the yawing gave the right-hand wing a higher speed than the left-hand one - and it therefore generated more lift - which would have required an opposite steering action with the ailerons; the normal procedure. Then, given the crosswind at the time, to stay in-line with the runway centre the right-hand wing would have to be kept lower to generate a lateral force opposite in direction to the crosswind with a magnitude equal to the lateral force caused by the crosswind, but that did not happen. As a result of not banking, under the influence of the crosswind, an aircraft drifts (relative to the heading followed). Incidentally, the right-hand wing should not be too low, as otherwise either the right-hand landing flaps or the wing tip would hit the ground at touchdown, which is one of the reasons for having a crosswind limit (§ 4.6.4).
Lining up with the runway heading started at radio altitude 150 ft (RvO), according to the NTSB at 104.3 ft. Earlier, in § 4.2.5, it was noted that at 450 ft altitude and 40 seconds before the landing, major steering inputs were already being given; far too early.
By keeping the wing lower the drag and therefore the rate of descent increase slightly which can be offset by the increase in pitch and engine power. However, the pilot flying pulled the engine throttles to idle early, so that compensation by engine power was no longer possible and the descent rate could also increase. By pulling the nose up with the elevator in the last two seconds the wing lift increased and an excessive descent rate was avoided. However, this was at the cost of the speed. You are referred to the pitch graph in Appendix 3 or in Appendix 9 (where this graph does continue).

4.6.2. The aircraft landed on the left-hand side of the runway and half next to it (§ 3.1.15). In § 4.2.4 the possibility was discussed that the aircraft might have approached the runway crossways from the left and did not quite reach it. This can be concluded from the recorded steering inputs and aircraft movements.

4.6.3. However, the aileron input to compensate the crosswind at the time was not given practically simultaneously with the rudder movement, as would be expected, but only 3 seconds later. By that time the aircraft must already have drifted towards the left-hand side of the runway under the influence of the crosswind component, even if it had been flying on the extended centre line of the runway. According to the RvO, at the time of touchdown the longitudinal axis of the aircraft had not yet been lined up with the runway but was still 11° to the right. The graph with magnetic heading which could be used to verify this was not included in the RvO but was included in the DFDR graph (Appendix 3 and Appendix 5). That also shows that throughout the approach the aircraft was not on the runway heading (106°). So they did not line up correctly, probably because the aircraft was still flying to the left of the runway. The speed and altitude graphs in Annex 9 of the RvO (Appendix 9) also do not show the last part, from 50 ft altitude, approximately 3 seconds before touchdown. Apparently, the NTSB did have this data from the DFDR, given their comments about this in the DFDR Factual Report(ref. 2), see Table 1 on page 7 and Appendix 3. The graph with the sideways acceleration (g, Appendix 3) shows that there were accelerations to the left and right during the landing. This also indicates that the aircraft was traversing while landing, i.e. was not lined up. As stated earlier, a traversing landing is not approved for a DC-10 (see also § 4.6.9 below). It appears that the manoeuvre to align the longitudinal axis of the aircraft with the runway and to keep it here was not undertaken in full and not correctly. This may have been caused by not following the correct ground track during the approach (see § 4.2.3) as a result of which the runway was approached from the side (§ 4.2.4). This is also indicated by the roll angle which, 7 seconds before the landing, was still 16° to the left and then 0 (wings horizontal) at a heading of approximately 112°, until one second before touchdown, at the crosswind at the time. This roll angle would not have been necessary if they were flying straight at runway; then the roll angle would have been in the other direction, against the wind. The captain may have wanted the aircraft to fly slightly more to the south to reach the centre line of the runway. At the last moment the rudder went slightly to the left and the roll angle to the right. After the landing the rudder went all the way to the left to keep the aircraft in a straight line. The roll angle increased to 22° to the right and then briefly went to 0.

4.6.4. The FCOM, 07-50-01, shows that with a fully compressed landing gear shock absorber and a pitch of 8°, the wing flaps hit the ground at a roll angle of 11° and the wing tip at 15°. The DFDR data shows that the roll angle was 22° for one second so that the wing flaps, wing tip and probably also the engine pod of the right-hand engine hit the runway. This is because the police report made reference to a scratched groove of approximately 60 m length, caused by the engine pod. The wing did not break off at that time.

4.6.5. *Descent rate during landing*. The forward approach speed was discussed in § 4.3 . In § 3.1.5 above it is stated that according to the RvO the descent rate increased to no less than 1,300 ft/min. The altitude data in the DFDR Factual Report (ref. 2) does not actually indicate that the descent rate was this high during the last few seconds of the flight (see Appendix 3). The radio altitude graph goes downwards in a straight line, i.e. without vertical variations. However, the pressure altitude does show minor variations during the last stage of the flight. It is not clear from the RvO if this graph was corrected for measuring errors of the pitot static measuring system which occur when the aircraft is flying in the ground effect. A radar altimeter does not suffer from these errors.
In the last 12 seconds of the approach an altitude difference of 120 ft was crossed, resulting in an average descent rate of 600 ft/minute. The DC-10 limit of 600 ft/min given in the RvO should be accompanied by the relevant aircraft weight (which is normally the maximum landing weight). A lighter aircraft leads to a higher limit. The CvO did not calculate the maximum permissible descent rate at the actual landing weight of MP495, but it may be assumed that the descent rate in the last stage of the flight was not extremely high. See also § 4.6.15.

4.6.6. *Landing distance.* Based on its own calculations for the weather conditions at the time the CvO concluded that for both poor brake action (flooded runway) and for medium braking action (wet runway) the required landing distance exceeded the available landing distance (RvO § 1.17.4). These conclusions could not be verified due to the absence of the data which the CvO apparently had available. According to the CvO the aircraft should not even have landed on a wet runway. This may have been stated because of familiarity with the following.

4.6.7. *Touchdown zone.* According to the airport data in RvO § 1.10.2 the touchdown zone of runway 11 had a length of 268 m. According to the NLR report (ref. 6) the initial contact with the ground was only at 392 m from the runway threshold; 124 m too far and also halfway next to the runway (§ 3.1.15). Apparently the NLR had more information than that contained in the RvO. It is inexplicable why this touchdown location and the cause of this were not described in detail in the RvO. The far touchdown location also indicates that the descent rate was not high, otherwise the aircraft would have touched down closer to the start of the runway. See Figure 8 below.

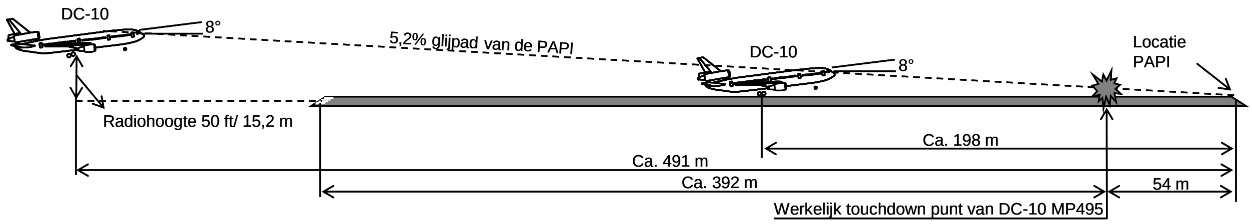


Fig. 8. Side view final approach and landing. Touchdown point from the NLR report.

4.6.8. If an approach is stable then during the approach it can usually be estimated quite accurately where the aircraft will touch down on the runway. It is quite possible that it was concluded that the touchdown location would have been beyond the touchdown zone which could have been the reason for pulling the throttles back early and reducing the speed as the pilots were aware that almost the whole available runway length would be needed to come to a stop.

4.6.9. *Traversing landing*. At the time of landing, the aircraft was not lined up with the runway direction; it was a traversing landing (10.7°), and as noted above in § 4.6.3, half next to the runway on the left side. A DC-10 is not approved for traversing landings. With many aircraft types (e.g. those by Boeing) landing on wet runways without lining up is actually recommended, to prevent drifting to the side of the runway or to limit this, and to ensure that the spoilers (on the wings) are deployed more quickly after touchdown so that the aircraft does not "bounce up" from the runway and that braking with all wheels can start more quickly.
It is clear that the crew of the MP495 did not want to make a traversing landing; however, the heading correction just before touchdown was not made correctly, so that they still made a travers-

ing landing. This is also shown by the graph for sideways acceleration in Appendix 3. At the time of touchdown the N1 rpm of the left-hand and right-hand engines had risen to 100%. Engine 2, the centre engine, accelerated less quickly (see Appendix 3). The crab angle limit of a DC-10 when landing on a wet runway is not known, only the crosswind limit. This would require further investigation.

4.6.10. *Locking wheel brakes* The rudder pedals are combined with the brake pedals, operated with the front parts of the feet, for the separate braking circuits of the left and right main landing gear, see Figure 9 below. To prevent the brake pedals being operated together with the rudder, the pilots have to keep the heels of their shoes on the cockpit floor before and during the landing. Then, after the landing with the nose gear firmly on the ground, to operate the wheel brakes, the feet have to be placed slightly higher up so that the front parts of the feet can be used to operate the brake pedals without operating the rudder, because that is needed to keep the aircraft on the runway while the rudder is still effective at the decreasing speed. Of course, a pilot with supple ankles (and shoes) can also operate the rudder with the heels.

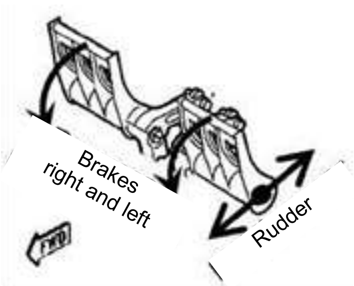


Fig. 9. DC-10 foot pedals

Graph 6 in the RvO (Appendix 9) shows that, certainly during the last minute and a half of the flight, the pilot flying regularly operated the right-hand brake pedal with up to 20% of the maximum travel. He continued doing that when CWS was selected; the movements even increased. This shows that a strenuous effort was made to line the aircraft up. The operation of the brakes during this stage of the flight certainly indicates that the pilot flying had not placed his right foot correctly on the pedals. The brake pedal graph stops 3 seconds before the landing, so that again the NTSB's DFDR Factual Report (ref. 2) will have to provide definite information, but it is almost certain that the landing was made with braked/locked wheels, which increased the forces on the landing gear even more than they already were due to the incomplete line-up. If the landing is not only traversing but also with locked and strongly actuated wheel brakes then the landing gear might not be strong enough and break off.

4.6.11. The left brake pedal was never touched, or the recording of its signals did not work. It should be noted that from approximately 40 seconds before the landing the operation of the right-hand brake pedal corresponds with the movement of the rudder to the left, which could also indicate incorrect connection or representation of the operation of the right-hand brake pedal. However, this is not mentioned in the translated part of the RvO (ref. 1).

4.6.12. *Anti-skid.* DC-10 landing gear has locked-wheel touchdown protection, rather like ABS, to prevent damage when landing with actuated brakes. According to the DC-10 FCOM page 14-10-04 from 1987 this system only operates on the rear bogie wheels which are normally the first to touch the runway. It has to be investigated if this was also the case with MP495.

4.6.13. *Landing gear.* The statement on the investigation of the runway by the police indicates that the following marks were found:

- "At approximately 20 m before the PAPI (i.e. 280 m beyond the runway threshold) marks by the right-hand main landing gear were visible on the runway. This mark was approximately 10 m beside the left side marking line and had a length of approximately 30 m;
- Approximately 60 m beyond the PAPI a scratched mark by engine no. three was visible on the runway. This mark was approximately 15 m beside the left-hand edge marking and had a length of approximately 60 m;
- Approximately 330 m beyond the PAPI there was a scratched mark visible caused by a rim of the center main landing gear. This mark had a length of 340 m. At the start this mark was 5 m inside of the left-hand runway edge marking and at the end approximately 30 m inside of the left-hand runway edge marking.
- After that, sliding marks were visible across the full width of the runway."

4.6.14. The distances mentioned differ from the distances published by the NLR. The above marks show that the right-hand landing gear did not break off immediately at touchdown; the mark with a length of 30 m could have been caused by the actuated brakes (§ 4.6.10). After that a mark scratched by engine no. 3 was visible, as mentioned earlier due to the roll angle which had in-

creased to 22° (§ 4.6.4), because the right-hand landing gear failed or because the breaking pin in the landing gear broke due to rearwards forces (see next paragraph). However, the broken off landing gear strut only scratched a mark in the runway tarmac 330 m beyond the PAPI, initially straight, then with a slight curve to the right.
The straight marks, initially in the same direction as the runway, show that the aircraft did not experience extreme lateral displacement at the time of the touchdown.
In message received from an employee working in maintenance planning it was stated that the scheduled replacement of the landing gear had been deferred twice at the request of Martinair and with permission of the Aviation Inspectorate (to save maintenance costs); this was because the aircraft had already been sold to the State. The RvO did not describe this, hence further investigation of the maintenance logs will be required.

4.6.15. The NTSB accident report (ref. 9) shows that the DC-10 landing gear is of a highly robust design, i.e. that it was developed to withstand a higher descent rate than the 12 feet/second (720 fpm) required by the regulations. Furthermore, the landing gear has breaking pins to sacrifice the landing gear to prevent forces in the rearwards direction being conducted to the wings (with fuel tanks). The RvO does not mention these pins, and neither does it mention possibly increased breaking limits due to the traversing landing. According to the report, Boeing is evaluating the options for fitting breaking pins against vertical overloads exceeding 2 g. Apparently, the landing gear could withstand loads up to 2 g without problems. A report on this investigation of the collapse of the landing gear and the effects of the deferred replacement (§ 4.6.14) was not available. Further investigation would be desirable.

4.6.16. *Touchdown and go-around*. Two seconds before touchdown the captain gave full throttle to initiate a go-around; there must have been a reason for that. But it took too long before the engines running at idle again developed enough thrust. The aircraft rolled approximately 5 degrees to the right which was corrected with the ailerons and rudder. Apparently, the aircraft had not reached the centre line of runway and made a traversing landing with a nose heading of 117 degrees, on the left and half next to the runway. The aircraft landed on the right-hand landing gear with a slight roll angle to the right and at a heading of 117°, as also concluded by the NTSB in ref. 2. The DFDR recorded throttle increase at 50 ft altitude; the vertical g changed from 0.75 to 1.1 g; an interrupted descent. One second later there was a g-peak as the aircraft touched the ground. What can be concluded from the DFDR data and the report (§4.6.13), is that the aircraft landed on the runway with a crab angle 11° to the right and while moving almost parallel with the runway. The wind at that time can be determined from the crab angle, direction of movement of the aircraft and the airspeed at touchdown. The aircraft had an airspeed of 126 kt and moved at a heading of 106° with a wind correction angle of 11 degrees. This indicates wind of 174° and 25 kt. The crosswind component was 23.1 knots, 8.1 kt above the maximum crosswind component for a wet runway and 18.1 kt above the maximum crosswind component for a flooded runway. The descent in the direction of the runway is indicated by the photographs of the deep, 340 meter long scratch which the rim of the center gear gouged in the tarmac, 5 m to the right of the left-hand edge marking and initially almost parallel to the runway centerline, later curving to the right (§ 4.6.13). The aircraft was not moving to the left when it touched down on the runway. This is consistent with the fact that no lateral acceleration due to sudden or constant to the left was measured (Appendix 3). This shows that at the time of landing the aircraft was not above, but half next to the runway.

4.6.17. *Spoilers*. Ground spoilers are intended to reduce the lift of the wings as soon as possible after landing to prevent the aircraft bouncing up again from the runway. If the spoiler system is armed by the pilots during the approach, which is the normal procedure, then the spoilers will deploy as soon as the wheels of the main landing gear start rotating. Another requirement is that the throttles are lower than a Throttle Resolver Angle (TRA) of 49°. However, that was not the case here. The captain had selected full throttle for a go-around; the spoilers should not have deployed. This may be due to a fault affecting the spoiler knockdown system of the DC-10 which occurs more often. This was not indicated in the RvO. It is impossible to say if the go-around would have been successful had the spoilers been retracted.

4.6.18. *Aileron steering error*. RvO graph 14 (Appendix 8) includes, among other things, the position of the ailerons. During a long part of the shown stage of the flight this was 5% to the right, while the ailerons should be in the centre during flight in a straight line, to prevent the activation of the spoilers which support the ailerons (at a position exceeding 7°). This could be an adjustment problem of the aileron controls and ailerons or a calibration error of the measuring system. It could also indicate that it was not possible to move the aileron controls fully to the right but only 5% less than that. The reason for this was not stated in the RvO. This graph too "stops" three seconds before touchdown.

4.6.19. ***Sub-conclusions - landing***. According to the NTSB (ref. 2) the lining up, the aligning of the longitudinal axis of the aircraft with the runway heading, using the rudder pedals (rudder) to prevent a traversing landing, already started at a radio altitude of 104.3 ft (ref. 2), according to the RvO (ref. 1) at 150 ft, 10 seconds before touchdown, but the graphs show that this already started at 450 ft altitude, 40 seconds before touchdown. That was too early. Both because of this and because of the insufficient opposite aileron input the aircraft was not aligned with the runway heading. It is also possible that the aircraft, because of the angled approach path, never reached the centre of the runway or even not quite reached the runway fully. According to the NLR the place where the aircraft first touched the ground was 124 m beyond the touchdown zone and half next to the runway; the RvO did not mention this. The overshot landing also indicates that the aircraft was not pushed into the ground by a downdraft. It is possible that the pilot flying realised they would land too far and therefore pulled the throttles back in time. The aircraft made a traversing landing with a crab angle of approximately 11°. Landing gear is normally strong enough for that and will therefore not be damaged on a wet runway; the maximum permitted crab angle is not known. During the last two seconds the nose was pulled up slightly which prevented a hard landing. The average descent rate during the final stage of the flight was not abnormal and was within the limits.

4.6.20. It appears that during the last minute and a half the pilot flying did not have his right foot in the correct position on the rudder pedals. Although again the last part of the relevant graph is missing, it can be stated with almost complete certainty that the right-hand brake pedal was pushed down and that some wheels of the right-hand main landing gear braked forcefully when the aircraft touched down which could have increased the forces on the landing gear during the landing so much that this may have led to the fatal collapse of the landing gear. The straight marks, initially in the same direction as the runway, show that the aircraft did not experience extreme lateral displacement at the time of the touchdown. The incorrect placement of the feet on rudder controls, and not just the traversing landing, may have resulted in the collapse of the right landing gear. These are results of incorrect action by the pilot, with serious consequences.

4.6.21. The aileron position graph was found to show a deviation of 5% to the right.

4.7. Windshear or turbulence

4.7.1. Windshear was said to have occurred during the approach. However, this cannot be confirmed based on the data in the RvO. However, it can be stated that there must have been light turbulence, given the variation in the normal vertical acceleration of the aircraft (±0.22 g, see Appendix 3) and speed variations, which were less than 15 kt (Appendix 9). This turbulence may have been caused by atmospheric movements but also because the wind was blowing across the dunes, and even by the pilot as mentioned earlier and discussed in § 4.7.5 . At a certain wind speed, mountain waves [lee waves] may develop above and on the downwind side of hills/rows of dunes. The height of the dunes and their effect at the wind direction and speed at the time were not mentioned in the RvO.

4.7.2. Weather data may have been measured at a distance of hundreds of metres from the aircraft. The black box data is much more objective; it is of much greater use in determining if there was any windshear. The movements the aircraft made, due in part to external influences, are recorded by the DFDR, the black box, which was read out by the American NTSB (ref. 2).

4.7.3. The vertical/normal acceleration (g, Appendix 3) indicates that there was some turbulence, but it was only light given the ICAO definitions (§ 3.1.11). In the seconds before the landing, which is indicated by a positive peak of 1.95 g in this graph, there is no downwards acceleration evident, other than that caused by light turbulence. Two seconds before the landing the vertical acceleration changed from +0.5 to +1.1 because the pitch increased and power was applied for a go-around. Incidentally, the FDR measured four vertical g's, apart from the 1.9533 g mentioned also 1.0923, 1.1083 and 1.2343 g. It is not clear where the four g's were measured. Clarification is required.
So, there was no external adverse influence on the vertical acceleration, on the vertical movement of the aircraft due to windshear or microburst, other than light to moderate turbulence. This is confirmed by the finding that the aircraft landed much too far down the runway. If the aircraft had

been hit by a windshear downdraft then it would not have landed so far down.
The graph of the sideways g (acceleration) shows that the landing was not tidy and straight, there were sideways accelerations, but only after the landing, not just before it. Hence, the recording system was working.

4.7.4. Given this objectively obtained data it may be concluded, even without weather messages and data, that there was no windshear which "threw" the aircraft against the ground or suddenly moved it sideways. The NTSB, given the data from the black box also did not conclude that there was windshear, as indicated in their letter (ref. 3).

4.7.5. The variations in the movement of the aircraft may also have been caused by the pilot. This is indicated in Appendix 5 using text boxes. As noted in § 3.2.3 unnecessary rudder inputs (30% - 90%) were given by the pilot flying, the side-effects included induced roll angle changes, which could partly be offset with the ailerons. It appears that the rudder movements were used to incorrectly adjust the heading to the runway heading, whereby an unwanted, varying slip angle was created as a result of which the drag varied and speed variations occurred. Partly due to this, the approach was far from stable and should have been aborted.

4.7.6. During the final stage of the approach, a strong crosswind with a tail wind component is said to have driven the aircraft to the left side of the runway (RvO § 2.2.3). This cannot be confirmed based on the DFDR graphs provided by the NTSB, there was hardly any sideways acceleration (Appendix 3). Similarly, this cannot be indicated using the other graphs in the RvO, because all the graphs which could show the horizontal and vertical movement of the aircraft during the last three seconds of the flight were left out or deleted. For inexplicable reasons the NTSB graphs were not used to complete the RvO graphs.

4.7.7. A radio altimeter measures the altitude from an antenna installed below the fuselage of the aircraft to the ground below the aircraft. The radio altitude of the aircraft, as displayed in the aircraft therefore also depends on the ground profile. When flying across dunes this shows on the radio altimeter. The ground elevation along the approach route was not given in the RvO and it is also not indicated if it was incorporated in the graphs.
The radio altitude graphs in RvO do not indicate that there were major variations because the aircraft was exposed to strong updrafts or downdrafts. Apparently, the autothrottle and autopilot systems were perfectly capable of maintaining both the glide path and the speed of the aircraft. However, a change in radio altitude at 500 ft altitude is used in the RvO to refer to the windshear effect, but this change occurred exactly when the aircraft, coming from the sea (across the dunes) crossed onto land, as stated above here, or was briefly below the specified glide path (§ 3.1.10).
The radio altitude graph in the RvO is missing for the last three seconds of the flight, from a radio altitude of 50 ft. The last three seconds were deliberately deleted or not presented, because in the NTSB's DFDR Factual Report (ref. 2) the radio altitude graph does continue after touchdown, actually for more than 5 seconds after the wheels touched the ground, see Appendix 3. The graph does not indicate any increase in the descent rate due to windshear.

4.7.8. The NTSB altitude graphs in Appendix 3 show another unusual thing. Although the RvO refers to radio altitude in all graphs, the NTSB report includes two graphs with altitude data; one with the barometric or pressure altitude (from 995 ft) and one with the radio altitude from 245 ft to the ground. Apparently these were combined in the RvO and, incorrectly, all referred to as radio altitude. It is also unclear if the required air pressure and ground elevation corrections were applied to these.

4.7.9. One of the items included in graph 18 of the RvO (see also Appendix 9) is the vertical speed. From approximately 6 seconds before touchdown there was an upwards peak of approximately 620 ft/min (fpm), i.e. 3.5 m/s, followed within two seconds by a downwards peak to -2,600 ft/min (-15 m/s). In two seconds the vertical speed changed from +620 to -2600 ft/min, a difference of 3200 ft/min over 2 seconds, which corresponds with 18.5 m/s. A vertical speed of 18.5 m/s for two seconds means a vertical distance travelled of 37 m (= 121 ft) and an acceleration of 9.3 m/s2, almost as large as the acceleration due to gravity (9.8 m/s2). This is practically impossible, furthermore, this change does not correspond with the vertical g and changes in the radio altitude presented in the same graph. See also § 3.1.5.
This vertical speed also stops, or was deleted, from three seconds before touchdown. The source of the vertical speed data is unclear, unrealistic and unreliable. Again, the full NTSB DFDR Factual Report could provide definite information. Hence RvO graph 18 should not be used to demonstrate

the occurrence of windshear. In § 3.1.5 it is stated that the descent rate was 1,300 ft/min and at the time of touchdown greater than 900 ft/min, a major difference with this graph.

4.7.10. Although shortly before the landing of the MP495 a departing flight reported "thunderstorm" the graphs which also include the radio or other altitude show that the radio or other altitude decreases almost continuously and that there are no major variations. It does not suggest that the aircraft was exposed to extreme influences of the weather resulting in uncontrollably large vertical movements. What movements that occurred were induced by the pilot flying; he was steering against the autopilot and CWS, instead of leaving those systems to do their job. See also § 3.2.3.
Furthermore, if windshear is expected, then according to the procedures in the FCOM (05.60.04) the pilot needs to take various measures, including already having a stable approach at an altitude of 1000 ft (§ 4.2.3), preventing major changes in power (hand on the throttles), increasing the approach speed, keeping an eye on the instruments indicating the vertical movements and being ready to initiate a go-around at any moment. If there is windshear and the flight path becomes marginal (± 15 kt, ± 500 ft/min, ± 5° pitch, ± 1 dot deviation from the glide path, or an unusual throttle position for a longer time), then according to the FCOM (05-60-11) the windshear recovery procedure should be initiated with involves immediately disengaging the autothrottle system and very rapidly providing the required power and raising the nose to 15° up (i.e. a go-around). None of these actions was taken by pilots, and the CVR did not include any comments about windshear or even turbulence; furthermore the precautions in case of serious turbulence or heavy rain were not taken (see also § 4.3.4). Other information relevant to demonstrating windshear is also missing from the graphs and was probably left out deliberately.
For now it should therefore be assumed that no windshear was expected, and that there was no windshear, at most some turbulence, which according to the pilots' statement was "mild to moderate" and which according to the g graphs of the FDR and ICAO standards (§ 3.1.11) was "light". The occurrence of windshear cannot be proven with the information provided in the RvO. It appears that the RvO was deliberately written to suggest windshear.

4.7.11. A letter included in the file, from the NTSB to the chairman of the CvO (ref. 3) concludes with the comment that, if the CvO was of the opinion that there was windshear during the approach, then it should be considered recommending that the training of pilots in windshear recovery should be implemented or reviewed. Apparently, the NTSB did not share the CvO's view of the occurrence of windshear. The NTSB analysed the flight data on the DFDR and therefore did have the DFDR data to be able to conclude that. With the diplomatically expressed comment the NTSB did not have to disagree with the CvO.

4.7.12. ***Sub-conclusions - windshear or turbulence***. The DFDR data provided so far does not indicate that there was windshear; there were no movements which could not be compensated by the aircraft systems (autopilot and autothrottle) and normal flying skills. The graphs needed to determine the occurrence and influence of windshear were left out of the RvO or partly deleted while they were available to the CvO (DFDR Factual Report by the NTSB, ref. 2). During the final approach there may have been light turbulence, furthermore, the pilot flying induced movements himself by unnecessary repetitive rudder inputs. The DFDR data also shows that there was no large lateral acceleration, but that the lateral movement to the left of the runway was due to an incorrect approach heading and incorrect lining up with the extension of the centre of the runway by the pilot.

4.7.13. There is no data to confirm the occurrence of windshear. The data which could be used to demonstrate that there was no windshear was left out of the RvO. If there had been windshear then the aircraft would not have landed beyond the touchdown zone. There is no explanation how they arrived at the conclusion that there was windshear. Analysis of the data rather indicates the opposite; there was no windshear at all during the approach of MP495.

4.8. Procedures

4.8.1. The letter from the NTSB (ref. 3) also lists procedures not followed by the crew which are prescribed in the FCOM on page 05-60-09. Some of these were mentioned above. If there is a risk of windshear, precautions have to be taken, including having a stable approach at an altitude of 1000 ft, avoiding major power reductions and changes in the speed trim, and considering an approach speed up to 20 kt higher. None of these procedural steps was taken and, as far as could be ascertained, neither did the RvO mention them, which could indicate that windshear was not considered and that in fact it was not there.

4.8.2. Although according to the DC-10 Airplane Operating Manual (source: RvO) the aircraft should not have departed from Schiphol with a faulty thrust reverser, this did not affect the flight and landing. According to the airworthiness directives a DC-10 may depart with one faulty thrust reverser, as long as the faulty thrust reverser is locked about before the flight, which was done.

4.8.3. In § 4.3.2 it was already concluded that there was an error in the FCOM with respect to the calculation of the approach speed and that the Martinair Landing Data Card did not have a space for specifying the approach speed.

4.8.4. The specified Landing Call was not given by the copilot.

4.8.5. ***Sub-conclusion - procedures***. During the approach, the experienced and trained crew did not undertake any of the windshear procedures defined in the FCOM which may indicate that no windshear was experienced during the approach. The landing call was also missing..

5. Notes on the comments by the Netherlands Aviation Safety Board

5.1. Introduction

5.1.1. The Raad voor de Luchtvaart [Netherlands Aviation Safety Board] (RVDL) was given the opportunity by the Portuguese CvO to assess the draft RvO. The comments of the RVDL on the draft (ref. 5) were also submitted for analysis. These comments (version RVDL3, also known as the "Blauwe rapportje" [Blue report] include both deletions of the original text of the Portuguese investigators and additions proposed by the RVDL. Not all the deletions and additions in version RVDL3 were accepted by the CvO, as shown by Chapter 3 of the final RvO. An appendix of the final RvO includes version RVDL4 of the comments by the RVDL, which again includes some changes relative to version RVDL3.
Notes on some of these general findings are given in § 5.2 below. The RVDL's deletions and additions to the established facts are presented and discussed in § 5.3, the causes and factors contributing to the accident in § 5.4 and § 5.5.
Appendix 10, Appendix 11 and Appendix 12 include tables with the established facts, the causes and factors contributing to the accident in the two versions by the RVDL mentioned and the final RvO.

5.2. RVDL – General

5.2.1. In the comments by the Netherlands Aviation Safety Board (RVDL3, ref. 5) it is stated on page 2 that there was thunderstorm activity at a distance of 8 nm west of the airport which was supposed to be indicated by the increased turbulence recorded by the DFDR. In that case, this thunderstorm would have been at the last turn before the landing (map in Appendix 2) and the aircraft would have flown through or underneath it, as the forecast was 1/8 - 2/8 Cb at 1,800 - 2,500 ft, depending on which page of the RvO one looks at ... The speed of the aircraft during the final approach was approximately 140 kt and the wind 150°/ 20 kt which resulted in a groundspeed of approximately 126 kt. The thunderstorm activity at a distance of 8 nm from the airport would have been at 3.8 minutes flight time from the airport. The touchdown was at 07:32:50 (radar time); in that case the increased turbulence would have shown on the DFDR at 07:29:02. However, the DFDR data presented in the RvO only starts at 07:31:00. Similarly, the data in the NTSB's DFDR Factual Report (Appendix 5) does not start that early either. The question arises which DFDR data the RVDL used, and is there relevant DFDR data which was not included in the RvO, or was the time difference between the various clocks used (§ 2.2) relevant here?

5.2.2. The RVDL stated that the crew were aware that there were isolated thunderstorms and that they checked the location of these with the on-board weather radar. According to the statement by the crew the closest thunderstorm was between 7 and 12 nm west of the airport. If that is correct, then they must have flown through or below it during the last turn, as discussed in the preceding paragraph. These statements are doubtful. The crew stated before the Committee that from the communications with departing flight TP120 they realised that TP120 flew through a thundercloud 1.5 minutes after their take-off. This time is not included in the English translation of the RvO. The CVR transcript of the last flight minutes does not include any comment about thunderstorm activity or verification.

5.2.3. On page 4 the RVDL referred to calculations by the NLR (ref. 6) demonstrating three areas with downburst/microburst activities around 700 ft altitude, between 600 and 300 ft and between 200 and 110 ft altitude. However, the altitude data in the NTSB's DFDR Factual Report (ref. 2, see Appendix 3 and Appendix 4) hardly showed any abnormal changes at these times. Similarly, the vertical acceleration did not vary more than between 0.8 g and 1.22 g (two peaks), a difference of at most 0.42 g, see also Appendix 3 and § 3.1.5 above. Even the lateral acceleration was almost zero (Appendix 3). The aircraft did move slightly, there was light turbulence (§ 3.1.11), but these movements could not be called downburst/microburst, that is going much too far. Between 600 and 300 ft altitude the pilot flying gave a number of unnecessary rudder inputs and thereby introduced variations in the movement of the aircraft (see § 4.2.5); unfortunately the RVDL did not write anything about those. At 150 ft altitude the rudder input started, to line up with the runway heading. Such a large, almost maximum, rudder movement obviously affected the movement along the longitudinal and lateral axes. However, the radio altitude graph (Appendix 3) only shows a small change upwards. The RvO graph of the elevator movement (Appendix 7) shows that the elevator was moved between +15° and -15° without the increase or decrease in airspeed being a reason for this, furthermore CWS was engaged and the pilot flying need only have made general corrections by applying slight pressure to the control organs, see the explanation of CWS in § 4.1.2. The graphs indicate nervous and incorrect steering action and also insufficient awareness of the CWS operation (also included by the NTSB in ref. 3).
According to the RVDL the NLR report indicated that the experienced windshear exceeded the aircraft performance limits, but nothing like that is evident in the graphs in the NTSB Factual Report (ref. 2, Appendix 3 and Appendix 4). Not a single control surface limit was reached; the lateral, longitudinal and vertical accelerations were always well within the limits and the decrease in radio altitude was almost linear. The autothrottle system did not reach its limits either. Hence the performance limits were not even approached, let alone exceeded.
Hence there was no windshear, but light turbulence and additionally movements induced by the unnecessary rudder inputs by the pilot flying.

5.2.4. During the approach there were supposedly increasing oscillations of the pitch, speed and engine power (ref. 5, page 5). These oscillations were supposed to have increased under the influence of the second and third microburst along the approach path, and due to the interaction of the autothrottle and pilot inputs. The oscillations were fairly large, but the FCOM parameters were not exceeded. A VOR approach was flown using PAPI, hence there is no objectively recorded data about this. There were indeed variations, but certainly not increasing ones, as shown by Appendix 3 and Appendix 4. At the "location of the microburst" the pilot gave unnecessary control inputs which, obviously, led to variations. This was incorrectly explained as the occurrence of microbursts.

5.2.5. The RvO includes a graph (Appendix 9) of the "rate of descent" which shows very large peaks. This data was supposed to be from the DFDR, but this data was not found in the DFDR Factual Report by the NTSB included in the RvO. As stated in § 4.7.9 the source of this data is unclear; this data should not be used to demonstrate the occurrence of windshear.
According to the RVDL this graph was calculated (without indicating on the basis of what) and "the data was not damped" which should be considered during analysis. The RVDL should have noted that this data is unrealistic. The aircraft simply cannot have made the suggested movements, as explained in § 4.7.9. The graph of the normal vertical acceleration in the NTSB's DFDR Factual Report (Appendix 3) shows that there were no major vertical accelerations.

5.2.6. Allegedly, the crew stated that the approach was flown correctly ("in the slot for landing") to an altitude of 200 ft and that the PAPI indicated that the aircraft was on the correct glide path (ref. 5, page 6). However, the ground radar records show that the approach was not flown correctly at all in terms of the heading, see § 4.2.3 and Appendix 2. The RVDL should have commented on this. The corrections needed twice to stay on the glide path were nothing unusual as such (see 3.1.10).

5.2.7. The problems started at approximately 150 ft, so states the RVDL on page 6 of ref. 5. The engine power went to 102%, the aircraft no longer descended and the speed increased. Allegedly the aircraft flew into the third microburst which was present at that location as calculated by the NLR. Although it is not known how the NLR calculated that, it will not have been on the basis of meteorological data but the aircraft data (AIDS?). In that case it is difficult to distinguish between microbursts and ordinary turbulence. What did happen according to the DFDR graphs (Appendix 6) was that the pilot flying moved the rudder almost fully to the left to line up the longitudinal axis of the aircraft with the runway heading. The engines had gone to 102% 15 seconds before that (due to the speed decrease and pitch increase to get back to the glide path (see § 3.1.3, § 3.1.10 and Appendix 7) and due in part to this the descent briefly reduced, but the speed did not increase. The accelerations in the three axes did not show anything unusual. There were absolutely no insurmountable external problems, other than the crosswind.

5.2.8. From 150 ft altitude (ref. 5, page 6) a left roll angle developed according to the RVDL after the pilot flying moved the rudder to the left to line up with the runway.
However, the roll angle was due to late and insufficient aileron counter-steering. Both pilots moved the ailerons to the right, but shortly after that the pilot flying steered to the left and the captain briefly and correctly kept steering to the right after which and because of which the CWS disengaged (Appendix 8). Both kept giving opposite inputs until the time the graph stopped/was deleted. The roll angle did change from 15° to the left to a few degrees to the right; the captain won. At the same time the speed reduced, according to the RVDL not only due to the reduction in engine power but also due to a developing tailwind. The wind turned to 150° (or to 190°? - table in RvO page 46), but that is not yet a tailwind if the heading is 111° + 11° wind correction angle. Later in the RvO (not in the meteo tables) reference is made to a sudden wind of 220°/35 kt. The tailwind component of this was less than 5 kt, the crosswind component 14 kt. However, the graphs (Appendix 3) do not show any lateral or longitudinal accelerations caused by external forces. The marks made by the tyres, engine scratch mark and the scratch mark of the collapsed right-hand landing gear strut were in the direction of the runway, not to the left. The 220/35 kt measurement was not recorded; in the RvO Annex 5, page 117 (CVR transcript) it is stated that these are "valores calculados"! The wind can also be calculated using the actual wind correction angle (11°), airspeed (126 kt) and ground track (106°): 174°/ 25 kt, the crosswind component of which is 23.1 kt, see also § 4.6.16.

5.2.9. According to the RVDL (ref. 5, page 7) a "high rate of descent" started from 80 ft altitude. The radio altitude graph in the NTSB report (Appendix 3) does not show at all that the rate of descent became high. The radio altitude graph in the RvO (e.g. Appendix 6) was deleted from 50 ft so that the high rate of descent is not evident in it at all. The DFDR was altitude available (for 7 seconds after the landing) but was not used. See also § 4.6.5.

5.2.10. Next the RVDL claim that the aircraft was moved quickly to the left-hand side of the runway, apparently because of the sudden change in wind direction and speed. However, a sudden change in wind direction and speed would be visible in the graph because lateral acceleration would occur (Appendix 3), which was not the case. However, at the last moment the captain steered to the right to stay or get above the runway, which was not successful.

5.2.11. The RVDL claim that at an altitude of 50 ft the captain was "startled by a sinking feeling" and then opened the throttles. That must be a joke, how could they know that? The radio altitude graph of the DFDR (Appendix 3) certainly did not give any cause for that.

5.2.12. According to the RVDL the aircraft touched down on the runway completely on the left-hand side, first on the right-hand landing gear while the aircraft rolled to the right (0 - 4°) with a wind correction angle of approximately 11° and a high descent rate. The roll angle to the right was far too late to stay aligned with the runway and may even be so large that the wing flaps or wing tip only just stayed clear of the runway, see § 4.6.4. The fact that the wind correction angle was still 11° means that the pilot had not managed to get to the centre of the runway in time. According to the NLR only the right-hand main landing gear touched down on the runway, the centre landing gear hit the shoulder between the runway lighting and ground; hence the left-hand main landing gear was entirely off the runway (§ 3.1.15). Neither the RvO nor the RVDL covered this. The NLR must have obtained this information from somewhere. Given the approach path followed which had an excessive angle (§4.2.3 and Appendix 2) the aircraft was never aligned with the runway and did not quite reach the runway, partly because they did not steer in time to the specified approach radial and/or runway heading and insufficient aileron use against the crosswind at the time.

5.2.13. Contrary to what the RVDL states on page 7 of ref. 5 landing gear is not "most likely to fail" when landing on the right-hand wheel if the roll angle is 4° to the right and the wind correction angle is 11° (on a wet runway). Landing gear is designed to withstand such forces and does not break just like that. Unfortunately, the RVDL does not mention the possibility of landing with wheels braked or locked by brake actuation (§ 4.6.10) although the graph showing that the brake was operated (Appendix 6) was available to them.

5.2.14. ***Sub-conclusion - general.*** The RVDL did not use the objective data from the NTSB's DFDR Factual Report to arrive at a correct description of the accident and its causes. Assumptions were made which can easily be refuted based on the DFDR data. It must be concluded that the analysis by the RVDL was not careful and that the cause may have been decided on in advance or preconceived under Martinair's influence.

5.3. RVDL – Established facts

5.3.1. The RVDL correctly proposed some amendments because the text of the draft RvO was not or could not be correct in some instances. But text which could place the responsibility on the pilots was also deleted and/or changed. This is detailed below.
This supplementary analysis is limited to the deletions and additions by the RVDL to the established facts of § 3.1 of the draft RvO. All the facts established by the CvO are included in the first column in Appendix 10. The second column lists the established facts included in the accident report. This shows that not all the amendments suggested by the RVDL were accepted by the Portuguese Committee of Inquiry, and correctly so. The following paragraphs include references to page numbers in ref. 5, to paragraph numbers in this analysis and to paragraph numbers in Appendix 10 of this analysis for further explanations or information.

5.3.2. The RVDL deleted the meteorological report that at the time of the accident there was a depression "250 nm west-south-west" of Faro (ref. 5, page 8). This was to be replaced by "Southwest of Portugal". Apparently the RVDL did not want to include the long distance, but in the end this suggestion was not adopted in the RvO (Appendix 10, § 8).
On page 9 of ref. 5, the sentence starting "The crew was not aware of the turbulence intensity" which the RVDL deleted is not left out from the final report, but written differently. Graphs 6 and 10 (Appendix 6 and Appendix 7) of the RvO do actually show that the pilot flying gave significant inputs with both the rudder and elevator as early as 40 seconds before the landing. So he was probably fully aware of the light turbulence (Appendix 10, § 13).

5.3.3. On page 10 of ref. 5 the RVDL proposed deleting "braking action poor". This sentence was later changed in the statement that the crew did not consider this information when determining the braking action. However, the required landing distances for the three braking actions had been calculated en route by the Flight Engineer and filled in on the Landing Data Card (Appendix 1 and Appendix 10, § 13).

5.3.4. The sentence about the wind information of the Area Navigation System (inertial navigation system, Appendix 10, § 17) was deleted as suggested by the RVDL, but this information was read out at the time the pilot flying had only just operated the rudder to line up with the runway. So this should have been considered as relevant. Additionally, the Martinair Flight Ops Manual (BIM) states in § 3.1.7 that when windshear is expected the inertial data should be monitored, as well as the speed, descent rate, pitch and engine power, for "early shear recognition". So there is nothing wrong with reading out wind information from the navigation system. In fact, the captain acted correctly and in accordance with the procedures, but unfortunately did not use the information and also did not monitor its use by the pilot flying. See also 2.3.11 and § 3.2.6.

5.3.5. The RVDL did not mention the use of different times and clocks in the RvO as an issue (§ 2.2.1).

5.3.6. On page 10 of ref. it is also stated that two minutes and 10 seconds (according to a different clock possibly even three minutes) after the accident SIO recorded a windshear warning, i.e. not before the accident (Appendix 10, § 21)!

5.3.7. According to the wind table in the RvO §1.7.4.4 on page 46 the average wind 20 seconds before the landing was 160°/ 21 kt max. 35 kt. On page 126 the RvO states that Approach Control did not inform the aircraft of the wind of 220°/35 kt. There is a major difference in angle between these two wind directions; which one is actually correct? Were several wind tables used? Again, the DFDR data (Appendix 3 and Appendix 4) indicates that the aircraft did not experience accelerations due to a gust.

5.3.8. On page 11 of ref. 5 (Appendix 10, § 23) the RVDL proposed deleting that the crew did not cooperate effectively, which was adopted. The RVDL also proposed changing the paragraph about the temporary reduction in visibility during the approach and the runway condition information which the crew received from the tower, such that the information would not have to lead to aborting the approach. Fortunately, this was not adopted in the Portuguese report and it correctly states that the crew interpreted the information sent to them incorrectly and therefore did not decide to abort the landing.

5.3.9. However, the proposed changes about the CWS on page 11 (Appendix 10, § 24) are correct. Unlike what the RvO states, according to AOM § 3.3.5-08 it is permitted to land with CWS engaged, but below an altitude of 150 ft the autopilot may not be switched from CMD Mode directly to disengaged, probably because of transients which might occur, see also § 3.2.7 and § 4.1.2.

5.3.10. The RVDL proposed adding that the reduction of engine power to flight idle was initiated at 150 ft by the autothrottle system and was followed through by the pilot flying ("follow through", Appendix 10, § 26). During turbulence and windshear, the pilot flying needs to put their hand on the throttles and feel the levers being controlled by the autothrottle to prevent that these are closed or pulled back too far (by the autothrottle) during speed and pitch variations due to turbulence and windshear. According to the RvO Martinair Flight Ops Manual BIM § 3.1.7 states: "Do not make large power reductions until beginning of flare". Normally, the autothrottle system only starts reducing gradually at 50 ft. However, the pilot flying pulled the throttles back too early and held them there, possibly because it looked like they were going to touch down too far on the runway. See § 3.1.12 and § 4.6.7.

5.3.11. The RVDL wanted to add (Appendix 10, § 27) that the descent rate had increased (to 1,000 ft/min) due to the early and excessive power reduction and the tail wind component (Appendix 10, § 29). If the wind had changed to 220° then this wind with a current heading (runway heading) of 106° (+ 11° wind correction angle) would not have amounted to a significant tailwind. If the wind speed had increased to 35 kt then it is certain that the landing limits on a wet (and also a flooded) runway would have been exceeded. The RvO states that the premature power reduction and sudden wind variations may have led to exceedance of operational aircraft limits. In the same paragraph it is stated that in the last 20 seconds before the landing no significant variations in the wind speed and direction were recorded.
Such a large increase in crosswind would have required a steering correction, however this was not made. This would also have been visible in the acceleration and other graphs (Appendix 3).

5.3.12. The RVDL wanted to add (page 11, Appendix 10, § 30) that the fracture of the landing gear was not only due to the high rate of descent but also by touching down on the "right hand aft wheel" and the crab angle. Aircraft always land on an "aft wheel" or do they mean "right-hand main gear"? With most aircraft types it is not a problem to land with a wind correction angle (on a wet runway), the landing gear is generally strong enough for that. The radio altitude graph provided by the NTSB (Appendix 3, because the last part of the graph in the RvO was deleted) does not show at all that the rate of descent was high. The vertical acceleration during the last seconds of the flight was at most 1.1 g. Neither the RvO nor RVDL mention locked brakes (§ 4.6.10). Additionally, according to the NLR the aircraft mostly ended up next to the runway (§ 3.1.15), something not mentioned either in the RvO and by the RVDL.

5.3.13. ***Sub-conclusion - established facts***. Some deletions and additions proposed by the RVDL were correct, but the other proposals appear to be clearly intended to exonerate the pilots and attribute the cause to the weather conditions based on non-objective data. As indicated by the final report, the Portuguese investigators did not adopt all the deletions and additions proposed by the RVDL but they did amend some text. The intention that windshear had to be the cause of the accident appeared to motivate the intentional proposal of changes and additions not based on objective data.

5.4. RVDL – Causes

5.4.1. The causes as mentioned in the English translation of the RvO provided do not correspond with the causes in § 3.2 of the final Portuguese version of the RvO (ref. 1, page 166). Both are included in Appendix 11. The deletions and additions by the RVDL about the cause as found in their comments (ref. 5) are given below.

5.4.2. The RVDL (ref. 5, page 13, see Appendix 11 § 48 - 54) proposed a completely different text about the cause. The CvO states that the cause was the excessive descent rate during the final

stage of the approach and the crosswind which the crew was not aware of but because of which the aircraft limits were exceeded. According to the RVDL the accident was initiated by a sudden and unexpected variation of the direction and speed of the wind (windshear) during the final stage of the landing, after which a high rate of descent and excessive lateral movement developed which caused a hard landing on the right-hand main landing gear which meant that, together with the significant wind correction angle, the structural limits of the aircraft were exceeded. Some comments by the RVDL were included in the causes as described in the final RvO, see Appendix 11, but blame was not placed exclusively on the weather conditions, as the RVDL wanted.
The graphs in the NTSB's DFDR Factual Report do not give any indication of sudden wind variations. Errors were made during the approach, lining up and the landing (with braked wheels), see § 3.2.3 and beyond. Furthermore, the runway was to short for the relevant braking action; a go-around should have been initiated.

5.4.3. ***Sub-conclusion - causes***. The causes described in the final report do not correspond with the objectively measured facts.

5.5. RVDL – Contributing factors

5.5.1. Similarly, the contributing factors to the accident do not all correspond with the RvO, see Appendix 12. The RVDL wanted to add (ref. 5, page 14, see Appendix 12 § 55) that, given the weather conditions at the time, neither the meteo nor the crew anticipated the possibility of windshear. This was not included in the RvO, but replaced by the correct conclusion that the approach was unstable (and should therefore have been aborted, as specified in the AOM) (Appendix 12 § 56).

5.5.2. The addition about maintaining idle thrust, probably by the crew, was correctly included by the CvO (Appendix 12 § 57).

5.5.3. In the last draft of the RvO it was stated that the wind information from the inertial navigation system on board was incorrect (Appendix 12 § 59 column 1). This sentence was indeed deleted; the wind information may not have been very accurate (there is no information about this) but the Martinair procedure required that it was monitored when windshear is expected, see also § 5.3.4. Hence the captain acted correctly and but did not monitor the correct use of this information. This factor should have been left in the RvO; the awareness of this (wind above the limit) should not have been ignored and should have led to a go-around.

5.5.4. At an altitude of 250 ft visibility was temporarily lost, apparently because it started to rain and the screen wipers were not on. As such, that is not a reason to abort the approach. The suggestion of the RVDL to delete this sentence was adopted, but the lack of approach lights was left as a contributory factor (Appendix 12 § 60). However, this was not considered as a contributory factor to the accident. Apparently this fact had been accepted by Martinair for some time as they were flying to Faro; apparently they considered the runway lighting to be sufficient and it was not against the rules.

5.5.5. The RVDL wanted to delete the contributory factor that the crew had assessed the runway condition incorrectly. This contributory factor remained unchanged in the RvO, and rightly so. The crew made a serious error of judgement which, apparently, the RVDL did not want to see mentioned in the RvO (Appendix 12 § 61).

5.5.6. As designed, the CWS disengaged at an altitude of 80 ft due to the conflicting inputs by the captain and the pilot flying. The RvO stated that this occurred below the specified altitude as a result of which, under manual control, the aircraft made a sudden flare and hard landing (Appendix 12 § 62). This was correctly amended by the RVDL. However, manual control need not have been a disadvantage. If that had been the case, the CWS would not have certified by the authorities. The transition to manual control was probably not even noticed by the pilots due to the high workload at the time and did not have an adverse influence.

5.5.7. The RVDL wanted to delete the sub-conclusion that the crew increased the engine power too late. This sub-conclusion was, correctly, left unchanged in the RvO (Appendix 12 § 63).

5.5.8. The RVDL wanted to delete the contributory factor that the lift coefficient was reduced by the heavy rain (Appendix 12 § 64). However, this contributory factor was left in the RvO. It should be noted that the lift of a wing can indeed reduce in heavy rain, but during the flight it can be compensated by pulling the nose up and increasing the engine power at the same time. According to the NTSB graphs, at 250 ft the nose was indeed pulled up slightly and the engine rpm increased. However, the speed which had reduced too much due to the negligence of the pilots had a much greater (quadratic) effect on the lift of the wings than the rain had.

5.5.9. The RVDL wanted to delete the factor that the collapse of the landing gear was caused by the high descent rate combined with the significant slip angle at the time of touchdown on the runway (Appendix 12 § 65). The CvO deleted this sentence as a contributory factor, but did include it as one of the causes of the accident (Appendix 11 § 49).

5.5.10. ***Sub-conclusion - contributory factors***. The RVDL's comments left much to be desired. They were not complete but, very clearly, aimed for windshear. Apparently they wanted to absolve the crew of blame and place this fully on Faro or the non-existent windshear. Fortunately, the Committee of Inquiry did not accept all of the RVDL's suggestions..

6. Conclusions about the RvO, analysis by the RVDL and this supplementary analysis

6.1. The sub-conclusions given earlier in this limited supplementary analysis are summarised below, stating the paragraph number where the explanation is given.

6.2. *Clock times* (§ 2.2). Three of the times used in the RvO, between which there were differences, were referred to as UTC; however, there is only one UTC, a clock time formerly known as Greenwich Mean Time. It must be concluded that, apparently, the CvO did not understand exactly what UTC is.

6.3. The CVR times in the RvO showed an inexplicable, increasing deviation from the UTC clock. The synchronisation moments used were not stated and could therefore not be verified. It was concluded that either the UTC in the RvO, or the CVR times in Annexes 5 and 6 of the RvO were incorrect in some cases and that the analysis undertaken on the basis of the CVR and/or UTC clock times was not accurate enough. It was also unclear if the radar and meteo times mentioned in relation to the facts and in the analysis in the RvO were corrected to UTC (incorrectly referred to as communications UTC) in the right way, for an accurate and correct analysis. In some cases, the deviation between the clocks was excessive. It may be concluded that the times used in the RvO are not reliable enough for a thorough analysis of the accident. This conclusion is also supported by the altitude and distance reports by the captain plotted in Appendix 2 and recorded on the CVR, which were found not to correspond with the altitudes the CvO used in the RvO. The use of at least five different clocks in a single RvO is highly confusing and is likely to contribute to errors in the analysis.

6.4. *Meteo* (§ 2.3). The weather and wind information presented in Chapter 1 (Factual information) of the RvO are not limited to purely factual information; it is therefore difficult, or even impossible, to reconstruct what happened, in meteorological terms, shortly before the accident. Sometimes the average wind is given, but at times when it is more convenient (in terms of attributing blame) a peak wind is given and then it is unclear if these are instantaneous values or averages during a particular time period, and what the source is. Incidentally, most of the meteo information presented concerns the period after the accident.

6.5. It may be concluded that the meteorological facts presented in the RvO, whose source is sometimes in explicable, cannot adequately contribute to correctly understanding the weather conditions shortly before and during the accident. The Chapter Meteorological information of the RvO (§ 1.7) is a chaotic collection of comments which was probably produced by several investigators.

6.6. Although the wind which traffic control informed the aircraft of was within the limits for the runway condition assumed by the crew ("wet runway"), the wind read out by the captain from his AINS, in accordance with the instructions, was far above that limit, which did not lead to the only appropriate action, i.e. a go-around. Despite traffic control twice informing MP495 that the runway was flooded this did not lead to the go-around required in this case. The wind was stronger than permitted for landing at Faro given the runway conditions. The runway would be too short.

6.7. The CvO also concluded that the required runway length for landing MP495 not only on a flooded runway but even on a wet runway would be longer than the available length. The CvO also concluded that in the last 20 seconds of the flight no significant changes in the wind speed and direction were recorded by the SIO.

6.8. *Airport and aircraft information* (§ 2.4). The 45 m difference in available landing distance of runway 11 is not explained in the RvO. Apart from the magnetic variation, for which an incorrect term is used, no reference is made to the 5° deviation in the approach course (offset) prescribed by the Portuguese authorities. Information about the classification of the hardened area, the strip of land besides the runway, and of the aircraft is missing.
It may be concluded that much of the data recorded on the DFDR about the last 50 ft of altitude was not included and presented in the graphs in Annex 9 of the RvO and was not used when analysing the events.

6.9. *Comparison of data in the NTSB's DFDR Factual Report NTSB and the RvO* (§ 2.5). The above comparison shows that much data is missing from the RvO, although it was included in the original NTSB DFDR Factual Report, and that there are excessively large differences in the radio altitude and control surface (ailerons and spoilers) positions a few seconds before the landing. It appears that the NTSB graphs have been cut and pasted. Furthermore, the representation of data about the control inputs by the pilots, which is extremely important to the analysis, in the graphs stops shortly before the time of landing. It is most likely that the copy of the DFDR Factual Report of the NTSB is not the original version with all relevant data which the NTSB provided to the investigators. Extremely important data is missing from the RvO (or was deleted) and data which was available was not used to supplement the graphs in the RvO.

6.10. *Approach in the RvO* (§ 3.1). The reconstruction of the accident was partly included in Chapter 1, which should only have contained factual information, and partly in Chapter 2, Analysis, however this does not contain a proper analysis but more of a list of conclusions. Differences were observed between the data in the DFDR Factual Report and the RvO. Altitude corrections to stay on the specified approach glide path and changes in engine speed were incorrectly explained as being the effects of windshear. According to the ICAO definitions, the aircraft was only subjected to light turbulence. The origin of the high descent rate is doubtful; this data cannot be correct. The altitude indicated as "radio altitude" in the graphs is not just the radio altitude; according to the NTSB report the available radio altitude was limited to 250 ft. The approach was abnormal, not along the specified course. The pilot flying started aligning the aircraft with the runway, in preparation for landing, too early. This alignment was not completed, hence there was a sideways movement (crabbing) during the landing. In many RvO graphs the last part is missing, from an altitude of 50 ft, although the NTSB graphs do continue. According to an NLR report the aircraft landed too far and half off the runway. The collapse of right-hand landing gear could also have been caused by landing with braked wheels.

6.11. *Windshear in the RvO* (§ 3.2). As far as the effects of the weather are concerned, the reconstruction of the final part of the flight was incorrect. There is absolutely no evidence of windshear. There was light turbulence but the movements were never extreme and also explicable. The RvO strongly veers towards windshear, while it cannot be concluded from the objective DFDR data that the aircraft made movements which approached the standards for windshear. The instability was explained as crossing through areas with upbursts and downbursts, while they were normal glide path corrections. The pilot flying caused the instability by unnecessary rudder actuation and he did not use the autopilot CWS mode appropriately. The captain caused the disengagement of the CWS by not taking over control appropriately.

6.12. The crew ignored the information about the runway conditions and landed on a runway with a crosswind component which was far too high for DC-10 under the weather conditions at the time; the crosswind limit was exceeded.

6.13. It may be concluded that nature was to be blamed for the accident. It is inexplicable that this reconstruction was accepted by the RVDL.

6.14. *Landing Data Card* (§ 3.3). The Landing Data Card contained old wind information which had already been superseded. The available landing distance at Faro with a wet runway would have been just sufficient for a DC-10; landing on a flooded runway would not have been possible. The application of the wind correction calculation method described in the Martinair FCOM leads to an approach speed which is too low when the autothrottle is used. The pilots did not add the minimum required 5 kt wind correction to the threshold speed provided by the Flight Engineer. The correct approach speed was not included on the Landing Data Card. The calculation of the approach speed in the Martinair FCOM is incorrect when the autothrottle is used.

6.15. *Approach heading* (§ 4.2). The last turn before the landing was flown too close to the runway and was too wide, thus it was not flown in accordance with the specified procedures. At and below 500 ft altitude the aircraft was still not flying the specified approach radial, the deviation from the specified approach heading was far too large and the corrections for the crosswind at the time were not in time and were insufficient. The pilot flying caused variations in the heading and roll angle through unnecessary steering inputs which also resulted in speed variations and engine speed variations; this suggests a training deficiency. Thus, the approach was most certainly not stable, as specified for altitudes below 500 ft and should have been aborted for various reasons. The approach was not flown correctly and not corrected in time by the captain.

6.16. *Approach speed* (§ 4.3). Differences were observed between the speed data provided by the NTSB and the speed data in the RvO graphs. During the first part of the approach the speed was already too low according to the NTSB. The approach speed set on the autothrottle was 139 kt, 5 kt too low, see also Appendix 5. Later the approach speed fluctuated, probably due to the automatic gust correction by the autothrottle system or due to the light turbulence, but also due to unnecessary rudder inputs by the pilot flying, and even fell to close to and below the threshold speed. The FCOM procedure is unclear with regard to the calculation of the approach speed with the autothrottle engaged. The captain did not intervene.

6.17. At 50 ft radio altitude (runway threshold) the speed had reduced to 134 kt. Hence the speed was 10 kt below the specified approach speed and 5 kt below the specified threshold speed, too low for a safe approach under the conditions at the time. The Martinair Landing Data Card did not include a space for the approach speed, only for the threshold speed. This made it more difficult to monitor the correct operation of the autothrottle and maintaining the correct, safe approach speed.

6.18. During the last part of the approach the engine throttles were already closed by the pilot flying at an altitude of 150 ft, against the instructions. The attempted go-around initiated by the captain 2.5 seconds before the landing was too late.

6.19. *Glide path* (§ 4.4). With respect to the flown glide path altitude, there were differences between the DFDR data, CVR transcripts and the glide path drawn in the graphs in the RvO. According to the CVR transcript the approach in the vertical plane was indeed up to 150 ft below the specified glide path for a while, but this was corrected in time and therefore did not have an adverse effect on the landing. The quality of the graphs and information about the source of the glide path altitude date in the RvO left something to be desired.

6.20. *Wind and runway conditions* (§ 4.5). The wind read out in the aircraft 10 seconds before the landing was higher than the specified limit. Additionally, the flooded runway would have been far too short to come to a halt in time. For these reasons too, the landing should not have been undertaken. The data required for this part of the analysis had also been "left out" of the RvO.

6.21. Landing (§ 4.6). According to the NTSB (ref. 2) the lining up, the aligning of the longitudinal axis of the aircraft with the runway heading, using the rudder pedals (rudder) to prevent a traversing landing, already started at a radio altitude of 104.3 ft (ref. 2), according to the RvO (ref. 1) at 150 ft, 10 seconds before touchdown, but the graphs show that this already started at 450 ft altitude, 40 seconds before touchdown. That was too early. Both this and the lack of counter aileron meant that the aircraft was not lined up and under the influence of the crosswind it moved to the left-hand side of the runway (drifted). It is also possible that the aircraft, because of the angled approach path, never reached the centre of the runway or even not quite reached the runway fully. According to the NLR the place where the aircraft first touched the ground was 124 m beyond the touchdown zone and half next to the runway; the RvO did not mention this. The overshot landing also indicates that the aircraft was not pushed into the ground by a downdraft. It is possible that the pilot flying realised they would land too far and therefore pulled the throttles back in time. The aircraft made a traversing landing with a crab angle of approximately 11°. Landing gear is normally strong enough for that and will therefore not be damaged on a wet runway; the maximum permitted crab angle is not known. During the last two seconds the nose was pulled up slightly which prevented a hard landing. The average descent rate during the final stage of the flight was not abnormal and was within the limits.

6.22. It appears that during the last minute and a half the pilot flying did not have his right foot in the correct position on the rudder pedals. Although again the last part of the relevant graph is missing, it can be stated with almost complete certainty that the right-hand brake pedal was pushed down and that the wheels of the right-hand main landing gear braked forcefully when the aircraft touched down which could have increased the forces on the landing gear during the landing so much that this may have led to the fatal collapse of the landing gear. The incorrect placement of the feet on rudder controls, and not just the traversing landing, may have resulted in the collapse of the right landing gear. These are results of incorrect action by the pilot, with serious consequences.

6.23. The aileron position graph was found to show a deviation of 5% to the right.

6.24. *Windshear or turbulence* (§ 4.7). The DFDR data provided so far does not indicate that there was windshear; there were no movements which could not be compensated by the aircraft systems (autopilot and autothrottle) and normal flying skills. The graphs needed to determine the occurrence and influence of windshear were left out of the RvO or partly deleted while they were available to the CvO (DFDR Factual Report by the NTSB, ref. 2). During the final approach there may have been light turbulence, furthermore, the pilot flying induced movements himself by unnecessary repetitive rudder inputs. The DFDR data also shows that there was no large lateral acceleration, but that the touchdown on the left-hand side of the runway was due to an incorrect approach heading and incorrect lining up with the extension of the centre of the runway by the pilot.

6.25. There is no data to confirm the occurrence of windshear. The data which could be used to demonstrate that there was no windshear was left out of the RvO. If there had been windshear during the last phase of the approach then the aircraft would not have landed beyond the touchdown zone. There is no explanation how they arrived at the conclusion that there was windshear; the CvO did not conclude this. Analysis of the data rather indicates the opposite; there was no windshear at all during the approach of MP495.

6.26. *Procedures* (§ 4.8). During the approach, the experienced and trained crew did not undertake any of the windshear procedures defined in the FCOM which may also indicate that no windshear was experienced during the approach. The required ‘landing call’ was also missing.

6.27. *RVDL - general* (§ 5.2). The RVDL did not use the objective data from the NTSB's DFDR Factual Report to arrive at a correct description of the accident and its causes. Assumptions were made which can easily be refuted based on the DFDR data. It must be concluded that the analysis by the RVDL was not careful and that the cause of the accident may have been decided on in advance or preconceived.

6.28. *RVDL - established facts* (§ 5.3). Some deletions and additions proposed by the RVDL were correct, but the other proposals appear to be clearly intended to exonerate the pilots and attribute the cause of the accident to the weather conditions based on non-objective data. As indicated by the final report, the Portuguese investigators did not adopt all the deletions and additions proposed by the RVDL but they did amend some text. The intention that windshear had to be the cause of the accident appeared to motivate the intentional proposal of changes and additions not based on objective data.

6.29. *RVDL - causes* (§ 5.4). The causes described in the final report do not correspond with the objectively measured facts.

6.30. *RVDL - contributory factors* (§ 5.5). The RVDL's comments left much to be desired. They were not complete but, very clearly, aimed for windshear. Apparently they wanted to absolve the crew of blame and place this fully on Faro or the non-existent windshear. Fortunately, the Committee of Inquiry did not accept all of the RVDL's suggestions.

7. Conclusions about the investigations by the CvO and RVDL

7.1. Information required for a correct and objective analysis of the accident was left out of both the RvO (ref. 1) and the graphs of the DFDR data included in the RvO and even out of the NTSB's DFDR Factual Report (ref. 2) included in the RvO. There is visible cutting and pasting in the appendix with the NTSB report (included in Appendix 3 and Appendix 4). There is a suspicion that information relevant to the correct analysis of the flight was left out deliberately, both for the whole and the last few seconds. Hence, information which is extremely relevant to the analysis of the accident, which must have been available, is missing from the RvO. However, using the information which is included it is still possible to identify a suspected cause of the accident, included in § 8 below, which differs from the RvO.

7.2. Several inaccuracies were noted in the RvO. It is inexplicable that the investigators themselves, the RVDL and their advisers did not notice and describe these.

7.3. The RVDL wrote its own comments on the final report by the Portuguese authorities, but did not use the objective information from the NTSB's DFDR Factual Report to arrive at a correct description of the accident and its causes. Assumptions were made which can easily be refuted based on the DFDR data (from § 5.3).

7.4. The RVDL added comments to the conclusions and cause in the final draft of the RvO and deleted text. Some deletions and additions proposed by the RVDL were correct, but the others appear to be clearly intended to absolve the pilots of blame based on non-objective information (from § 5.4). Rightly, the Portuguese Committee of Inquiry did not include all the deletions and additions proposed by the RVDL in the final RvO.

7.5. It appears that the intention was to blame windshear and that this was done, and that all objective information which could have demonstrated that there was no windshear had to be and was left out of or deleted from the RvO. This became clear, again, when analysing the comments by the RVDL on the RvO (§ 5).

7.6. This gives a strong impression that accident investigators and their advisers who are assumed to be independent made a significant effort to ensure that the pilots and therefore the airline could not be blamed for anything.

8. Main conclusions about the causes of the accident

8.1. Despite the fact that significant data had been left out of or deleted from the RvO, based on the information about the final stage of the flight presented in words, numbers and graphs by NTSB in their DFDR Factual Report (ref. 2), and the factual information in the Accident Report (ref. 1) it could be concluded, provisionally and objectively that:

(1) the crew were informed at least four minutes before the landing that the runway was "flooded" (covered in water), which would result in "braking action poor". The captain was aware of the meaning of the term "flooded". The runway length required under these conditions would, according to the Landing Data Card calculated and drawn up by the crew themselves, be approximately 600 m (!) longer than the actual length of the runway. If the aircraft had landed correctly then the aircraft would not have come to a halt in time on the flooded runway;

(2) the crosswind limit for the condition of the runway at the time ("flooded") was exceeded;

(3) the approach at an altitude of 500 ft was not stable in terms of altitude, approach angle, speed and engine power, as specified in the FCOM;

(4) the difference in the angle between the approach path followed by the aircraft and the prescribed approach radial in the horizontal plane was too large. No attempt was made to correct this, although time for this was available. The aircraft approached the runway at an excessive angle, not steering enough into the crosswind, and therefore did not reach the runway;

(5) the throttles of the three engines were pulled back or held back prematurely as a result of which the engine speed and airspeed reduced too early and much too much during the last part of the approach and the go-around initiated by the captain at the very last moment before the landing failed;

(6) the standard manoeuvre to align the longitudinal axis of the aircraft up with the runway heading, to prevent a traversing landing, was initiated with significant hesitation too high and too early and the roll angle required for alignment with the runway was not adopted and maintained, as a result of which the aircraft was not aligned with the runway and landed with a drift angle;

(7) the aircraft landed half next to the runway and far beyond the touchdown zone and almost certainly with braked wheels as a result of which the forces on the landing gear increased enormously and, in conjunction with the crab angle, resulted in its collapse, 300 m after touchdown;

(8) the graphs of the black box data and discussions recorded in the cockpit did not provide any indication that during the approach the aircraft passed through a windshear area. Furthermore it was found that the descent rate was normal and that there was no hard land-

ing, but a traversing one, which is not a problem on a wet runway. According to the ICAO definition the turbulence experienced was only light;

(9) the crew did not act in accordance with the instructions for flying during or recovering from experienced windshear, and hence neither expected nor experienced windshear;

(10) during the approach there were several reasons, based on instructions, to make a go-around, which was not done;

(11) the throttles were operated incorrectly and not in accordance with the instructions and the CWS mode of the autopilot was used inappropriately;

(12) the crew did not make the approach in accordance with the prescribed Martinair procedures and also not in accordance with the approach procedure and route prescribed by the Portuguese authorities;

(13) the calculation of the approach speed in the Martinair FCOM is incorrect when the autothrottle is used.

8.2. These main conclusions could be used to define the causes of the accident..

9. Causes of the accident

9.1. The accident was caused because the crew:

(1) ignored the current wind data communicated to them and read out on aircraft and ignored the condition of the runway and did not respond to these by making a timely go-around and diverting to an alternative airport. The crosswind limit was exceeded;

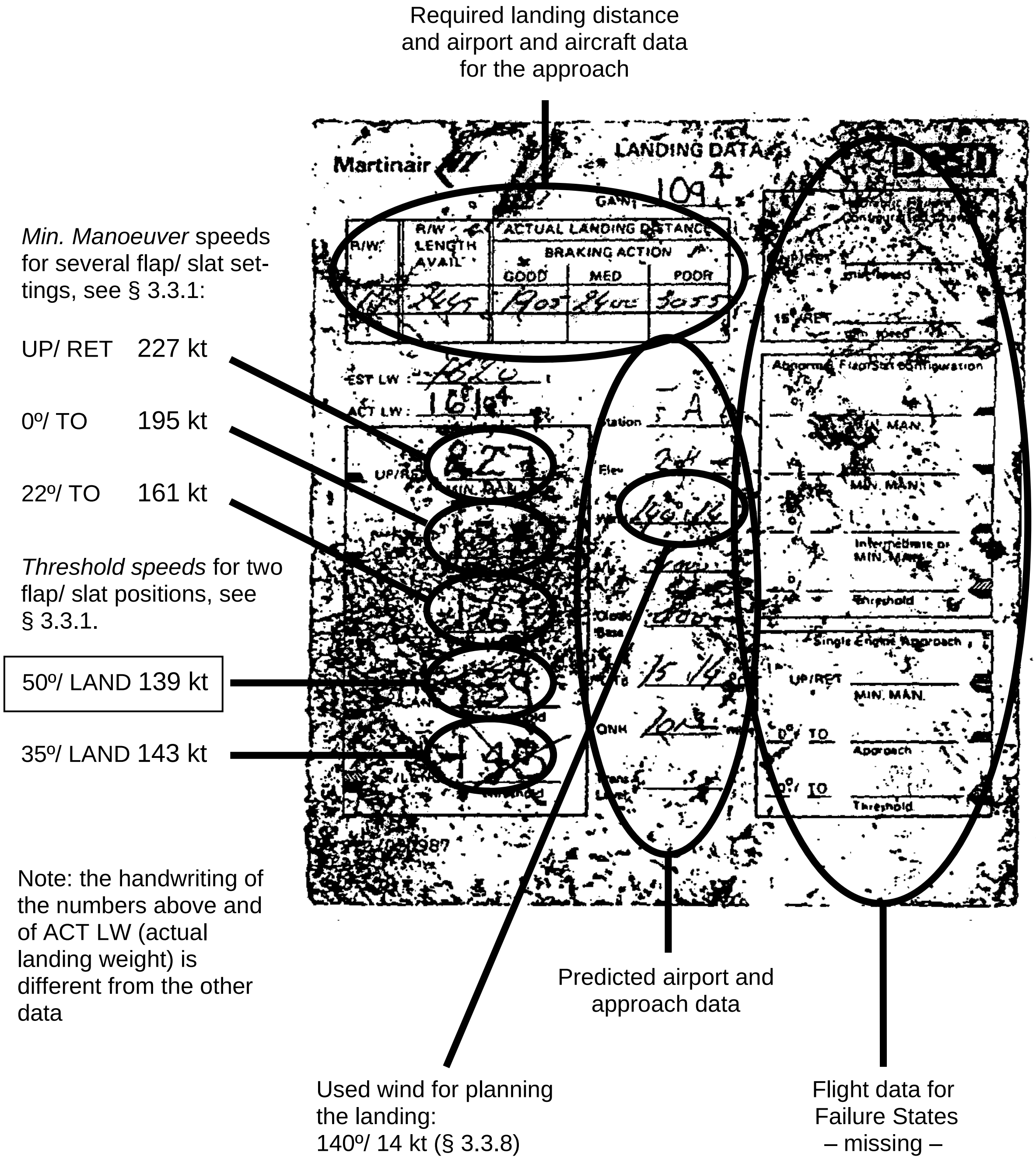
(2) during the final approach, deviated too much from the approach path (Approach Chart) prescribed by the Portuguese authorities and were still not flying stably on the approach path at the altitude defined in the FCOM and, despite this, continued the approach and did not make the prescribed go-around;

(3) pulled the engine throttles fully back too early, as a result of which the go-around initiated at a very low altitude failed;

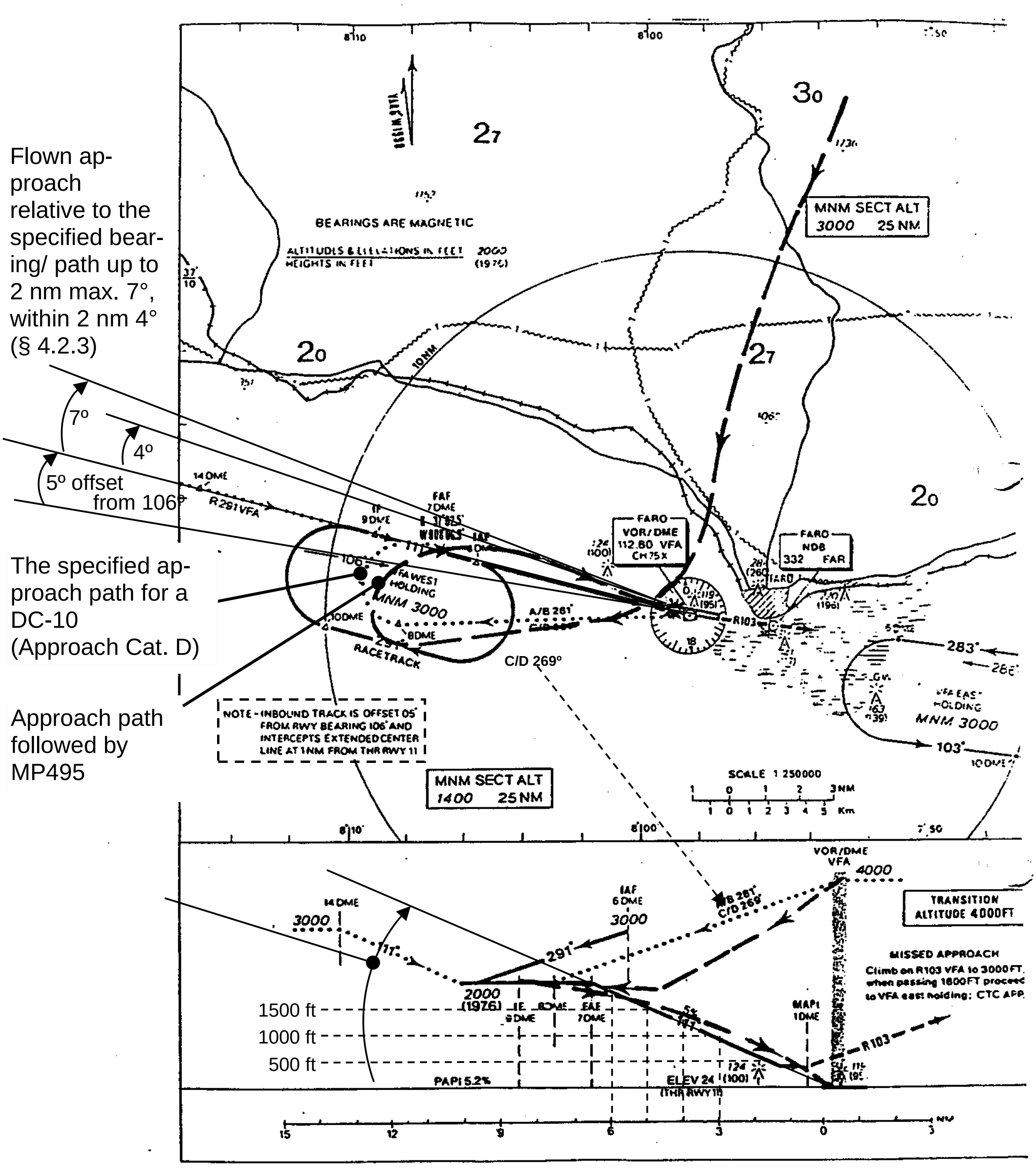
(4) made serious, even fatal procedural and operating errors, both during the final approach and during the landing, as a result of which the aircraft touched down partly to the side of the runway and with braked wheels, due to which structural limits were exceeded;

(5) handled the autopilot, autothrottle system and crosswind landing incompetently.

Appendix 1. Martinair DC-10 Landing Data Card MP495



Appendix 2. Approach Chart Faro Runway 11 with radar data plot MP495.



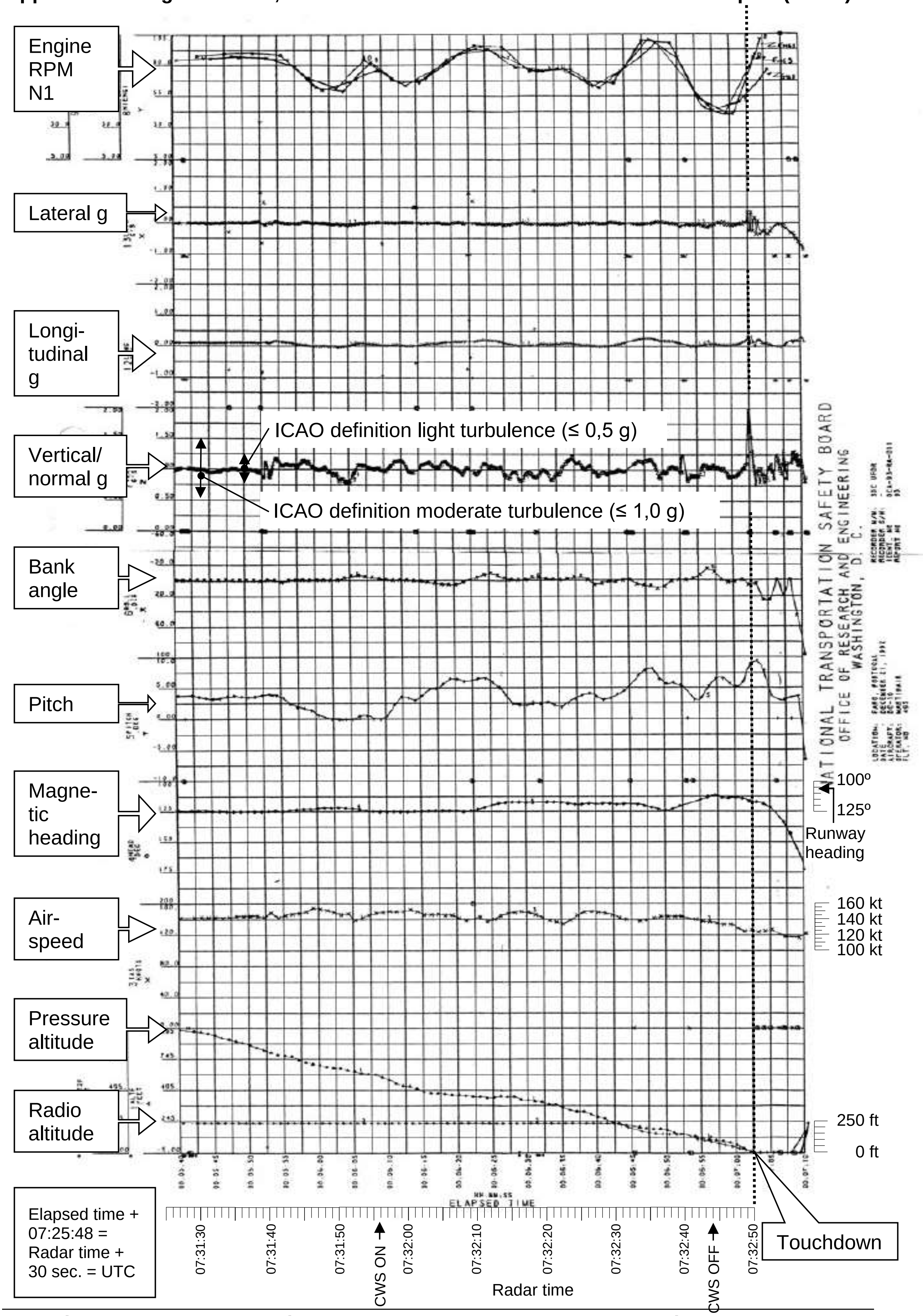
AEROPORTO DE FARO

TRAJECTÓRIA RADAR DO VOO MP 495

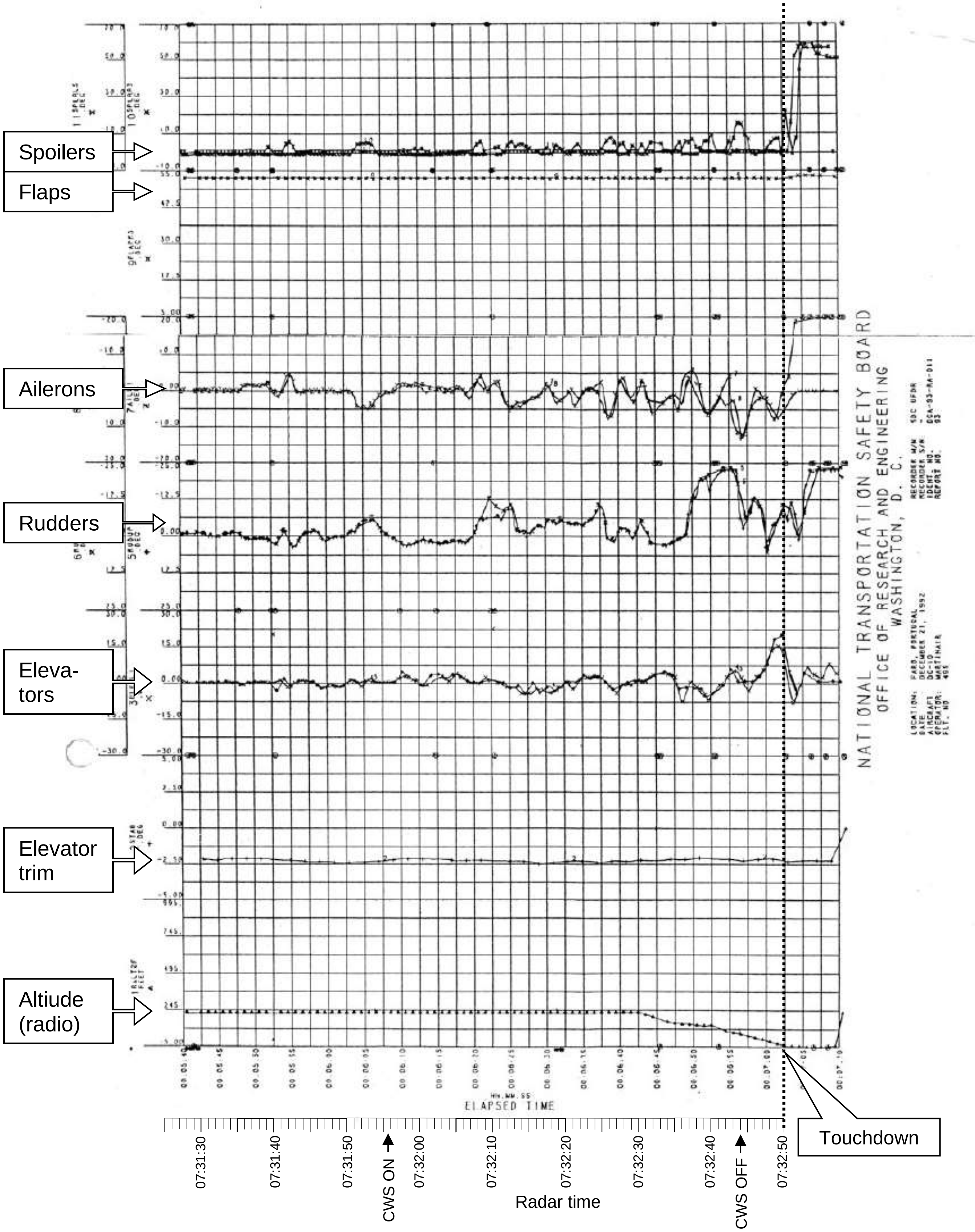
CVR reports		Altitude at 5,2% (-24 ft) glideslope:	
DME:	Altitude:	QNH:	Radio:
6 nm	1730 ft	1841 ft	1817 ft
5 nm	1430 ft	1524 ft	1500 ft
4 nm	1120 ft	1209 ft	1185 ft
3 nm	820 ft	893 ft	869 ft

If the aircraft flies the specified glide path, at Faro 5.2% (= 2.98°), then at the listed DME distances the altimeter will show the altitudes in column QNH and the radio altimeter the altitude in column Radio. Distance PAPI to VOR/DME is approx. ¼ nm. Radio altitude = QNH - 24 ft runway elevation (if the terrain is flat). The altitude was slightly too low during the entire approach..

Appendix 3. Page 1 of RvO, Annex 15. Part of the NTSB's DFDR Factual Report (Ref. 2).

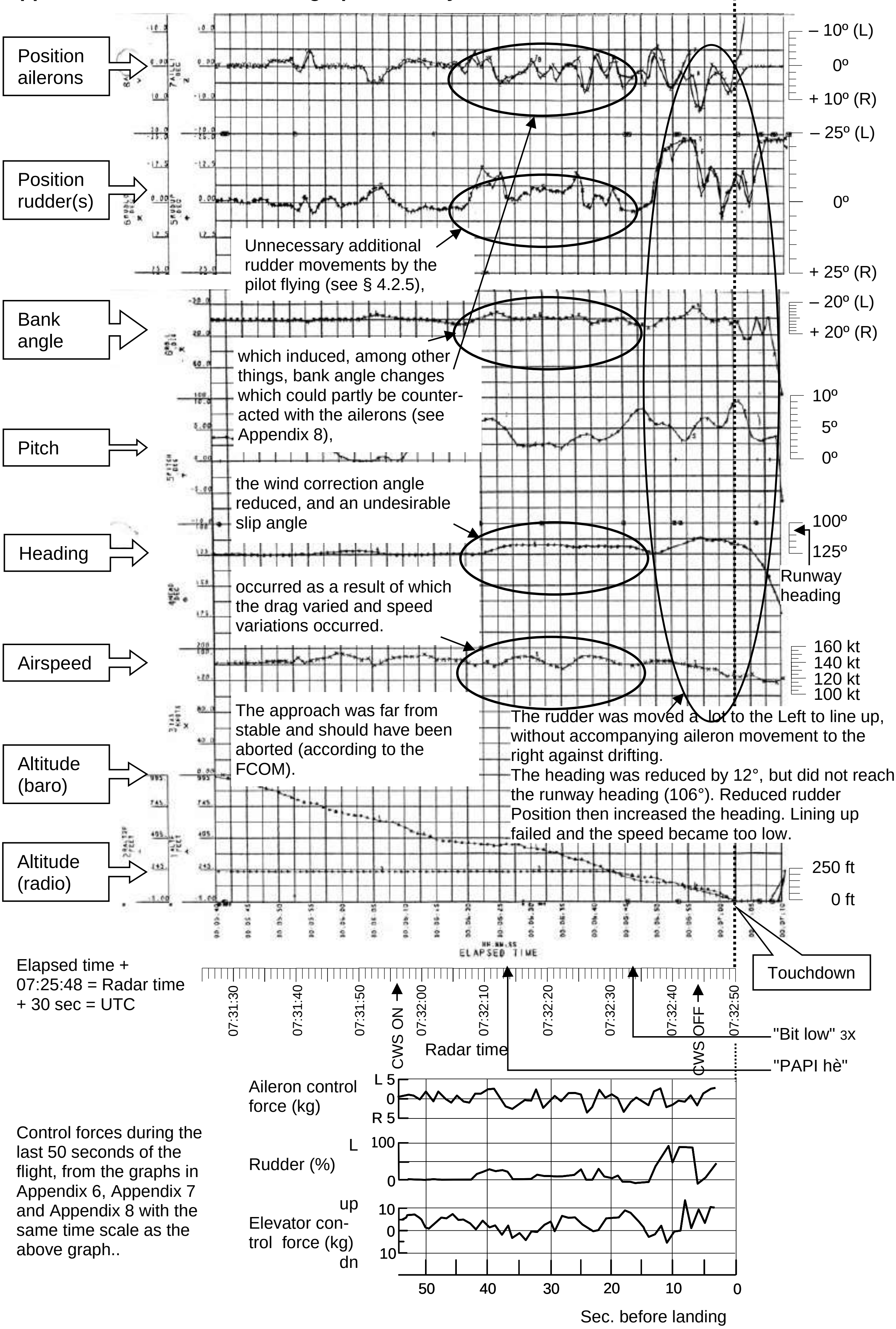


Appendix 4. Page 2 of RvO, Annex 15. Part of the NTSB's DFDR Factual Report (Ref. 2).

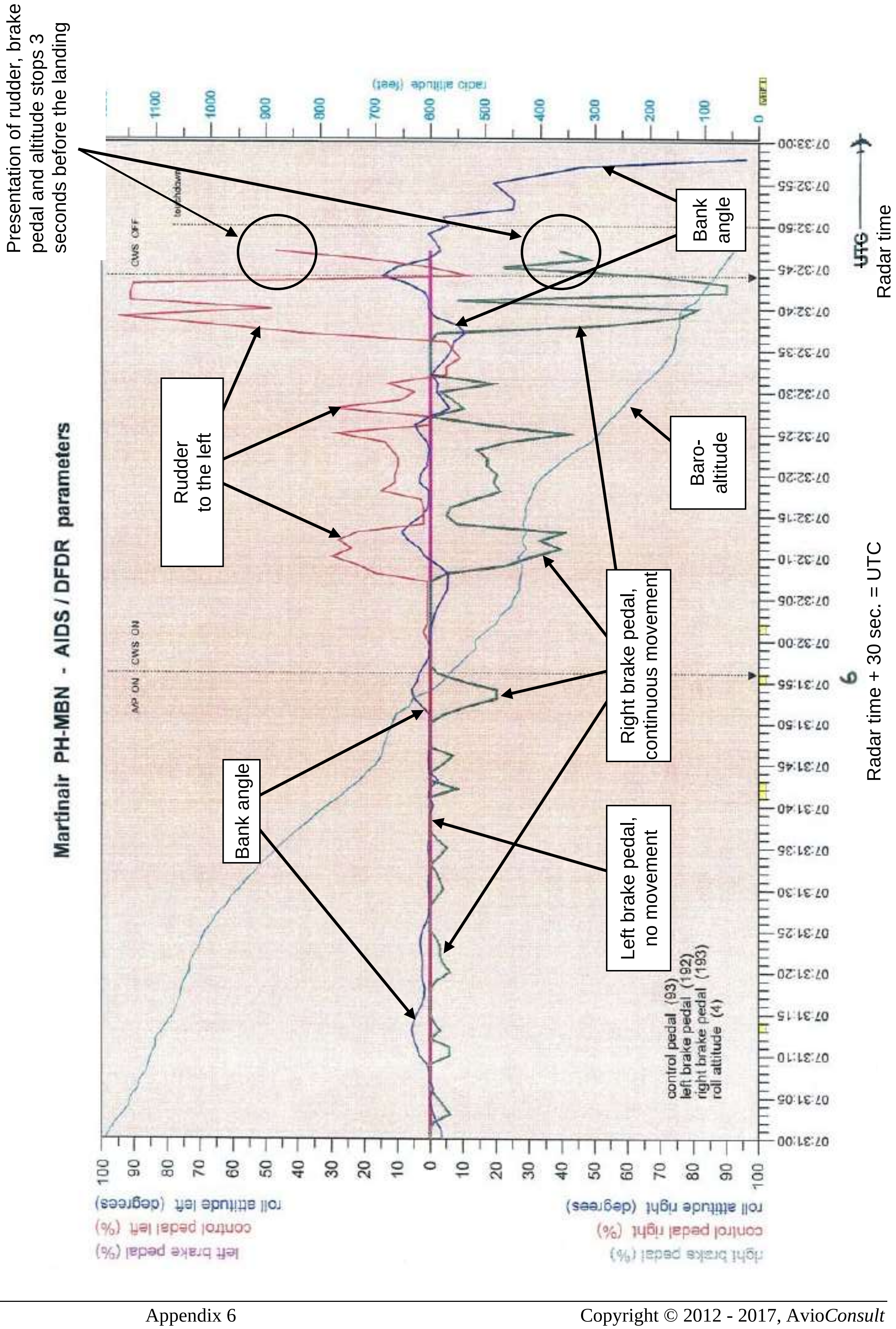


Elapsed time + 07:25:48 = Radar time + 30 sec. = UTC

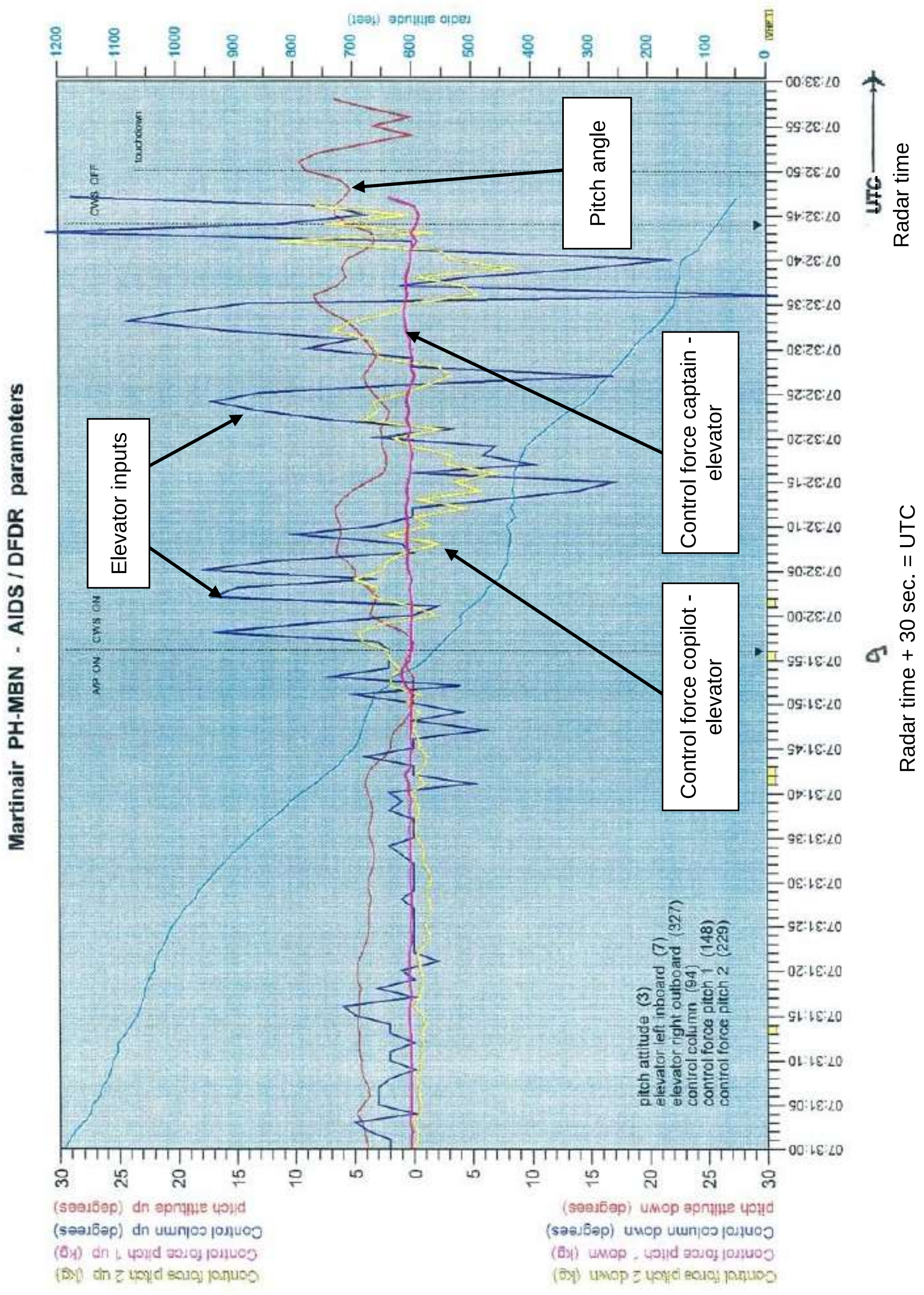
Appendix 5. Combined DFDR graph for analysis



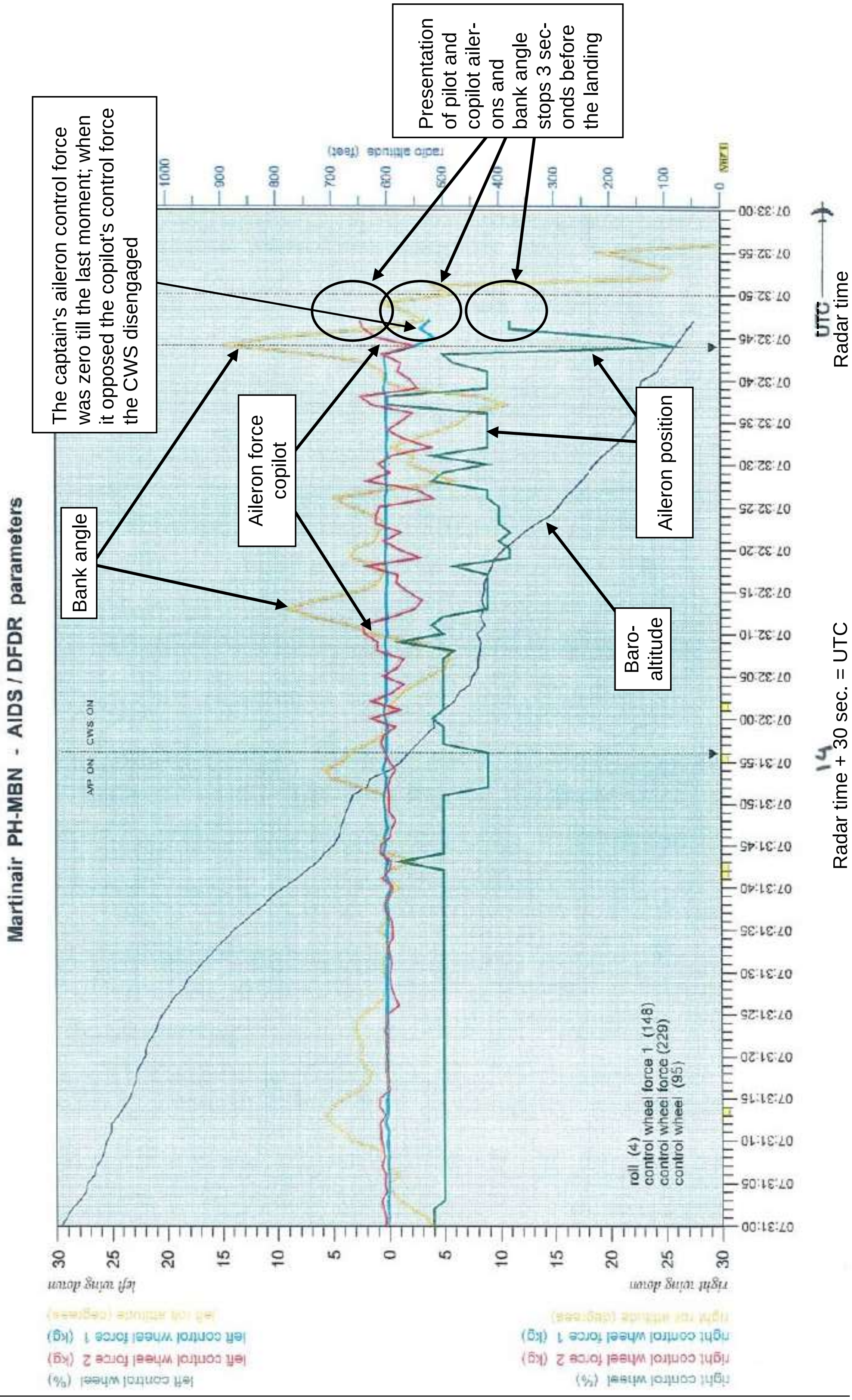
Appendix 6. Graph 6 from the RvO, Annex 9. Rudder, brakes, roll angle



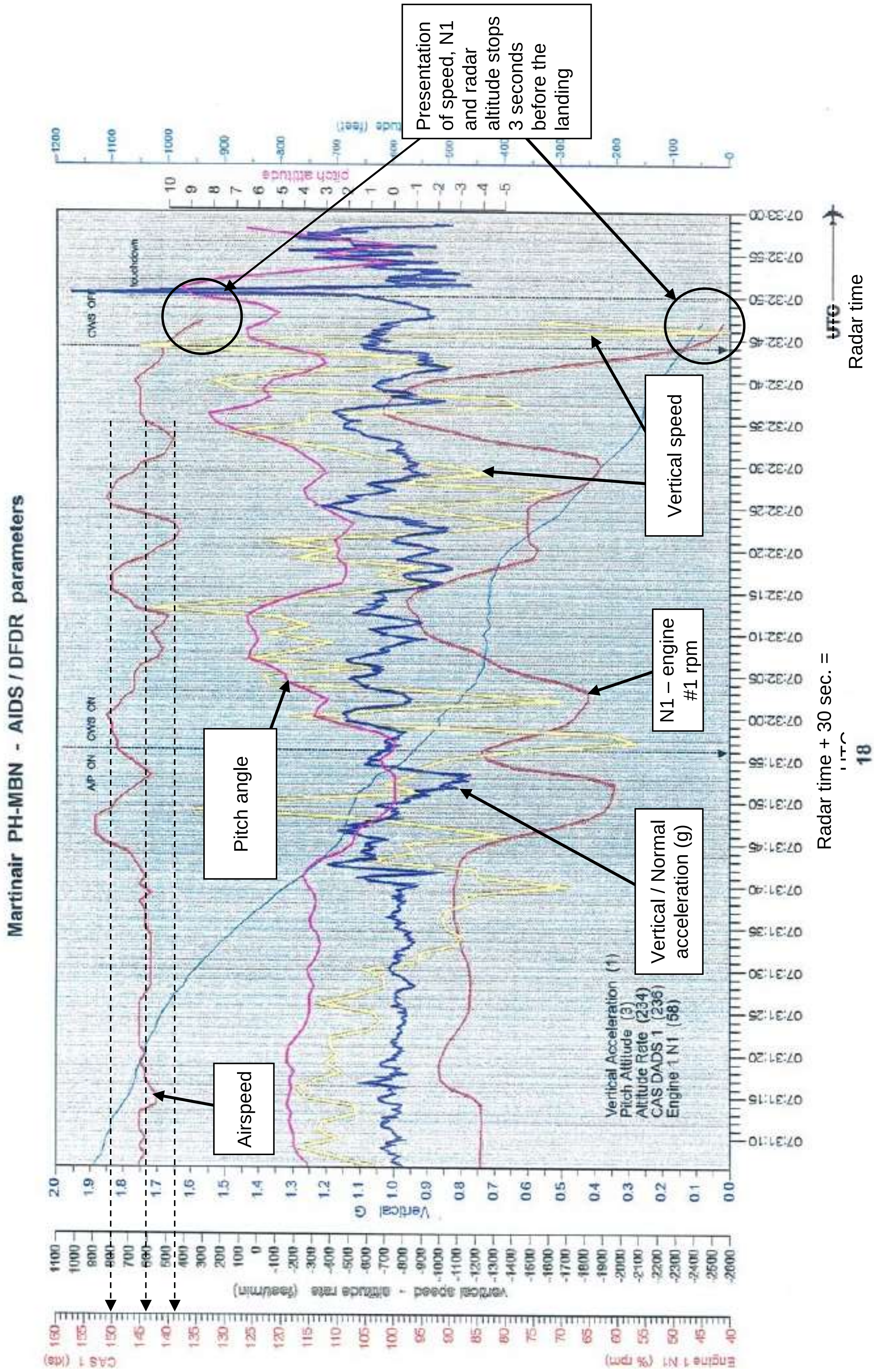
Appendix 7. Graph 9 from the RvO, Annex 9. Elevator and pitch, altitude



Appendix 8. Graph 14 from the RvO, Annex 9. Aileron, bank angle and altitude



Appendix 9. Graph 18 from the RvO, Annex 9. Speed, pitch, g, N1, descent rate



Appendix 9. Established facts and comments in versions of the RvO § 3.1

The table below is limited to the established facts as presented in draft and final version of the Accident Report (RvO). In the middle, shaded, column contains an unofficial (computer) translation from the Portuguese of § 3.1 of the formal Portuguese final Accident Report.
In first column (RVDL3) contains the comments sent by the Raad voor de Luchtvaart (RVDL) on 6 Sept. 1994 to the Portuguese CvO [Committee of Inquiry] on the draft of the RvO, with the ~~strike outs~~ and ***additions*** as desired by the RVDL (ref. 5, also called the Blauwe Rapportje [Blue Report]).
The fourth column (RVDL4) contains the findings of the RVDL that differ from the Portuguese final RvO findings, which have been included in an Appendix to the Final Report of the Accident. Only the deviations have been included and ***highlighted*** as in the Appendix. The <u>changes</u> in respect of the 2nd column have been underscored.
The last column contains references to paragraphs in this analysis where explanations are given. An exclamation point in this column marks major differences between RVDL and Final Report.

The times are UTC times = Radar time (of the graphs) + 30 seconds.

§	**Draft Report § 3.1, 21-7- '94, with changes RVDL3:** ~~**strike outs**~~ **|** ***<u>additions</u>***	**Final Portuguese Report, 31 okt. 1994:** **<u>changes</u>**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** **|** **<u>changes</u>**	**Agree ✓ Disagree × See §**
1.	The aircraft was in an airworthy condition and was correctly certified for the flight.	The aircraft was in an airworthy condition and was correctly certified for the flight.		
2.	The weight and balance was within the approved limits	The weight and balance was within the approved limits		
3.	There were no indications of faults on the aircraft or its systems that could have contributed to the degradation of safety nor could have increased the workload on the crew during the final phase of the flight.	There were no indications of faults on the aircraft or its systems that could have contributed to the degradation of safety nor could have increased the workload on the crew during the final phase of the flight.		
4.	The inoperative items at departure from Amsterdam, did not affect the aircraft operation.	The inoperative items at departure from Amsterdam, did not affect the aircraft operation.		✓ 4.8.2
5.	The crew was correctly licensed, qualified and certified for the operation of the aircraft.	The crew was correctly licensed, qualified and certified for the operation of the aircraft.		
6.		<u>The Air Traffic Controllers were properly licensed and qualified</u>.		
7.	The crew and the air traffic controllers were working within the limits of the prescribed working and rest time regulations.	The crew and the air traffic controllers were working within the limits of the prescribed working and rest time regulations.		
8.	The meteo conditions at Faro airport area were influenced by a depression centered at the accident time ~~at about 250 nm ESE of Faro airport~~ *<u>South West of Portugal</u>* with a pressure of 1006 hPa in the center. The depression extended at altitude with an axis practically vertical, bringing into circulation a mass of very humid and unstable maritime air, with an insta-	The meteo conditions at Faro airport area were influenced by a depression centered at the accident time at about 250 nm ESE of Faro airport with a pressure of 1006 hPa in the center. The depression extended at altitude with an axis practically vertical, bringing into circulation a mass of very humid and unstable maritime air, with an insta-	The meteo conditions at Faro airport area were influenced by a depression centered at the accident *time South-West of Portugal* with a pressure of 1006 hPa in the center. [remaining unchanged]	5.3.2

§	**Draft Report § 3.1, 21-7- '94, with changes RVDL3:** ~~**strike outs**~~ **|** ***additions***	**Final Portuguese Report, 31 okt. 1994:** **changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** **|** **changes**	**Agree ✓ Disagree × See §**
	bility which extended practically until the troposphere. In the South-East border of the depression were developing organized lanes of convergence with bank of clouds in which Cb were embedded, with great vertical development that gradually reached the Faro region. The forward part of one of these lanes arrived at the Faro airport about 07.30 UTC and at 12.00 UTC still affected the region. As a consequence strong thunderstorms and heavy rainshowers developed with very significant local wind variations, with gusts developing that in the airport region reached a velocity of 40 kts. The average wind came from South-East and S.S.E. with an average force of 10-17 knots, that, occasionally, with the passing Cb could surpass 20 to 25 knots. The surface visibility was 6 to 9 km, being reduced to 2 - 4 km during the periods of intense rainfall.	bility which extended practically until the troposphere. In the South-East border of the depression were developing organized lanes of convergence with bank of clouds in which Cb were embedded, with great vertical development that gradually reached the Faro region. The forward part of one of these lanes arrived at the Faro airport about 07.30 UTC and at 12.00 UTC still affected the region. As a consequence strong thunderstorms and heavy rainshowers developed with very significant local wind variations, with gusts developing that in the airport region reached a velocity of 40 kts. The average wind came from South-East and S.S.E. with an average force of 10-17 knots, that, occasionally, with the passing Cb could have surpassed 20 to 25 knots. The surface visibility was 6 to 9 km, being reduced to 2 - 4 km during the periods of intense rainfall.		
9.	The forecast for Faro airport for the period 04.00 - 13.00 UTC gave a surface wind of 150°, 15 knots, visibility more than 10 km, 3/8 stratus at 500 ft, 4/8 cumulus, 1200 ft, 5/8 stratocumulus 2500 ft, temporary visibility 6000 m, some moderate showers and some lightning, small or moderate small hail, intermittent vis more than 10 km, moderate thunderstorm and 2/8 Cb at 1800 ft.	The forecast for Faro airport for the period 04.00 - 13.00 UTC gave a surface wind of 150°, 15 knots, visibility more than 10 km, 3/8 stratus at 500 ft, 4/8 cumulus 1200 ft, 5/8 stratocumulus 2500 ft, temporary visibility 6000 m, light rain showers or light or moderate thunderstorms, with rain but no hail, intermittent vis more than 10 km, moderate thunderstorm and 2/8 Cb at 1800 ft.		
10.	At 04.45 UTC the meteo center of Lisbon airport sent a sigmet valid between 06.00 - 12.00 UTC in which was warned for clear air turbulence, moderate and locally severe, above FL 340 and thunderstorms and ice formation in Lisbon FIR.	At 04.45 UTC the meteo center of Lisbon airport sent a sigmet valid between 06.00 - 12.00 UTC in which was warned for clear air turbulence, moderate and locally severe, above FL 340 and thunderstorms and ice formation in Lisbon FIR. This sigmet was not transmitted to the aircraft.		

§	**Draft Report § 3.1, 21-7- '94, with changes RVDL3:** ~~**strike outs**~~ **|** ***additions***	**Final Portuguese Report, 31 okt. 1994:** **changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** **| changes**	**Agree ✓ Disagree ✗ See §**
11.	At 07.09:58 UTC Faro Approach Control gave the following meteo information to MP495: Wind 150° 18 kt, vis. 2500 m, present time thunderstorms, clouds 3/8 at 500 ft, 7/8 at 2300 ft, 1/8 Cb at 2500 ft, Temp. 16°, QNH 1013.	At 07.09:58 UTC Faro Approach Control gave the following meteo information to flight MP495: Wind 150° 18 kt, vis. 2500 m, present time thunderstorms, clouds 3/8 at 500 ft, 7/8 at 2300 ft, 1/8 Cb at 2500 ft, Temp. 16°, QNH 1013.		
12.	The aircraft in the final phase of the approach passed a turbulence area associated with windshear and downburst phenomena that initiated a longitudinal instability of the aircraft.	The aircraft in the final phase of the approach passed a turbulence area associated with windshear and downburst phenomena that initiated a longitudinal instability of the aircraft.		✗ 4.7
13.	~~The crew was not aware of the turbulence intensity due to the influence of the automatic flight control systems operating correctly, degrading the crew's perception of the seriousness of the situation.~~	The use of the automatic flight control systems (ATS + CWS), could have degraded the crew's perception of the turbulence and the instability of the approach.	*The crew was less aware of the turbulence intensity and its consequences on the aircraft stability, due to the influence of the operation of the automatic flight control systems (ATS and CWS).*	✗ 3.2.3 !
14.	The aircraft was informed by Approach Control that the runway was flooded…	The aircraft was informed by Approach Control that the runway was flooded.	The aircraft was informed by Approach Control that the runway was flooded.	✓
15.	…and the crew did not consider this information when calculating the landing distance ~~for braking action POOR~~.	The crew did not associate the term flooded with bad braking conditions (Poor), due to a lack of update of the ICAO phraseology in the Aircraft Operating Manual and Crew Training Manual.	… and the crew did not consider this information *when determining braking action.*	
16.	Approach Control transmitted to the aircraft the instantaneous wind from runway 29 instead of runway 11.	Faro Approach Control transmitted to the aircraft the instantaneous wind instead of the 2 minute average wind and the wind from runway 29 instead of runway 11.	Approach Control transmitted to the aircraft the instantaneous wind from runway 29 instead of runway 11. *In view of the fast changing weather, in the last phase of the approach, the Board considers that this omission had no bearing on the accident, since, even if the correct selection for runway 11 had been made, the warning of the ATC controller would to all probability have come too late to be effective.*	!
17.	~~The wind information by the Area Nav System was not correct owing to the system not taking into account the side slip of the aircraft.~~			✓ AOM 2.15.4 - 06
18.	At 07.32:15 UTC Approach Control transmitted the last wind information. Wind 150° - 15 kts, max. 20 kts.	At 07.32:15 UTC Approach Control transmitted the last wind information. Wind 150° - 15 kts, max. 20 kts.		

§	**Draft Report § 3.1, 21-7- '94, with changes RVDL3:** ~~strike outs~~ | ***additions***	**Final Portuguese Report, 31 okt. 1994: changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** | **changes**	**Agree ✓ Disagree ✗ See §**
	Approach Control transmitted to the aircraft the instantaneous wind from runway 29 instead of runway 11.	Faro Approach Control transmitted to the aircraft the instantaneous wind instead of the 2 minute average wind and the wind from runway 29 instead of runway 11.		
19.	Approach Control did not transmit to the aircraft the wind information on runway 11 that reached 220° with 35 kts between 07.32:40 and 07.33:30 UTC.	Faro Approach Control did not transmit to the aircraft the wind information on runway 11 that reached 220° with 35 kts between 07.32:40 and 07.33:30 UTC.		✗ 5.2.8
20.	*At 07.33:20 UTC the Accident Occurred.*	At 07.33:20 UTC the accident occurred.	*At 07.33:20 UTC the Accident Occurred.*	
21.	At 07.35:30 UTC. The SIO registration gave a warning for windshear.	At 07.35:30 UTC. The SIO registered a warning for windshear.	[2 min 10 sec after the accident]	5.3.6
22.	About 08.00 UTC farm workers gave indications that in the airport zone a very strong wind developed along a narrow lane that passed the beginning of runway 11 from South to North, that destroyed some plastic greenhouses South and North of runway 11, and destroyed part of the airport fence, near the sensors of runway 11, which locally is named Manga de Vento (wind sleeve) and was of sufficient intensity to affect the operations of landing and take-off at Faro airport.	About 08.00 UTC farmworkers gave indications that in the airport zone a very strong wind developed along a narrow lane that passed the beginning of runway 11 from South to North, that destroyed some greenhouses South and North of runway 11, and destroyed part of the airport fence, near the sensors of runway 11. The farmworkers attributed this destruction to a local phenomenon which is locally named Manga de Vento (wind sock) and which would have been of sufficient intensity to affect the operations of landing and take-off at Faro airport.	[27 min. after the accident]	
23.	~~The crew did not integrate~~. The instability and the momentary visibility degradation in the final approach ~~and the runway surface conditions which were transmitted to them, in order to take~~ *were not of such a magnitude that the crew should have made* the decision to discontinue the approach.	The crew did not integrate informations concerning the instability and the momentarily visibility degradation in the final phase of the approach, and having wrongly interpreted the communication of the runway condition (Flooded), did not take the decision to abandon the approach.	The instability and the momentary visibility degradation in the final approach *were not of such a magnitude that the crew should have made* the decision to discontinue the approach	✓ 5.3.8 !!
24.	The ~~function~~ *autopilot* CWS *mode disengaged* ~~was switched off~~ at R.A. 80 ft, apparently non-intentional. ~~When the crew had done it intentionally it should have been done above 150 ft.~~ *The crew did not notice the resulting "autopilot red light" flashing signal*.	At 80 ft RA the autopilot disengaged the CWS mode, apparently not intentionally. There are no clear indications that the crew became aware that the warning light for this condition was lit.	The autopilot CWS mode disengaged at R.A. 80 ft, apparently non-intentional. *There is no evidence that the crew noticed the resulting "autopilot red light" flashing signal.*	✓ 5.3.9 !

§	**Draft Report § 3.1, 21-7- '94, with changes RVDL3:** **~~strike outs~~ | *additions***	**Final Portuguese Report, 31 okt. 1994:** **changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations* | changes**	**Agree ✓ Disagree × See §**
25.		The function CWS of the autopilot was switched off at (RA) 80 ft, apparantly not intentionally, while it should have been done by crew decision at a height not below 150 ft above the runway threshold.		✓
26.	~~The power was reduced at 150 ft instead of at 50 ft by autothrottle action.~~ *At 150 ft the power was reduced to flight idle. This power reduction was in all probability initiated by the ATS with a follow through by the F.O. Also the sustained flight idle thrust condition was most probably a result of action of the F.O.*	At 150 ft (RA) power has been reduced to flight idle through ATS and kept at flight idle, probably by copilots action. Under normal conditions the ATS retard mode starts at 50 ft (RA).	*At 150 ft the power was reduced to flight idle. In all probability this power reduction was initiated by the ATS with a follow through by the F.O. Also the sustained flight idle thrust condition was most probably a result of action of the F.O. Normally. The ATS Retard Mode starts at 50 ft RA.*	✓ 5.3.10 4.6.19
27.	The ~~premature power reduction and the~~ sudden wind variation in direction and intensity *during the last phase of the final approach* created a crosswind component which exceeded the aircraft limits in the AOM, ~~aggravating the rate of descent~~.	The premature power reduction and the sudden wind variation probably increased the rate of descent, which reached values exceeding the operational limits of the aircraft.' According to the values registered in the SIO, there has not been a significant variation of wind speed and direction in the last 20 seconds.	The sudden wind variation in direction and intensity *during the last phase of the final approach* created a cross-wind component which exceeded the aircraft limits in the AOM.	× 5.3.11 !!
28.	The crew intervention for power increase of the engines was too late to stop the high rate of descent.	The captain's intervention during the whole approach seems to have been too passive, and concerning the last power increase, it came too late.		✓
29.	*Due to the premature large and sustained power reduction and the tailwind component* ~~The aircraft~~, in the final approach phase *the aircraft* attained a rate of descent of about 1000 ft/min, ~~that exceeded the operational limit of 600 ft/min, for max. landing weight conditions as mentioned in the AOM.~~		*Due to the premature large and sustained power reduction and the sudden wind shift (tailwind component)* in the final approach phase *the aircraft* attained a rate of descent of about 1000 ft/min.	× 4.6.5
30.	The fracture of the right landing gear was caused by the combination of the *touchdown on the right hand aft wheel, the crabangle and the* high rate of descent a~~nd the significant sideslip to the right~~.	The fracture of the right main landing gear was due to the combination of the high rate of descent and the drift correction taking place at the moment of contact with the runway.	The fracture of the right landing gear was caused by the combination of the *touchdown on the right hand aft wheel, the crabangle and the* high rate of *descent*	× 5.3.12 4.6.10 3.1.15

§	Draft Report § 3.1, 21-7- '94, with changes RVDL3: ~~strike outs~~ | *additions*	Final Portuguese Report, 31 okt. 1994: changes	Comments RVDL4, 6-9-'94 in Appendix of Final report: *deviations* | changes	Agree ✓ Disagree × See §
31.	The wind sensors from runway 11 are installed 17 m above runway level, near a hole 7 m deep, located between the sensor and the runway.	The wind sensors from runway 11 are placed 17 m above runway level, next to a hole 7 m deep, located between the sensor and the runway.		
32.		The average wind is determined by a scaled average of wind direction and intensity of the wind during the given period and not by a vectorial average.		
33.	The meteo clock of SIO showed a lag of one minute and 30 sec relative to the reference ATC clock	The meteo clock of SIO showed a lag of one minute and 30 secs relative to the reference ATC clock		3.3
34.	There were no written procedures for time synchronization. SIO registration did not include all meteo information displayed in the tower control positions.	There are no written procedures for time setting of the SIO clock. SIO registration does not include all meteo information displayed in the control tower positions.		
35.	There are no written agreements between INMG and ANA about the way of working of the SIO.	There is no written agreement between INMG and ANA about the way of processing the information supplied by SIO.		
36.	There are no defined responsibilities about the calibration of the meteo sensors.	The definitions concerning the calibration of the meteo sensors are interpreted in a different way by ANA and by INMG.		
37.	On the tower there are no individual displays for each separate sensor.	On the control tower there are no individual displays for each of the zones covered by each pair of sensors.		
38.	The visual displays do not have a clear indication of the zone of runway they represent.	The wind displays do not have a clear indication of the area from which the information comes.		
39.	There are no written procedures concerning the checks to be carried out by ATC personnel prior to start of their work.	There are no written procedures concerning the checks to be carried out by ATC personnel prior to start of their work, neither concerning their tour of duty, in order to assure the correction of available information.		
40.	There are no published Air Traffic Service procedures to decrease the possibility of human error.	There are no written Air Traffic Service procedures to minimise the possibility of human error.		
41.	It was not evident that DGAC had inspected the ATC Service at Faro airport.	It has not been evident that DGAC had inspected the ATC Service at Faro airport, according to paragraph 0, of article 3rd, of law decree 242/79.		!

§	**Draft Report § 3.1, 21-7- '94, with changes RVDL3:** ~~**strike outs**~~ **|** ***additions***	**Final Portuguese Report, 31 okt. 1994:** **changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** **| changes**	**Agree ✓ Disagree × See §**
42.	The action of the fire fighting personnel was hampered by the difficult terrain at the place of the accident.	The action of the fire fighting personnel at the airport was hampered by the access conditions to the place of the accident.		
43.	The fire was started by the rupture of the integral tanks of the right wing, after the impact with the runway.	The fire was started by the rupture of the integral tanks of the right wing, after the impact with the runway.		
44.	The survivability was conditioned by the fire which broke out and propagated after the impact.	The survivability was conditioned by the fire which broke out and propagated after the impact.		
45.	The accident was generally survivable. The action of the fire fighting personnel had a significant contribution to the survivability of the aft section, keeping open the escape routes.	The accident was generally survivable. The action of the fire fighting personnel had a significant contribution to the survivability of the aft section, keeping open the escape routes.		
46.	The emergency plan was activated correctly but development of the plan was affected by insufficient coordinating instructions.	The emergency plan was activated correctly but its further development was affected by insufficient coordinating instructions.		
47.	The medical equipment at Faro airport was in certain areas insufficient.	The medical equipment at Faro airport at the time of the accident was inadequate in certain aspects.		

Appendix 10. Causes from Accident Report versions § 3.2

See the comments at the top of Appendix 10 on page 54.

The RVDL wanted to completely replace the causes drawn up by the CvO with its own (1st column). The CvO did not adopt this in the final report (highlighted 3rd column). The amendments desired by the RVDL were retained the Appendix to the RvO (4th column).

§	**Draft Report § 3.2, 21-7- '94, with changes RVDL3:** ~~**strike outs**~~ **|** ***additions***	**Final Portuguese Report, 31 okt. 1994: changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** **| changes**	**Agree ✓ Disagree ✗ See §**
48.	~~The commission of inquiry determined that the probable causes for the accident were:~~	The commission of inquiry determined that the probable causes for the accident were:		
49.	~~- The high rate of descent in the final phase of the approach.~~	- The high rate of descent in the final phase of the approach and the landing made on the right landing gear, which exceeded the structural limitations of the aircraft.		✗ 4.6.5
50.	~~- The crosswind which occurred in the final phase of the approach, not known to the crew, which exceeded the aircraft limits~~	- The crosswind, which exceeded the aircraft limits and which occurred in the final phase of the approach and during landing.		✓ 4.5.2
51.		The combination of both factors determined stresses which exceeded the structural limitations of the aircraft.		✗ 4.6.5
52.	*The commission of inquiry determined that the accident was initiated by:*		*The commission of inquiry determined that the accident was initiated by:*	
53.	*- a sudden and unexpected wind variation in direction and speed (windshear) in the final stage of the approach.*		*- a sudden and unexpected wind variation in direction and speed (windshear) in the final stage of the approach.*	✗ !!
54.	*Subsequently a high rate of descent and an extreme lateral displacement developed, causing a hard landing on the right-hand main gear, which in combination with a considerable crab angle exceeded the aircraft structural limitations.*		*Subsequently a high rate of descent and an extreme lateral displacement developed, causing a hard landing on the right-hand main gear, which in combination with a considerable crab angle exceeded the aircraft structural limitations.*	✗ !!

Vervolg met de aan het ongeval bijdragende factoren op de volgende pagina.

Appendix 12. The contributing factors to the accident from versions RvO § 3.2.

See the comment at the top of Appendix 10 on page 54.

§	**Draft Report § 3.2, 21-7- '94, with changes RVDL3:** ~~**strike outs**~~ **|** ***additions***	**Final Portuguese Report, 31 okt. 1994: changes**	**Comments RVDL4, 6-9-'94 in Appendix of Final report:** ***deviations*** **| changes**	**Agree ✓ Disagree × See §**
55.	- *From the prevailing weather neither the meteorological office (SIO) nor the crew of MP495 did anticipate the possibility of the existence of windshear phenomena.*		- *From the forecast and the prevailing weather the crew of MP495 did not expect the existence of windshear phenomena..*	✓ 5.5.1
56.		The instability of the approach.		✓
57.	- The premature large power reduction and *sustained idle thrust, most probable* due to crew action.	The premature power reduction, and the sustaining of this condition, probably due to crew action.	- The premature large power reduction and *sustained idle thrust, most probable* due to crew action.	✓ 5.5.2
58.	- The incorrect wind information delivered by Approach Control.	The incorrect wind information delivered by Approach Control.		
59.	- ~~The incorrect wind information delivered by the Area Nav on board.~~			× 5.5.3
60.	- ~~The crew's decision to continue the approach for a runway without approach lights, after having lost visual reference at about 250 ft altitude.~~	The absence of an approach light system.		× 5.5.4
61.	~~- The incorrect evaluation by the crew of the runway condition.~~	The incorrect evaluation by the crew of the runway conditions.		✓ 5.5.5
62.	- CWS mode being ~~switched off below the prescribed altitude~~, *disengaged at 80 ft RA* causing the aircraft to be in manual control ~~with as a consequence an abrupt flare and a hard landing~~ *at a critical stage in the landing phase*.	CWS mode being switched off at approx. 80 ft RA, causing the aircraft to be in manual control in a critical phase of the landing.	- CWS mode being *disengaged at 80 ft RA* causing the aircraft to be in manual control *at a critical stage in the landing phase.*	× 5.5.6
63.	~~- The delayed action of the crew in increasing power.~~	The delayed action of the crew in increasing power.		✓ 5.5.7
64.	- ~~The degradation of the lift coefficient due to the heavy rain.~~	The degradation of the lift coefficient due to the heavy showers.		× 5.5.8
65.	- ~~The fraction of the landing~~ gear~~, caused by the high rate of descent, combined with the significant side slip of the aircraft on impact with the runway.~~			× 5.5.9

.