REPORT ON THE ACCIDENT

OF

PAKISTAN INTERNATIONAL AIRLINES A300

FLIGHT PK268 (AP-BCP)

ON

28 SEPTEMBER 1992

His Majesty's Government of Nepal
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This report has been published by His Majesty's Government of Nepal as submitted by the Commission for the Accident Investigation of PK 268 Airbus, established for the purpose of advancing aviation safety, in accordance with Annex 13 to the Convention on International Civil Aviation.

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His Majesty's Government of Nepal established the Commission for the Accident Investigation of PK268 for the purpose of advancing aviation safety. It is not the function of the Commission to assign blame or determine civil or criminal liability.

SYNOPSIS

The accident was notified to national and foreign authorities by His Majesty's Government of Nepal, Ministry of Tourism and Civil Aviation, Department of Civil Aviation. Accredited representatives were nominated by Pakistan (the state of registry and of the operator) and France (the state of manufacture). The State of occurrence also requested assistance through the International Civil Aviation Organisation (ICAO) and specialist investigators were provided by the British, Australian and Canadian air accident investigation branches. These investigators arrived in theatre on 2nd and 3rd October. The formal investigation commenced on 3rd October following a meeting of the Commission. This report has been prepared by the Commission appointed by His Majesty's Government of Nepal.

The ill-fated aircraft departed Karachi Airport, Pakistan, at 0613 hours UTC on 28 September 1992 as Pakistan International Airlines Flight Number PK268, a non-stop service to Kathmandu, Nepal. The accident occurred at 1430 hours local time (0845 hours UTC) when the aircraft struck a mountain during an instrument approach to Kathmandu's Tribhuvan International Airport. The impact site was at an altitude of 7280 feet above sea level (2890 feet above airport level), 9.16 nautical miles from the VOR/DME beacon and directly beneath the instrument approach track.

An aerial search for the aircraft was conducted shortly after it failed to respond to ATC transmissions. People in a village below the impact area heard but did not see the crash. Later, flames were seen through the mist which enveloped the crash site and the location was reported to the staff of a navigation facility. Rescue services coordinated by the Royal Nepalese Army, the Nepalese Police and the Department of Civil Aviation reached the accident site within three hours but all 167 persons on board had lost their lives in the impact.

The balance of evidence suggests that the primary cause of the accident was that one or both pilots consistently failed to follow the approach procedure and inadvertently adopted a profile which, at each DME fix, was one altitude step ahead and below the correct procedure. Why and how that happened could not be determined with certainty because there was no record of the crew's conversation on the flight deck. Contributory causal factors were thought to be the inevitable complexity of the approach and the associated approach chart.

1 FACTUAL INFORMATION

1.1 History of the flight

Pakistan International Airlines flight 268 departed Karachi on 28 September 1992 at 0613 hrs UTC for a direct flight to Kathmandu. On board were four flight deck crew, eight cabin crew, four air guards, three ground engineers and 148 passengers of various nationalities, fuel for the flight to Kathmandu and much of the fuel required for the return flight to Karachi. The flight through Pakistani and Indian airspace appears to have proceeded normally. At 0825 hrs UTC (1410 hrs local time) two way contact between Pakistan 268 and Kathmandu Area Control West was established on VHF radio and the aircraft was procedurally cleared towards Kathmandu in accordance with its flight plan. After obtaining the Kathmandu weather and airfield details, the aircraft was given traffic information and instructed to report overhead the SIM (Simara) non-directional beacon (214°R/39 nm from Kathmandu's KTM VOR/DME[1]) at or above Flight Level (FL) 150 as cleared by the Calcutta Area Control Centre. At 08:37 hrs the co-pilot reported that the aircraft was approaching the SIM beacon at FL 150, whereupon procedural clearance was given to continue to position SIERRA (202°R/10 nm from the KTM beacon) and to descend to 11,500 feet altitude. No approach delay was forecast by the area controller and the co-pilot correctly read back both the clearance and the instruction to report at 25 DME. At 0840:14 hrs he reported that the aircraft was approaching 25 DME whereupon the crew were instructed to maintain 11,500 feet and change frequency to Kathmandu Tower.

Two-way radio contact with the Tower was established a few seconds later and the crew reported that they were in the process of intercepting the final approach track of 022°M (Magnetic). They were instructed to expect a SIERRA approach and to report at 16 DME. At 08:42:51 hrs the first officer reported "ONE SIX DME AT ELEVEN THOUSAND FIVE HUNDRED". The tower controller responded by clearing the aircraft for the SIERRA approach and instructing the crew to report at 10 DME. At 08:44:27 the first officer reported 10 DME and three seconds later he was asked "REPORT YOUR LEVEL". He replied "WE CROSSED OUT OF EIGHT THOUSAND FIVE HUN' TWO HUNDRED NOW". The controller replied with the instruction "ROGER CLEAR FOR FINAL, REPORT FOUR DME RUNWAY ZERO TWO". The co-pilot responded to this instruction in a normal, calm and unhurried tone of voice; his reply was the last transmission heard from the aircraft.

Thirty two seconds after the co-pilot reported 10 DME the aircraft crashed into a steep, cloud-covered mountainside at 7,280 feet amsl and 9.16 nm on radial 202

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1 Two co-located radio navigation beacons which give magnetic bearing in degrees (radial) and distance in nautical miles (DME) from the beacon site. The letters KTM which are transmitted in morse code identify the beacons.

from the VOR/DME beacon (9.76 nm from and 2970 ft above the threshold of runway 02 which is 77 feet below the airport datum).

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	19	148	None
Serious	None	None	None
Minor/none	None	None	

1.3 Damage to aircraft

The aircraft was totally destroyed.

1.4 Other damage

Trees and vegetation on the mountainside were burned over one main and several adjacent smaller areas. Rocks and loose soil were dislodged by the impact and by subsequent rescue and inspection activities on the site.

1.5 Personnel information

1.5.1 Aircrew

Commander:	Pakistani male aged 49 years
Licence:	ALTP No 373 issued by Pakistan CAA on 3 Nov 73
Certificate of Validity:	Valid to 9 Dec 92
Types on licence:	Group 1: Airbus A-300 Group 2: None
Instrument Rating:	Renewed 21 May 92 valid to 9 Dec 92
Instructor Rating:	Route check pilot wef 12 July 87 Simulator instructor wef 8 Jun 89
Last route check:	25 May 87
Last simulator check:	21 May 92
Last medical check:	Class 1 medical renewed on 31 May 92 endorsed "subject to use of corrective glasses". The commander's hearing acuity had been reducing over a period of years and at his last audiometry check, on 19 November 1990, it had reduced to the category of "borderline".

Hours flown: (At time of reporting for duty on 29 Sep)

Type	Command	Co-pilot
A300	6260:30	1:00
B707-200	2136:46	726:23
DC-10	0	888:30
Propeller aircraft	1493:35	1688:18
Total	9890:51	3295:44
Grand total	13186:35	

Recency (At time of reporting for duty on 29 Sep 92)

Previous:	24 hrs	Month	3 Months	6 months	Year
Hours/mins:	0	36:13	121:41	223:38	605:31

Duty period last 24 hours:	3 hrs 45 mins
Previous operations to Kathmandu during 1992:	23 Jul, 20 Feb, 6 Feb, 9 Jan

Co-pilot:	Pakistani male aged 38 years
Licence:	CPL No 842 issued by Pakistan CAA on 24 Dec 84
Certificate of Validity:	Valid to 11 Nov 92
Types on licence:	Group 1: None Group 2: Airbus A-300
Instrument Rating:	Renewed 23 Jun 92 valid to 28 Dec 92
Instructor Rating:	None
Last route check:	10 Apr 91
Last simulator check:	23 Jun 92
Last medical check:	Unrestricted class 1 medical renewed on 21 Apr 92
Hours flown:	(At time of reporting for duty on 29 Sep)

Type	Command	Co-pilot
A300		1469:26
B737		518:48
Propeller aircraft	295:20	3565:26
Total	295:20	5553:40
Grand total	5849:00	

Recency (flight hours at time of reporting for duty on 29 Sep)

Previous:	24 hrs	Month	3 Months	6 months	Year
Hours/mins	3:57	67:43	196:45	378:32	625:08

Duty period last 24 hours:	3 hrs 45 minutes
Previous operations to Kathmandu during 1992:	18 June 1992

Operating Flight Engineer:	Pakistani male aged 40 years
Licence:	FEL No 224 issued by Pakistan CAA on 13 Mar 82
Certificate of Validity:	Valid to 10 Dec 92
Types on licence:	Airbus A-300
Instructor Rating:	None
Last route check:	N/A (Recently returned from 3 year secondment to Malaysian airlines and operating under supervision)
Last simulator check:	18 Sep 92 (by Malaysian airlines)
Last medical check:	Unrestricted class 2 medical issued on 11 Dec 91
Hours flown:	(At time of reporting for duty on 29 Sep)

A300	2516:25
B707-200	2773:26
Total	5289:51

Recency (flight hours with PIA at time of reporting for duty on 29 Sep)

Previous:	24 hrs	Month	3 Months	6 months	Year
	0	3:24*	3:24*	3:24*	3:24*

*Had flown 1634.08 hours during secondment to Malaysia between Aug 89 and 18 Sep 92

Duty period last 24 hours: 3 hrs 45 mins

Previous operations to Kathmandu during 1992: None

Supervisory Flight Engineer:	Pakistani male aged 42 years
Licence:	FEL No 185 issued by Pakistan CAA on 25 Sep 78
Certificate of Validity:	Valid to 24 Nov 92
Types on licence:	Airbus A-300
Instructor Rating:	Route check engineer wef 15 Nov 88 Simulator instructor wef 20 Feb 89
Last route check:	29 May 92
Last simulator check:	10 Sep 92
Last medical check:	Class 2 medical re-issued on 25 May 92 Medical category withdrawn on 13 Apr 92 for 4 weeks due to a diabetic problem.
Hours flown	(At time of reporting for duty on 29 Sep)

A300	4503:53
B707-200	3716:56
Total	8220:49

Recency: (At time of reporting for duty on 29 Sep)

Previous:	24 hrs	Month	3 Months	6 months	Year
Hours/mins:	1:00	46:32	161:37	185:07	492:40

Duty period last 24 hours: 3 hrs 45 mins

Previous operations to Kathmandu: Before 1st April 1992

1.5.2 Air Traffic Control

There were several controllers on duty in Air Traffic Control at the time of the accident but only the Tower controller was in R/T contact with the aircraft during its approach.

Tower controller:	Nepalese male aged 35 years.
Licence:	Not issued and not required under Nepalese regulations.
Ratings:	Not formally issued. All controllers are trained for and rotate through the area control centre, ATS reporting office and control tower positions after qualifying as controllers.
Training:	Completed 52 week ATC course in Kathmandu in Feb 82. Completed approach control (non-radar) course in Sri Lanka in Dec 91
Experience:	Employed as an air traffic controller at various Nepalese airfields since completion of Nepalese training in Feb 82. Returned to Kathmandu airport in early 1990.

Duty period last 24 hours:	3 hrs 30 mins

1.6 Aircraft Information

1.6.1 Leading Particulars

Type:	Airbus Industrie A300-B4
Constructor's number:	025
Date of manufacture:	1976
Certificate of Registration:	The Civil Aviation Authority of Pakistan issued the aircraft with Certificate of Registration number 590 on 22 April 1986.
Certificate of Airworthiness:	The Civil Aviation Authority of Pakistan issued a Certificate of Airworthiness, number 543/1 for the aircraft on 28th April 1986. The Certificate was renewable annually, and was last renewed on 22nd April 1992. It was therefore current at the time of the accident.
Total airframe hours/cycles:	At the time of the accident, the aircraft had achieved 39045 hours and 19172 cycles.
Engines	The engines were GE CF6-50C2 turbofans, manufactured by General Electric Aircraft Engines of Cincinnati, Ohio, USA.
Maximum take-off weight:	165,000 kg
Actual take-off weight:	147,302 kg
Centre of gravity at take-off:	25.9% mean aerodynamic chord
Maximum landing weight:	134,000 kg
Estimated weight at impact:	130,500 kg

1.6.2 Maintenance history

1.6.2.1 General

A review of the aircraft documentation revealed no accidents or accidental damage to the aircraft since it entered service with PIA. No discrepancies were noted in the incorporation of mandatory modifications, airworthiness directives or local modifications.

1.6.2.2 Scheduled maintenance

The aircraft was required to be maintained in accordance with a Maintenance Schedule approved by CAA Pakistan under the Certificate of Approval HQCAA/2210/3/AW issued to PIA. Documentation obtained from the airline showed that all scheduled checks had been accomplished prior to the departure of PK268 on 28th September 1992.

1.6.2.3 Pilots defect reports

The pilots defect reports for the three months prior to the accident were examined and assessed. As with any large airliner, there was a considerable number of reported defects, including recurring problems with the weather radar, thrust reversers and electrical power generation. However the statistical breakdown of the defects revealed no undue incidence of recurring defects. Any defects reported by the flight crew must be considered with reference to the Minimum Equipment List (MEL). This document contains a preamble which explains the functions of the MEL, the following is an extract from it:

> 'The CAA rules require that all equipment installed on an aircraft in compliance with the Airworthiness Standards and Operating Rules must be operative. However, the rules also permit the publication of a Minimum Equipment List where compliance with certain equipment requirements is not necessary in the interest of safety under all operating conditions. Experience has shown that with the various levels of redundancy designed into aircraft, operation of every system or installed component may not be necessary when the remaining operative equipment can provide an acceptable level of safety.'
> "..........The MEL is intended to permit operation with inoperative items of equipment for a period of time until repairs can be accomplished. "

Paragraph 3.4 of the MEL states the following requirement:

For defects that are carried forward ex-base (*ie* Karachi), the status report will be sent to Flight Standards Directorate, CAA, every three days.'

At the time of departure of PK268 from Karachi there were two uncleared defects that were within the limits imposed by the MEL.

a) 20th September 1992: The No.1 autopilot trips on flap extension and cannot be re-engaged.

b) 24th September 1992: The No.2 thrust reverser stuck in the deployed position. It was deactivated and secured in the stowed position.

Each of these unseviceabilities is allowed by the MEL for a maximum of ten days; and neither exceeded this limit. The A300 is equipped with two autopilot systems and there was no record of problems with the No. 2 autopilot. The MEL allows for one thrust reverser to be inoperative provided it can; *a)* be deactivated and stowed; *b)* no operational procedure is dependent on its use; and *c)* the autothrottle is disarmed on final approach.

A review of the MEL defects over the three months preceding the accident revealed that approximately 65% were being cleared before the aircraft next departed from Karachi. However, it was established that Paragraph 3.4 of the MEL was not being complied with in that PIA were not sending the carry-forward defect summaries to the CAA; furthermore the CAA were not applying any pressure to the airline to supply them.

The aircraft was carrying one additional item of unserviceability that had not been rectified and was not covered by the MEL. This was reported on 29th September 1992 and concerned the right hand mechanical downlock indicator, which was flush with the wing surface. This had been assessed as having no airworthiness significance and had been held over for rectification during a major service.

1.6.2.4 Ground proximity warning system (GPWS) maintenance history

The ground proximity warning computer (GPWC) was a Sundstrand Mark II, Part Number 965-0476-088. The computer takes inputs from the No. 1 air data computer (ADC) and the No. 1 radio altimeter transmitter/receiver (Rad Alt T/R). All these components are maintained "on condition". The GPWC component history card showed that it had been released from PIA's avionics workshops on 27 November 1989 (this was the unit's first workshop visit in PIA's ownership) and installed on AP-BCP on 2nd January 1991.

The pilots' defect reports for the three months prior to the accident contained the following GPWS defects:

a) 14th August 1992: GPWS test u/s and Rad Alt No. 1 flag came on. (On the ground at Jeddah)

b) 21st August 1992: TERRAIN and PULL UP audio warnings triggered in the cruise and No. 1 Rad Alt OFF flag appeared.

The first was listed as an MEL item and carried until 15th August when the No. 1 Rad Alt T/R was changed, resulting in a satisfactory BITE test. In the second case, the rectification action was to interchange both Rad Alt T/Rs, which resulted in a satisfactory ground test.

The GPWS is a Category B item in the MEL, meaning that it is required to be repaired within three days of a malfunction being reported. There is also a "Supplemental Procedure" requirement which states:

'...May be inoperative provided it does not render any other aircraft system or equipment inoperative but (the aircraft) must not depart from Karachi with inoperative GPWS.'

PIA have not encountered significant reliability problems with the GPW Computer, as the following A300 fleet component removal statistics indicate:

1990:	1 removal.	Removal rate 0.04/1000 hrs (no confirmed failures)
1991:	3 removals.	Removal rate 0.15/1000 hrs (one confirmed failure)
1992:	Nil removals	

1.6.2.5 Cockpit voice recorder (CVR) maintenance

The replay of the CVR revealed that the cockpit area microphone (CAM) was inoperative. Although the "test" button is operated by the crew during the pre flight checks, this only tests the recording heads and the tape, and not the signal supply to the recorder. There is provision for a full system test by utilising the microphone jack on the microphone monitor panel to monitor the audio signal. This check is conducted by maintenance personnel during scheduled maintenance. The last CAM check on AP-BCP was a transit check carried out three sectors prior to the accident, with no problems being reported.

1.7 Meteorological information

1.7.1 General situation.

There was high pressure at the 850 millibar level (approximately 5000 feet amsl) to the east and to the west of Kathmandu with a shallow low pressure area to the south of Patna in India. The monsoon season in the Kathmandu valley was almost over but the situation was changing only slowly. The 0825 hrs UTC satellite picture showed no significant cloud over northern India, about four oktas of cloud over western Nepal and about seven oktas over eastern Nepal including Kathmandu.

1.7.2 Forecast weather

Terminal aerodrome forecasts (TAFs) were issued by the Kathmandu meteorological office at 0100 hrs UTC and again at 0300 hrs UTC. For the time of the accident, there was no significant difference between the forecasts which were:

Wind 240°/08 kt, visibility more than 10 kilometres, 2 (later 3) oktas of stratocumulus (SC) base 3000 feet aal (above airfield level), 3 oktas of altocumulus

(AC) base 10,000 feet aal and temporarily 1 okta of cumulonimbus (CB) base 2000 feet aal.

1.7.3 Observed weather

Routine weather reports for Kathmandu airport are issued at 50 minutes past the hour. The report preceding the accident and the report issued five minutes afterwards are tabled below:

Observed weather at Kathmandu airport						
Time UTC	Wind Vel knots	Visibility km	Cloud & Base (oktas and feet)	Temp	QNH (mb)	Trend
0750	300°/06	More than 10	7 oktas coverage 3 CU at 2000 1 CB at 2500 6 SC at 3000	25°C	1015	No significant change
0850	210°/05	More than 10	7 oktas coverage 3 CU at 2000 6 SC at 3000	24°C	1014	No significant change

1.7.4 Pilot reports

The commander of an aircraft which arrived at Kathmandu two hours before the accident reported that there was a large cumulus cloud developing into a cumulo-nimbus to the east of the SIERRA approach track at 28 DME and a well-developed cumulo-nimbus cloud on the approach track at about 18 DME. He diverted by some 5 to 7 nm off-track to avoid the second cloud, remaining in VMC (visual meteorological conditions), and then regained track. He did not see the airport until 8 DME. He also stated that, in his experience, at that time of the year any turbulence encountered is invariably associated with cloud.

The commander of the aircraft which completed the preceding SIERRA approach, one hour before PK268, stated that he experienced no turbulence between 25 DME and landing. There was an easterly wind of about 10 kt during the approach and one or two cumulo-nimbus clouds two or three nautical miles east of the approach path. From 16 DME to 5 DME he was in IMC (instrument meteorological conditions) within cumulus cloud and rain was encountered between 8 DME and 5 DME. He broke out of cloud at 6000 feet amsl (1700 ft aal) and the runway was visible from that time.

The commander of Pakistan 268 reported to the Calcutta and Kathmandu area control centres that, in the vicinity of the Nepalese/Indian border, he was deviating by 10 to 15 nm to the right of planned track to avoid towering clouds. About 55 nm from Kathmandu he broadcast a message to his passengers on the Cabin PA (passenger address) system stating that "THE WEATHER BUILT UP VERY FAST IN THE AREA OF SUCH NATURE OVER THE HIMALAYAN RANGE"; he then relayed to them the Kathmandu weather report in general terms. At 0838:41 (about 34 DME) whilst in descent from FL 150 to 11,500 feet, he made another PA broadcast to the passengers and cabin crew stating "WE ARE ENTERING INTO THE AREA OF TURBULENCE AND I REQUEST ALL OF YOU TO REMAIN SEATED".

1.7.5 Weather at the accident site

Eye witnesses close to the accident site at the time of impact stated that there was little or no wind, no rain and no thunderstorm in their vicinity. The visibility was about 20 metres in mist. Observers at the airport reported that small patches of blue sky were visible but the tops of the mountains to the south of the airport were hidden by cloud.

1.8 Aids to navigation

The primary navigation aids are the co-located VOR/DME beacons sited 0.6 miles from the threshold of runway 02 and in line with it. There are also non directional beacons (NDB) on the airfield, at 6.5 DME on radial 106 and at 4 DME on radial 202. There is a fan marker at 8.2 DME beneath the SIERRA approach path and runway 02 is equipped with an optical approach slope indicator system (TVASI) and high intensity approach lights.

The VOR equipment is an AWA Doppler VOR Beacon Type VRB-50D; the DME is a Northrop Wilcox 596B. Both were installed in the 1970s and are flight-checked on a biennial basis. Checks completed on 9 Oct 90 and on 29 Oct 92 found that the equipment was operating satisfactorily within prescribed tolerances; there was no change in DME pulse width or spacing between the two calibrations. Both sets of equipment are provided with main and standby power supplies and are remotely monitored in a control centre at the airport. Each morning the equipment is site checked and operating tolerances are recorded. Alarm systems at the Tower and Area Controller positions sound if either equipment fails.

All aids were reported as being serviceable both prior to and after the approach of PK268. At the time of the accident another aircraft 14 nm from Kathmandu was receiving DME range indications.

1.9 Communications

Air Traffic Control communications with aircraft entering Nepalese airspace is primarily by VHF radio. PK268 communicated with Kathmandu Control West and Kathmandu Tower on the published VHF frequencies; no difficulties were evident or reported. Voice communication with these agencies was recorded. A transcript of the recordings is attached at Appendix A.

1.10 Aerodrome information

1.10.1 Aerodrome

Tribhuvan International Airport is situated in a bowl-shaped valley about 14 nm in diameter and surrounded on all sides by high ground. The minimum safe altitude to the north of the airport is 21,000 feet; to the south it is 11,500 feet. The transition altitude is 13,500 feet. The aerodrome reference point is at 27° 41.8' North 085° 21.7' East. The airport elevation is 4390 feet above mean sea level. There is a single bitumen runway aligned 022°/202° which is 3050 metres long and 46 metres wide. The runway 02 threshold elevation is 4313 feet. All relevant airport facilities were reported as serviceable.

1.10.2. Air Traffic Control Procedures

The Kathmandu FIR (Flight Information Region) is divided into two sectors: Nepalgunj to the west and Kathmandu to the east of longitude 83° east. The Kathmandu sector is further divided into two sub-sectors: east and west. The division is aligned with the 160° and 360° radials from the VOR beacon. The aerodrome control zone extends from ground level to 8500 feet amsl out to 10 nm. The TCA (terminal control area) extends out to 25 nm from the aerodrome from 8,500 feet to FL 460. The area to the north of the aerodrome is shaped, due to the terrain, and is defined in the Nepalese AIP.

There is no radar at Kathmandu. Control of IFR (Instrument Flight Rules) traffic is procedural and based on position reports relative to the VOR/DME beacon. Control of all traffic in the control zone and traffic in the TMA at and below 11,500 feet is vested with the Tower controller.

1.10.3 Instrument approach procedures

There are two published instrument approach procedures to the airport. The ECHO approach from the east and the SIERRA approach from the south. Airways traffic arriving from the Calcutta FIR normally arrives using the SIERRA approach procedure which has been in use since 1978. It is published on charts available from at least four sources (HMG/N Dept of Civil Aviation; Jeppesen, SAS and Aerad). A copy of the Jeppesen SIERRA approach chart which should have been used by the crew of PK268 is at Appendix B. However, there was evidence to suggest that many crews made a hand drawn version of the procedure, in order to clarify the letdown, and used this rather than the official chart during the procedure.

1.10.4 The State Instrument approach chart

The State chart bears the legend "INSTRUMENT APPROACH CHART - ICAO" near the top left corner and so it is assumed that the approach was designed to conform with ICAO Procedures for Air Navigation Services - Aircraft Operations

(PANS OPS). The design of the State chart was compared with the current volume (Doc 8168 - OPS/611 Volume II Third edition 1986.)

The procedure appears to accord broadly with current PANS OPS principles except in the matter of procedural segments and descent profiles. The main exceptions are listed below together with the corresponding sections of PANS OPS in brackets.

a. The final approach fix is not designated. (Page 3-37 para 6.1). It is assumed to be the start of the steep section at the SIERRA fix (10 DME)

b. The number of step-down fixes in the final approach segment exceeds the recommended maximum of two for the final segment of a DME approach. (Page 3-16 para 2.8.3)

c. Although distance information is available from the DME, descent profile advisory information for the final approach is not provided to assist the pilot to maintain the calculated descent gradient. There should be a table showing altitudes/heights through which the aircraft should be passing at each 2km or 1 nm. (Page 3-5 para 1.8 and page 3-134 para 26.5)

d. The descent gradients for the final approach segment are not displayed on the chart. The gradients between 10 DME and 5 DME exceed the recommended maximum of 6.5% (3.73°) for a VOR/DME approach. (Page 3-133 Para 26.4.4.1)

1.11 Flight recorders

The Cockpit Voice Recorder (CVR) was a Sundstrand AV557A which has a 30 minute duration. A satisfactory replay was obtained by the French Bureau Enquetes at their facility in Paris. Three of the four channels (crew members 1, 2 & 3) were replayed satisfactorily and transcribed. The fourth channel (the cockpit area microphone) had no recorded signal on any part of the tape. Therefore, as the crew did not have boom microphones on their headsets, only messages broadcast to the passengers on the cabin PA (passenger address) system and brief transmissions to and from Indian and Nepalese ATC agencies were recorded. Apart from the PA messages, the CVR recording merely verified the Kathmandu ATC recording. A full record of the CVR readout process is contained in the Flight Recorders Report supplied separately.

The Sundstrand Digital Flight Data Recorder (DFDR) was also taken to Paris for replay. The recorder crash protected enclosure was severely damaged by heat and the recording tape had broken. After careful cleaning and preparation the tape was replayed but the information relating to the last 107 seconds of the flight could not be extracted by conventional means due to heat and mechanical damage to the tape.

Valuable data from the damaged section was eventually recovered by an optical technique using a microscope and a garnet but it was not possible to recover all the data. However, the recovered data were sufficient to reconstruct the ground track and altitude profile during the last few minutes of the flight.

A full record of the DFDR readout process is presented separately in the Flight Recorders Report. Graphs of the extracted data are shown at Appendix C.

1.12 Wreckage and impact information

1.12.1 Accident site details

The aircraft crashed into the southern flank of a mountain 9.76 nm from the threshold of runway 02. The impact point was assessed as 7,280 feet above sea level which was some 150 ft below the crest of the mountain. The average slope of the impact area was 45°, with some areas, including the cockpit impact point, being close to the vertical. There was a steep gulley below the main impact area, into which many items of wreckage had fallen. The aircraft was almost totally destroyed by the impact and subsequent fire.

1.12.2 Wreckage distribution.

A formal survey was not conducted due to the difficulty and danger associated with accessing and identifying specific components. A photograph of the accident site, together with a site sketch showing the relative positions of the major wreckage items, is presented at Appendix D.

The impact point was characterised by a series of indentations in the mountainside, which, from a consideration of the aircraft dimensions, were assessed as having been made by respectively, the No.1 engine, the aircraft nose, and the No. 2 engine when viewed from left to right, looking along the flight path. A fan-shaped area of wreckage extended upwards and to the left of the impact point, and it was apparent that the vegetation had been scorched in areas that contained comparatively little wreckage. This feature was attributed to the effects of the fireball which undoubtedly occurred at impact, following the release of fuel from the wing tanks.

The only major part of the aircraft that had remained relatively intact was the tail section. This had separated aft of the rear pressure bulkhead and had come to rest below the impact point. Above and to the right of the tail was a large section of the right wing, from the tip to the landing gear attachment. The spoiler surfaces and sections of the ailerons remained in place.

Below and to the left of the tail section was a large accumulation of wreckage that had been subjected to an intense ground fire. It was apparent that this had consumed a considerable amount of material. At the lower end of this main wreckage area was the No. 2 engine, which was generally intact but had suffered considerable fire damage. The No. 1 engine was much more extensively broken up, with components being distributed down the gulley. Other components identified in the main wreckage area included the main landing gears and a large section of a thrust reverser assembly.

The fuselage was highly fragmented, and parts were distributed all around the main impact area. The largest piece was approximately 3 metres by 5 metres and included a number of cabin windows. This was located below and to the left of the impact point. A section of the fuselage crown was found on the shoulder of the mountain to the right of the impact point.

1.12.3 Impact parameters

At the impact point, the central indentation was confirmed as being produced by the nose of the aircraft by the discovery of a fragment of radome attachment structure embedded in the earth. A horizontal scar extended either side of the depressions attributed to having been caused by the engines. A few fragments of green navigation light cover were found at the right hand extremity of the scar, thereby confirming the impact point of the right wing tip, and also showing that the scar had been caused by the wing leading edge. The horizontal orientation was indicative of a wings level attitude at impact.

Below and to the right of the right wing tip impact point was a tree, the upper branches of which had been freshly cut in a horizontal plane assessed as being approximately 1.3 metres below that of the wing leading edge scar. Consideration of the aircraft geometry, and the positions of the tree and wing tip mark in relation to the impact track of approximately 020°, suggested that the tree had been cut by the trailing edge of the outboard flaps which were fully extended. This provided a broad indication of a near-level pitch attitude at impact, since, at such an attitude, the flap trailing edge is lower than the wing leading edge.

1.12.4 Examination of wreckage.

1.12.4.1 Structures

The extent of the damage to the aircraft precluded making any definitive finding as to the possibility of an in-flight fire or explosion. However, those parts which could be examined revealed no evidence to suggest such an occurrence. Similarly, there was no evidence that indicated an airborne structural failure, especially as representative portions of the nose, tail and wings were all found on site.

1.12.4.2 Systems.

The examination of the wreckage, which was conducted before the replay of the DFDR, was mainly confined to observations made at the crash site. The steep terrain and the remoteness of the location presented major salvage difficulties. In the event, sufficient DFDR data was obtained to render a salvage unnecessary for investigation purposes. The following is a summary of the findings that resulted from the wreckage examination:

The extended condition of the main landing gear actuators, plus the degree of damage to the legs and bogies, was indicative of the landing gear being extended at impact.

Eleven out of the total of twelve flap beams and jack screws were located, the positions of the carriage trunnions on the jack screws providing consistent indications of the flaps being fully extended at impact. The carriage positions on the leading edge slat screw jacks were also consistent with the slats being fully extended, although only three of these were located.

There was tentative evidence, from the observed positions of most of the spoiler panels, that the spoilers had been in the retracted, or faired positions.

The horizontal stabiliser pitch trim actuator, located in the comparatively intact tail section, was found at a setting which equated to a stabilser angle of 7.25° leading edge down relative to the fuselage horizontal datum (*ie* nose-up trim).

Examination of the engines revealed damage to the rotating assemblies which was consistent with engines rotating under power at impact. The main engine control (MEC) from the No. 1 engine was recovered from the accident site and subjected to a strip examination at the manufacturers. Witness mark evidence on parts of the mechanism within the unit was indicative of approximately flight idle fuel flow at impact. This corroborated with the observed positions of the No. 2 engine variable stator vanes, although those on the No. 1 engine were too badly damaged to provide, on their own, a reliable indication of power level. The conclusion resulting from the examination of all the available hardware was that the engines were operating, most likely at flight idle at impact.

Only two flight deck instruments were recovered; an airspeed indicator (ASI) and a radio altimeter, the serial number on the latter indicating it had been installed in the No.2 position. The burned dial of the ASI bore a very faint impression which could possibly have been made by the indicating needle; this mark was at a position corresponding to 146 kts. The indicating ribbon from the face of the radio altimeter had been torn away, although a considerable amount remained coiled on the drum and associated feed mechanism: this enabled the value that had been showing on the face to be estimated at around 70-80 ft.

1.13 Medical and pathological information

The accident was not survivable and everyone on board was killed in the impact. Bodies were found in two distinct groups: one group was located in a small area in the main wreckage beneath the impact point; the other was scattered in an arc above, beyond and to the left of the impact point. The bodies were recovered to Kathmandu by the Nepalese police using surface transport and helicopters. There they were examined by a team of pathologists, odontologists and identification experts. None of the flight crew was identified. There was no medical evidence of any pre-impact explosion. An expanded medical and pathological report is provided separately.

1.14 Fire

There was approximately 20.4 tonnes of kerosene fuel on board the aircraft at the time of impact and this was consumed by fire. Fires burned over the main impact site and several smaller areas adjacent to it. The crash site was totally inaccessible to fire fighting vehicles and the fire burned itself out.

1.15 Survival aspects

Search and rescue action started after the aircraft failed to report at 4 DME. A Puma rescue helicopter departed the airport at 0919 hrs UTC to search the area surrounding the aircraft's last position report. Later, three more helicopters and one fixed-wing aircraft joined in the search. The crash site was located from the air after about two hours of searching. The helicopter was unable to land at the crash site due to unfavourable weather and terrain but some rescue team members were landed nearby. The remaining rescue team members travelled to the crash site by road and on foot. An expanded report is provided separately.

1.16 Tests and research

1.16.1 Position Fixing

A Magellan Global Positioning System (GPS) receiver was used to establish the precise position of the accident site. To minimise errors, the receiver was set up to take 50 consecutive fixes and to calculate the average. Check fixes using this method were taken at the airport and the VOR/DME beacon. These fixes were within 15 metres in plan and 50 feet in elevation from the published positions.

1.16.2 Flight Simulator

Tests were carried out in an A300-B4 flight simulator in the presence of representatives from Airbus Industrie and the investigation team. The following parameters relating to the accident flight were simulated: motion; weight; centre of gravity; atmospheric conditions; airport altitude and VOR/DME position. The terrain surrounding Kathmandu was not simulated.

The objectives of the tests were:

a. To examine aspects of the flight deck ergonomics.
b. To examine the aircraft's autopilot/autothrottle relationship.
c. To examine the relationship between indicated airspeed and rate of descent in the landing configuration.
d. To reproduce the last 15 miles of the accident flight.
e. To fly the correct SIERRA approach flight profile.
f. To examine modified SIERRA approach procedures.
g. To examine procedures for terrain avoidance following an unexpected ground proximity warning.
h. To record the tailplane trim position (TPI) during the approach.

The tests showed that:

a. Approach charts were difficult to read if they were placed under the clip between the inertial navigators on the control pedestal, because the eye to chart distance was 92 cm at an angle of about 40° from ahead. Moreover, the speedbrake selector handle, whether in the stowed or the armed position, obscured the commander's view of the lower half of the chart. If placed under the clip on the side wall, the eye to chart distance was 48 cm and charts were readable if the pilots turned their heads through about 40°and looked even further to the side. Charts were easily read if they were placed under the clips on the control columns, where the eye to chart distance was about 40 cm and the chart was directly in front of the pilot.
b. The volume of the flight deck loudspeakers was reduced during radio transmissions made by the pilots using hand microphones.
c. The GPWS audio warning was emitted through both flight deck speakers; the warning volume could not be adjusted by the pilots and it was unaffected by simultaneous radio transmission.
d. The approach profile flown by PK 268 could be replicated without using speedbrakes or unusual manoeuvres. The profile simulated by following the airspeeds, altitudes and configurations used by the crew of PK 268 resulted in a very similar flight profile to that recorded by the FDR.
e. In the landing configuration, with engine thrust at idle and airspeed at V_{APP}, the rate of descent was about 1,600 feet per minute. On a SIERRA approach the aircraft was always significantly above the minimum altitudes at 8,6,5 and 4 DME. If the rate of descent was maintained after 4 DME the aircraft intercepted a 3 degree slope between 2 and 3 miles from the runway threshold. These characteristics were very similar to those predicted by PIA's senior A300 check-pilot.
f. At V_{APP}+ 15 knots, the rate of descent increased to 2,000 feet per minute and was sufficient to match the SIERRA minimum altitude descent profile between 10 DME and 4 DME. The aircraft could be descended to the

minimum altitudes for 8, 6 and 5 DME, although the autopilot workload was much increased above that required to fly the approach at V_{APP}.

g. With 6,800 feet set on the autopilot altitude selector, in the same conditions as sub-para f above, the autopilot began to reduce the pitch attitude between 7,600 and 7,400 feet. In a repeat of the test with 151 knots set on the autothrottle speed selector the engine thrust increased to maintain airspeed as the nose rose. The pitch attitude and thrust lever activity at 7200 feet was very similar to that recorded on the FDR during the three seconds before impact.

h. Modifying the SIERRA approach profile to have one 6° approach slope (instead of four) between 10 DME and 4 DME made the approach more stable and easier to fly because fewer and smaller changes to pitch attitude were required to maintain the optimum descent profile. This profile was flown at V_{APP}+ 10 to 15 knots.

i. If the "go-around" button on a thrust lever was depressed during a simulated approach in the landing configuration, with autopilot engaged and engine thrust at idle, the aircraft descended a further 120 feet and regained the altitude at which the button was pressed within 12 seconds. The ensuing climb with gear retracted and flaps at 15° stabilised at a pitch attitude of 15° and a climb rate of 2400 feet per minute. Pilot intervention did not succeed in reducing the amount of height lost and the time to regain the original height was reduced by just one second.

j. The tailplane trim setting, at 9 DME on each approach made in the landing configuration, was between 6.5° and 7.5°, depending upon instantaneous speed and angle of descent.

1.17 Additional information

1.17.1 Radio Altimeters

The aircraft was fitted with two independent radio altimeters which indicated height above the ground up to a maximum of 2,500 feet via indicators on each pilot's instrument panel. A moveable decision height index could be set by the pilots up to a maximum of 499 feet. Amber lights and an audio warning would be triggered when the aircraft descended through the decision height set on the indicators. One radio altimeter recovered from the accident site had the decision height index set to 499 ft.

1.17.2 GPWS (Ground Proximity Warning System)

1.17.2.1 Operation

A GPWS was fitted to the aircraft to prevent inadvertent controlled flight into terrain. The equipment has five different sets of conditions known as modes which trigger aural and visual.warnings on the flight deck. The aural warning is a synthetic male voice broadcast by the flight deck loudspeakers irrespective of whether or not the crew were using headsets. The visual warnings include a red light labelled "PULL UP" on each pilot's instrument panel. Of the five modes, only modes 1 and 2 are intended to warn the crew of and abnormally high rate of descent depending on ground proximity. These were:

Mode 1: Excessive (barometric) rate of descent relative to the terrain.
Mode 2: Excessive terrain closure rate (the rate at which radio height was reducing)

Modes 1 and 2 have maximum and minimum radio heights above and below which all "SINK RATE", "TERRAIN" and "PULL UP" warnings are suppressed. Between these heights, the conditions which trigger a warning vary as a function of several parameters including Mach number (a derivative of true airspeed), radio altitude, barometric sink rate, terrain closure rate and flap position. Also, in the landing configuration, the mode 2 warning is cut off between 200 and 600 feet radio height as a function of barometric descent rate to minimise nuisance warnings during approaches.

The system may be tested by the crew before flight. The built-in-test produces a "PULL UP" audio warning and illuminates lights on the instrument panel. System failure during test is indicated by the absence of a warning and/or the illumination of a 'GPWS FAIL' lamp on the control panel.

1.17.2.2 Events

Operation of the GPWS is recorded by the FDR once per second as one of two states: active or inactive. The FDR tape contained data relating to the 11 flights immediately preceding the accident flight. These data were searched for GPWS events. Two events were located on the first and second flights on the day before the accident during approaches to other airports. The first warning was triggered by a steep-sided mountain about 1700 feet beneath the aircraft and the second by a high rate of descent as the aircraft descended through 300 feet to land. These warnings were assessed as genuine. The same commander was aboard on both occasions, but later stated that he does not recall them.

1.17.3 Terrain altitude data

Attempts to determine the altitude of the terrain beneath the SIERRA approach path from a helicopter equipped with a radio altimeter were only partially successful. Additional terrain data was extracted from a 1:63,360 scale GSGS 5501 map. The map was 'rigourously surveyed from vertical air photographs' and had 100-foot contour intervals. The altitude of the impact site and the altitudes indicated on the map were consistent with the data gathered by the helicopter and the GPS. Some radio heights were recorded by the FDR in the last minute of flight. These data were augmented with synthetic radio heights calculated by correcting barometric heights recorded on the FDR to true height and subtracting the terrain height determined from the map. The combined data were used by the GPWS manufacturer to determine the probability of a pre-impact warning.

1.17.4 PIA Approach Procedures

Brief details on how and when PIA pilots should prepare their aircraft for the approach to Kathmandu are laid down in the airline's supplement to the Jeppesen approach chart (the 'T chart') (see Appendix B). The T chart is not a graphical document - it is a mix of tables and text. It warns of local hazards around the airport, states that the commander is to execute the landing and advises that he is likely to end up too high and too fast unless the aircraft departs the 10 DME fix fully configured for landing. The instructions regarding configuration and target airspeeds are as follows:

a. Flaps at 15° and speed at not more than V_3+10 (165 kts at maximum landing weight) should be achieved by 16 DME.

b Flaps and landing gear fully down by 10 DME with speed at the final approach speed V_{APP} (137 kts at maximum landing weight).

1.17.5 The PIA approach technique for the A300

In common with other wide-bodied aircraft of similar size the A300's descent rate in the landing configuration cannot match the glidepath of the SIERRA approach between 10 DME and 5 DME. At 130 tonnes weight the rate of descent at the final approach speed of 136 kts is 1512 fpm (feet per minute). The rate required to make the 8 and 6 DME fixes at the minimum altitudes would be about 2000 fpm. One technique adopted by PIA to match the rate of descent by allowing the aircraft to drift above the minimum altitude profile on the steeper segments and then maintaining the maximum descent rate for the final shallow segments until the minimum altitude profile is regained.

The technique was explained by the airline's senior A300 pilot. The procedure is to descend at idle thrust with the autopilot's airspeed and heading modes engaged. The airspeed is maintained at V_{APP} and the aircraft remains above all the minimum altitudes within this section. There is no need to level off unless it reaches the minimum descent altitude without the runway in sight. Normally a 3° glidepath is intercepted at about 2 DME and the remainder of the approach is flown visually.

1.17.6 PIA Training Policy

The training policy section of PIA's Fight Operations Manual dated 29 May 1988 and approved by the Pakistan Civil Aviation Authority (CAAP) did not state the requirements for renewal of pilot's supervisory ratings. These requirements were, however, contained in the earlier training policy document dated 18 May 1982. This policy document stated:

a. Flight/Simulator Instructors will be exempted from Command Renewal Checks/Route Checks. However, they will have to do their Instrument Renewal checks.
b. A Route check Pilot is exempted from route checks but must fulfil the other formalities for his licence renewal.

1.17.7 Flight Crew Qualification for Kathmandu

PIA's training policy document of May '88 listed route qualification requirements for pilots but not flight engineers. Route/airfield qualifications were combined and based on the concept of area qualifications. Qualification requirements were divided into aircraft categories and then subdivided by geographic area and airfield. There were four methods of qualification (quoted verbatim):

a. In flight familiarisation as a member of the flight as an observer.
b. Familiarisation by means of programmed instructions on route documentation. (RCU)
c. Simulated means used to acquaint pilot in the use of the instrument approach to land, arrival and departure procedures which he may utilise in the operation. (These sessions would also include route/area briefing).
d. Route checks to demonstrate adequate knowledge of route/airfield.

Qualification was valid for one year. Pilots were expected to know (amongst many other details) the terrain and minimum safe altitude for an airport.

The appropriate area for Kathmandu was India/Bangladesh. Within this area Kathmandu was listed as *not* requiring qualification for captains and co-pilots of wide bodied aircraft such as the A300 but it was required for Boeing 707/737 pilots.

1.17.8 Crew training records

The crew's training records were scrutinised for any unusual entries which might have been relevant to this accident. There were no such entries in any file except the commander's. The relevant entry in his file related to his landing at Kathmandu on 5 October 1989 when he braked so heavily that the mainwheel tyres of his aircraft deflated after landing. The episode came to the attention of the Chief Pilot A300 who wrote the following letter to the commander:

"While operating PK-264/051089, during approach Flight recorder read out shows excessive rate of descent and speed which resulted in activation of fusible plug deflating tyres after landing. A circular issued in June 1989 and T-chart gives definite procedure to be followed for this airfield which was not adhered to. Director of Flight Operations is displeased on this incident and you are hereby cautioned to be more careful in future."

1.17.9 PIA Services to Kathmandu

PIA had approximately 44 A300 flight crews and only two scheduled flights to Kathmandu per week on Mondays and Thursdays. The Monday flight was usually flown by a Boeing 707 and the Thursday flight by an A300. However, on Monday 28 September, the traffic load was such that it required an A300.

1.18 Useful or effective investigation techniques

The assistance of a Senior Psychologist specialising in Air Traffic Control and aviation matters and an aviation medical practitioner was obtained to provided advice on the human factor aspects.

2 ANALYSIS

2.1 Introduction

The analysis of the evidence begins with a brief summary of the available evidence. The mechanical and external factors which could have contributed to the accident are then reviewed and discounted leading to the conclusions that the aircraft was serviceable and under control when it struck the ground. The potential error mechanisms which could have caused the accident are discussed leading to the deduction that human factors caused the crew to misinterpret the approach chart. Other factors which probably contributed to the misinterpretation process are then identified and the mechanisms which could have averted the accident are reviewed and their failures explained. Finally, deficiencies within the SIERRA approach to Kathmandu, its ATC environment and the GPWS are outlined and remedial measures are suggested. Measures to address other causal factors and unsafe practices are addressed as they arise. The report ends with a summary of the findings, conclusions and recommendations.

2.2 The Accident Sequence

2.2.1 Extract of evidence

A brief extract of the evidence established in Part 1 of this report follows:

The aircraft struck ground 7,280 feet above sea level on the correct final approach track at 9.16 DME. At that DME the aircraft would normally have been descending through 9,000 feet although the minimum safe altitude was 8,200 feet. At impact the slats, flaps, spoilers and landing gear were correctly configured for landing. The aircraft's wings were level, its heading was consistent with maintaining track and the airspeed was about 14 kts above the final approach speed. Both engines were at flight-idle for most of the descent but were producing slightly more than idle power at impact. The pitch (fuselage) attitude was near zero (level) which, for the configuration and power setting, was consistent with the rate of descent required to follow the altitude profile shown on the approach chart. There was no evidence of pre-impact fire, explosion, disintegration or major mechanical malfunction.

The FDR provided a detailed record of the aircraft's performance during most of the accident flight although the last two minutes of data were damaged by the post impact fire. However, brief 'snapshots' of data including the last three seconds before impact were recovered. The data showed that the flight controls and engines were responding normally to control inputs. The CVR and ATC recordings provided a detailed record of ATC clearances and position reports from the aircraft. These data, together with the FDR data were sufficient to reconstruct the aircraft's speed, configuration, ground track and altitude during the approach. Flight simulator tests showed that the flight profile could be replicated without resort to extreme or unauthorised manoeuvres such as spoiler deployment.

There was no physical evidence of any improper maintenance and the aircraft documentation was comprehensive and up to date. There were two deferred defects which affected the aircraft's performance: the number two (right) engine thrust reverser was inhibited and one of the two autopilots was unusable whilst the flaps were extended.

2.2.2 Potential mechanical and external factors

The following mechanical and external factors which could have contributed to the accident are reviewed and each is considered separately.

1. Unlawful interference
2. Pilot incapacitation
3. Loss of control
4. Autopilot malfunction
5. Altimeter error
6. Significant VOR/DME error
7. ATC clearance error(s)
8. Extreme weather conditions

2.2.3 Unlawful interference

The possibilities of interference on the flight deck or bomb damage were considered. There was no indication in any radio message from the aircraft that the crew were under duress. PIA have stringent security precautions and the armed guards on board the aircraft should have deterred or defeated any attempt to overpower the crew. Shortly before the accident, the commander spoke to the passengers on the cabin passenger address system (PA) implying that only the weather was causing him any concern and the last radio transmission before impact was made in a normal, calm, unhurried tone of voice. There was no evidence of pre-impact explosion damage to the aircraft and no sign of associated injuries to the passengers. Therefore, the possibility of unlawful interference was discounted.

2.2.4 Pilot incapacitation

There was no evidence of either pilot suffering a very recent medical or personal problem and both had had the opportunity for adequate rest before the flight.

PIA's standard operating procedures (SOPs) state that the non-handling pilot should make all the radio calls. The commander made all the calls until the start of the descent; thereafter the co-pilot made all the calls in a tone of voice consistent with normal operations. The changeover is indicative of a change in the handling pilot from the co-pilot to the commander and consistent with the T-chart's instruction for the commander to execute the landing. Clearly both pilots were well at the start of the approach and the co-pilot was well 30 seconds before impact.

Had the commander become unwell during the approach, the co-pilot may or may not have had noticed his illness. If the co-pilot had noticed it, he would have been able to abandon or continue the approach with the assistance of the flight engineers. Moreover, he would almost certainly have informed Kathmandu if the Captain had collapsed so that the flight would receive clearance to divert or priority to land. Given the probable frequency of conversation during the high-workload phase after 13 DME, if the co-pilot failed to notice the commander falling ill, this could only have happened in the last minute of flight by which time the accident sequence was well-established. On balance, the probability that either pilot became incapacitated during the approach is remote. Moreover, the possibility that incapacitation contributed to the accident sequence is extremely remote.

2.2.5 Loss of control or thrust

The possibility of a sudden forced descent due to severe flap asymmetry or loss of thrust was considered. The aircraft struck the ground wings-level and to maintain this attitude with thrust or flap asymmetry would require appreciable rudder and/or aileron deflection. The FDR data showed only small rudder and aileron deflections from the start of the approach through to impact and no signs of engine failure or thrust abnormality. Furthermore, mechanical evidence within both engines indicated that they were operating, probably at idle power at impact Loss of control or thrust may, therefore, be discounted.

2.2.6 Autopilot malfunction

The No 1 autopilot had a minor defect which prevented it being used whenever flap was lowered. The crew were probably aware of this defect since it was adequately documented. Only one autopilot can be engaged during a VOR/DME approach and the FDR data show that the commander used the No 2 autopilot in the command mode (holding specific values such as altitude, heading and airspeed) throughout the approach including the final second before impact.

Because the aircraft crashed wings-level, on track, and on a sensible heading, a roll mode malfunction can be eliminated. Secondly, because the autopilot acquired and held the flight levels or altitudes assigned by ATC until 21 DME and then captured 10,500 feet until 16 DME, the altitude hold mode was working Thirdly, the airspeeds flown were in accordance with PIA's procedures until 10 DME; thereafter airspeed was steady during the final descent from 10 DME with the engine thrust at idle. As the FDR showed that the steadiness of the speed was not a function of autothrottle, it must have been controlled by the autopilot pitch mode. Therefore, the autopilot's modes of pitch (airspeed), heading and altitude hold appear to have been working. On that basis, it is very unlikely that autopilot malfunction was a contributory factor.

2.2.7. Altimeter error

The possibilities of a large altimeter error were considered. Firstly, the difference between the standard cruise altimeter pressure setting and the correct setting for the approach was one millibar. If the crew had forgotten to change the setting the ensuing error would have been about 30 feet. Secondly, the FDR altitude trace shows that one second before impact the aircraft's barometric altitude was 7,165 feet. When corrected for temperature and pressure errors, the barometric altitude equates to a true altitude of 7,266 feet. The GPS derived true altitude at the impact point was 7,350 feet but its performance was slightly degraded by obscuration of all satellites to the north by steep terrain. However the barometric altitude of the helipad just above the site was 7,310 feet. After applying corrections for temperature and the height above the site, the true impact altitude was calculated to be 7,280 feet. The results of these three methods of determining the true impact altitude vary by less than 100 feet and, excluding the GPS method, the difference was 14 feet. Allowing for small FDR and GPS tolerances, then it is reasonable to conclude that the aircraft's altimeter error was less than 100 feet. The design of the instrument approach takes into account errors of this magnitude but PK268 was more than 900 feet below the minimum altitude for that stage of the approach. Altimeter error could not possibly be responsible for this deviation and was not a causal factor.

2.2.8. Significant VOR/DME error

There was no warning in ATC of power failure to the VOR/DME beacons and the R/T transcript shows that another aircraft was receiving DME range at the time of the accident. The aircraft crashed on track and so a significant VOR error was not a factor. There were no pilot reports of DME errors on that day and the beacons were flight checked after the accident and found to be working correctly. Therefore, significant errors in or failures of the VOR and DME beacons can be discounted.

The aircraft had twin DME sets and each pilot had a display of both DME ranges so a single receiver failure would not have deprived either pilot of DME range. There were no recent reports of DME malfunction in the technical log and the crew did not query the serviceability of the beacon on the R/T. Moreover, the FDR track plot shows that the 25 DME and 16 DME position reports were made at the correct ranges. Therefore, at least one of the DME receivers was working correctly during the early stages of the approach.

However, DME performance may have degraded during the latter stages of the approach as indicated by the fact that the 10 DME position report was made early. The aircraft crashed at 9.16 nm from the DME beacon 32 seconds after the start of the 10 DME call. During this period the aircraft was flying at 151 kt IAS which was maintained to impact. This equates to a groundspeed of 168 kt. In 32 seconds the aircraft would have travelled 1.49 nm; therefore, the 10 DME report was made at or very close to 10.65 nm from the DME beacon. Since the constant airspeed at idle power would result in a steady rate of descent, interpolation of the FDR altitude trace indicates that the R/T call started as the aircraft descended through 8,100 feet. The ground two miles ahead of the aircraft rose to 7,500 feet and the aircraft crashed into it at 7,280 feet. The DME system requires line of sight and so beacon reception would have been lost before impact due to the terrain interrupting the line of sight. Whether the equipment indicated loss of lock before the call was made cannot be determined because actual performance often varies considerably from the theoretical and DME receivers have a memory facility to cater for brief loss of signal. However, if the DME went into memory and the range indication froze, the indicated range would be greater than the true range (eg showing 10.7 DME at 10.0 nm from the beacon) and the call would have been made after 10 DME whereas, in the event, the converse happened.

The DME position was given as the final waypoint in the flightplan. This position could and should have been entered into the inertial navigator system (INS) to check for a gross DME error. The cruise portion of the flight was flown by the co-pilot and he would probably have used INS for navigation in the area of the Nepal/India border because of the sparsity of VOR/DME beacons. If he had forgotten to change his HSI (horizontal situation indicator) selector switch from INS to VOR/ILS for the approach, the HSI would have indicated the INS computation of range to the DME beacon. After 150 minutes of flight a small discrepancy between the INS and DME ranges would be very likely but it is unlikely to have been so large as to be an obvious error. The crew may have anticipated the 10 DME position, they may have lost DME reception and estimated 10 DME or the co-pilot may have inadvertently used INS range to the beacon as a cue for the call. Whatever they did, there is no evidence of DME error within the beacon or the receivers. Furthermore, in the time it took to travel the 0.7 nm apparent error, the aircraft would have descended 475 feet. This is not enough to explain why the aircraft was more than 900 feet too low. Consequently, although a small DME error cannot be eliminated, any error present does not explain the accident.

2.2.9. ATC clearance error(s)

The flight was cleared in accordance with normal ATC practice to intercept the final approach track at the minimum safe altitude (MSA) of 11,500 feet. There were no compulsory reporting points indicated on the SIERRA approach chart but position reports at 25 DME and 16 DME were requested by ATC and made by the crew. Both position reports were accompanied by altitude reports of 11,500 feet. At 16 DME the crew were cleared for the SIERRA approach and instructed to report at 10 DME. At the time they were not instructed to report their altitude at 10 DME and no clearance to a lower altitude was given or needed because clearance to descend in accordance with the approach procedure is an integral part of clearance for the approach. The ATC transcript shows that at no stage during the approach were the crew issued with a confusing or incorrect clearance and the clearances given were in accordance with well established normal procedures.

The tower controller's failure to react to the incorrect altitude report which followed the pilot's 10 DME report did not contribute to the sequence which led to the accident. However, had then responded to the incorrect report, this may have alerted the crew to impending danger. The controller's performance is analysed later in the report.

2.2.10. Extreme weather conditions

The weather forecasts and reports for Kathmandu did not include severe weather other than cumulo-nimbus (CB) clouds. These are large convective clouds several thousand feet deep which can contain severe turbulence, hail stones and icing. The commander was aware of these clouds; he had deviated from track before the approach to avoid some and he had informed his passengers on the PA system of their presence around Kathmandu. It is possible that the commander's later request to the cabin crew and passengers to remain seated was an indication of proximity to these clouds or the presence of a CB cloud on the final approach which he was unable to avoid. On the other hand, it is good aviation practice to order seat belt fastening before penetrating any significant layer of cloud purely for passenger safety and the commander would probably have mentioned seat belt tension if he was committed to penetrating an active cloud. If he had penetrated a very active cloud, the aircraft would have been subjected to moderate or severe turbulence which would show up on the FDR trace as large, random vertical accelerations. There was no sign of any vertical acceleration greater than 0.2g either side of the 1g normal datum. Therefore, the aircraft did not penetrate a very active CB during the approach.

Cumulo-nimbus clouds often develop into thunderstorms which can also produce damaging lightning strikes and very strong downdraughts some distance from the cloud. These downdraughts (also called microbursts) can affect airspeed and rate of descent in a dangerous way (windshear). The FDR data show that this did not happen and, at the time of the accident, eye witnesses close to the impact site reported that there were no thunderstorms in the area, little or no wind and a visibility of 20 metres in fog. Therefore, extreme weather conditions as a causal factor in this accident are discounted.

2.3 Controlled flight into terrain

In the absence of any probable external factor, pilot incapacitation or aircraft system malfunction, and considering that the approach was progressing normally in all respects except altitude and airspeed, it is reasonable to assume that the aircraft was basically serviceable and under control. Therefore, it flew into the ground because the flight crew were unaware that their flight path was dangerously low. Had they followed the correct SIERRA approach procedure, they would have been about 900 feet above the mountain which they struck and so, clearly, the crew failed to follow the correct altitude profile.

The central issue of this report is, therefore: Why did the crew deviate from the approach procedure? There are three options: they were attempting a visual approach; they intentionally deviated from the procedure, at least initially; or they mis-interpreted the approach chart.

2.3.1 Attempted visual approach

There are three sets of circumstances which could have encouraged the crew to attempt a visual approach. Firstly, and most improbably, the flight instruments could have failed. There are two sets of most instruments and three sets of the critical ones, driven from separate power sources. Complete failure of them all is statistically most improbable but, had it occurred, the crew would probably have declared an emergency and diverted to another airfield.

Secondly, they could have forgotten or mislaid the approach chart. PIA's flight planning section had assembled the chart case for the PK268 route which was normally flown by another aircraft type. There should have been two binders of approach charts - one for each pilot - and one binder was recovered from the accident site. The SIERRA approach chart was missing from it, which is logical since the pilots would normally remove the chart from the binder and place it under a chart clip. If the crew had arrived without the chart because it was not put into either binder, they might have been tempted to fly the approach from memory. However, neither pilot had been to Kathmandu for two months and, given the number of airports and instrument approaches in PIA's A300 route structure, it is unlikely that either of them would remember the SIERRA procedure in sufficient detail to proceed with it. In these circumstances it is more likely that the crew would have asked ATC for help or diverted to an airfield in northern India where there was little or no cloud.

The third and most probable reason for attempting a visual approach is that the crew could see the ground beneath them and wanted to dispense with the complexity of an instrument approach. The weather observation made at the airport five minutes after the accident included almost full cloud coverage but patches of blue sky were visible so there must have been gaps in the cloud layer through which the ground was visible. Had the commander been exploiting these gaps, frequent moderate heading changes would be likely but no such activity was recorded by the FDR. It is possible that the cloud coverage was quite different outside the Kathmandu valley and that the aircraft was above most if not all of the cloud seen from the ground until shortly before impact. Certainly the mountain tops beneath the approach were in cloud but cap clouds can be quite shallow in depth. Above these, the air might have been clear or there may have been individual clouds with vertical gaps between them. On the other hand, the weather situation was changing very slowly. The pilot who flew the preceding SIERRA approach an hour earlier encountered instrument flying conditions between 16 DME and about 5 DME. The only difference in cloud structure between the weather observations made around the time of his approach and that of the accident flight was the disappearance of one okta of cumulo-nimbus. Therefore, it is more probable that the crew of PK268 were in cloud rather than out of it between 16 DME and impact.

There is also an indication on the FDR trace that the aircraft was in cloud (but not cumulo-nimbus cloud) for most of the approach. The recording of vertical acceleration shows small 'bumps' which are symptomatic of light turbulence. The wind was light and an experienced Nepalese pilot stated that turbulence at that time of the year is invariably associated with cloud. These small bumps are present throughout the recorded data for the last 5 minutes of flight.

The commander had operated to Kathmandu at least seven times before and the co-pilot at least five. Both must have known that high ground surrounded Kathmandu. With no clear view of the ground it seems extremely unlikely that two professional pilots of their experience would descend below the correct approach profile, in cloud, in a mountainous area, in an attempt to achieve visual conditions.

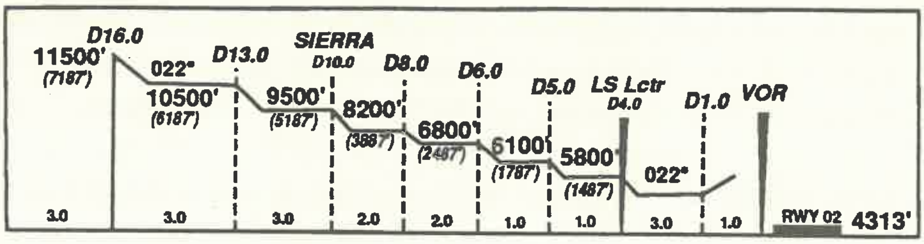
2.3.2. Intentional deviation

It is possible, for the reasons which will be discussed in paragraphs 2.4 and 2.5, that the captain elected not to follow the procedure and intentionally entered it 1,000 feet too low. However, no professional crew would purposely fly an entire approach procedure in cloud at a consistent 1,000 feet below the profile. Furthermore, there is no doubt that even though they deviated at the beginning, they certainly would have intended to regain the profile well before the location of the accident.

2.3.3 Mis-interpretation of the approach chart

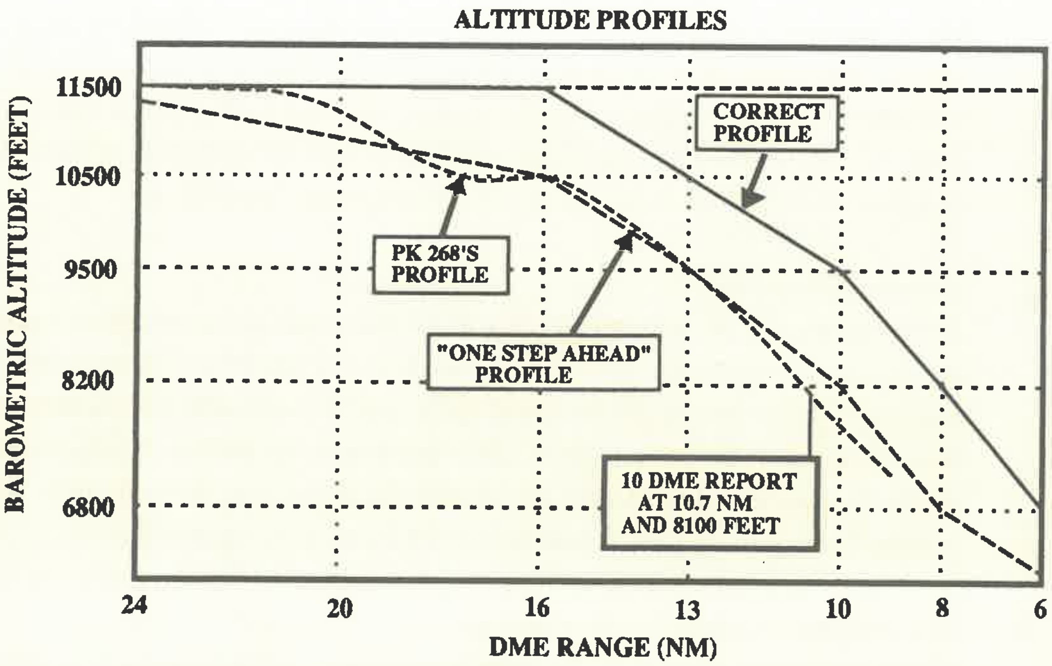
Given that the likelihood of the crew attempting a visual approach is minimal, it is probable that they mis-interpreted or misread the approach chart. The aircraft began descent from 11,500 feet at 22 DME when it should have waited until 16 DME. It then levelled off at 10,500 feet until 16 DME before resuming its descent at a rate of about 1,800 fpm. Since they descended to precisely 10,500 feet and maintained that altitude until reaching 16 DME, it is possible that they believed the correct altitude at 16 DME was 10,500 feet. The altitude profile of the Jeppesen chart (shown below[2]) shows that 10,500 feet is correct at the next check point of 13 DME.

[2] Not an exact copy of the Jeppesen chart altitude profile.



(Please refer to actual chart)

At 16 DME the crew were 'one altitude step' ahead of the correct profile. If this situation had persisted,the crew would have been aiming to be at 9,500 feet at 13 DME, 8,200 feet at 10 DME and 6,800 feet at 8 DME. The correct profile, the misinterpreted or 'one step ahead' profile, and the aircraft's actual flight profile are shown on the diagram below. From the diagram it is clear that the aircraft passed through 9,500 feet at 13 DME but then continued below the 'one step ahead' profile until impact.



The co-pilot reported "WE CROSSED OUT OF EIGHT THOUSAND FIVE HUN - TWO HUNDRED NOW" five seconds after starting his 10 DME position report. However, the crew made their 10 DME report at 10.7 nm from the beacon when the aircraft was passing through 8,100 feet. If, for whatever reason, they thought they were at 10 DME, then they were close to their target altitude of 8,200 feet. The initial reference to "FIVE HUN" which was rapidly amended to "TWO HUNDRED" may have been because the previous target altitude was 9,500 feet; certainly the aircraft was closer to 8,200 than 8,500 feet when the transmission started.

On this misinterpreted profile, they should have expected to be midway between 8,200 feet and 6,800 feet halfway between the check ranges of 10 and 8 DME. This would place them at 7,500 feet at their estimate or indication of 9 DME. At the groundspeed of 168 kts, the time to cover one nautical mile is 21 seconds. The 10 DME call started 32 secs before impact so, if the DME range error was consistent, they would see 9 DME 21 seconds after the R/T call and 11 seconds before impact. Therefore, if they were attempting to regain the 'one step ahead' profile they should have been less than 100 feet below 7,500 feet 11 secs before impact. An FDR "snapshot" 12 seconds before impact showed the aircraft at 7,484 feet which means they were just 56 feet below their target (one step ahead) profile and correcting towards it.

There is a very close match between the altitudes achieved by PK 268 and the target altitudes obtained by misreading the altitude profile through being 'one step ahead'. The match is almost perfect if the crew's position report at 10 DME is accepted as meaning the crew believed they were at precisely 10 DME. Proof that the crew had mis-interpreted the chart by 'one step ahead' would be some indication that they were attempting to match 9500 feet to 13 DME, 8,200 feet to 10 DME. and 6800 feet to 8 DME.

2.3.3.1 Handling pilot intervention

Although it was not possible to determine from the wreckage what altitude or modes were selected on the autopilot control panel, the FDR did give an indication of when the autopilot 'COMMAND' mode was being over-ridden by movement of the control column (see the FDR report). (With the autopilot in COMMAND mode, temporary changes of pitch angle or roll can be achieved by light pressure on the control column. Indication of this event is displayed on the FDR listings as a change from '0', indicating autopilot COMMAND mode, to '1', indicating pilot intervention). There was no pilot intervention until the period between 85 seconds and 65 seconds before impact. During this period the aircraft reduced its DME range from 13.2 to 12.2 nm and descended from 9,570 feet to about 9,100 feet; it also altered heading by 3° to the right. A small heading change would normally be accomplished by changing the heading selected on the control panel. It is unlikely that control wheel pressure would be used for a small heading change. After 13 DME the rate of descent increased and so the intervention probably represents a demand from the handling pilot for a greater rate of descent. The need for this would coincide with the start of the steeper phase of the approach if the chart was misread by one altitude step. (On misreading, before 13 DME the gradient is 333 feet/mile; after 13 DME it is 433 feet/mile).

The next intervention occurs 13 seconds before impact and again at 1 second before impact; during this period the aircraft's heading was steady, its pitch attitude was reducing and engine power was increasing to just above flight idle. These changes were too small and too slow to have been the start of a terrain avoidance manoeuvre. The sustained and slow change had to be a pilot or autopilot demanded reduction in rate of descent. Previous autopilot altitude captures were completed without pilot intervention and so it seems likely that the handling pilot was reducing the rate of descent in order to avoid descending below 6,800 feet before reaching 8 DME. The movement of the throttle can be explained by the pilot wishing to maintain the airspeed, either manually or by having the autothrottle engaged to hold 151 knots.

2.3.3.2 Autopilot altitude capture

The A300 technical manual states that in a climb or descent, altitude capture (ie raising or lowering of the nose in order to level off at the required altitude) commences when the difference between present and the required altitude is one third of the rate of descent. Thus with a steady rate of descent of about 1,800 fpm when the call of 10 DME was made, and a constant airspeed thereafter, the autopilot should have started to reduce the pitch attitude when the aircraft reached 7,400 feet barometric altitude. During the flight simulation of the accident profile, the pitch attitude and thrust lever activity at 7200 feet (indicated) was identical to that recorded on the FDR during the three seconds before impact. Therefore, it is likely that either 6,800 feet was set on the autopilot control panel or, that the handling pilot was assisting the autopilot (intervening) to be at 6,800 feet at 8 DME. His reason for assisting the autopilot may have been because it descended about 50 feet below 10,500 feet (FDR), whilst capturing that altitude just before 16 DME.

2.3.4 Deduction that the approach chart was mis-interpreted

The FDR data clearly indicates that the handling pilot was attempting to control the rate of descent so as to pass through 9500 feet at 13 DME, 8200 feet at his perception of 10 DME, and to remain at or above 6800 feet until 8 DME. Therefore, the sum of the evidence discussed in this section is sufficient to deduce that the handling pilot was attempting to follow the correct SIERRA approach profile, but that he was following a profile which was one height step ahead of the published profile.

2.4 Human factors

This section of the report covers the human factors which may have combined to cause the crew's cognitive error(s). They should have maintained 11,500 feet until 16 DME but the FDR data show that the aircraft began descent at 22 DME and approached 16 DME in level flight at 10,500 feet. The analysis links the premature descent at 22 DME to the co-pilot's incorrect altitude report of 11,500 feet at 16 DME and postulates three different sets of circumstances which could explain both anomalies. Each set of circumstances is logically developed to see if they might explain the accident sequence.

2.4.1 Explanations for the incorrect altitude report

The altimeters were accurate and the autopilot was operating normally, so the descent to 10,500 feet had to be deliberate. The commander was handling the aircraft. He would have initiated the descent and he must have known that the aircraft was at 10,500 feet but he did not make the altitude report, the co-pilot made it; therefore, it had to be either a deliberate deception or an inadvertent error by the co-pilot. There is one explanation for a deliberate deception and two more for an inadvertent error. Since there is no record of the crew's conversation, whichever happened can only be conjecture. The assistance of an aviation psychologist and an aviation medical practitioner was obtained. They suggested the following explanations.

a. Deliberate deception so as to achieve an early descent

The co-pilot knew that the aircraft was at 10,500 feet. He fully realised that this altitude was incorrect but neither he nor the commander wished ATC to know that they had deliberately deviated from the published altitude profile in order to make the approach easier.

b. Inadvertent speech error

The co-pilot knew that the aircraft was at 10,500 feet. He and the commander believed that this altitude was correct at 16 DME, but he used the wrong words on the R/T.

c. Inadvertent monitoring error

The co-pilot thought that the aircraft was still at 11,500 feet. He had not been monitoring his altimeter and he did not realise that the commander had descended to 10,500 feet.

2.4.2 Deliberate deception

It is possible that having studied the Jeppesen chart, the commander reasoned that all the high ground was inside 13 DME and there was no hazard to the aircraft if he descended to 10,500 feet. He could then simplify his workload by decelerating and configuring for the approach in level flight before intercepting the published profile at 13 DME. The co-pilot may have felt obliged to accept this outwardly safe variation to the published procedure because criticising a training captain's flying technique could be career-limiting.

It is difficult to see the point of such a deception; there was little to be gained from premature descent by 1,000 feet at 22 DME since the steep part of the approach did not start until 10 DME. There was more to be gained by prematurely reducing speed rather than altitude since they could then begin the process of lowering the flap and landing gear earlier than recommended on the T chart without having to deviate from the profile. However, this did not happen. The FDR data show that at 16 DME the aircraft was configured in accordance with company advice and at the recommended airspeed, but at 10 DME it was 14 knots too fast. The commander, who was a training captain, had already had one highly embarrassing incident at Kathmandu when he allowed the aircraft to get too high and too fast on final approach. If he was so concerned, he is unlikely to have waited until 13 DME before lowering approach flap and landing gear, thereby allowing the aircraft to be too fast at 10 DME.

Moreover, if the commander and the co-pilot knew exactly what they were doing and had intended to regain the correct profile at 13 DME, it is difficult to see why they both consented to a rapid descent on reaching 16 DME. Therefore, the probability that the commander and the co-pilot deliberately decided to deceive ATC by descending early with the intention of regaining the correct profile is very low.

2.4.3 Inadvertent speech error

If the co-pilot and the commander believed that 10,500 feet was the proper altitude to be at, but the co-pilot used the wrong words, the question arises as to why the other three members of the flight crew did not correct him.

It is possible that none of them heard his R/T transmission and, in the case of the commander, his borderline hearing would have increased this likelihood. PIA's A300s are equipped with elderly earphone headsets which do not have boom microphones attached and all R/T transmissions have to be made with a hand-held microphone. Company standard procedures are to wear the earphones during climb and descent but to use the flight deck loudspeakers above each pilot's head to monitor R/T during the cruise. There are two loudspeakers, each about 45 cm from the pilot's nearest ear and at least 75 cm from the flight engineer and supernumary positions. The volume of both loudspeakers is reduced during R/T transmissions to prevent feed-back to the microphone causing a background howl. According to some crews the headphones are uncomfortable to wear and some have flown approaches using the speakers and not the headphones. If the crew of PK 268 were not wearing headsets and the flight deck was noisy, it is possible that nobody heard the co-pilot's mistake.

It is also possible that the crew were wearing headsets or heard the co-pilot say 11,500 feet by listening to his voice or the loudspeakers but his words did not register as an error. The flight engineers were not expected to participate in this phase of the approach and they may not have been watching the pressure altimeters. Alternatively, they.may have been engrossed in other tasks or they may have been distracted by a visitor to the flight deck. The commander should have heard the co-pilot whether or not he was wearing earphones but he would have been busy and his workload was such that he might have lacked the spare mental capacity to monitor the co-pilot's R/T.

However, a potential failure by the remainder of the crew to correct the co-pilot's mistake does not explain the process whereby both pilots (and possibly the flight engineers) arrived at the conclusion that 10,500 feet was the correct altitude at 16 DME. Although the speech error may have been genuine and passed unnoticed by the other flight crew, it is difficult to see how it could fit into a logical sequence of events which explain the accident. It does not explain why the commander believed that 10,500 feet was the correct altitude nor does it explain why, later on at 13 DME and again at 10 DME, both the co-pilot and the commander failed to notice that their descent profile had deviated from the published profile. To explain these later errors it is necessary to construct a theory whereby the commander believed that they were at the correct altitude at each DME fix point from 16 DME to 10 DME, and that they should be at 6800 feet at 8 DME.

2.4.4 Monitoring error

It is possible that the co-pilot believed that the aircraft was still at 11,500 feet. The commander was handling and so the co-pilot would have been selecting and monitoring the flaps, slats and landing gear as well as making the R/T transmissions. The descent from 11,500 feet at 22 DME was accompanied by slat extension and reduction of power from 80% N1 to 43% N1 (flight idle). It is highly unlikely that the co-pilot was unaware that the aircraft was descending - it was slowing down and he would have operated the slat/flap extension lever which was beside the throttles which were closing as he moved the lever.

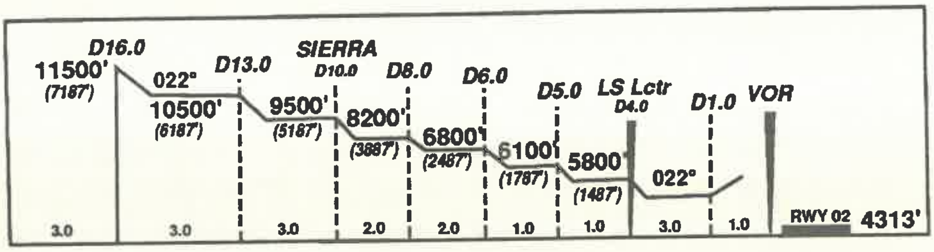
The next two flap extensions were made in quick succession in level flight at 10,500 feet as the aircraft approached 16 DME. The cue to the altitude report was the DME - not the altitude. The co-pilot might have been concentrating on the DME range and flap position to the exclusion of altitude. On making the report he may not have checked the altimeter but simply read off the appropriate altitude from the chart or repeated the altitude which he had memorised earlier. He might also have mentally expected the aircraft to still be at 11,500 feet since ATC had neither cleared them to a lower altitude nor cleared them to commence the approach. However, a monitoring error can explain only how the co-pilot came to mis-report the altitude at 16 DME. It does not explain why the commander believed that 10,500 feet was the correct altitude at 16 DME nor does it explain why, later on at 13 DME and again at 10 DME, both the co-pilot and the commander failed to notice that their descent profile had deviated from the published profile.

2.5 Chart misinterpretation

The common factor between the alternatives of a speech error or a monitoring error by the co-pilot is that neither explains why the commander believed that 10,500 feet was the correct altitude at 16 DME. To understand the accident process, it is necessary to consider whether at least one pilot misinterpreted the Jeppesen chart by one altitude step at 16 DME. Thereafter, it is necessary to explain why both pilots carried forward this mistake to the ultimate conclusion and why no-one else in the flight crew noticed these mistakes.

2.5.1 The Jeppesen chart

PIA crews use Jeppesen charts for all approaches to airfields within the airline's route structures. Both pilots had been employed by PIA for several years and both would have been very familiar with the Jeppesen chart conventions. Therefore, if the layout of the chart contributed to their mis-interpretation of it, it is likely that some abnormal feature or illustrative technique on this particular chart may have misled them. There was nothing abnormal in the plan portion of the chart apart from the omission of the fan marker and the presence of several notes. On the vertical profile, however, the data was unusually dense when compared to other VOR/DME approach profiles at airfields in PIA's A300 route structure. It too omitted the fan marker. The profile is illustrated below:



2.5.2 DME/Altitude dissociation

The omission of the fan marker from the chart was not a contributory factor in this accident. The descent profile is based on DME range and PK 268 struck a mountain before it reached the marker. However, the correct altitude at 16 DME was not printed on the plan portion of the chart; it was printed only on the elevation profile. Therefore, the initial mistake would appear to be that someone interpreted the elevation profile in such a way that the association between 16 DME and the clearly printed figure of 11,500 feet next to it was lost. As an informal trial indicated, if the altitude of 11,500 feet at 16 DME is obscured by the holder's thumb, the starting altitude is less obvious.

A study of Jeppesen charts for other VOR/DME approaches revealed that the minimum altitudes figures are normally placed beside the vertical line denoting the DME fix. In this way the user instinctively links the altitude to the DME fix closest to it; no conscious or deliberate mental process is necessary. However, there is a limit as to how much data can be clearly shown on a Jeppesen chart within a box 12 cm by 4 cm. Seven DME fixes together with their associated altitudes and pictorial representations of the VOR and runway are contained in the box. The result is erosion of the the obvious association between altitude figures and the DME fixes to which they relate. Most of the figures are mid-way between the DME fix lines and it is not instantly clear to which fix the figures relate. Moreover, after 13 DME the minimum altitude figures are generally in line with the level portion of the previous segment which could be interpreted to mean that there is some association between the altitude and the previous segment. In the later stages of the approach, this perception could reinforce an earlier association between the altitudes and the DME fix lines to the left.

2.5.3 Fix/altitude interpretation

Jeppesen's illustrative technique is technically correct but requires the chart user to interpret the minimum altitude at the DME fix point. The correct mental process is very simple; the logic is: "If 8,200 feet is the minimum altitude *between* 10 DME and 8 DME then 8,200 feet is the minimum *at* 8 DME". Despite its simplicity, this mental process does not allow the pilot to check in one glance the minimum altitude at the next DME fix point. A glance may be all the time that the busy pilot can spare during a demanding approach.

2.6 Subsequent errors.

2.6.1 Chart transcription

One explanation for the subsequent mis-interpretation throughout the approach could be that the descent profile was transcribed from the chart. Two A300 pilots stated that they did this. One of them said that it was common practice amongst most of the pilots he had flown with because they thought the profile was too cluttered to use for quick reference. This pilot stated that during the flight, he copied the DMEs and altitudes on to scrap paper and arranged them into a tabular format which he found quicker and easier to read than the Jeppesen chart. He then used this table to brief the crew for the approach. This, however, did not necessarily occur on this flight.

If the commander or co-pilot of PK268 had done something similar, both pilots would have had the same data and cross-checking between them during the approach would not have revealed an earlier mistake by one of them. As an informal trial indicated, if the altitude of 11,500 feet at 16 DME is obscured by the holder's thumb, the starting altitude is less obvious and by reading off a succession of lower altitudes, the initial mistake could be carried forward to each DME check point.

2.6.2 Pilot dialogue

Another explanation might be that the commander mis-read the procedural altitude at 16 DME and decided to descend without asking or checking with the co-pilot that that was correct. After 16 DME the co-pilot would have briefed the commander on the minimum altitudes at 13, 10 and 8 DME but he may not have briefed the commander on each DME/altitude pair. If at each fix the commander had wanted to know only the next altitude, the co-pilot might have checked the current altitude on the altimeter, which by this stage was already too low, and looked up the next lower altitude on the chart.

At each stage of the descent, the manner in which the questions are asked cues the respondee to the data source; ie if asked for current information, the respondee refers to the aircraft instrumentation, if asked for a future reference point, he refers to the chart. The chart is not error tolerant. If a user makes a mistake there is little or no way he can deduce his error from the chart itself. He could, however, do this by cross-referencing the DME reading and the altimeter. But, given that he had no suspicion that an error has been made, he is unlikely to do this. If neither the commander nor the controller queried any of the co-pilot's responses, the co-pilot would have had no reason to suppose that the approach was not progressing normally and he would have been unlikely to have been tracking his own behaviour."

2.6.3 Co-pilot inactivity

A third explanation for the consistent error could be that the co-pilot was not monitoring the altitude until he was asked to report it following his 10 DME position report. He might have been concentrating on something other than the commander's flying whilst the commander misinterpreted the chart and flew the wrong altitudes. It is possible that he first looked at the altimeter when asked to report an altitude he was not expected to report. This could explain this initial use of the words "FIVE HUN' in his report which he later amended to "TWO HUNDRED". However, a study of the transcript shows that he reported a similar string of superfluous numbers at 08:35:03 hrs and no special significance should be attributed to his error at 10 DME. The possibility that the co-pilot was not paying attention during the approach cannot be denied but it is unlikely given his experience and unblemished training record.

2.6.4 Control of airspeed

The excess speed (151 kts instead of 137 kts) after 10 DME was another anomaly during the approach. It may have arisen because, in misreading the chart, the crew had descended an extra 300 feet between 13 and 10 DME, it may have been because the commander waited too long before lowering the landing gear and full flap, or it may have been because the commander intended to fly the approach at about 150 kts.

However, having arrived at 10 DME at close to the crew's interpretation of the minimum altitude, but with 14 kts excess airspeed, the commander had only two options: raise the nose to reduce speed and drift above the minimum altitude profile; or, accept the excess speed and follow it. The constant speed of 151 kts until impact shows that he chose the latter option. The excess speed was not dangerous but it would have increased his workload. On the other hand, the commander may have reasoned that it was easier to get rid of excess speed on final approach than it was to get rid of excess height and that he could bleed off the extra 14 knots during the final two miles.

It is also possible that the commander intended to be fast after 10 DME, either as a precaution against anticipated turbulence, a possibility suggested by the cabin PA announcement, or so as to attain the 2000 fpm rate of descent required to achieve 6,800 feet altitude by 8 DME. Rate of descent instruments tend to lag behind aircraft performance and for accurate attainment in the A300 it is necessary to know the airspeed or pitch angle which corresponds to the required rate. Simulator tests showed that lowering the nose and engaging IAS hold at 151 kts was a quick and simple way to set up a rate of descent of 2,000 fpm. Moreover, the movement of the throttles at 151 kts just before impact indicates that the commander wanted to maintain that extra speed at 8 DME. However, this does not explain why he departed 10 DME with the excess speed. It seems likely that either the commander had his own technique for the approach, or that he deliberately increased speed as a precaution against turbulence, or that the correct final approach speed had been miscalculated.

2.7 Main factor summary

It is not possible to determine from the evidence why the approach procedure was flown one step ahead, whether one or both pilots did so, or whether the co-pilot made an inadvertent error when he reported the altitude at 16 DME. Why the initial error was not detected at later fix points is uncertain. Either both pilots misinterpreted the approach procedure or the remainder of the crew failed to notice that the co-pilot was not briefing the commander correctly and the commander was not checking his own Jeppesen chart. It is also possible that the commander was flying the approach incorrectly and no-one was monitoring him. Most of these possibilities could have been eliminated with the help of a CVR record of the crew's conversation. All that seems certain is that the chart was, at some point, misinterpreted by at least one of the pilots. What is not known is the exact point at which the error was made, i.e. directly from the chart or a photo copy of it, from the chart to the hand drawn version, or from the hand drawn version. Which ever is the case, this would appear to be the initiating factor in the accident sequence.

2.8 Other factors

The SIERRA approach and the Jeppesen chart for it have been used by many pilots - including the pilots of PK268 - without leading to a similar accident. Therefore, there may have been other factors which contributed to the error process. This section of the analysis addresses probable and possible underlying factors which could have contributed to the cognitive error(s) and the crew's collective failure to notice them.

2.8.1 Complexity of the approach

The SIERRA approach to Kathmandu is a challenging approach for the pilot of a large aircraft. There are no ILS (instrument landing system) beams for the autopilot to couple to and heavy demands are placed on the pilot's instrument flying skills. The non-precision approach is guided by the VOR beacon in azimuth and by the DME range in elevation. VOR beacon reception can suffer from interference between 9 DME and 6 DME and for that portion of the approach the pilot must use another, less-accurate locator beacon at 4 DME for track guidance. From the fix at 16 DME to the missed approach point at 1 DME there are several changes to the glidepath and it is necessary to make frequent changes to the rate of descent if the aircraft is to follow the minimum altitude profile. The steepest glidepath of 6.5 ° is over twice the normal ILS glidepath of 3° and steeper than the maximum recommended by ICAO for a VOR/DME approach. Finally, high altitude and warm air temperatures in the Kathmandu valley result in the true airspeed being about 15% greater than the indicated airspeed. Although the rate of descent for a given airspeed is largely unaffected by the altitude and temperature, the increase in true airspeed reduces an aircraft's ability to descend steeply at normal approach speed and makes the landing run longer. The approach demands a high workload and is considered to be the most demanding one in PIA's A300 route structure. Opportunities to simplify the approach should be exploited.

2.8.2 Pilot feedback on the Jeppesen chart

It was clear that a significant number of PIA's A300 pilots believed that the Jeppesen SIERRA chart was too cluttered but there was no evidence of any previous instance of misinterpretation resulting from that aspect or evidence to show that anyone had raised this problem with the management. Some pilots had resorted to transcribing the chart onto paper and then used the transcription to brief and fly the approach. Steps should be taken to stop this dubious practice and pilots should be encouraged to alert their management and their pilots' association (PALPA) to approaches and associated charts which they considered to be unsatisfactory.

2.8.3 Chart clips

During the high workload phase of the approach it would have been the co-pilot's duty to read out the next DME fix and its corresponding minimum altitude to the commander. The commander should have been cross-checking against his Jeppesen chart but he may have found this difficult. Some of PIA's A300s have chart clips fitted to the control wheels but the accident aircraft did not. The pilots had two options for securing their charts and papers: they could have used a central clip between the INS displays on the centre pedestal or a clip beneath the sliding window at each pilot's side.

The simulator tests showed that the central clip was an unsuitable location for the approach chart. Despite its obvious unsuitability, PIA crews have been observed using it for that purpose and with both pilots sharing the same chart. The clips to each pilot's side were better but reading the chart required the pilot to rotate his head and look even further to his left or right. Frequent rotations of the head are tiresome and can induce pilot disorientation if the head movement is swift.

With a high workload, with no easy view of the chart, and with the aircraft descending rapidly, it is quite possible that the commander's concentration on handling the aircraft diminished his ability to refer to the chart. He may well have relied solely on the information provided verbally by the co-pilot and failed to notice that the heights briefed did not match those on the chart for the next DME fix.

A chart clip fixed to the control wheel is available as a minor modification from the aircraft manufacturers. In this position charts would be about 40 cm from the pilots eyes and directly in front of them. Placing the chart in a convenient position enhances the ease of reading it and allows quick glances without the risk of disorientation. Only two of PIA's A300 aircraft have control column chart clips; it is recommended that PIA should fit control column chart clips to all its A300s.

2.8.4 Headsets

The need to use hand-held microphones and the temptation to dispense with uncomfortable headphones during high-workload approaches is unsatisfactory. Moreover, if the crew had been wearing boom microphones which record continuously on the CVR (hot microphones), there would have been three channels of recorded speech instead of one, which despite recent testing, is blank. This redundancy would have made the investigation much simpler and quicker. It is recommended therefore that:

1. PIA should equip all its aircraft with sufficient lightweight-headsets for each member of the flight crew and that those headsets should have boom microphones.

2. PIA should adopt the hot microphone system for CVR recordings.

2.9. Crew training and standardisation

All the members of the flight crew had been flying the A300 for some time and so analysis of their conversion training is inappropriate. However, routine training and testing of aircrew twice a year was normal PIA procedure and a review of this process is appropriate.

2.9.1 Flight Preparation

The A300 crew were not rostered for the flight but they were given 12 hours notice. For the pilots, Kathmandu was not a frequent destination; neither pilot had operated there within the previous two months, although the commander had flown there four times in 1992.. Had they wished to refresh their memories on the procedures and approved techniques for the approach, they would have had difficulty unless they had retained a personal copy of the briefing circular issued in June 1989.

PIA normally had a route conversion unit (RCU) at their training facility a few miles from the airport terminal. The RCU had the necessary information and normally pilots could use it for self-briefing. However, one month before the accident, the unit had been disestablished to make way for a flight simulator and no alternative location had been found. There was no other company briefing material in the Operations Manual about the approach, apart from the 'T' chart which was all text and did not contain the approved technique for coping with the very steep stages of the approach. This situation was unsatisfactory, particularly as the RCU was supposed to be used by pilots for renewing currency to operate some routes. Airlines could have a place in or very close to their crew reporting centre where aircrew can study briefing material for airfields classified as unusual or difficult. Ideally, the rudiments of this material would also be part of the aircraft's on-board library. The material could vary, from printed text and maps for the less difficult but unusual approaches, to audio-visual briefings for the more difficult airports. The SIERRA approach to Kathmandu is so demanding, particularly in the A300, that it deserves more than the text of the T chart. An explanation of the approved flying technique is warranted and recommended, so is a visual explanation of the proximity to high ground in the 10 to 8 DME sector. It is recommended that PIA expand their briefing material for difficult instrument approaches and make this material available in or very near the crew reporting centre.

2.9.2 Simulator training

All the flight crew had been flight checked in the simulator within the previous three months. PIA did not own its own A300 simulator and these checks were carried out on other companies' simulators outside Pakistan. The checks were predominantly tests of handling skills and emergency procedures. The flight simulator training was listed as one of PIA's four methods of route training. The commander had practiced approaches to at least nine other airports in the simulator, but Kathmandu had never been practiced, even though it was recognised as the most demanding approach in the A300 routes. This was because it was not in the database of the rented simulators.

Kathmandu was not in the database of the simulator used for the flight tests after the accident. The essential facilities were easily entered; all that was needed to practice the approach was a VOR/DME beacon and the atmospheric conditions of temperature, pressure, turbulence, wind and weather. The data was then entered in minutes by the console operator. A full visual simulation of the airport and surrounding terrain is not necessary for practicing the instrument approach. It is recommended, therefore, that PIA should practice the SIERRA approach in the simulator as part of the process of pilot qualification to operate to Kathmandu and that such approaches should be part of a line-orientated training session.

2.9.3 Route checking

The commander had never been route-checked into Kathmandu. This situation arose because he was 'promoted' from Boeing 707 captain to A300 captain in April 1983. He had never operated the '707 to Kathmandu and did not visit the airport as part of his A300 command qualification flying because PIA did not begin A300 operations to Kathmandu until six years later (March 1989). He was route-checked to other destinations twice a year until he was appointed as an A300 route check captain in July 1987 and, in accordance with company training policy, he had not been route-checked since. The commander could have developed his own technique for the approach. There was no routine check of his performance other than basic handling skills and instrument flying in the flight simulator. Route checks for route-check captains are necessary if an airline is to ensure that the standards it desires are being set by those whose job it is to teach and enforce those standards. It is recommended, therefore, that PIA should ensure that all its route-check pilots are route-checked at least once per year.

2.9.4 Cockpit resource management

Whether the co-pilot erred or lied when he mis-reported the altitude at 16 DME is immaterial . If it was a speech error then the crew were not monitoring either the co-pilot's R/T or the commander's flying. If it was a deliberate deception, then the pilots failed to adhere to the published procedures; the flight engineers may have been unaware of the deviation, they may have consented to it, or they may have expressed their discontent in vain. If the co-pilot simply failed to monitor the commander's flying, he had forgotten his true purpose for being on the flight deck. Whatever happened, it was a breakdown in flight deck discipline. Training in cockpit resource management (CRM) could have helped to prevent the breakdown. There were three active participants in the flight crew and the workload could have been more evenly shared between them. The flight engineer could have been actively involved in interpreting the approach chart, a critical task which the co-pilot alone may have performed. That he was not involved is conjecture, but only two copies of the chart were normally available, one for each pilot. Flight engineers are not trained by PIA to read approach charts or to assist with piloting tasks and the airline's SOPs do not encourage their voluntary participation. Apart from calling out radio heights on late final approach, their normal duties were confined to reading checklists and systems management.

At the time of the accident PIA were considering their options for introducing a CRM course. It is recommended that

a. PIA should provide CRM training as soon as practicable for captains, co-pilots and flight engineers.

b. PIA should train their flight engineers to interpret non-precision approach charts and provide them with charts for all difficult non-precision approaches flown by the company.

2.9.5 Flight data monitoring

In addition to a crash-protected flight data recorder, PIA's A300s also have a performance maintenance recorder (PMR) which records flight data. The PMR could be used to monitor the way in which the aircraft is flown and a computer could be used to scan the recorded data to monitor events in areas such as bank angle, rates of descent, control inputs, altitude and navigational excursions, and engine/systems readouts. Some airlines do this for every flight, allowing the data to be examined for trends as well as exceedances. In this way poor flying techniques can be monitored and pilot training needs assessed, with maintenance cost reductions providing an additional benefit. Some airlines lack the resources to implement data monitoring as a daily routine. Nevertheless, random but reasonably frequent playbacks of recorded data could act as a deterrent to pilots who might otherwise decide to deviate from standard operating procedures and techniques. PIA clearly possessed the resources to replay the FDR of the commander's previous incident at Kathmandu and there seems no obvious reason why they could not adopt at least random checks. It is recommended that PIA carry out checks of recorded flight data to ensure that company standard operating procedures are being followed.

2.9.6 Flight operations inspection

The Civil Aviation Authority of Pakistan (CAAP) has no automatic right to observe and comment upon the conduct of flight operations from the flight deck. There are flight operations inspectors assigned to PIA's fleets but they are senior pilots from PIA who were nominated by PIA. There is no reason to suppose that they are anything other than totally suitable for the posts but being employees of the airline, they cannot be isolated from commercial pressures. No man can serve two masters, especially two who are in dispute. The proper monitoring and maintenance of high standards on the flight deck requires effort from *both* the airline and the regulatory authority. Therefore, it is recommended that the CAAP should appoint and provide flight operations inspectors and that PIA should allow them on the flight deck as observers.

2.10 Averting the accident

Like most civil aircraft weather radars, the aircraft's radar had no capability for terrain avoidance. The crew were unaware that they were dangerously low and so, if the accident was to be averted, some internal or external cue to their predicament was required. There were only three ways in which this cue could arise. They were: intervention by ATC; a GPWS warning; or, a radio altimeter warning.

2.10.1 Air Traffic Control

2.10.1.1 Performance

Once the aircraft had been cleared for the approach, the reporting of position and altitude was at the controller's discretion and he followed the common practice of asking for position reports at 16, 10 and 4 DME. He did not ask for simultaneous altitude reports but the co-pilot reported 16 DME at 11,500 feet which was correct. The controller had no way of knowing that anything was wrong until the co-pilot replied to his request for an altitude report at 10 DME. There was no other traffic in the vicinity of PK268 and the controller was unable to give a logical reason for wanting to know its altitude. He had asked out of habit; the request had been common practice until some time before the accident when it was discontinued.

The Tower controller was not perturbed by the reported altitude of 8,200 feet even though he knew that the minimum altitude was 9,500 feet. Because there was a time delay between the position report and the poorly phrased altitude report "WE *CROSSED* OUT OF EIGHT THOUSAND *FIVE HUN TWO* HUNDRED *NOW*", the controller may have thought that the aircraft had passed 10 DME and was descending *to* 8,200 feet which was the next - and correct - minimum altitude after 10 DME. It also emerged that, in visual flight conditions, local pilots sometimes avoided cloud on the mountain tops by departing from the published procedure and taking advantage of the river valley to the west of the approach track. It is possible that altitudes below 9,500 feet had been reported before, at or about 10 DME, without any associated danger in the minds of the controllers who observed the practice from the Tower. It is, however, more likely that he was not paying any attention to terrain separation because terrain avoidance was the pilot's responsibility. Moreover, he admitted that he did not know the height of the ground in the vicinity of 10 DME. When asked when would he challenge a pilot's incorrect altitude report, the controller stated that he did not think it right to remind a pilot of the correct altitudes unless the pilot said he was confused or unfamiliar with the descent profile.

2.10.1.2 Reaction times

If the controller had challenged the co-pilot's altitude report, it is doubtful whether the crash could have been avoided. The altitude report ended just 25 seconds before impact when the aircraft was descending through 7,800 feet. Tests in the simulator showed that if a terrain avoidance climb was initiated at 7500 feet, it took 11 seconds to arrest the rate of descent, enter a climb and regain 7,500 feet. Bearing in mind the difference in height between the impact site and the top of the mountainside, the accident became inescapable 15 seconds before impact. Consequently, the controller only had 10 seconds in which to convince the crew of their dangerous altitude. His first reaction might reasonably have been to ask the crew to confirm their altitude in case he had misheard it and they would have replied something less than 8,200 feet. Only then would he have been sure that he heard them correctly the first time. Next he would have to convince the crew that they were dangerously low. Their natural reaction might be to check their approach charts or at least to spend time wondering why, if they really were too low, had not the GPWS or radio altimeter alerted them to the situation. Given that neither the controller nor the crew were native English speakers, and that the co-pilot sounded entirely confident, it is doubtful whether the exchange of R/T messages and the realisation of serious danger by both parties could have been completed within 10 seconds. Nevertheless, the controller did not know how little time he had and his failure to challenge the altitude report represented a missed opportunity to alert the crew to impending danger.

2.10.2 GPWS

2.10.2.1 Serviceability

The GPWS did not perform its intended function of warning the crew of their inadvertent flight into terrain. Although the flight data record was intermittent during the last two minutes of flight, there was no indication of a warning at any time including the last second before impact. The possibility that the GPWS had failed was considered but the probability was considered remote for the following reasons:

a. The system gave two warnings on the day before the accident. Although the commander at the time could not recall either event, a detailed study of the data showed that both were genuine warnings (but not dangerous since the crew could see the ground). The first warning lasted 3 seconds and the second lasted 4. During both periods there was a noticeable raising of the nose indicating that the handling pilot had reacted to the warnings. Since the second warning occurred at 300 feet above the ground on final approach, when the pilot's attention would definitely have been directed outside the cockpit, he almost certainly heard it rather than saw it. Therefore, the system was serviceable at that time and there was no record of it having malfunctioned or been disturbed subsequently.

b. The flight data was sent to the GPWS manufacturers for assessment. They confirmed that, had there been a warning, it would have occurred between 18 and 16 seconds before impact. The co-pilot's last R/T transmission started at 19 seconds before impact and finished 16 seconds before it, a period which coincided with the most probable time for GPWS activation. Since he was using a hand microphone, had the warning sounded, it should have been audible on the CVR and ATC recordings. It was not audible on either recording.

c. PIA crews used the Airbus Industrie Flight Crew Operating Manual as their on-board operational manual. The 'normal procedures' section states that the the GPWS is to be tested before each originating flight. This test is carried out before the FDR starts and thus is not recorded. The crew of PK268 should have tested the equipment before leaving Karachi and their regulations did not allow the aircraft to depart without a serviceable GPWS.

2.10.2.2 Explanation for the absence of a warning

The possibility that a member of the crew intentionally disarmed the GPWS cannot be discounted but there was no obvious reason to do so. Nuisance warnings were experienced by PIA crews from time to time but the Kathmandu approach was not thought to be prone to such warnings. Unlike some airlines, PIA did not have a policy for de-activating the GPWS at certain "difficult" airports; consequently there was little likelihood that someone else had inhibited the system the previous day. The commander may have had his own personal technique for following the minimum altitude profile of the SIERRA approach, but because of the ample terrain clearance, he was unlikely to get a nuisance warning.

The most likely reason for the absence of a warning was the logic of the elderly Mark II GPWS; the aircraft was 16 years old and the latest variant is the Mark VII. The relevant FDR parameters together with the best available blend of synthetic and recorded radio height data were used by the manufacturers to determine the probability of a warning before impact. The data *indicated* that there would have been no warning although the margin for giving a warning was so close that they could not be certain, especially as the data accuracy could not be substantiated.

2.10.3 Radio Altimeter

The radio altimeter was unlikely to have alerted the crew since the decision height on at least one of the indicators was set to 499 feet, the maximum setting. The more modern GPWS computers generate a synthetic voice warning of "MINIMUMS! MINIMUMS!" when the aircraft descends to the decision height set on the radio altimeter. The minimum descent height for the SIERRA approach is 807 feet. If the crew of PK268 had had the 'smart' radio altitude callout of 'minimums' (they did not), and if they had been able to set 807 feet as a decision height (they could not, 499 was the maximum), then they would have heard a 'minimums' warning some 25 seconds before impact. This warning could have altered the crew to the fact that they were below the required approach profile and possibly enabled them to take timely remedial actions to avoid ground impact. Enabling the 'minimums' smart callout is a minor modification which requires wiring from the radio altimeter to the GPWS. The Marks V to VII GPWS also have 'smart' radio altitude callouts only heard on non-precision approaches. In view of the superior technology available, it is recommended that all airlines which operate regular scheduled services to Kathmandu should, where necessary, modify their GPWS equipments to provide automatic callouts of radio height.

2.11 Corrective Measures

This section of the analysis addresses measures to prevent a repetition of the primary cause of this accident whereby the crew misinterpreted the Jeppesen approach chart. There were, however, at least three other charts for the SIERRA approach used by different airlines. Therefore, it is pertinent to consider measures which would improve the clarity and accuracy of all the charts and not just the Jeppesen chart. Moreover, some unsatisfactory features of the Jeppesen chart are related not to the Jeppesen style but to the design of the approach State chart which confirmed with PANS/OPS in effect at that time.

2.11.1 The SIERRA approach charts

The four SIERRA approach charts at Annex B have marked differences in layout, convention and symbology. When describing the chart, the psychologist stated:

> "Each of the charts has some good features and a number of them share common elements, which is not altogether surprising. However, no one chart encapsulates all the better aspects. The area allocated for the vertical profile on each chart seems cramped and consequently leads to inconsistent and, in some cases, ambiguous information presentation, particularly as it relates to DME and relative advisory altitudes."

Variation in chart conventions has been criticised as a causal factor in other air accidents. (For instance see the accident to a Boeing 737 at Unalakleet, Alaska on 2 June '90 when the crew descended too early because they mis-interpreted the DME range at which to begin descent). It is recommended, therefore, that ICAO review the conventions of commercial approach charts with a view to encouraging standardisation and reducing chart clutter.

2.11.2 Jeppesen chart style

Jeppesen were the only chart producers to illustrate the SIERRA altitude profile as a series of steps with a short descent phase and a longer level flight phase between each DME fix point. The profile shown cannot be followed in a large jet aircraft. The speed and inertia of these aircraft is such that establishing a high rate of descent and then levelling off cannot be achieved in the space of one, two or even three nautical miles. The rate of descent must be controlled such that the aircraft arrives at the next DME fix point at or slightly above the recommended altitude. The data required to do this efficiently is a recommended altitude for each whole mile of DME range. In that way, the pilots have a target altitude every 25 seconds or thereabouts on which to assess the accuracy of the descent rate and then to make small adjustments to it so that they arrive overhead the next fix at the recommended altitude. Some indication of the rate of descent or glidepath between the DME fixes is very helpful when planning and briefing the approach on the flight deck. The only chart which complied with PANS OPS recommendations in that it had both glidepath data and recommended altitudes for each mile was the SAS chart which used a table to organise the DME/altitude pairs.

2.11.3 The advantages of data tabulation

The advantages of showing the DME/altitude relationship in a table are:

a. The data is easily assimilated without any interpretation.

b. The layout of the table is error resistant since the eye need only read from right to left or top to bottom depending on the orientation of the table.

c. Placing the DME fix and its associated altitude in a table makes it unambiguous.

2.11.4 Jeppesen conventions

Like SAS, Jeppesen could have used a tabular format to display the DME/altitude pairs; a tabular format is sometimes used on other Jeppesen charts. A table conforming to the Jeppesen standard would look similar to the table below:

KTM DME	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0
ALTITUDE (HAT)	9500' (5187')	8800' (4487')	8200' (3887')	7500' (3187')	6800' (2487')	6100' (1787')	5800' (1487')	5600' (1287')	5300' (987')

However, the notes produced by Jeppesen to explain their chart legend and conventions state:

> "The top of the profile view on certain non-precision approaches contains a table of *recommended* altitudes/heights at various DME fixes to allow a constant rate of descent. The altitudes/heights are *recommended* only; minimum altitudes in the profile view apply."

Jeppesen's charting specifications do not allow its compilers to publish a table of recommended altitudes unless this information is published on the State chart. Conversely, if the State chart does publish such a table, Jeppesen's specifications require that it be included in their chart.

2.11.5 Tabular data on the State chart

It is important to remember that Jeppesen did not design the SIERRA approach. The company designed, produced and distributed an approach chart which conformed to their presentation style and specification. Their chart was based on the State chart and had the State chart contained a table, Jeppesen would have copied it onto their chart. Therefore, it is appropriate that tabular DME/altitude data should be compiled and shown on the State chart where it could be copied by all the commercial chart suppliers.

It is recommended therefore that:

a. HMG/N Department of Civil Aviation should re-design the State SIERRA approach chart to comply with ICAO PANS OPS by including a table of recommended minimum altitudes for each nautical mile of the final approach.

b. The chart producers should ensure that their SIERRA approach charts comply with ICAO PANS OPS by including a table of recommended minimum altitudes for each nautical mile of the final approach.

2.12 Possible improvements

This section concentrates on improvements to the ATC environment and aircraft systems which, whilst not directly related to the accident, could help to reduce the probability of a similar accident recurring.

2.12.1 The State SIERRA approach chart

The State chart is the foundation for the commercially available charts. Therefore, it is recommended that the State chart should be thoroughly reviewed to ensure that it meets the PANS OPS standards for displaying all the data which is needed by pilots. Obvious additions are the identification of the final approach fix, the significance of the fan marker and the inclusion of glidepath angles.

2.12.2 The SIERRA approach (medium term)

The current SIERRA approach has been aptly described as a theoretical solution to a practical problem. Whilst the extraordinary nature of the terrain surrounding Kathmandu prevents the approach designer from adopting some conventions, the multiple variations of glidepath angle and the awkward exit from the holding pattern make the approach more complex than it need be.

The complexity detracts rather than adds to the safety of the approach. Improvements and simplifications to the SIERRA altitude profile and holding pattern could be made in order to make them safer and easier to fly. It is recommended that the Nepalese Department of Civil Aviation should address the following aspects:

a. Unnecessary variations in the glidepath angle should be eliminated. For example, one glidepath of 6 degrees between 10 DME and 4 DME would simplify the approach considerably without reducing terrain separation.

b. At present, if an aircraft enters the holding pattern, it normally holds in the clean configuration at 10,500 feet on a race track pattern between 10 and 13 DME. The outbound leg of the holding pattern takes the aircraft to the west of the inbound track. In strong crosswinds it would be very difficult to roll out at 13 DME exactly on the required inbound track. When an aircraft in the hold is cleared for the approach, it needs to start the approach (by descending at 13 DME) before the holding pattern is completed at 10 DME, but the descent is not permitted unless the aircraft is "established" on the radial (ie within about 1 nm and closing towards it). Moreover, the aircraft configuration must be changed from gear and flap up to gear and flap fully down - which takes time and distance - before the aircraft reaches 10 DME. These are unnecessary complications which could be avoided if the holding pattern were revised to give more time before commencing the steep part of the approach at 10 DME.

c. There is no external facility for checking the validity of the DME range before the approach commences. Since the safety of the instrument approach depends heavily on accurate DME, this deficiency should be addressed. A facility should be sited so as to validate DME range before the descent below minimum safe altitude commences.

2.12.3 The SIERRA approach (long term)

There would appear to be nothing wrong with the present VOR/DME installation and no point in replacing it. However, there are two equipment installations which could improve flight safety: radar and a precision approach guidance system. Of the two, precision approach guidance is considered more important than radar coverage.

2.12.3.1 Precision approach guidance

Safe approaches in bad weather are best made by coupling the autopilot to a precision approach aid such as ILS or MLS. Few if any of the airlines routinely using Kathmandu have MLS fitted to their aircraft and equipping their fleets for Kathmandu alone would be economically prohibitive. Precision approach radar is another option but its effective use would require thorough additional training for controllers and pilots alike. However, aircraft on international routes have to be equipped for ILS approaches and their pilots are proficient at the approach technique. Propagation problems apart, there would appear to be no practical reason why an ILS localiser could not be installed and used to give precision azimuth guidance (including autopilot coupling) to the runway. An ILS glidepath would have to provide adequate ground clearance and avoid nuisance warnings from the GPWS. It would also have to be usable beyond the normal maximum of 10 nm and free of interference.

ILS installations are used in mountainous areas (eg Chamberey in France) and glidepaths of 4° or more are used by commercial jet aircraft. It is not clear whether an ILS could be installed at Kathmandu but the installation would undoubtedly improve the safety of IFR flights. Therefore, it is recommended that the Nepalese Department of Civil Aviation should study the practicalities of providing an ILS at Kathmandu.

2.12.3.2 Radar

The primary purpose of air traffic control radar is the safe and expeditious vectoring of aircraft within busy airspace. Primary radar would not have prevented this accident because the aircraft was on track but it could have prevented another recent air accident near Kathmandu. However, secondary surveillance radar (SSR) with an altitude interrogation (mode C) facility would have allowed an alert controller to notice that PK268 was too low. It would also allow controllers to identify individual aircraft (if they are transponder equipped) and monitor their flight path. Unfortunately the provision of radar would not in itself make instrument approaches safer. The equipment would have to be kept serviceable and the controllers would have to be trained and tested in its proper use. Nevertheless the provision of radar for Kathmandu airport may well be justified by its rapid growth in international and internal air traffic. Therefore, it is recommended that the Nepalese Department of Civil Aviation should study the practicality of providing radar coverage around Kathmandu.

2.12.4 Air traffic controller status

Observations and statements taken during the investigation indicated that the majority of Kathmandu's air traffic controllers did not consider that they had a part to play in preventing aircraft from flying into the ground. The recurrent theme in their statements of their professional objectives was "The safe, orderly and expeditious flow of air traffic". They saw their role as preventing aircraft from colliding with one another and they did not feel entitled or empowered to intervene in matters of pilotage such as terrain clearance.

The Nepalese controller's working conditions were pleasant but some of those interviewed expressed poor motivation and desired more training. They had no licence, no specific ratings for different tasks and no regular assessment of their skills. Apart from their academic qualifications they had no symbols of professional status and no incentive to believe that they could prevent pilots from making fatal mistakes. Their low self-esteem was probably the root cause of the Tower controller's failure to challenge PK268's pilots. Therefore, it is recommended that Nepal's Department of Civil Aviation should consider taking steps to improve air traffic controllers' motivation, performance and self-esteem by:

a. Issuing formal air traffic controller's licences.

b. Introducing specific controller position training and ratings.

c. Introducing periodic competency checks.

d. Immediately introducing improved salaries and allowances to operational ATCOs at Tribhuvan International Airport.

2.12.5 GPWS improvements

It is unfortunate that a timely GPWS warning depends so heavily on the distance between the aircraft and the ground beneath it rather than the ground ahead of it, a dependence which has obvious limitations in mountainous terrain. The system cannot be optimised for every type of terrain and the majority of international airports are surrounded by lower and less steep terrain. In these areas, the equipment has worked well and has prevented accidents. To have prevented this accident, the equipment would have had to warn the crew at least 15 and, allowing for typical pilot reaction times, probably 20 seconds before impact. At that time the aircraft was almost a mile away from the mountain it hit and over 500 feet above the ground directly beneath it.

The GPWS system could be augmented by giving it a capability to look forwards as well as downwards. Two methods of achieving this would be forward looking sensors and digital map correlation.(a navigation system which computes position by comparing the terrain profile sensed by the radio altimeter or laser to terrain elevation data stored in a digital computer). Both are existing military technologies and there may be scope for adapting these technologies for civil aviation. A detailed analysis of these systems is beyond the scope of this report. Nevertheless, it is recommended that ICAO should sponsor research into improving GPWS technology so as to improve system performance in mountainous terrain.

2.12.6 Crew reaction to GPWS

There were no written procedures for pilots to follow in response to a GPWS warning except for one paragraph in the aircraft manufacturer's operating manual under the FINAL (approach) section of the normal procedures which was repeated in PIA's A300 SOPs. The stated procedure was:

"In case the GPWS is activated react with pitch control and power without delay"

This statement is common sense but not as useful as it might be. In visual conditions the pilot can judge the appropriate reaction himself but in cloud it begs the questions: how much pitch and how much power? The procedure for swiftly establishing the maximum sustainable climb angle is what the pilot really needs to know. Therefore, it is recommended that Airbus Industrie should amplify the instructions in their Flight Crew Operating Manual regarding pilot response to GPWS warnings.

3 CONCLUSIONS

(a) Findings

(i) The flight deck crew were properly licensed and medically fit.

(ii) The aircraft had been properly maintained and was fit for the flight and the essential aircraft systems were operating normally during the approach.

(iii) The SIERRA approach to Kathmandu is a demanding approach in any wide-bodied aircraft.

(iv) Unlawful interference and extreme weather were not causal factors.

(v) The crash site was enveloped in cloud at the time of the accident.

(vi) There was no ATC clearance error.

(vii) The VOR/DME beacons used for the approach were operating satisfactorily and there was no evidence of failure or malfunction within the aircraft's DME equipment.

(viii) The aircraft acquired and maintained the correct final approach track but began descent too early and then continued to descend in accordance with an altitude profile which was consistent with being 'one step ahead' and below the correct profile.

(ix) At 16 DME.the co-pilot mis-reported the aircraft's altitude by 1,000 feet.

(x) The commander did not adhere to the airline's recommended technique for the final part of the approach which commenced at 10 DME.

(xi) The 10 DME position report requested by the Tower controller was made at an altitude below the minimum safe altitude for that portion of the approach.

(xii) The altitude profile on the Jeppesen approach chart which should have been used by the pilots was technically correct. However, the profile illustrated could not be flown in the A300 at Vapp, in common with any other wide bodied jet of similar size and the minimum altitude at some DME fixes was not directly associated with the fix.

(xiii) The aircraft did not have control-column mounted chartboards.

(xiv) As described in the report, there is scope for improving the SIERRA approach procedure and its associated charts.

(xv) Kathmandu was not a frequent destination for PIA's A300 crews and neither pilot had operated there within the previous two months.

(xvi) PIA's training of air crews, briefing material and self-briefing facilities for the SIERRA approach to Kathmandu leave room for improvement.

(xvii) PIA's route-checking and flight operations inspection procedures were ineffective.

(xviii) The accident was inevitable 15 seconds before impact.

(xix) The Tower controller requested an altitude report immediately after the co-pilot reported at 10 DME. His failure to challenge the low altitude reported at 10 DME was a missed opportunity to prevent the accident but, even if he had done so, it is doubtful whether the accident could have been averted.

(xx) Some air traffic controllers at Kathmandu had a low-self esteem and were reluctant to intervene in piloting matters such as terrain separation.

(xxi) The GPWS was probably serviceable but failed to warn the crew of impending flight towards high ground because of the combination of elderly equipment and rugged terrain.

(xxii) Advice within the aircraft manufacturer's operating manuals regarding pilot reaction to a GPWS warning was incomplete.

(xxiii) The MEL was being breached in that PIA were not supplying their CAA with the required carry-forward defect summaries for analysis, neither was the CAA requesting them.

(b) Cause

The balance of evidence suggests that the primary cause of the accident was that one or both pilots consistently failed to follow the approach procedure and inadvertently adopted a profile which, at each DME fix, was one altitude step ahead and below the correct procedure. Why and how that happened could not be determined with certainty because there was no record of the crew's conversation on the flight deck. Contributory causal factors were thought to be the inevitable complexity of the approach and the associated approach chart.

4 SAFETY RECOMMENDATIONS

It is recommended that:

4.1 ICAO should review the conventions of commercial approach charts with a view to encouraging standardisation and reducing chart clutter.

4.2 His Majesty's Government of Nepal, Ministry of Tourism and Civil Aviation, Department of Civil Aviation should re-design the State SIERRA approach chart to comply with ICAO PANS OPS by including a table of recommended minimum altitudes for each nautical mile of the final approach.

4.3 HMG/N, Department of Civil Aviation should improve and simplify the SIERRA approach procedure by addressing the following aspects:

a. Unnecessary changes in the glidepath should be eliminated.

b. The holding pattern should be revised.

c. A facility should be provided to validate DME range before the descent below minimum safe en-route altitude commences.

4.4 The chart producers should ensure that their SIERRA approach charts comply with ICAO PANS OPS by including table of recommended minimum altitudes for each nautical mile of the final approach.

4.5 The operator should take steps to stop the dubious practice of some crews transcribing data from approach charts.

4.6 The airline's crews should be encouraged to alert their management and their pilots' association to those charts which they consider to be unsatisfactory.

4.7 The airline should fit control column chart clipboards to all its A300s.

4.8 The airline should equip all its aircraft with sufficient lightweight-headsets for each member of the flight crew and those headsets should have boom microphones.

4.9 The airline should adopt the hot microphone system for CVR recordings.

4.10 The airline should expand its briefing material for difficult instrument approaches and make this material available in or very near the crew reporting centre.

4.11 The airline should practice the SIERRA approach in the simulator as part of the process of pilot qualification to operate to Kathmandu and that such approaches should be part of a line-orientated training session.

4.12 The operator should ensure that all its route-check pilots are route-checked at least once per year.

4.13 The airline should provide Cockpit Resource Management training as soon as practicable for captains, co-pilots and flight engineers.

4.14 The airline should train its flight engineers to interpret non-precision approach charts and provide them with charts for all non-precision approaches flown by the company.

4.15 The airline should carry out checks of recorded flight data to ensure that company standard operating procedures are being followed.

4.16 The Civil Aviation Authority of Pakistan should appoint and provide flight operations inspectors and the airline should allow them on the flight deck as observers.

4.17 Airlines which operate regular scheduled services to Kathmandu should, where necessary, modify their GPWS equipments to provide automatic callouts of radio height.

4.18 HMG/N Department of Civil Aviation should study the practicalities of providing an instrument landing system (ILS) and radar coverage at Kathmandu.

4.19 HMG/N Department of Civil Aviation should consider taking steps to improve air traffic controllers' motivation, performance and self-esteem by:

a. Issuing formal air traffic controller's licences.

b. Introducing specific controller position training and ratings.

c. Introducing periodic competency checks.

d. Immediately introducing improved salaries and allowances to operational ATCOs at Tribhuvan International Airport.

4.20 ICAO should sponsor research into improving GPWS technology so as to improve system performance in mountainous terrain.

4.21 Airbus Industrie should amplify the instructions in their Flight Crew Operating Manual regarding pilot response to GPWS warnings.

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