ACCIDENT TO INDIAN AIRLINES
AIRBUS A-320 AIRCRAFT VT-EPN
ON 14TH FEBRUARY, 1990
AT BANGALORE

REPORT OF
THE
COURT OF INQUIRY

HON'BLE Mr. JUSTICE K. SHIVASHANKAR BHAT,
JUDGE, HIGH COURT OF KARNATAKA

Assessors :

Capt. B. S. Gopal, Director Flight Safety,
Air India.

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Bangalore,

Dated :

REPORT OF ACCIDENT TO INDIAN AIRLINES AIRBUS A-320 AIRCRAFT VT-EPN AT BANGALORE ON 14TH FEBRUARY, 1990.

1.	Aircraft :	Type	: Airbus A-320-231
		Nationality	: Indian
		Registration	: VT-EPN
	Engine :	Type	: IAE V 2500.A1.
		Port	: Sl.No.V-0021
		Starboard	: Sl.No.V-0040
2.	Owner and Operator		: Indian Airlines
3.	Place of Accident		: About 1250 feet short of Runway 09 beginning at Bangalore Airport.
4.	Date and time of accident		: 14th February, 1990 13:03:16 hours (IST)

CONTENTS

S. No.	Contents	Page No.
1.	Decision of Government of India	I-XXXIII
2.	Court of Inquiry Report on the accident to Indian Airlines Airbus A-320 aricraft VT-EPN on 14th February 1990 at Bangalore	1-581

Government of India
Ministry of Civil Aviation
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Sub: Government of India's decisions on the Report of the Court of Inquiry on the accident to Indian Airlines Airbus A-320 aircraft on 14th February, 1990 at Bangalore

On 14th February, 1990, an Indian Airlines Airbus A-320 aircraft VT-EPN operating a scheduled passenger flight from Bombay to Bangalore, crashed on its final approach to the Bangalore Airport. 92 persons lost their lives in the accident. A Court of Inquiry was appointed under Shri Justice K. Shivashankar Bhat, a sitting Judge of the Karnataka High Court, to investigate the cause of the accident. The report of the Court of Inquiry was received by the Government on the the 3rd December, 1990. It runs into 581 pages including its appendices.

2. The "**Probable Cause of the Accident**" is given in Part IX of the report. There are **85 Findings** in Part VIII of the report and **62 Recommendations** in Part X of the report.

Probable Cause of the Accident

3. The full text of Part IX of the report entitled "Probable Cause of the Accident is as follows:

"Failure of the pilots to realise the gravity of the situation and respond immediately towards proper action of moving the throttles, even after the Radio altitude call-outs of "Four Hundred", "Three Hundred" and "Two Hundred" feet, in spite of knowing that the plane was in idle/open descent mode. However, identification of the cause for the engagement of idle/open descent mode on short final approach during the crucial period of the flight is not possible."

4. The first sentence of the quotation above deals with the " cause of the accident ", while the second sentence deals with the " cause of the aircraft going into the idle/open descent mode on short final approach".

5. As regards the cause of the accident, at several places in the main body of the report, the Court of Inquiry has been much more specific and clear-cut about the cause of the accident. These are illustrated below in paras 6.1 to 6.7.

6.1 For example, in paragraph 33 at page 324 of the report, the Court has observed as follows:-

> (33) It is clear that, the pilots failed to convert the idle/open descent mode to speed mode (for whatever reason) even when they saw that the plane was in idle/open descent mode and the plane was already in the crucial phase of landing. After runway was in sight, short finals announced and landing checks completed, pilots diverted their attention to find out the reason for the idle/open descent mode, rather than reacting to the situation by acting on the throttle levers. Crucial seconds were spent in checking the FDs and the auto-pilots. **The entire crash is the result of what the pilots did not do between 295 to 320 seconds - during 25 seconds (i.e. less than half of a minute) and not what they did.**

6.2 In para 37 at page 326 of the report, the Court has observed as follows:-.

> "(37) A discussion on the events during these crucial seconds leads to one inevitable conclusion, that the pilots in spite of noticing the plane in idle/open descent mode failed to react immediately at the final phase of landing; instead, they tried to find out the cause for the idle descent mode and in this they spent some valuable moments...."

6.3 In para 50 at page 334 of the report, the Judge has observed as follows:-

> "(50) I am of the view that there was an unnecessary diversion of attention to check the cause for the idle/open descent mode of the plane and the instinctive reaction to resort to the thrust levers did not come out at the crucial moment."

6.4 In para 53 at page 334 of the report, the Judge has commented as follows:-

> "(53) There is nothing to indicate that pilots were aware of the speed falling; these are two experienced pilots out of whom one is on his first route check in this aircraft. The calmness of cockpit atmosphere indicates that their mind was elsewhere; if not at that point of time, pilots should have resorted to manual operation of the throttles, instead of searching for the cause for the idle/open descent mode...."

6.5 Furthermore, in finding No.15 at page 437, the Court has remarked:-

> "(15) At 13:02:42 (295 DFDR Time Frame - i.e., about 35 seconds before the time of first impact with the ground), the aircraft was at a height of 512 feet AGL. Since then it started coming down below the profile and aircraft speed was falling below the target approach speed. **There is no specific indication that the crew monitored the speed and height since then**."

6.6 In finding No.20 at page 438 of the report, the Court has specifically identified what the pilots did not do with reference to the Court's observations in paragraph 33 at page 324 quoted above in para 9.1. The Court has observed as follows in its finding No.20:-

> "(20) This crash would not have happened:
>
> (a) if the vertical speed of 700 feet as asked for by Capt. Fernandez at about DFDR 294 seconds had been selected and aircraft had continued in speed/vertical speed mode;
>
> (b) if both the flight directors had been switched off between DFDR seconds 312 to 317 seconds; or
>
> (c) by taking over manual control of thrust i.e. disconnecting auto thrust system and manually pushing the thrust levers to TOGA (take off - go around) position

at or before DFDR 320 seconds (9 seconds to first impact on golf course).

6.7 In addition to the above three factors mentioned by the Court in finding No.20, it is important to add another factor which also has been commented upon by the Court in the main body of its report (para 2 at pages 107-108, page 310). This fourth factor is that if the go around altitude of 6000 ft. had been selected on the FCU in accordance with the standard procedure, at the time it was asked for by the pilot flying, the accident would not have occurred. In such a case, the aircraft would not have gone into idle/open descent mode because it is not possible to go into this mode below the FCU selected altitude.

Reason for engagement of idle/open decent mode

7. In regard to the reason for engagement of idle/open descent mode on short final approach, the Court has observed that "identification of the cause for the engagement of idle/open descent mode on short final approach during the crucial period of the flight is not possible". However, the Court itself has drawn attention to the most probable cause in other parts of the report. In a nutshell, the most probable cause for the engagement of idle/open descent mode was that instead of selecting a vertical speed of 700 feet per minute at the relevant time i.e. about 35 seconds before the first impact, the pilot CM.2 had inadvertently selected an altitude of 700 feet. The vertical speed and altitude selection knobs of the Flight Control Unit (FCU) are close to each other, and instead of operating the vertical speed knob, the pilot CM.2 had inadvertently operated the altitude selection knob. The altitude of 700 feet that got selected in this manner was lower than the aircraft altitude at that time and therefore the aircraft had gone into idle/open descent mode. That this is the most probable cause for the engagement of idle/open descent mode is recognised by the Court in para 14 at page 310 of the report where it has discussed this matter, and in recommendation No.29 where the Court has specifically suggested a design change with respect to the two knobs. Paragraph 14 at page 310 and recommendation No.29 are reproduced below in full:

Para 14, page 310

"Another probability is that CM.2 dialled the wrong knob (thinking that he dialled the correct knob) resulting in the selection of a lower altitude (a possibility spoken to by Capt. Thergaonkar). It is also probable that he wanted to select go around altitude first and therefore selected the altitude knob, but, while dialling it, the words just told to him by CM.2 regarding vertical speed, influenced his action and thus he selected the altitude of 700 feet without even realising that he selected the wrong altitude. There are occasions when an action taken with a particular object in view, gets confused because of another object influencing it. If CM.2 had acted at TF.294 to dial V/S knob at a time when plane was in Alt* zone, he might have failed to follow the requisite procedure. This is also quite probable because having thought that he selected the vertical speed of 700 feet at the most appropriate time, he was surprised to find the plane in idle/open descent mode a few seconds later and therefore he expressed to CM.1, by stating "you are descending on idle/open descent aa, all this time".

Recommendation No.29

"Due to possibility of mistaking altitude and vertical speed knobs one for the other, a modification is recommended where vertical speed knob would have a wheel to be operated vertically up and down instead of the present clockwise and anti-clockwise direction of movement of the knob".

Government's acceptance of the report

8. The Government has accepted the finding of the Court as regards the probable cause of the accident. However, taking into account the above mentioned observations and findings of the Court, the probable cause of the accident may be expressed specifically as follows:-

"Failure of the pilots to monitor speed during final approach, probably because they diverted their attention to find out the reason for the aircraft going into idle/open descent mode rather than realising the gravity of the situation and responding immediately towards proper action.

This crash would not have happened if the pilots had taken any one of the following action:-

(a) if the vertical speed of 700 feet as asked for by Capt. Fernandez at about DFDR 294 seconds had been selected and aircraft had continued in speed/vertical speed mode;

(b) if both the flight directors had been switched off between DFDR seconds 312 to 317 seconds;

(c) by taking over manual control of thrust i.e. disconnecting auto thrust system and manually pushing the thrust levers to TOGA (take off - go around) position at or before DFDR 320 seconds (9 seconds to first impact on golf course).

(d) if the go around altitude of 6000 feet had been selected on the FCU in accordance with the standard procedure at the time it was asked for by Capt. Fernandez."

9. The most probable cause for the engagement of the idle/open descent mode during the short final approach is that instead of selecting the vertical speed of 700 feet per minute, the pilot (CM.2) had inadvertently selected an altitude of 700 feet by operating the altitude selection knob. As this altitude selected on the FCU was lower than the altitude of the aircraft at that time, the aircraft went into the idle/open descent mode.

Aircraft and its systems, including the engines

10. The Court has ruled out any sabotage or structural, engine or any aircraft system's failure as the cause of the accident. All the systems of the aircraft, including the engines, were found to be performing normally. Specifically, the Court has observed as follows:-

"There was no defect reported, on the airframe, engines and their systems prior to the ill-fated flight nor any defect, abnormality or emergency reported during flight by the pilots, till it crashed."

(Finding No.2, page 435)

"There was no apparent indication of any abnormality of flying controls".

(Finding No.3, page 435)

"All primary and secondary flight controls appeared to have operated normally."

(Finding No.80, page 448)

"The engines have operated normally throughout and have not contributed towards the cause of this accident."

(Finding No.82, page 448)

Non-availability of ILS system at Bangalor Airport

11. In finding no.84 of the report, the Court has observed that if ILS was available at Bangalore for runway 09, most probably this accident would not have occurred. This finding of the Court is based on the presumption that if ILS had been available, the pilots would have chosen to make the ILS approach, and moreover, a correct ILS procedure would also have been followed. This cannot be said with certainty. The pilots in this case have not chosen to follow a full VOR/DME approach even though such facility was available at the Bangalore airport. This accident has occurred primarily due to non-adherence to procedures, particularly non-monitoring of the speed in the final approach. Furthermore, the accident has occurred on a clear day with excellent visibility condition and without much traffic. Therefore, it is not possible to accept this finding of the Court of Inquiry.

Findings of the Court of Inquiry

12. In Part VIII of its report, the Court has given 85 findings. These are reproduced in Appendix I to this Memorandum together with the Government's views on each one of them. The Government is unable to accept the finding Nos.17, 19, 35, 60, 62, 65, 73, 74, 75, 76 and 84 for the reasons stated against each one of them.

Recommendations of the Court of Inquiry

13. In Part X of its report, the Court has made 62 recommendations. These are reproduced in Appendix II to this Memorandum together with the Government's views on each one of them. The Government is unable to accept recommendation Nos. 1, 26, 30, 31, 33, 34, 35, 36, 44, 46, 48, 49, 52, 54, 55 and 57.

FINDINGS	COMMENTS
1. The aircraft had a valid certificate of Airworthiness and was maintained in accordance with the approved maintenance schedules.	Agreed.
2. There was no defect reported on the airframe, engines and their systems prior to the ill-fated flight nor any defect, abnormality or emergency reported during flight by the pilots, till it crashed.	Agreed.
3. There was no apparent indication of any abnormality of flying controls.	Agreed.
4. Investigation of the engines revealed that the engines were developing power and were at or near full power when they sheared off from the wings after hitting the embankment.	As per DFDR data and engine examinations, the engines had accelerated to high power and not full power at the time of impact with embankment.
5. DFDR data reveals that there was no failure of aircraft electrical, hydraulic, yaw damper and cabin pressurisation and communications systems. There was no smoke or fire warning. The GPWS activated 'Sink Rate' warning four times from DFDR seconds 324 onwards.	Agreed.
6. The wreckage examination revealed that the slats were extended, flaps were in full down position, spoiler lever armed and landing gears were down thereby indicating landing configuration of the aircraft.	Agreed.
7. Weather conditions were clear.	Agreed.
8. All security procedures	Agreed.

prior to commencement of the flight were carried out and there is no evidence of sabotage.	
9. The pilots were appropriately licensed to undertake the flight.	Agreed.
10. Capt. C.A. Fernandez was flying the aircraft from the L.H. seat as CM.1 and it was his first route check for command endorsement under supervision of Capt. Gopujkar, Check Pilot of A-320 aircraft.	Agreed.
11. Although VOR-DME approach was discussed between the pilots, it is not clear whether VOR-DME let down procedure as per Jeppessen Manual was followed. From 42 NM to 7 NM the aircraft was under surveillance of Bangalore Air Route Surveillance Radar and from 7 NM onwards indications are that visual approach or a mixture of visual with Non-precession approach was being followed.	Agreed.
12. The aircraft reported R/W in sight when it was 7 NM west on left base of R/W 09 and was cleared to land by Bangalore Tower at 13:02:17 hrs. which was acknowledged by the flight crew.	Agreed.
13. Landing checks were completed but go around altitude was not set. Similarly, Flight Directors were not put off at the time of landing checks.	Agreed.
14. The aircraft was slightly higher and also having higher speed when landing clearance was given but thereafter it came to proper profile for approach to land.	Agreed.
15. At 13:02:42 (295 DFDR	Agreed.

Time Frame - i.e., about 35 seconds before the time of first impact with the ground), the aircraft was at a height of 512 ft. AGL. Since then it started coming down below the profile and aircraft speed was falling below the target approach speed. There is no specific indication that the crew monitored the speed and height since then.	
16. The relationship between the pilots was quite cordial.	Agreed.
17. When Capt. Fernandez (CM. 1) was pulling the side stick control off to pitch up the nose and arrest the sink rate, the aircraft entered the Alpha protection zone (high incidence protection) at 318 seconds and finally at 323.1 seconds Alpha floor (thrust protection to increase thrust to take off power) was triggered and in all probability at 323.9 seconds (or at 324.3 seconds), Alpha floor was activated by Capt. Fernandez taking the side stick movement to full back position.	Not acceptable as Alpha floor is a self actvating system when certain conditions are met and is not triggered intentionally by the pilot. This finding needs to be re-worded as follows : "When Capt. Fernandez (CM1) was pulling the sidestick control to pitch up the aircraft and arrest the sink rate, the aircraft entered the Alpha protection zone at 318 seconds and finally at 323.1 seconds Alpha floor got triggered and in all probability at 323.9 seconds (or at 324.3 seconds) Alpha floor **got** activated".
18. Airbus Industrie was not aware of the exact delay between Alpha floor triggering and its activation due to signal transmission through a number of computers and the delay seems to have been investigated only after the accident. Even now there is no definite knowledge of the exact delay which may vary from 0.8 to 1.2 seconds. None was aware of this delay factor so far.	Agreed.
19. Basically Alpha floor functioning is built as a protection against wind shear, but the pilots seem to be	Not acceptable as the features of Alpha floor protection are clearly explained during the training of pilots. Comments

under the impression that the protection from this system will be available to increase power of the engines in any emergency without any time delay and a false sense of faith has been reposed on this system.

against finding No. 17 may also be seen.

20. This crash would not have happened :

(a) if the vertical speed of 700 ft. as asked for by Capt. Fernandez at about DFDR 294 seconds had been selected and aircraft had continued in speed/vertical speed mode;

(b) if both the flight directors had been switched off between DFDR seconds 312 to 317 seconds; or

(c) by taking over manual control of thrust i.e., disconnecting auto thrust system and manually pushing the thrust levers to TOGA (take off - go around) position at or before DFDR 320 seconds (9 seconds to first impact on golf course).

Agreed. This finding could be amplified further by adding that 'had the pilot set the go round altitude of 6000 feet on the FCU, it would have prevented the aircraft from going into idle open descent mode as it is not possible for the aircraft to go into idle open descent mode below FCU selected altitude.'

21. In all probability one of the pilots acted to put off FD.2 by about TF.313 seconds, but FD.2 failed to go off resulting in confusion in the mind of Capt. Gopujkar.

Agreed.

22. There is nothing to show that the pilots realised the gravity of the situation even after the Radio Altimeter Synthetic call-outs of 400 feet, 300 feet and 200 feet.

Agreed.

23. Whatever be the exact timing of the throttle movement, it was too late an action to prevent the crash.

Agreed.

24. Alpha floor protection was triggered at 323.1 seconds

Agreed.

and got activated at 323.9 seconds (or 324.3 seconds) which again was too late to develop sufficient power in the engines to prevent the crash.	
25. At DFDR seconds 329.8 the aircraft first impacted the golf course. At what point of time 6.125 'G' was experienced and whether its recording by the DFDR was correct, are not decided. No expert witness was examined by anyone to explain the nature of 'G' force and the manner in which DFDR records the said force.	The timings of first impact is agreed. However, the force of first impact is not relevant to the accident.
26. Soil testing report indicated that the first touch down area was harder as compared to the second touch down point.	Agreed.
27. The aircraft bounced for nearly 1.194 seconds after first impact of about 0.42 seconds.	Agreed.
28. The impact against the embankment caused the detachment of both engines, landing gears and crushing of lower front fuselage.	Agreed.
29. Thereafter the aircraft hopped over the 'nullah' and parallel road and landed on a marshy land about 320 feet from R/W 09 boundary wall and came to rest about 150 feet short of the boundary wall after dragging on the ground.	Agreed.
30. Forward portion of the aircraft was engulfed in a huge fire in the beginning. The fire propagated later towards the rear.	Agreed.
31. The rear left door was opened by an airhostess and most of the surviving passengers escaped through this	Agreed.

door. A few passengers escaped by opening emergency exit windows.

32. The percentage of survivors in the front, middle and rear zones of the aircraft were around 16%, 27% and 73% respectively of the passengers occupying the seats in these zones.	Agreed.
33. RA emitted auto call-outs of 400, 300, 200, 100 and 50 (or 30) till the first touch down.	Agreed.
34. CVR-DFDR corelation reveals that at about 38 to 40 seconds prior to the first touch down the aircraft was in proper auto thrust speed mode and was descending in vertical speed mode. At DFDR seconds 292 altitude capture mode was activated indicating that a selection on the FCU panel close to MDA of 3300 ft. had been made at an earlier stage of the flight.	Agreed.
35. Prior to 305 seconds, the aircraft went into idle open descent mode. A conclusive finding as to what pilots did at this point of time is not possible.	Agreed to the extent that "Prior to 305 seconds the aircraft went into idle open descent mode". As regards the cause for engagement of Idle/Open descent mode, the Court itself at page No. 310, para 14 has noted. "It is also probable that he wanted to select go around altitude first and therefore selected the altitude knob, but while dialing it, the words just delivered to him by CM-1 regarding vertical speed influenced his action and thus he selected the altitude of 700 feet without even realising that he has selected wrong altitude". It was this action of the pilot (CM-2) which most probably put the aircraft in idle open descent mode.

36. DFDR recording shows that auto thrust speed select discrete changed status from '1' to '0' at 295 seconds. There is no doubt that plane was in idle open descent mode by 305 seconds, by which time the plane was at an altitude lower than 400 feet Radio altitude.	Agreed.
37. The aircraft could not sustain the height and speed in the approach profile because of fixed idle thrust in idle open descent mode.	Agreed.
38. The aircraft never went to speed mode thereafter, though it was the most proper mode for landing.	Agreed.
39. In all probability, for some reason the pilots did not realise the gravity of the situation of idle/open descent mode and being at a Radio altitude below 300 ft. at DFDR TF. 305 seconds.	Agreed.
40. The ATC tape at Bangalore Airport was found recording the tower and approach frequencies only and time was not recorded.	Agreed.
41. The crash fire tenders of HAL Airport must have reached the boundary wall of the airport at the earliest point of time, but, subsequently there was delay in opening the gate and reaching the fallen aircraft.	Agreed.
42. Capt. Fernandez had occupied L.H. seat after more than 2 months of operating as CM.2 from RH seat without any simulator or aircraft training prior to change over.	Agreed. It should however, be clarified that there is no stipulation of imparting any training for change over to left hand seat after operating from right hand seat.
43. The aircraft touched on its main wheels for the first time in the Golf Course of	Agreed.

Karnataka Golf Association approximately 2300 feet short of the beginning of R/W 09.	
44. During the short flight between first and second touch downs four trees, in line with the two main gears and the two engines, were broken by the aircraft at heights from 10 feet to 7 feet 2 inches and the aircraft hit the ground on its landing gear in a slightly right wing low altitude.	Agreed.
45. There was an explosion when fire commenced and there was also a major fire, forward and aft of the right wing.	Agreed.
46. RH rear door had been opened from outside by airport fire services personnel when they reached the aircraft.	Agreed.
47. Few passengers escaped through overwing exits and through fuselage openings created by crash/explosion.	Agreed.
48. 86 passengers and 4 crew lost their lives at the time of the accident. Two more died later in hospitals. 21 passengers and one crew suffered serious injuries.	Agreed.
49. 81 of 90 passengers who died at the time of the accident have died due to shock as a result of burns sustained.	Agreed.
50. 32 victims had injuries to lower limbs, 20 to the head and 7 had thoracic injuries causing possible physical inability to escape the fire in time.	Agreed.
51. Cause of death of Capt. Gopujkar and Capt. Fernandez was due to shock as a result of burns sustained. Autopsy reports indicated no fractures.	Agreed.

52. Tail section behind rear galley housing CVR and DFDR and APU showed no signs of damage.	Agreed.
53. Though major part of fuselage was destroyed by fire the RH portion of cockpit structure which had the front wind shield, No.2 sliding window (Direct Vision window) and No.3 window survived the fire though partially burnt.	Agreed.
54. The RH No.2 sliding window was in an openable condition at the time of the crash.	Agreed.
55. A witness had seen a person hitting against the cockpit RH side window before fire engulfed the plane.	Agreed.
56. All computer units had suffered extensive damage.	Agreed.
57. Speed drop from 132 Kts. to 106 kts. has taken 26 seconds from DFDR times 297 and 323 seconds.	Agreed.
58. Computers have not held the actual angle of attack at design limit of 15 degree or at speeds of Alpha max as indicated in FCOM. Actual angle of attack has gone beyond and speed has dropped below the appropriate values.	Will be referred to Airbus Industrie.
59. Movement of left and right elevator towards maximum allowable up position as indicated against DFDR time frame 330 is according to design and condition of flight (without expressing anything about the reliability of DFDR recording at this point of time).	Agreed.

60. The times of change of FMGC used FD mode and GFC 1 bus (18) discrete status do not correspond to the time of CVR conversation of FDs to be put off and putting them off.	The finding is not based on material evidence; hence not *acceptable*.
61. Idle/open descent mode of auto thrust system has engaged some time after DFDR time 295 seconds. The exact reason for this mode engagement cannot be explained or proved because of non-availability of FCU selected altitude data or FCU controls selection data on DFDR.	Acceptable to the extent that FCU selected altitude or FCU control selection data are not recorded on DFDR. As regards engagement of idle open descent mode, the most probable cause has been explained in comments on finding No. 35.
62. Right bank has been induced when CM.1 pulled side stick fully aft and Rudder has been used to lift wing at DFDR times 323 and 327. Loss of about 7 feet has been attributed to this cause by Airbus Industrie.	Technically it is difficult to establish such a corelation.
63. CVR has shown no sign of panic or anxiety about speed loss till CM.1 spoke - "Hey we are going down". There were no calls of speed deviation though speed was 106 kts. at DFDR time 323 seconds.	Agreed.
64. Low speed display on PFD on A-320 is excellent and they are computer generated. If correct they cannot be mistaken and speed trend display is compelling. There is no digital read out of value of current speed. PFD Air Speed display data is not recorded on DFDR.	Agreed.
65. Power awareness may be deficient in A-320 pilots when auto thrust is active, as even an Airbus Industrie test pilot was not aware of power required during final approach at 1000 FPM rate of descent.	In regard to this finding, it must be pointed out that in aircraft of this class, auto thrust system is meant to reduce the workload of the pilot on the final approach by maintaining the required speed. It is the speed which is of

paramount importance and when flying with manual thrust on this aircraft, it is easy to maintain speed even without referring to engine power indications. This is because of the facility of the speed trend arrow.

66. There is no warning if auto thrust brings thrust to idle for whatever reasons during approach.

Agreed.

67. Idle/open descent on short final though corresponding to an aircraft in dangerous configuration leading to limit flight condition, is indicated in 'GREEN' on PFD and not in 'RED'.

The finding relates to design features of the aircraft and will be referred to Airbus Industrie.

68. Movement of one side stick control is not reflected on the other.

The finding relates to design features of the aircraft and will be referred to Airbus Industrie.

69. Static thrust levers when auto thrust is active removed the feel of thrust lever movement and visual indication of position corresponding to actual thrust or thrust change trend. Only way to know the thrust is to read the value on ECAM.

The finding relates to design features of the aircraft and will be referred to Airbus Industrie. An A-320 operators conference held in Cairo early this year to review the auto-thrust fixed throttle concept supported the concept of non-moving throttles incorporated in A-320 aircraft.

70. Use of VOR/DME during visual approach is in conformity with Indian Airlines and Aeroformation procedures. Use of FD during visual approach is not prohibited by Airbus Industrie. The pilots in the instant case, followed a visual or a mixture of VOR/DME with visual procedure in all probability.

Agreed.

71. CM.1 pulling side stick backed up by moving thrust levers to TOGA is in conformity with training imparted to pilots by Aeroformation.

Agreed.

72. Information in documentation provided by Airbus Industrie to pilots during training and to Indian Airlines has not been very clear and sometimes not appropriate to Indian Airlines aircraft.	The finding is not specific. It should be pointed out that the documents are continuously updated.
73. The very grave consequences of IDLE/OPEN DESCENT mode engagement either inadvertently by the pilots or automatically due to a system malfunction is not part of the simulator profile training. This indicates that no one may have visualised such an occurrence to ever take place.	Not acceptable. All aircraft while descending from cruise level, descend normally on idle open descent until the aircraft reaches approach profile. At this stage speed has to be carefully monitored. This is a part of training programme of the pilots and there is nothing special as far as A-320 is concerned. However, the Airbus Industrie has carried out modifications to ensure that the aircraft reverts to speed mode during final approach, if aircraft gets into a low speed situation.
74. The flight control computers seem to have permitted the aircraft to maintain the minimum speed of 106 kts. which had been reached at DFDR time 323 seconds. The speed increase to 113 kts. before the first touch down and conversion of this kinetic energy into potential energy was prevented. Was this prevention due to the computers is a matter to be considered.	Finding is not clear. Due to inertia of motion an aircraft in descent would take some time to arrest the descent and start climbing. There can be no sudden reversal of descent into climb. The angle of attack can also not be excessive. The computers have an angle of attack protection system of the aircraft designed to prevent stalling of the aircraft.
75. Landing mode of the flight controls may have contributed during the last 3 seconds in the prevention of conversion of kinetic energy into potential energy.	As in finding No. 74.
76. It seems that Aeroformation simulator training on simulator fitted with CFM 56 engines has been accepted by	Not acceptable. European certification authorities have certified the A-320 simulator with CFM-56 engines for train-

the concerned department of the DGCA without obtaining full data on the simulator capability even though this had been thought of and concern had been expressed earlier during 1986-87 regarding use of an incompatible simulator even for recurrent training and proficiency checks. No additional stipulations had been prescribed after this acceptance.	ing pilots on A-320 aircraft with V-2500 engines.
77. Part of the CA.40.B (J) check in case of both these pilots was carried out on a simulator with CFM.56 engine data.	Agreed.
78. Recommendation for approving Airbus Industrie/ Aeroformation instructors has been made and approval granted without receiving confirmation of A.320 PIC rating and A.320 PIC experience in the case of two pilots.	Agreed. It may be stated that the two pilot instructors were approved instructors of Airbus Industrie and Aeroformation and were already imparting training to A-320 pilots.
79. The subject of Bangalore HAL Airport holding a licence or not was not relevant and would have in no way affected this crash.	Agreed.
80. All primary and secondary flight controls appeared to have operated normally.	Agreed.
81. Increase of N2 RPM on slats extension on VT-EPN was less than those recorded on Airbus Industrie aircraft and two other Indian Airlines aircraft.	Agreed.
82. The engines have operated normally throughout and have not contributed towards the cause of this accident.	Agreed.
83. Under conditions prevailing and based on the DFDR data and CVR transcript, the acci-	Agreed.

dent commenced at approximately DFDR time 321 seconds. The aircraft had no chance of survival thereafter.

84. If ILS was available at Bangalore for R/W 09 most probably, this accident would not have occurred.	Not acceptable. This finding of the Court is based on the presumption that if ILS had been available, the pilots would have chosen to make ILS approach and moreover a correct ILS procedure would have been followed. This cannot be said with certainity. The pilot in this case have not chosen to follow a full VOR-DME approach even though such facility was available at Bangalore airport. This accident has occurred primarily due to non-adherence of procedures, particularly non-monitoring of the speed in the final approach. Furthermore, the accident occurred on a clear day with excellent visibility condition and without much traffic.
85. But for the severe fire, the loss of lives would have been considerably less.	Agreed.

RECOMMENDATIONS	COMMENTS
1. Accident/incident investigation authority should be totally independent of the DGCA and all organisations connected with aviation in India. Only this can ensure an impartial and unbiased investigation looking into the role of every organisation connected with the accident/ incident including the DGCA.	At present only minor accident/ incidents are investigated by DGCA as in other countries. Any major fatal accident is invariably inquired into by a Committee or by a Court of Enquiry, totally independent of DGCA or the Ministry. Therefore, this recommendation is not acceptable.
2. Whenever an investigation is ordered under Rule 71 of the India Aircraft Rules, 1937 and later a formal investigation is ordered under Rule 75, automatically the Inspector of Accidents should only indicate the finding based on factual evidence and no interpretation or recommendation should be made to avoid embarrassment to the formal investigation.	This is acceptable. But the stipulation is to be laid down by the Committee or by a Court of Inquiry.
3. A highly experienced pilot should always be associated with the Inspector of Accidents officially if he is from an engineering background and the pilot's report should be recorded whenever an airline accident is to be investigated.	Recommendation is accepted to the extent of association of a Pilot with the investigation whenever necessary.
4. DGCA should formulate procedures and develop information formats which has to be completed in all respect every time a new aircraft is introduced into the airline to cover all training aspects and exemptions/validations to be granted.	Acceptable
5. DGCA should form a board of officers competent to deal with all aspects of training with if necessary senior experienced training personnel from the airline to assist such a board officially to evaluate the proposed training programmes prior to acceptance whenever a new aircraft is introduced into the airline in	Acceptable.

the future. Minutes of meetings of such a board should be properly recorded.

6. DGCA should develop a machinery in coordination with the Ministry of Defence for supervision of Government aerodromes including Ministry of Defence aerodromes in respect of facilities offered to civil aircraft operating through those aerodromes on scheduled flights to ensure adequate safety standards.	Acceptable.
7. DGCA should insist that on the first route check, be it for release as a co-pilot or for training towards PIC endorsements, should be with an approved flight instructor or examiner.	The DGCA has already implemented this recommendation even prior to the receipt of report and has made extensive changes in the norms of route checks.
8. It would be advisable to have at least a category I ILS installed at every airport in India and for every R/W used by jet transport aircraft on scheduled services.	The NAA is already installing ILS facilities at many airports in India. To install an ILS on every airport and on every runway would require heavy capital investment and an ILS may not be necessary in airports which are infrequently used.
9. Time recording should always be available on ATC tapes and regular checks should be carried out to ensure proper recording.	Acceptable
10. HAL should have proper communication facilities with the airport emergency services and all communications between the ATC and the emergency services should be recorded on one of the ATC channels.	Acceptable.
11. A crash siren at Bangalore airport should be installed which could immediately alert all fire stations of HAL. They may look into having two different types of sirens, one to indicate an aircraft emergency and the other to indicate a factory emergency.	Acceptable.

12. The crash fire bell at the airport fire station should be of good quality and should be louder and similarly the red light should be larger and brighter.	Acceptable.
13. The bushes on either side of the road and ramp should always be kept cut to a low level so that visibility is not impaired at any time even for a person sitting in a low level vehicle.	Acceptable.
14. HAL should develop good roads leading to all exit gates of the airport on which all fire and rescue vehicles could move at high speed. One set of keys to the locks of every locked gate should be available with every airport fire services vehicle.	Acceptable.
15. Mock exercises should be carried out by the airport fire services for fighting an aircraft fire outside the airport boundary wall.	Acceptable.
16. HAL should evaluate the VASI at Bangalore to improve its colour identification from longer distances during the hours of bright sunlight.	Acceptable.
17. All audible sounds generated by movement of various controls and levers which could be recorded on the CVR tape should be carefully analysed to obtain a corelation with the DFDR as accurately as possible particularly during the most critical period of the flight. The excellent capabilities that are available with various premier establishments in India should be properly documented for use in future.	Acceptable to the extent of maintaining a library of audible sounds generated inside the cockpit for identification of sounds recorded on CVR tape, of the same type of aircraft. Exact co-relation with DFDR, however, may not be possible for technical reasons.

18. As the DFDR data can have highly erroneous recordings, a very critical analysis of every critical DFDR parameter in comparison to factual evidence should be made for acceptance or rejection of such data.	This is normally done in all investigation of accident/incidents.
19. Similarly a very careful analysis of CVR transcript is necessary to look at all possibilities before it could be used towards any conclusions.	This is normally done in all investigation of accident/incidents.
20. Due to considerable number of dead passengers having leg injuries which may have prevented them from escaping, a provision of a foam pad around the bottom rear bar of the seat should be examined wherever the pitch between the seats is such that it could cause these types of injuries.	Acceptable for the purpose of future study.
21. As large number of passengers and survivors had faced neck and head injuries possibly due to the seat ahead not being vertical, it is advisable to issue instructions to all cabin crew to check and insist on the laid down procedures of seats to be upright, seatbelts tightly fastened and tray tables stored properly. Seatbelts sign could be put on earlier for them to carry out this function.	Already being followed. Instructions will be repeated.
22. DGCA should distribute a large number of printed autopsy formats corresponding to their air safety circular 3 of 1984 to all airports in India. They must be available in adequate numbers depending on the passenger capacity of the aircraft using the airfield and these should be made available to police authorities in case of any fatal accident with a request for strict adherence to its contents.	Acceptable and noted for action.

23. Experienced aviation pathologists either from Civil or Military Aviation should be made use of in an advisory capacity. A large number of copies of the above circular if sent to various hospitals around airports could assist in wider dissemination of information among the doctors of the hospitals.	Acceptable and noted for action.
24. In the light of the test flight conducted at Toulouse in the presence of an Assessor Airbus Industrie needs may examine the design aspects of the accelerometers and the DFDR recording system as used on the A-320 to improve accuracy of recordings particularly after a flight at high angles of attack.	Airbus Industrie will be informed.
25. Some slides did not display when door exits were opened from inside. It is recommended that slide activation mechanism should be evaluated for improvement.	Airbus Industrie will be informed.
26. Installation of a conventional airspeed indicator unconnected with any computers with a speed bug which could be manually set at the desired V-app, generating an unmistakable audio warning (again unconnected with any computers) fitted on all aircraft when speed drops more than 5 knots below the bug, which have computer generated display of airspeed to be used as the primary speed display may be considered. A provision should be available to check this warning, during the pilots pre flight check. Such warning should be serviceable, for release of the flight. Airbus Industrie and Indian Airlines to evaluate retrofit such a feature in place of their present standby airspeed indicator on the A-320.	Not acceptable as a conventional air speed indicator with a provision of speed bug setting is already available in the aircraft. Too many warnings would only tend to confuse the pilots.
27. Expanded indication of the value of the current against the lubber line in the	Acceptable. Would be brought to the notice of the Airbus Industrie.

PFD is recommended for better appreciation of current speed value.

28. A provision of a low speed warning even under pitch normal law should be examined by the certification authorities at about 1.14 to 1.15 Vsg for this type of FBW aircraft to prevent a similar accident in future.

Airbus Industrie has already brought out a modification by which the aircraft will automatically go into speed mode whenever the speed reaches Lowest Selectable Speed (VLS). As such, this recommendation is not necessary.

29. Due to possibility of mistaking altitude and vertical speed knobs one for the other, a modification is recommended where vertical speed knob would have a wheel to be operated vertically up and down instead of the present clockwise and anticlockwise direction of movement of the knob.

This will be referred to Airbus Industrie as it requires a design change.

30. A very serious human factors evaluation is necessary using ordinary line pilots regarding the loss of direct physical and visual cues by the type of sidestick controls in use in A-320 when compared to dual control wheels operating in unison of the earlier aircraft to determine the adverse impact it may have under critical conditions of flight like that of VT-EPN. Human factor evaluation of moving auto throttles giving feel of thrust increase or decrease versus the static thrust levers of the A-320 auto thrust system using line pilots is recommended to establish advantages and disadvantages.

Airbus Industrie has informed the Court that in a conference of users of A-320 aircraft held in Cairo early this year, there was an unanimous opinion for not adopting moving thrust levers. The recommendation is, therefore, not acceptable.

31. Option of moving auto throttles is desirable in all future aircraft if static auto thrust system similar to A-320 is to be installed in such aircraft.

Airbus Industrie has informed the Court that in a conference of users of A-320 aircraft held in Cairo early this year, there was an unanimous opinion for not adopting moving thrust levers. The recommendation is, therefore, not acceptable.

32. After gear down and below 2000 feet radio altitude it is recommended that idle/open descent mode should be indicated in flashing red on the FMA associated with a single stroke chime.	Partly acceptable and Airbus Industrie will be requested to have a different colour for idle/open descent mode display on FMA during final approach.
33. Airbus Industrie should evaluate the provision of a feature, by which low thrust level occurring, during final approach, even on speed mode due to gusty wind conditions, would attract immediate attention of the pilots; if it occurs every close to the ground it could lead to unsafe situations.	Not acceptable technically, as while on approach a pilot has to monitor speed and too many warnings at the critical phase of landing would only cause confusion.
34. It is recommended that the low range scale of the EPR gauge upto 1.10 should be expanded to give a better indication by the needle of a low thrust condition.	Not acceptable as considered not necessary.
35. Airbus Industrie may look into providing a range in red colour upto 1.02 EPR to attract pilots' attention of a low thrust situation when on final approach.	Not acceptable as considered not necessary.
36. Similar features as above could be evaluated and provided for operation in N1 mode.	Not acceptable as considered not necessary.
37. It is recommended that the emergency exit sliding window in the cockpit (direct vision window) should have the operating handle in the forward end to give a better leverage than at present, so that it could be easily opened by a comparatively frail lady pilot using any one hand only. Indian Airlines may check with Airbus Industrie if a retrofit modification is possible for their present fleet and future aircraft.	Acceptable - will be referred to Airbus Industrie.
38. Safety of operations would demand that Airbus Industrie execute the proposed modifications of increased approach idle by 2.5% N2 and	Already being incorporated.

auto thrust mode changing to speed mode when aircraft speed drops to VLS, as top-most priority modifications. Indian Airlines should pursue the matter vigorously with Airbus Industrie in co-ordination with DGCA.	
39. Installation of a single master switch conveniently located to switch off both FDs when required is recommended; slave switches could be used to switch them `on' individually or repositioning of both switches centrally be considered.	Acceptable. It will be referred to the manufacturer as it requires a design change.
40. A modification to prevent auto thrust mode change from sped mode to thrust mode during Alt* just by change of altitude selection is highly desirable. The mode change should occur only by pulling the altitude knob after change of altitude selection.	Already being incorporated.
41. Airbus Industrie should clearly define in their procedures and flight patterns the position at which they need the flight directors to be put off.	Use of flight directors is emphasised during training of pilots and a circular would be issued by the Indian Airlines.
42. Airbus Industrie should immediately amend A-320 FCOM bulletin No.09/2 of June 1990.	The FCOM bulletin has already been amended.
43. Indian Airlines should introduce simulator training session whenever a line pilot is required to change his seat from the co-pilot seat to the captain seat after a long period of operation from the right hand seat even when this is for obtaining 100 hours experience prior to PIC route check.	Partly acceptable to the extent that it will be followed during conversion of co-pilots to pilot-in-command.
44. In the interests of quality of training and safety, it is recommended that DGCA accords approval for all the 100 hours co-pilot experience to be obtained by a pilot slated for direct PIC training	Not acceptable as every pilot has to fly both from the left and right hand seats depending upon the situation.

on to any type from the left hand seat only under the supervision of an approved check pilot/flight instructor/ examiner. If airline needs to use these pilots from RH seat during this training period pilot should be given simulator training as PF from RH seat also.

45. Operation of the cockpit emergency exit windows (direct vision windows) either during pre flight check by pilots prior to commencement of their first leg of their series of flights or during daily certification of flight by aircraft maintenance engineers would ensure easy operation of the window by preventing the seals from sticking to the framework causing higher force requirements to open when need arises.

Redundant, as this is usually done.

46. A re-emphasis regarding a 3 seconds delay in alpha floor activation by angle of attack in case of windshear should be made to all A-320 pilots and Indian Airlines should recommend that pilots should not wait for alpha floor but react on thrust levers immediately if an adverse situation is encountered.

Not acceptable as Alpha floor is not activated by the pilot. The features of Alpha floor protection are adequately taught during the training.

47. It is recommended that Airbus Industrie and certification authorities to carefully re-evaluate the limit of 15^{o} angle of attack (alpha max) was both simulator experiment and Airbus Industrie flight test under direct law going to slightly higher angles of attack have shown better performance and reduced altitude loss.

Attention of Airbus Industrie will be drawn.

48. In view of the results of the test flight at Toulouse it is recommended that, certification authorities including DGCA should carefully evaluate acceleration characteristics of an engine at high angles of attack to give better informa-

Not acceptable as Certification Authorities do not issue Type Certificate of Engines unless these parameters are carefully evaluated.

tion to pilots as Airbus Industrie test flight has demonstrated different acceleration characteristics by the same two engines in the four profiles.

49. With the drastic change in high bypass turbo fan engine designs from the 1960's to the present day and the acceleration characteristics and net thrust developed during various stages of acceleration of present day engines it is recommended that certification authorities may re-examine the existing engine acceleration certification requirements.

Not acceptable as Certification Authorities do not issue Type Certificate of Engines unless these parameters are carefully evaluated.

50. Indian Airlines should include inadvertent engagement of ;IDLE/OPEN DESCENT on short final at heights very close to the ground as a profile during simulator training of pilots being converted onto A-320 and also during recurrent training and proficiency checks till such time all their A-320 aircraft are modified with the new proposed modifications.

This is a basic concept of jet flying which is already being taught.

51. As documentation supplied by Aeroformation to a large number of Indian Airlines pilots during training did not fully correspond to the Indian Airlines aircraft (which was not according to the minutes of the training conference) it is necessary for Indian Airlines to update these documents in co-ordination with Aeroformation.

Documents are continuously updated.

52. Indian Airlines should include recovery from a situation of low speed at idle thrust in close proximity to the ground in their check pilot training and instructors training on the simulator.

Not acceptable. Training is given to recognize the situations and to avoid them.

53. It is recommended that all pilots in India operating automated aircraft be advised that in case of any malfunc-

Acceptable. A circular will be issued to all pilots.

tion of any auto pilot or auto thrust systems or any engagement of undesired mode occurs at altitudes below 1000 feet above ground level manual control should immediately be taken over and if considered necessary a go around should be carried out. No critical investigation or correction on the automated system should be carried out at critical altitudes prohibiting the idle/open descent mode below 1000 feet radio altitude should be seriously considered.	
54. Indian Airlines should very carefully evaluate with the DGCA and Airbus Industrie the advantages of introducing manual thrust operation when manual flight is being carried out on the A-320.	Not acceptable as auto-thrust provides greater safety level.
55. Indian Airlines should carefully evaluate with Airbus Industrie the auto thrust behavior during gusty wind conditions when speed suddenly increases beyond V-app and decreases at altitudes below 200 feet AGL and adverse implications if any to determine the limits of use of auto thrust system. This may have to be evaluated in both cases of Magenta speed or selected speed.	Not acceptable as considered not necessary.
56. The U.V. recording and sound spectrum analysis would help to identify the voices, as well as various other sounds; research and study of the science may be undertaken, so that in future its benefit would be available whenever necessary.	This is being done for the last 12 years in the DGCA.
57. A Human Factor Research' centre may be established to study and analyse Human Factors in Aviation.	Not acceptable. This work is being done in other parts of the world where sophisticated aircraft are being manufactured.
58. A careful study be made to evaluate the advantages of having backward facing passen	This concept is being evaluated by many certification authorities.

ger seats with a shoulder harness towards improved passenger survivability at the time of accident. Such backward facing seats may prevent the type of head injuries, injuries to legs and hands, arms etc., that occurred in this accident.	
59. Due to severe fire developing with hardly 3000 to 3300 Kgs., fuel, burning completely the interior furnishing, top of the fuselage and the floor of the cabin, DGCA should carefully evaluate along with other certifying authorities and manufacturers, the feasibility of providing oxygen cylinders for crew and for passengers in the least fire risk areas (well away from the fuel tanks namely front and rear of the fuselage), with a provision of a valve close to the cylinders which would be closed at levels below 1000 feet. This may help in delaying the spread of the fire in comparison to the oxygen generators distributed throughout the aircraft and may contribute to saving more lives.	Acceptable. Will be brought to the notice of Airbus Industrie.
60. DFDR should record the selections made by the pilots in the FCU; at present it is not possible to infer many of the actions taken by the pilots during the last phases of the flight. Practicability of getting DFDR recordings of instrument displays such as speed display also should be considered.	Acceptable.
61. All Airports used for civil transport aircraft operation should be inspected, assessed and certified as fit for such operation, by a competent authority.	Acceptable.
62. The DGCA shall be strengthening in all is aspects to meet the growing technological requirements, as indicated in Part-VII of this Report.	Acceptable.

PART I

A. INTRODUCTION

On the 14th February, 1990 Indian Airlines Airbus A-320 aircraft VT-EPN was operating a scheduled passenger flight IC 605 from Bombay to Bangalore. Capt. S. S. Gopujkar was in command of the flight. Capt. C. A. Fernandez was the second pilot operating the flight as pilot in command under supervision. There were five cabin crew on board. There were a total of 135 passengers and 4 infants on board this flight.

The aircraft took off from Bombay at 11.58 hrs. IST. During the final approach to R/W 09 at Bangalore the aircraft first contacted ground within the boundary of the Karnataka Golf Association approximately 2300 ft. prior to the beginning of R/W 09. The aircraft went up into the air for a very short duration after which it again contacted the ground on the 17th green of the golf course on all three gears, then hit an embankment at the boundary of the golf course. The fuselage and the wings with other components in various stages of disintegration flew over a nallah and a road adjacent to it just outside the golf course and came to rest on a partially marshy area outside the boundary wall of the airport.

The aircraft was destroyed due to impact and fire. 92 persons on board including the two pilots and two cabin crew died in the accident. Of these, two persons died after admission to hospitals due to the injuries and burns sustained.

The accident occured during the mid afternoon at approximately 13.03 hrs. IST.

The DGCA ordered an investigation of the accident under Rule 71 of the Indian Aircraft Rules 1937 by appointing an Inspector of Accidents.

Thereafter, Government of India, (Ministry of Civil Aviation, New Delhi, vide their Notification No. AV 15013/2/90 SSV dated 17.2.1990) ordered a formal investigation into the circumstances of the accident to Indian Airlines Airbus A-320 aircraft VT-EPN while operating a scheduled flight IC 605 from Bombay to Bangalore on 14.2.1990. The Government ordered this formal investigation under Rule 75 of Indian Aircraft Rules 1937. The Notification is reproduced here:

GOVERNMENT OF INDIA

Ministry of Civil Aviation

S.P. Bhawan, Parliament Street,
New Delhi - 110 001.

17th February, 1990.

NOTIFICATION

S.O. WHEREAS, on 14th February, 1990 Indian Airlines Airbus A-320 aircraft VT-EPN while operating flight

IC 605 from Bombay to Bangalore crashed near Bangalore resulting in the death of 90 persons (including 4 crew members) on board;

AND WHEREAS it appears to the Central Government that it is expedient to hold a formal investigation into the circumstances of the said accident.

AND NOW, in exercise of the power conferred by the Rule 75 of Aircraft Rules, the Central Government hereby directs that a formal investigation of the said accident be held.

The Central Government, is further pleased to appoint Shri.Justice K.Shivashankar Bhat of the Karnataka High Court to hold the said investigation.

The Central Government is also pleased to appoint:

(i) Capt. B. S. Gopal, Director Flight Safety, Air India.

(ii) Capt. C. R. S. Rao, Director of Training (Retd.) Air India.

(iii) Shri S. G. Goswami, Director of Airworthiness (Retd.) DGCA to act as Assessors to the said investigation.

Shri K.P.Rao, Controller of Airworthiness, Bangalore, will function as the Secretary to the Investigation.

The Court will complete its inquiry and make its report to the Central Government by 31st May,

1990. The Headquarters of the Court will be at Bangalore.

Sd/-
(A. V. GANESAN)
Secretary to the Govt. of India.

No. AV 15013/2/90-SSV

B. Sequence of Events in Investigation

1. On 18.2.1990, the Secretary to the Court along with Sri. Satendra Singh, Inspector of Accidents, under the authority of DGCA letter No. AV 15013/3/90-AS dated 15.2.1990, met me in my residence at about 16.00 hrs. and the Inspector of Accidents apprised me of the progress made in carrying out the investigation of the crash till that date. The next day at 11.30 hrs. I, along with the Secretary, Inspector of Accidents and one of the Assessors namely Capt. C. R. S. Rao, visited the crash site. The area in Bangalore Golf Course where the aircraft made initial touch down and also the final wreckage spot were inspected. The Inspector of Accidents was advised to continue the investigation on behalf of the Court.

2. On two occasions, I along with the Assessors and the Secretary to the Court visited ATC and fire fighting facilities available at HAL, Air Traffic Control Tower. During the process we also visited the VASI (Visual Approach Slope Indicator), VHF, VOR ground facilities etc.

3. On 27.2.1990, Sri H. S. Khola, DDG, along with Capt. Thergoankar of Indian Airlines and the Secretary of the Court along with Assessors met me at my residence at about 19.30 hrs. and they explained the decoding of DFDR data including the figures which

were furnished by the Canadian Air Safety Board, Ottawa, Canada. The CVR tape was also replayed. The Inspector of Accidents, who was also present, was asked to complete his report on or before 31st March, 1990.

4. Since Airbus A-320 aircraft is sophisticated in systems incorporating many new features such as, Fly by Wire technology, Alpha Floor Protection etc., it was decided to study technical background from Indian Airlines training facilities at Hyderabad. As such, all the Assessors visited CTE (Central Training Establishment) of Indian Airlines at Hyderabad from 5-3-1990 to 7-3-1990.

5. Again from 19-3-1990 to 23-3-1990 the Court and all the Assessors, along with the Secretary to the Court visited CTE, Indian Airlines, Hyderabad. During this period, I got acquainted with the cockpit layout and other technical subjects. Cockpit mockup layout were utilised to show various displays and control switches. Simulator for A-320 aircraft was still being installed by the Canadian experts. Along with the Assessors, I visited and experienced the flight simulators on Boeing 737 aircraft and A-300 simulators which were operational.

6. Sri S. G. Goswami, one of the Assessors visited Maintenance/Overhaul facilities and Engineering

Training School at Palam from 9.4.90 to 12.4.90. Various test equipment and test benches for Radio, Electrical, Instrument and other shops were in the process of installation. Discussion on various technical aspects with instructors and shop AMEs were held.

Sri K.P.Rao, Secretary to the Court along-with the Inspector of Accident proceeded to CASB (Canadian Air Safety Board), Ottawa, Canada, from 17.4.90 to 23.4.90 to get the DFDR of another A-320 aircraft VT-EPO invloved in go around/touch and go exercise.

7. It was also decided to feed certain computer programmes on Indian Airlines Simulator at Hyderabad to obtain various profiles to match the actual flight path of the ill fated A-320 aircraft, so that useful inference could be drawn regarding the crucial phase of the accident. Capt. B.S.Gopal, (an Assessor) was authorised to explain the required programme; he was also authorised to meet the Secretary, Ministry of Civil Aviation and explain the purpose of this programme since, foreign exchange was involved. Thereafter, Capt. B.S.Gopal also went to CAE, Electronics, Montreal, Canada, who were the makers of Indian Airlines simulator at Hyderabad to prepare the required flight profiles.

8 (a) As the human factor subject is new and to understand its effect on the pilots of the ill

fated aircraft, it was decided to send the Assessors to NASA (National Aeronautics and Space Administration, USA) where intensive research work on the subject was being conducted. As such, the Assessors visited NASA establishment at Sanfrancisco on 12th June, 1990. In a meeting, detailed deliberations were made by a group of experts on human factors. Pilot's reflex action in most modern cockpits during emergency, effects of earlier experience and training on conventional type of aircraft, their behaviour in abnormal circumstances etc., were discussed. Literature on these subjects were distributed to the Assessors. They were also informed that a system of voluntary submission of reports of any abnormal happening due to psychological effects or mistakes committed due to personnel factors has been evolved and the system is believed working satisfactorily; several reports were being received and the same are reported to the concerned operators for further action without revealing the identity of the concerned pilots, these data are systematically recorded and study undertaken to analyse human factor effects in each case and reports are also published to apprise various operators and their flight crew.

8 (b). On 13th June, 1990, the Assessors visited IAE engine production facilities at East Hartford. Here various stages of production and assembly of the engines were shown. Build up of nacked rotor

assembly, fitment of various components on bare engine, engine build up for test bed run were witnessed by the Assessors. Production test facilities, test bed set up various parameters recording and printout facility were observed. Arrangement to simulate varying altitude and temperature was available. The air was drawn in by creating suction at the exhaust end. But the facility for tilting the engine to simulate air flow at different angles of attack did not exist. Engine acceleration test results were shown.

8 (c). From 18th June, 1990 to 21st June, 1990, the Assessors visisted Toulouse, France. The Assessors utilised VACBI facility to know more about technical subject of A-320 aircraft. The technical subjects covered were same as given in the FCOM Vol.1. The system utilised audio visual aids to impart training to the pupils without the presence of any instructor; it was found that the instructor could be called at any time to explain certain lessons which were not clear to the pupil and a particular portion of the audio visual aids could be repeated at the discretion of the pupil for proper understanding.

Subjects incorporated in FCOM Vol.II & III were taught in fixed base simulator (FBS) and fully flying simulator (FFS).

A few items of lessons on FBS & FFS were demonstrated. A test flight was undertaken by Airbus Industrie to carry out requested profiles. Capt. Rao was on Board this flight.

8 (d). The Secretary along with an officer from DGCA visited Paris, France to get FMGC, CFDIU, FCU and all servo actuators tested from 17.6.90 to 24.6.90.

9. I along with the Secretary, Court of Inquiry, visited Indian Airlines engineering maintenance facilities at Palam, New Delhi on 28th June, 1990. The following areas such as; Shop Complex for P & W JT-8D, GE CF6-50 and IAE V-2500 engine including Test Bed to undertake major maintenance/repair including overhaul and testing IAE V-2500 engines were observed.

Besides, I visited Radio, Electric, Instrument and accessory overhaul shops. In instrument shop, facilities for testing various computers by ATEC (Automatic Test Equipment Complex), DFDR Decoding facilities for A-320 aircraft and other facilities were found being set up keeping in view a target date for speedy completion. Practical demonstration of five parameters FDR foil readout of Boeing 737 aircraft was also witnessed.

After returning from Delhi on 29th June, 1990, I had a meeting with the Assessors on 30th June, 1990, and on the same day I along with Secretary to the Court proceeded to Hyderabad to visit A-320 simulator which was by then fully operational with both motion and visuals. Visit to simulator was necessary to familiarize myself with the subject involved in this investigation. While returning we were flown in an A-320 aircraft. I was occupying the observer's seat to have better appreciation of the various cockpit displays and recovery from simulated stall.

10. On 4-7-90 at NAL the CVR was again replayed in the presence of all participants along with their Counsel. A definite click sound was established in between the words of Capt. Fernandez "Hey, we are going down". Later, ultra violet recording of the CVR replay was done at NAL.

11. As the CAE, Canada intimated that the programme was ready and a representative would be coming to Hyderabad to feed the data on Indian Airlines simulator, a trip was made by the Assessors to Hyderabad from 17.7.90 to 20.7.90. I, along with the Secretary to the Court of Inquiry also went to Hyderabad on 18.7.90. Due to limited time available, the relevant recording and data was made available to the participants by placing the recordings and the data as part of Court records. The printout of all the simulator profiles could not be taken during our stay at Hyderabad. During this time, the sound of side stick movement upto the stop (full backward), throttle movement to the full forward position and cockpit door movement to close position was recorded.

12. These sounds were further plotted in U.V. recording and compared with the click sound heard during CVR replay. It was believed that the click sound was perhaps not of side stick movement as thought earlier.

13. It was decided by the Court to confirm the voices in the CVR tape from DFDR T.F. 294 seconds when Capt. Fernandez said "O.K., 700 ft. rate of descent". As such, after obtaining consent of Mrs. Gopujkar, a formal request was sent by the Court to her to come to Bangalore. Accordingly, she came to Bangalore on 27.7.90 and the CVR tape was replayed at NAL on 28.7.90 in the presence

of the Counsel of all the participants, Assessors, the Secretary to the Court and myself. She identified the voices of Capt. Gopujkar and Capt. Fernandes whom she knew very well. Her identification did not make any change in CVR tape transcript.

14. The Court in all examined 35 witnesses and 173 exhibits were marked. This apart, there were several documents collected in the course of correspondence as part of the investigation conducted by the Assessors having regard to the technical nature of the questions involved.

15. The following were given the participant status:

1) Indian Airlines Corporation ('IAC');

2) Indian Commercial Pilots Association ('ICPA');

3) Hindustan Aeronautics Limited ('HAL');

4) Airbus Industrie ('AI')

5) International Aero Engines ('IAE');

6) All India Aircraft Maintenance Engineers Association - (It did not ultimately participate in the proceedings).

7A) The Consumer Action Group, Madras;

7B) Air Passengers Association of India; and

8) Consumer Education and Research Society, Ahmedabad-6.

16. All the participants were represented by their respective advocates.

In addition, Mr. Shroff appeared personally representing his group, Consumer Education and Research Society, Ahmedabad.

In the course of the proceedings, the Director General of Civil Aviation appeared through Mr. Mukunda Menon, the Additional Standing Counsel for Central Government for a limited purpose of examining a witness.

17. I considered it prudent to have the assistance of an independent Counsel having regard to the likely questions that may arise in the course of the proceedings. It was not possible to foresee the various situations at the time the Court started functioning. In these circumstances, initially I had requested the Govt. of India to spare one of its Senior Law Officers, such as any Addl. Solicitor General to assist the Court but Govt. of India could not depute any one of its Law Officers. Therefore, I requested the then Advocate General of Karnataka, Sri B.V.Acharya to assist the Court as its Counsel. Sri B.V.Acharya inspite of his busy schedule came forward to act as Counsel of Court and he was assisted by Mr.Ashok Harnahalli, who is one of the Standing Counsel for the Central Government.

18. There were several Advocates appearing for various parties. IAC was mainly represented by Mr.G.E. Vahanvati, Sr. Counsel assisted by Mr. N.M. Seervai, Mr. R.N.Karanjawala & Ms.Rekha. CAG & APAI were represented by Sri P.B.Appaiah. AI was represented by M/s D.C.Singhania, Alok Mahajan and

A.S.Krishnamurthy; ICPA was represented by Mr.Mohan Parasaran; IAE was represented by Mr.Udaya Holla and was assisted by Ms.Naina Bahl

19. The Court had published a Notification in all leading newspapers inviting participation or seeking relevant information in the proceedings. After the Court decided about the participation status, the participants were required to file their statement of cases. To finalise the procedure, the first sitting of the Court, as a pre-hearing session, was held on 24th April, 1990, which was attended by the participants and they were informed of the procedure to be followed during the Inquiry. The participants were told that, wherever necessary, affidavits already filed, and further affidavits, if any, of all the respective witnesses shall be treated as part of their examination-in-chief and the proceedings in the Court will be from the stage of cross-examination and onwards. This has saved considerable time for the Court and the Counsel. The participants were given specific dates within which to file the affidavits of their witnesses with copies to the other participants. Similarly, the participants were told of the re-playing of the CVR at NAL, Bangalore on the same day. Recording of evidence

commenced on 7th May, 1990. This went up upto 23.5.1990, except during public holidays. By 23.5.1990, 19 witnesses were examined. Thereafter, the proceedings were adjourned to 25th June, 1990 for further evidence. In the meanwhile, the Assessors and the Court had to investigate some more matters. Similarly, the Court also had to familiarize itself about the systems of this aircraft (A-320 Airbus). However, the witnesses could be examined only on 2nd July, 1990 on which date 3 witnesses were examined. This included the sitting on the next day also. The examination of Witness No.23 concluded only on 6.7.1990. Some more witnesses were examined between 9th July, 1990 to 9th August, 1990. Since Advocates required time to prepare their arguments, proceedings were adjourned; the participants were directed to file written arguments and furnish copies to the other participants. The oral arguments in the Court were confined to salient features only. This commenced on 17th September, 1990 and hearing of arguments concluded on 20th September, 1990. Court adjourned to prepare the Report.

PART II

1. FACTUAL INFORMATION:

2.1. HISTORY OF FLIGHT:

On the 14th February, 1990 Indian Airlines Airbus A-320 aircraft VT-EPN operated the first flight of the day IC 669/670 on sector Bombay Goa Bombay. These flights were uneventful. The aircraft was then scheduled to operate flight IC 605 from Bombay to Bangalore. Capt.C.A.Fernandez was to fly the aircraft for his first route check for pilot in command endorsement under the supervision of Capt.S.S.Gopujkar, a check pilot on A-320 aircraft. Capt.S.S.Gopujkar being a check pilot was the commander of the flight. There were 5 cabin crew members and 139 passengers including 4 infants on board the aircraft.

The aircraft took off from Bombay at 11:58 hrs. IST after a delay of about 1 hr. from its schedule time departure. The aircraft was cleared to fly on route W 17 from Bombay to Belgaum via Karad and then on route W 56 from belgaum to Bangalore at flight level 330. The aircraft climbed to the assigned cruising level and reported over Belgaum at 12:23 hrs. IST. The aircraft contacted Bangalore approach at 12:25 hrs. giving the estimate for entry into Madras FIR at 12:38 hrs and arrival Bangalore at 13:04 hrs. IST. Bangalore approach passed the prevailing weather at Bangalore to the aircraft as "Wind variable 05 knots, visibility 10 kms., clouds 2 octa 2000 ft., temparature 27°C, QNH 1018 Millibars". The R/W in use was indicated as 09. At 12:39 hrs. IST Bangalore approach passed the new QNH of 1017 Millibars.

Routine contact with Indian Airlines flight despatch had been established on company channel giving the ETA Bangalore as 13:04 hrs. IST. At 12:44 hrs. IST, descent was requested, Bangalore cleared the aircraft to descend to flight level 110. During the descent the pilots discussed certain finer points of descent planning and also planned to carry out a VOR DME approach to R/W 09 which included leaving 6000 ft. at 11 miles and 4500 ft. at 7 miles for the MDA of 3230 ft. Speed brakes were used during descent as the aircraft was slightly high. At 12:53 hrs. IST Bangalore radar identified the aircraft at a distance of 42 nautical miles on radial 316°. Aircraft was asked to turn right onto heading 140° for vectors visual approach R/W 09. At 12:57 hrs. the heading was changed to 150° by radar. The crew changed the altimeter setting to QNH of 1017 and checked the height at 8500 ft. At 12:58 hrs. approach check list was completed and approach was activated. At 12:59 hrs. Magenta speed which is the managed approach speed was cross checked as 132 knots. Various stages of flaps and gears were selected whilst continuing descent to 4600 ft. as cleared by the ATC. At 13:00 hrs. IST the aircraft was 7 miles west on left base for R/W 09 with the R/W in sight. The autopilot was disconnected. The aircraft changed over to Bangalore tower after being transferred by radar. Landing checks were carried out at about 13:02 hrs. and cabin crew were instructed to be at stations for landing. The aircraft went well below the normal approach profile and initially touched the ground within the boundaries of the Karnataka Golf Club on its main wheels at a distance of approximately 2300 ft. prior to the beginning of R/W 09 and about 200 ft. on the right side of the extended centre line of the runway. The aircraft went up into the air again after rolling on the ground for about 80 ft., remained in the air for about 230 ft., thereafter came down on to the ground again on the 17th green of the golf course. This time all three gears have dug into the ground for a considerable depth and at one stage the right engine also dragged on the raised portion of the ground. Shortly thereafter the aircraft impacted an embankment which is approximately 12 ft. in height. The undersurface of the fuselage and the centre section of the wings appeared to have rubbed against the top portion of the embankment with the engines and landing gear directly impacting the embankment. This led to the separation of both the engines from the wings and the undercarriage. The aircraft wings cut off some small trees on top of the embankment. The aircraft in this condition flew over an adjacent nullah and road just outside the boundary embankment of the golf course and came to rest in a grassy, marshy and rocky area between the embankment and boundary wall of the airport. It is estimated that the aircraft fuselage must have come to rest at its final position at approximately 13:03 hrs. IST.

An intense fire which commenced at the forward portion of the fuselage later spread towards the rear of the aircraft. A few passengers escaped through the overwing emergency exits and other openings as a result of breakages in the fuselage. Some more passengers escaped through the rear left door which had been opened by one of the surviving cabin crew members.

The final resting position of the aircraft was outside the boundary wall of the airport in the final approach area of R/W 09. The front end of the aircraft fuselage was approximately 150 feet from the boundary wall. The elevation of the site is approximately 2840 to 2850 feet above mean sea level. Accident occured in broad day light.

2.2: <u>Touch Downs:</u>

(i) Two air-hostesses who survived the crash have given some idea about the flight.

Mrs.Sadhana Pawar (Witness No.4) told the Court that she did not experience any abnormality in the flight in question till the plane landed. The take off was quite normal from Bombay and cruising was also normal. She did not experience any peculiar high speed as the plane came down. She was sitting at the rear side facing the tail and therefore she could not look through the window after the announcement to the crew to position themselves for landing. She has also spoken about the 3 touch downs which will be referred later when the occasion arises. She has also filed a copy of the report signed by her after the crash. Earlier on the date on 14.2.1990 she was a crew member in Flight 629 to Nagpur and Bombay in a different A-320 plane. The said flight was commanded by Capt.Gopujkar. However, the co-pilot was one Capt.Gaurav. After the completion of the previous flight the entire crew including Capt.Gopujkar were shifted to the ill-fated Flight 605 in VT-EPN. The co-pilot was changed to Capt. Fernandez. (who flew the plane as CM1 under Route Check and Capt.Gopujkar functioned as the Pilot Non-flying - PNF or CM2, while checking CM1). According to her the pre-flight checks of this plane did not disclose any defects. However, at Bombay, after the doors were closed, another member of the crew Mrs.Swami came to the cockpit and reported that water flow from boiler No.2 in her galley was flowing non-stop. Capt. Gopujkar instructed her to shut off the main water valve situated in F.W.D. galley but she said, valve could not be closed. However, Capt.Gopujkar tried and managed to close the main valve with some difficulty. She also reported that after the landing announcement was made, all the crew members were positioned at their respective stations for landing, when Captain announced "Cabin crew to your stations".

(ii) Mrs.Neela Sawant is another Air-hostess who was in this flight. Her report also is annexed to her deposition. She substantially corroborates Mrs.Sadhana Pawar's statements. Both these two witnesses speak of only 3 touch downs of the plane. According to Mrs.Sadhana Pawar, the first touch down of the plane did not give any impression of any abnormality. She thought it was a normal landing. Thereafter she experienced something like, being dragged but not a feeling of jumping. The second impact was heavy and terrible. The third landing was on a marshy land, which was the final stop. She stated "I am quite certain that in all, there were three touch downs out of which the second was the heaviest". To the same effect she had stated in her report after the crash.

(iii) Mrs. Neela Sawant who was also sitting at the rear side, at the time of landing, states that there were three impacts altogether. The last resulted in the plane stopping finally and the first impact gave her the impression that it was a normal landing. At the time of the second impact she was thrown off her seat and fell on the floor of the plane. She was on the floor when the final impact occurred. Both these witnesses speak of the fire coming out in the front portion of the plane. There was heavy smoke and intense fire. Mrs. Sadhana Pawar had opened the left side exit door while Mrs. Neela Sawant moved in the cabin asking the passengers to go out. She said it was impossible to open the central exit as cabin was full of smoke.

(iv) Mr. Hemchand Jaichand was one of the passengers (Witness No. 6). He is employed in Union Bank of India. According to him the take off at Bombay was an usual take off. During cruising, except for some turbulance for a short while, everything was normal. The turbulance was when the plane was flying through the dense clowds. He had the impression that the plane was flying low prematurely before landing. However he thought that the plane was moving for a normal landing. Before the touch down he saw barren fields and the plane was almost level to the fields.

a landing in an airport situated at a higher altitude as in the case of Bajpe airport. According to him the passenger next him actually gave out a curse and many passengers were opening the seat belts. After the first touch down there was a jerky movement of the plane, though nothing violent was experienced. Thereafter the plane thudded against a hard surface. The plane came to a halt immediately after the second touch down described by him as thudding. At the time of the second touch down his fore-head hit the front seat. Immediately he removed the seat belts and he was afraid of the explosion and came out of the plane. When he was running away from the plane after getting out of it he was looking back towards the plane. According to him fire fighting operation had not started at that time. The experience of first touch down was similar to his experiences of landings when he went to Mangalore.

(vi) Mr. E.S.Sridhar is another passenger (Witness No.7). He is a frequent traveller in air. On the previous day he went to Ahemadabad and then returned to Bombay. According to him the take off at Bombay to Bangalore was a normal take off. The flight was normal and only at one point there was some turbulance. Before the first touch down he felt that the plane was coming down fast. The first touch down was a mild one and he thought that the plane landed on the runway. Thereafter there was some movement before the second touch down. At the time of the second impact he fell forward, the seat belt snapped and he thereafter went on his feet when the plane finally stopped at the time of the third impact. This witness said that he lost his three teeth and sustained some injury on the right leg. He saw the rear door exit open and he simply ran out. As he lost his spectacles his vision was slightly dim though he saw yellow flames from the front portion.

(vii) In the course of the enquiry certain questions arose about the nature of the various touch downs. It has come out that actually there were 3 impacts after the first touch down. After the first touch down the plane had rolled for about 82 feet on the Golf Course and slightly went up into the air and moved forward for about 234 feet and then came down near the 17th hole of the Golf Course. Earlier at the time of first touch down only two gears touched the ground. At the 17th green three gears were on the ground. The plane was on its main wheels for about 102 feet. The right engine grazed the ground for about 40 feet, and impacted against the embankment. The said embankment is about 12 feet height. After this impact against the embankment the two engines got separated from the plane. The momentum of the plane took it further in the air and ultimately it landed on the marshy land just about 135 feet from the boundary wall of the airport.

2.3: The duration of the aircraft on ground during first touch down is estimated as 0.42 second (0.418 second) and the short flight during the bounce is inferred as 1.194 seconds at an average ground speed of 116 knots. Severe deceleration must have taken place between the second touch down and the impact with the embankment.

2.4: INJURIES TO PERSONS:

INJURIES	CREW	PASSENGERS	OTHERS	TOTAL
Fatal	4	88*	nil	92
Serious	1	21	nil	22
Minor/None	2	30	nil	32
Total	7	139	nil	146

* Two passengers of these 88 succumbed to their injuries in hospital.

2.5 DAMAGE TO AIRCRAFT:

The aircraft was destroyed as a result of impact with ground and subsequent fire.

2.6 OTHER DAMAGES:

One cow was killed in the final rest area of the aircraft. A small portion of the golf club fencing was damaged due to impact with aircraft.

2.7 CREW PERSONNEL INFORMATION:

The crew consisted of two pilots and five cabin attendents. Both the pilots were properly qualified and licenced to operate this flight in accordance with the stipulations laid down by the DGCA, India under the Indian Aircraft Rules 1937. All the cabin crew had been trained and were competent to undertake this flight.

2.8.1 PILOT IN COMMAND:

44 year old Capt. S.S. Gopujkar was an Indian national holding ALTP licence No. 854 issued on 7.7.1976. He was employed as a pilot in Indian Airlines during the year 1969. From 1971 to 1981 he flew the HS 748 as a co-pilot and later as a captain. He obtained a Boeing 737 co-pilot rating on 1.8.1981, and a pilot in command rating on 24.2.1983. After satisfactory completion of conversion training on

Airbus A-320 aircraft at Aeroformation, Toulouse, France, he was granted co-pilot rating on 4.8.1989. He was granted a pilot in command rating on A-320 on 5.9.1989. Capt.S.S.Gopujkar had total flying experience of 10340 hrs. of which 7176 hrs. were as pilot in command. In the A-320 he had 48 hrs. as co-pilot and 212 hrs. as Pilot in Command till the date of the accident. He had flown 4:20 hrs. in the past 24 hours, 16:50 hrs. in the past 7 days and 56:15 hrs. in the past 30 days.

Since his first medical examination in October 1968, for the issue of Commercial Pilots Licence he has been continuously fit to fly in all his subsequent medical examinations. The last medical examination was done at IAM, Bangalore on 5.10.1989.

He was approved and released to fly as check pilot on A-320 aircraft on 27.11.1989. He had no earlier accident record. He was involved in a taxying incident in a HS 748 on 1.8.1979, at Cochin but he was not found blameworthy. Prior to his conversion training on A-320 he had been approved as a flight instructor on Boeing 737 aircraft. Investigation of his activities on the previous day did not reveal anything abnormal.

On this flight he was carrying out the duties of both co-pilot and check pilot.

2.8.2 PILOT IN COMMAND UNDER SUPERVISION:

46 year old Capt. C. A. Fernandez was an Indian holding ALTP licence No.955 issued on 31.10.1977. He joined Indian Airlines as a pilot. He flew HS 748 as co-pilot and captain till 1983. He obtained co-pilot rating on Boeing 737 on 2.7.1983 and Pilot in Command rating on 19.10.1984. After satisfactory completion of ground/simulator training at Aeroformation, Toulouse, and the required flight checks in India, he was granted a co-pilot rating on Airbus A-320 aircraft on 19.12.89. He had a total flying experience of 9307 hrs. out of which 5175 hrs. were as Pilot in Command. On the date of the accident he had 68 hrs as co-pilot on A-320. He had not flown during the past 24 hrs. He had 11:55 hrs. in the past 7 days and 59:30 hrs. in the past 30 days. His first medical for issue of Commercial Pilot's Licence was in July 1967 and was carrying out his medical examinations at regular intervals. In February 1985, he was found to have an ECG abnormality and was declared temporarily medically unfit. After review at the Airforce Central Medical Establishment, New Delhi, in March 1985 he was declared fit and he continued to remain fit. His last medical examination

was on 28.8.1989 at IAM, Bangalore. He was not involved in any accident or incident earlier.

While granting type endorsement on A-320, the DGCA had advised Indian Airlines that Capt.Fernandez's performance be positively monitored in -

a) operation of FMGS

b) single engine handling and procedures

c) single engine non-precision approach

which required improvement and reports on his performance in these areas to be specifically raised. These shall be taken into consideration at the time of issue of PIC rating to Capt. Fernandez.

This advisory had been issued based on his overall performance during his training at Toulouse. DGCA had also advised that the next six monthly profeciency check of Capt.Fernandez are to be endorsed in DGCA Headquarters only.

Indian Airlines had intimated the DGCA that the performance of Capt.Fernandez in operating FMGS will be monitored when he was undergoing Pilot in Command route checks and the remaining recommendations would be acted upon during his next IR/LR check after commissioning of the

the A-320 simulator.

Investigation of his activities on the previous day did not reveal anything abnormal.

2.9.1 AIRCRAFT INFORMATION:

The Airbus A-320-231, bearing Indian Registration VT-EPN was manufactured by Airbus Industrie and rolled out from their plant at Toulouse, France during the fourth quarter of 1989. The manufacturer's serial number was 079. After acceptance by Indian Airlines the aircraft arrived in India on 24.12.1989 with an export certificate of airworthiness No.15379 of 22.12.1989 issued by the DGAC, France. A certificate of airworthiness No.1946 was issued on 26.12.1989 by the DGCA, India. It was valid upto 21.12.1990. A certificate of registration No.2447 was also issued on 26.12.1989 assigning the registration markings as VT-EPN.

Airbus A-320 is a narrow body, single aisle, subsonic jet transport aircraft. The fuselage is pressurised throughout except nose cone, tail cone, landing gear bays and air-conditioning compartment. All aircraft and system controls for the conduct of the flight are arranged in such a manner that the crew positions are forward facing and both crew members can monitor instruments and systems.

In the Indian Airlines configuration the aircraft can carry 168 passengers in 28 rows, each row having 6 seats. The seats are 3 on either side with a central aisle.

The flight deck of the aircraft is designated for two pilot operation. The aircraft uses a new technology Fly By Wire flight controls operated by sidestick controls replacing the conventional control columns. It has six large cathode ray tube (CRT) displays replacing the conventional instruments. This is known as Electronic Instrument System which is divided into two parts namely EFIS (Electronic Flight Instrument System) and ECAM (Electronic Centralised Aircraft Monitor). The EFIS has two CRT's each in front of the pilots and displays mainly flight parameters and navigation data on the PFD (Primary Flight Display) and the ND (Navigation Display). The ECAM utilises two CRT's one below the other on the centre instrument panel known as Engine/Warning display and System display. The displays on these are engine primary indications, fuel quantity indications, flaps and slats position indications, warning and caution alerts, memo messages, aircraft systems synoptic diagrams, status messages, flight data etc.

The flight management and guidance systems

(FMGS) is a pilot interactive system which provides autopilot control, flight director commands, auto thrust control, rudder commands, flight envelope computations, navigation, nav radio auto tuning, performance optimisation and information display management. The aircraft is provided with Full Authority Digital Electronic Engine Control (FADEC) which provides a full range of engine control and receives its commands from FMGS.

The Fly By Wire flight system controls the primary and secondary control surfaces. The crew inputs through the sidestick controls are received and processed by various computers which in turn give commands to hydraulic actuators for related flight control movements.

The airplane was powered by two V-2500 A1 engines manufactured by International Aero-engines. These are high bypass turbofan engines developing a sea level static thrust of 25000 lbs. The manufacturers serial numbers of the engines were V-0021 installed in the No.1 position and V-0040 installed in the No.2 position. On the glare shield panel centrally positioned there is the FCU. It provides short term interface between FMGC (Flight Management and Guidance Computer) and crew allowing:

a) Engagement of auto pilot, flight

director and auto thrust systems.

b) Selection of required guidance modes

c) Manual selection of flight parameters such as Speed/Mach, Heading/Track, Altitude or vertical speed/flight path angle.

Most actions on the FCU lead to an immediate change in the guidance or control of the aircraft.

2.9.2 POWER PLANT:

The aircraft is fitted with two International Aero Engine IAE V-2500 high bypass ratio (5.44:1) turbo fan engines rated at 25000 lbs. take off thrust at sea level and flat rated to ISA + 15°C. The aircraft is equipped with a FADEC (Full Authority Digital Electronic Engine Control) system which provides gas generator control, engine limit protection, power management, automatic engine starting, flight deck indication data, thrust reverser control and feed back and acts as a propulsion data multiplexer making engine data available for condition monitoring.

Engine thrust control is provided by FADEC. Thrust selection is achieved by means of the thrust lever in manual mode or the FMGS in auto thrust mode to maintain a given speed or required thrust setting.

MANUAL MODE:

In this mode engine is controlled by the position of the corresponding thrust lever (throttle), provided auto thrust function is not engaged or engaged but not active (thrust lever not in ATS operating range and alpha floor protection not activated).

AUTOMATIC MODE:

In the automatic mode thrust is computed by FMGC and is limited to the value corresponding to the thrust lever position (except if alpha-floor mode is activated). The thrust lever does not move in accordance with the thrust produced under the command of FMGC. Auto thrust mode can be engaged (provided at least one Flight Director is 'ON'),

i) manually, by pressing the auto thrust push button on FCU on ground with engine stopped or in flight when above 40 feet radio altitude.

ii) when the pilot initiates a take-off or go-around, OR

iii) if there is an alpha-floor detection after lift off and down to 100 feet radio altitude on landing.

Auto thrust is active when the mode is engaged and thrust lever is set between IDLE and MCT/

FLX (Max. continuous thrust/flexible take off) position. When the active auto thrust function is disengaged while the thrust lever is in MCT/FLX or CL (climb) position, the thrust of both engines is frozen at the value defined before auto thrust disengagement. Manual thrust control is recovered by selecting a position of the thrust lever different from the present position. In that case the new EPR (Engine Pressure Ratio) given by the thrust lever position is reached smoothly.

ALPHA FLOOR AND AUTO THRUST:

In the particular case of Alpha floor detection, the max. take off thrust is automatically selected irrespective of the position of the thrust lever. Alpha floor function becomes active when:

angle of attack is more than 9.5° in config. 0,

or

angle of attack is more than 15° in config.1, 2 or 3

or

angle of attack is more than 14.5° in config. full.

It is also active when sidestick is more than 14° nose up and if pitch attitude is greater than 25° or if angle of attack protection is active. Alpha floor function is inhibited below 100 feet radio altitude. During the course of inquiry, Airbus Industrie have evaluated and informed the Court that a delay of 0.8 to 1.2 seconds could

2.9.3 PARTICULAR AIRCRAFT: VT-EPN

Airbus A-320 - 231 aircraft bearing Sl.No.079 was assembled/manufactured at Toulouse plant of M/s.Airbus Industrie, Blagnac, France. Both engines were installed on 3.8.1989. The aircraft completed 8 hours 35 minutes flight hours and made 7 landings between 19.9.1989 and 22.12.1989 in France. Export Certificate of Airworthiness No.15379 was issued in respect of this aircraft on 22.12.1989 by DGAC/Bureau Veritas of France. On the strength of the export certificate of airworthiness (C of A) Director General of Civil Aviation, India, also issued on short term C of R (Certificate of Registration) assigning registration No.VT-EPN to this aircraft and short term C of A which was valid from 22.12.1989 to 22.12.1990 to enable the aircraft to fly to India under Indian Registration and with Indian C of A. All the requirements of CAR (Civil Airworthiness Requirements) Series 'F' Part IV Issue II were followed in this regard including Certification of Flight Release at Toulouse by duly approved Indian Airlines AME (Aircraft Maintenance Engineer) prior to the flight.

The aircraft arrived in India on 24.12.1989.

After thorough checks the full term C of R No.2447 and full term C of A No.1941 were issued by the Director General of Civil Aviation on 26.12.1989 classifying the aircraft in the normal category for Public transport for carriage of passengers, mail and goods. The C of A was valid upto 21.12.1990.

The aircraft was maintained in accordance with maintenance programme drawn up on the basis of recommendations of the manufacturers and experience of the operator and approved by the Director General of Civil Aviation. As per this programme the maintenance schedules approved are as follows:

Schedule Inspection		Periodicity
1. Preflight check	-	To be performed before every flight.
2. Daily check	-	To be carried out during night halt or lay-over period not exceeding 36 hours elapsed time.
3. Weekly check	-	To be accomplished at every 75 flight hours or 8 calender days, whichever is earlier.
4. 'A' Check (Flight Release Certification)	-	To be performed every 300 flight hours or 40 days elapsed time whichever is earlier.

List of the above checks carried on this aircraft and hours done by the aircraft since last such check are as follows:

Last check on VT-EPN	Hours done since the check till the time of accident.
1. 'A' Check done on 31.1.90 at Delhi, at airframe hours 277:55 and Flight Release Certificate issued valid till 11.3.1990/ 577:55 FH.	92:40 FH(Flight Hours)
2. Weekly check done on 7.2.90 at Bombay at 327:30 FH valid till 15.2.90/402:30 FH	42:53 FH
3. Daily check done at Bombay on 13.2.90 at 366:55 FH valid till night halt on 14.2.90	03:28 FH
4. Preflight check done at Bombay on 14.2.90, at 368:55 FH	01:28 FH

The aircraft did not exceed the flight hours or elapsed time limit of any of the approved maintenance schedules.

The aircraft completed total Airframe hours 370:32 FH and 302 landings.

Since the aircraft was pressed into service on 27.12.1989 till the accident occured (50 days) following defects were reported:

1) Flap system:- "Wing tip brake fault" was reported 15 times in 10 days. However, the snag was not confirmed on 10 occasions. C.B. (Circuit breaker)

recycling, cannon plugs cleaning or allowing sufficient cooling time and resetting rectified the defect which was last reported on 13.2.1990.

2) Elac - 1 fault was reported 11 times in 7 days. This snag was not confirmed on 3 occasions. Computer was re-racked once and C.B. was recycled 7 times to cure the defect. After C.B. recycling on 9.2.1990 the snag got cured of its own.

3) Elac - 2 fault was reported 6 times in 3 days. The defect was not confirmed once and C.B. was recycled on 4 occassions. On 13.2.1990, however, the Elac - 2 was replaced.

Before operating the ill-fated flight IC-605 (Bombay-Bangalore) on 14.2.1990 there were two reported defects on completion of the earlier flights IC-669/670 (Bombay-Goa-Bombay) Viz.,

a) "Rain repellant in yellow band" which was rectified by replacing rain repellant can.

b) "First Officer seat lumber vertical adjustment un-serviceable" which was being carried forward since 11.2.90 and was also carried forward during flight IC-605. CAR (Civil Airworthiness Requirement) Series 'B' Part I Issue III Permits carrying forward of such defects, which do not affect safety of Airworthiness of aircraft and as such not included in the MEL (Minimum Equipment List)

2.9.4 THE ENGINES:

The details of IAE V-2500-A1 engines installed on VT-EPN are as follows:

Engine position	No.1(left)	No.2(right)
Serial Number	V-0021	V-0040
Hours done since new	396:33 FH	396:13 FH
Cycles done since new	318	329
Date of installation	3.8.1989	3.8.1989
Date of Overhaul	N/A	N/A
Date of Manufacture	Jan.1989	Feb.1989.

The engines were also maintained as per approved maintenance schedules by approved AME. There was no repetitive defect reported on the engines. No mandatory inspection was outstanding on the engines or associated systems.

None of the components of Airframe and engines exceeded its stipulated "life". The aircraft was airworthy and its Certificate of

Airworthiness was valid upto 21.12.1990.

2.9.5 WEIGHT AND BALANCE:

In the Indian Airlines configuration the passenger cabin had 168 passenger seats as indicated earlier. There are five cabin crew seats in the cabin, three of which are near the aft entry doors and two are near the forward entry doors. The flight deck has two pilot's seats, one observer seat and another occupant's seat. During the subject flight the aircraft was carrying 2 pilots, 5 cabin crew and 139 passengers which included 4 infants. As per the Load and Trim sheet the take off weight of the aircraft at Bombay was 61470 kgs. Computed CG position was 28.9% of MAC. The take off fuel was 6950 kgs. Estimated trip fuel was 3390 kgs. Estimated landing weight was 58080 kgs. The take off weight, the landing weight and the computed CG were all well within the operational limits of the aircraft. The load details are:

1.	Operating empty weight	..	42,664 kgs.
2.	Pantry load	.. (+)	500 kgs.
3.	Dry. operating weight	..	43,164 kgs.
4.	Total traffic load (baggage, Mail & Cargo 1851 kgs. and passenger 9505 kgs.)	(+)	11,356 Kgs.

5.	Zero fuel wt. for the flight	..	54,520 kgs.
6.	Take off fuel	..(+)	6,950 kgs.
7.	Take of weight	..	61,470 kgs.
8.	Trip fuel	..(-)	3,390 kgs.
9.	Landing weight	..	58,080 kgs.

Note:

a)	Max. zero fuel wt.	..	60,500 kgs.
b)	Dry operating wt. for the flight	..(-)	43,164 kgs.
c)	Allowable traffic load	..	17,336 kgs.
d)	Actual traffic load	..(-)	11,356 kgs.
	Traffic underload	..	5,980 kgs.

2.10 METEOROLOGICAL INFORMATION:

At the time of the accident, the prevailing weather at Bangalore was good. The Bangalore met. reports for 12:30, 13:00 and 13:30 hrs. IST were as given below:

Time	1230 (0700 UTC)	1300 (0730 UTC)	1330 (0800 UTC)
Surface Wind	140/05 Kts.	Var/05 Kts	Var/04 Kts.
Visibility	10 kms.	10 kms.	10 kms.
Clouds	2/8 2000 ft.	3/8 2000 ft.	3/8 2000 ft.
Temperature	28°C	28°C	29°C
Dew Point	15°C	14°C	14°C
QNH	1017 HPA (30.03")	1016 HPA (30.00")	1016 HPA (30.00")

QFE	914 HPA (26.99")	914 HPA (26.99")	913 HPA (26.96")
Trend	No Sig	No Sig	No Sig

The met reports indicated the existence of fair weather conditions at the time of the accident. No significant changes in the weather had been anticipated between 12:30 and 13:30 hrs. The Bangalore Control tower had indicated the prevailing surface wind as 120/05 kts. at the time of issuing a clearance to land based on the display in the control tower.

The QNH which has been conveyed to the aircraft was 1017 HPA. Though QNH had changed to 1016 at 13:00 hrs.IST the report may not have reached the tower controller by the time of the crash. The one HPA change is not considered significant in respect of this crash.

Good visibility had been confirmed by the pilot of IC-605 by reporting R/W in sight at a distance of 7 nautical miles.

2.11 AIDS TO NAVIGATION:

Bangalore airfield is served by a Non-Directional Beacon (NDB), a VHF Omni Range (VOR) and a Distance Measuring Equipment (DME). There were no known navigational aid difficulties.

Instrument Landing System (ILS) had not been installed at Bangalore airfield.

R/W 09 at Bangalore is served with a three bar visual approach slope indicator (VASI) lights. It was reported to be serviceable on the day of the accident. VASI lights had last been caliberated on 20.10.1986 and thereafter they were checked at irregular intervals. It was last checked on 17.12.1989 and found satisfactory. The serviceability check of the lights had been carried out on 14.2.1990 at 0900 hrs. IST, they had been found serviceable.

Approach radar is installed at Bangalore which provides navigational assistance to aircraft during departures and arrivals and as an aid to provide air traffic services. Approach radar had given assistance to IC-605 until 7 miles from runway 09 for carrying out a direct approach on R/W 09. As IC-605 had the R/W in sight, approach radar service was terminated. There was no navigational difficulties experienced by IC-605.

2.12 COMMUNICATIONS:

There were no known difficulties with communication equipment or facilities experienced by IC-605.

At Bangalore ATS (Air Traffic Services) Establishment, a 45 channel recorder is available for recording various communications channels. However only two channels namely 123.5 Mhz (TWR freq.) and 122.7 Mhz (APP freq.) were recorded. Even the time signal had not been recorded. Hence it was not possible to establish the exact timing of communication on TWR and APP channels with aircraft IC-605. However the transcript with the approximate co-relation with CVR/DFDR has been used for investigation by the Inspector of Accidents in his report.

2.13 AERODROME INFORMATION:

Bangalore airport is in the city of Bangalore in the state of Karnataka and is under the administrative control of Hindustan Aeronautics Limited (HAL). The co-ordinates of the aerodrome reference point are 12°57' 03.39" N and 77°39' 56.58" E. The elevation of the ARP is 2914 feet. The airfield has a single R/W 09/27 which is 10850 feet long and 200 feet wide. The R/W has a considerable hump in the middle. The magnetic bearing of the R/W are 088°/268. The elevation of R/W 09 threshold is 2872 feet. The declared distances of TORA, ASDA and LDA for R/W 09 and R/W 27 are

10850 feet. TODA for R/W 09 is 11850 feet and R/W 27 is 11480 feet. There are no obstructions in the approach and take off areas. All other operationally significant obstructions are lighted and marked. The R/W is marked with R/W threshold, touchdown, centreline and R/W side line markings. The taxiways leading to the R/W have centre line markings and taxi holding position markings. There are three wind direction indicators, two lighted indicators at either end of the R/W and one unlighted indicator at the signal area. There is an aerodrome beacon flashing white and green at 12 flashes per minute.

The airfield is used by both civil and military aircrafts and an arrestor barrier is raised when required, at which time the TORA and TODA for the R/W in use will reduce to 10000 feet. The airfield boundary wall is 8 feet high and runs across the approach path of R/W 09 at 1085 feet ahead of the R/W threshold. The North South boundary wall across the approach path of R/W 09 turns at right angles towards the east, outside the right hand corner of the basic strip. There is a gate made of steel grills at this corner which opens southwards and is normally kept locked. There is an approach road which runs parallel to R/W 09/27 on the south side. At approximately the middle portion of the R/W towards the south of the R/W, the aerodrome control tower and the fire station are located from where access to this approach road and the R/W are available. There is a slightly raised portion in the road leading from the tower building to the approach road which is called the ramp from where arriving and departing aircrafts could be seen in clear weather.

Beyond R/W 09 threshold on this approach road, is a hump which is approximately 3 feet high. The road passing over the hump is not properly paved and is very rough and has a steep gradient up and down. Underneath the hump is the channel for the arrestor barrier cable. This approach road leads to the gate mentioned above and any vehicle which has to cross the hump should traverse this portion at a very slow speed.

Bangalore airport meets the ICAO category VII requirements in respect of fire and rescue services. There are two crash fire tenders and one rapid intervention vehicle. An ambulance under the control of senior manager, aerodrome which is at a different location and is used in case of emergencies. HAL has three other fire stations at different locations and they have two crash fire tenders and one water tender in total. They would also be pressed into service in case of an emergency. The type of foam used in the crash fire tenders is aqueous film forming (flouro protein) foam.

Aerodrome fire station has an overhead water tank of 5000 gallons capacity for filling the crash fire tenders by gravity feed. There are three static water tanks one at each end of the R/W and one at the middle with 18000 gallons capacity each. Communication between the tower and the aerodrome fire station are by an internal HAL telephone link. There is no crash siren but the tower indicates flying operations requiring preparedness of fire crew by audio visual signals below:

1) Flying in progress : Amber light displayed on both side walls of fire station.

2) Declared emergency : Amber light and buzzer.

3) Aircraft accident/fire : Red light and bell.

There is no RT communication facility between the tower and fire fighting vehicles. A portable radio transmitter is available for communication between tower and aerodrome fire station but was not serviceable on the day of the accident.

Whenever aircraft movement is expected or is in progress, tower indicates the status by switching ON the amber light. One crash fire tender is started and is kept in readiness with full crew on board. If an arriving aircraft reports an emergency it is indicated by amber light and buzzer and the fire fighting vehicles are required to move to the ramp position and they would proceed towards the aircraft as required. In case of a fire or accident, red light and crash bell is sounded and all fire fighting equipment are turned out immediately. The walkie talkie has to be used for further information about the fire/ accident.

2.14 FLIGHT RECORDERS:

2.14.1 COCKPIT VOICE RECORDER (CVR):

The aircraft was equipped with a Fairchild Cockpit Voice Recorder model A 100A, serial No.53675. The CVR installed in the tail section was found in a good condition with no damage. It was brought to Delhi and was opened in the Air Safety Directorate of the DGCA. The magnetic tape was in good condition and was cut at a distance of about 6" from the erase head. The tape was then played on the Racal Instrument Tape Recorder and a copy of the original tape was simultaneously prepared in all the 4 channels. The recording on the CVR was good and a transcript was prepared from the taped copy.

2.14.2 DIGITAL FLIGHT DATA RECORDER (DFDR):

A Fairchild DFDR model 17M 800 251, serial No. 3768 was installed in the tail section of the aircraft. It was recovered in a good condition with no damage.

Sri H.S.Khola, the then acting DGCA, heading a team of two other members carried the DFDR to the Canadian Aviation Safety Board (CASB), Ottawa The magnetic tape was removed from the DFDR and was cut before the record head in order that the physical end of the tape represented the end of the data. A detailed DFDR readout of approximately the last 5 minutes of the flight was prepared. A full flight DFDR data for the flight from Bombay upto the time of accident with a few selected parameters was also prepared by the CASB.

2.15 WRECKAGE AND IMPACT INFORMATION:

2.15.1 GROUND MARKS:

The aircraft initially contacted the ground on its main wheels in the golf course which lies in the approach funnel of R/W 09. The first touch down point is about 2300 feet from the beginning of the R/W and slightly to the right of the extended centre line. The aircraft after rolling about 80 feet on the main wheels, went up into the air and remained in the air for about 234 feet. Small trees in the way of the aircraft were cut by landing gears and engines. Aircraft again hit the ground on the slightly rising 17th green of the golf course on practically all thred gears creating deep furrows. Even the central bottom part of the bogey beam on which the four wheels of each main landing gears are fitted, left considerable indentation between the tyre furrows. The left main gear marks we[illegible]rved for a distance of 102 feet approximately. On the raised ground ahead of the right hand main gear the right engine cowling grazed the ground for about 40 feet. Possibly because of the support afforded by the right hand engine nacelle the right main gear wheel marks and the nose gear wheel marks were shorter in length than the left main gear marks. The nose gear marks were for a distance of 30 feet only. The aircraft then collided with a trapezoidal embankment which forms the boundary of the golf course. This embankment is approximately 12 feet high with a base width of 70 feet. There were some eucalyptus trees over the embankment about 15 feet in height by comparison to other trees which are existing outside this area. The lower part of the fuselage rubbed over the embankment and the engines and the gear directly impacted the embankment. Trees on the embankment were cut off by the wings as the aircraft moved forward. The engines got detached from the wings and fell ahead of the embankment. The right engine fell into the nullah and the left engine fell on to the road after the nullah. All three landing gears broke as a result of the impact. The aircraft fuselage with the bottom portion severely damaged and broken landing gears hopped over the nullah and it impacted the ground approximately 280 feet on the other side of the embankment. During this hop of the aircraft the various broken and disintegrated components of the aircraft fell down and lay scattered all over the ground between the road and its final resting place. Aircraft skided on its belly for about 170 feet before coming to a final stop with the forward end of the aircraft about 150 feet short of the boundary wall of the airfield.

2.15.2 <u>WRECKAGE DETAILS:</u>

The main wreckage of the aircraft at the final rest position was about 150 feet short of the west side boundary wall of the Bangalore airport. The scatter of wreckage is mainly confined between the embankment and the final rest position of the aircraft. Wreckage trail extends to about 500 feet behind the main body of the aircraft.

Engines 1 and 2 which separated from the wing after impact with the embankment fell in the nullah and the road respectively. Both the nullah and the road run adjacent to the embankment which forms the boundary to the Karnataka Golf Club. The pylon of the No.1 engine was still attached to the engine. However the pylon of the No.2 engine had separated from its attachments to the engine but it continued to cling on to it. Both the engines had disintegrated into three major portions namely Fan casing, Booster stages along with portion of fan blades and the remaining part of the engine. Fan casings of both the engines caught fire after breaking away from the engines as the oil and fuel system units are installed on the Fan casings.

Main and nose landing gear structure sheared from their attachments and were dragged forward along with the aircraft. Some portion of these components fell in the trail of the wreckage. Bogey beam of both the main under-

undercarriages along with the supporting structure suffered extensive damage. Nose wheel strut and its supporting structure disintegrated. The wings remained attached to the fuselage. Extended slats and flaps on both the wings suffered damage due to impact with the trees on the embankment.

Scatter behind the aircraft included the broken surfaces of right hand elevator, portions of right hand flap surfaces and parts of structure of the front fuselage. Some of the units of the electronic equipment bay were also scattered. These included a number of computer units which suffered extensive damage.

Lower portion of front fuselage ahead of wings was severely damaged by impact with the embankment. Rear fuselage behind the wings however remained in shape till the fire caused severe damage. On the right hand wing there are ruptures and openings on the front and rear spar near the root end from where the fuel leaked supporting the fire. There is evidence of the wing being on fire at the wing root area and forward and aft spars area. Forward spar buckle outboard of slat track No.1 and a 10" x 6" hole in the forward spar just outboard of slat track No.2 and aft spar buckle on the rear spar with spar web broken and forced outwards, may give the indication of a post crash explosion inside the tank. The left wing damage is much less than the right wing. Main landing gear separation has caused damage to rear spar which appeared to be more severe. Upper spar boom is exposed and cracked. Fuel may have split due to the damage caused. However approximately 200 litres of fuel was retrieved from the left wing tank. The forward wall and approximately 30% of the forward tank roof of the centre tank was completely destroyed by the intense fire. The aft wall was fully intact with fuel valves etc., fully in place. Flaps of right wing were completely destroyed and on the left wing only 7 feet of outboard flaps were left. Slats were also badly destroyed on the right wing and on the left wing the slats damage was comparatively less.

Seats, cabin floor galley equipment and the front fuselage forward of the wing root were totally consumed by fire. Few partially burnt and damaged portions of the fuselage containing forward doors and forward cargo hold doors were left. Also the right hand half of the cockpit shell was remaining with the front and side wind shields in position. Though there was some burn damage to the wind shields, the outer skin of the fuselage surrounding the wind shields did not show any evidence of wrinkling, crumpling cracks etc., particularly around the right hand sliding window. Even on the inside, the RH sliding window framework was firmly intact with minimal burn damage. The window handle appeared to be intact with the release button in the pressed position. The bottom rail of the sliding window did not indicate any burn damage, but the top rail showed burn damage in the aftmost 4" to 5".

In the middle and rear fuselage most of the seats and flooring were burnt and the top portion of the fuselage shell upto the window level in this area was also consumed by fire. The rear galley equipment has been exposed to severe cabin fire. Severe longitudinal/circumferential crumpling has been observed aft of the centre wing box. About 11 feet aft of the wings rear spar, there is a fuselage fracture about 9" wide extending from just above the window line to the lower belly on the left hand side. On the RH side this is not observed. The tail section aft of the rear passenger doors is generally intact, though on the inside, the floor and the galley are damged due to fire. Externally the doors were in better condition. The LH horizontal stabilizer and the elevator were in good condition but some outboard part of the RH stabilizer and some portion of the RH elevator had been broken by impact. The position indicator of the trimmable horizontal stabilizer was reading close to 6° nose up. The rear pressure bulkhead was in a fairly good condition except for damage to the lower section due to crumpling. The crash recorder racks behind the rear pressure bulkhead were undamaged and the recorders were retrieved in good condition by cutting out an opening on the LH side. The stabilizer actuators were in good condition. There is no evidence of any damage to the APU or the structures surrounding the APU.

The fin and rudder appeared to be in structurally good condition.

The left rear passenger door had been opened with its escape slide extended and deflated. The arming lever of the door was in the "Armed" position but the inflation reservoir of slide was still pressurised. The right rear passenger door had been opened most probably from the outside as the opening lever was in the UP position and the escape slide was not extended. The centre pedestal showed flaps and slats handle in full extended position. The master levers of both engines were in the ON position. Ground spoiler lever was in the "Armed" position and thrust levers in TOGA position. Trim wheel was jammed and was showing 5.2° nose up. Parking brake lever was OFF. Gravity gear extension handle had come out. All four transfer switches were found in normal positions. (ATT/HDG, AIRDATA, DMC, ECAM/ND). On both audio control panels INT/RAD switch was in INT position. Radar select switch was on position 2. On glare shield panel VOR/ADF switches were in VOR 1 and VOR 2 positions. Arc mode and 10 miles range had been selected on both sides. On the overhead panel external light switch positions were normal, for day time flight and during approach for landing. Engines 1 and 2 and APU fire switches were found in normal and guarded positions. Sidesticks of pilot and co-pilot were burnt.

Only three overwing emergency exit windows out of the four could be located. Handle position of two windows indicate the possibility of their being pulled. The third window was heavily burnt and no indication of the position of the handle is available. Escape slide of left overwing exit was lying outside but its inflation reservoir could not be seen, being under the fuselage. The RH overwing escape slide was found packed and partially burnt inside the fuselage indicating that it was not deployed.

2.16 MEDICAL AND PATHOLOGICAL INFORMATION:

The illfated flight had 146 persons on board which consisted of 2 pilots, 5 cabin crew and 139 passengers including 4 infants.

The A-320 seat configuration indicating the allotted seat positions of the survivors and the dead is found as an annexure to Exhibit 1.

An intense fire initially started in the forward fuselage and later spread towards the rear. 16% (8 out of 50) of passengers in zone A, 27% (13 out of 48) in zone B and 73% (35 out of 48) in zone C survived.

Dead bodies were identified by forensic experts with the help of the relatives of victims. Bodies of 25 unidentified victims were cremated enmasse. Bodies of the 2 pilots and 2 air hostesses were identified and claimed by their relatives.

Indian Airlines doctors at Bombay, Dr.V.K.Kunte and Dr.S.V.Thakkar had carried out the preflight medical examinations of Capt. Gopujkar and Capt.Fernandez prior to this flight and they were found fit to fly. No breath analyser tests were carried out as they were not suspected for alchohol consumption by the doctors

Though 56 had survived the crash at the time it occurred, 2 of them died later in hospitals. Out of the above 56, 54 had been initially admitted in the Indian Air Force and HAL Hospitals at Bangalore and subsequently some were shifted to other hospitals.

The analysis of the injuries suffered by survivors indicated that 8 persons had burn injuries, 28 persons had face, neck and head injuries, 8 persons had nasal bone injuries and 16 persons had fractures in other parts of the body. Many cases had multiple abrasions, lacerations, etc.

There was some confusion in the identification of the body of Capt.S.S.Gopujkar initially. Dr.S.B.Patil, Assistant Professor, Forensic Medicine, BMC, Bangalore, had carried out the post mortem examination of the identified body of Capt.Fernandez. The death was due to shock and the burns sustained and the burns were ante mortem in nature. There was no abnormal smell in the stomach contents. There was no injury to the body prior to death. He did not find any fractures.

Dr.Patil had also carried out the post mortem of a body (Sl.No.36) which was later identified as that of Capt.Gopujkar. The age mentioned in the autopsy report was copied from the age indicated in the police report. Dr. Patil was aware that subsequently doubt arose about the identity of the body and relatives of Capt.Gopujkar later identified another body as that of Capt.Gopujkar. Dr.Patil was not present at the time of identification. No dental imprints of any of the deceased were furnished to him for use towards indentification.

Dr. S. C. Shankaralingiah, Assistant Surgeon, Jayanagar General Hospital, Bangalore, conducted the autopsy of the body of a victim later identified as the body of Capt. Gopujkar by his relatives. He had died of burns and the consequential shock. There were no fractures of any bones. Histopathological and toxicological examination of the samples of body sent to IAM, indicated no abnormality. Though there was a report of post mortem burns based on the examination of skin sample sent to IAM, Dr. Shankaralingiah who carried out the autopsy categorically stated during his deposition that Capt. Gopujkar had died due to burns followed by shock. He stated that possibly ante mortem skin had not been examined by IAM. (It may be noted that an eye witness, Mr. Laxmiah Reddy who had seen the aircraft coming to the final rest position, and had run towards the nose of the aircraft has stated that he had seen someone thumping against the RH cockpit window whom he thought to be a pilot before the fire engulfed the plane. Possibly skin sample sent to IAM may have been a part of burnt skin with no ante mortem portion).

Analysis of autopsy reports of the 90 persons killed in this crash was carried out. Seat allocations of identified passengers were considered and an attempt has been made to co-relate the injuries sustained. Dr. Vijai Kumar, Deputy Director, Medical Services, Air India and Wg. Cadr. Roopnarayan, Aviation Pathologist of Indian Air Force posted at IAM, Bangalore, gave very valuable assistance towards this analysis. The following are the observations:

The autopsies had been performed at Victoria Hospital, Bowring Hospital and Jayanagar General Hospital at Bangalore.

The formats used for the autopsies were the general autopsy formats used by hospitals in this region. Some were in English and some were in Kannada language. These formats were not corresponding to the requirements of DGCA, Air Safety Directorate Circular 3 of 1984. Several details which may be of use in air crash investigation have therefore been left out.

Seating patterns of 65 victims based on seat allocation are indicated separately and attached to this report as an appendix. Body No.88 and body No.59 were both shown against seat 6E. However by injury pattern it is likely that body No.38 was seated in 6C. Out of the 65, 4 infants had occupied the seats along with adults. The rest of the 25 being unidentified could not be placed on the seat charts.

Of the 90 victims cause of death for 81 have been mentioned as shock due to burns sustained. Only in 9 cases burns were not mentioned in the autopsy reports. But almost all these were stated to be allotted seats in rows 2, 3, 5 and 6. As there was severe fire during the initial stages in the forward portion of the aircraft it is difficult to comprehend that these bodies had not sustained burns. Possibly the burns may have been post mortem.

In 13 individuals only, there was evidence of severe injuries with shock present. This would indicate that 4 of these had sustained both severe injuries with shock as well as burns. The pattern of injuries is indicated in the document appended to this report. It is seen that 32 persons sustained injuries to the lower limbs, 20 sustained injuries to the head and 7 sustained thorasic injuries. It is highly probable that at least some of these have died of burns because of physical inability to escape quickly.

It is evident from the seating pattern from the identified bodies, that most of the deaths have occurred in passengers occupying the first 10 rows and rows 17 to 20, the cock-pit crew and the two hostesses occupying the forward seats. Passengers in the vicinity of the emergency exits and those near the rear door generally have managed to escape.

It seems extremely unlikely that Sl.Nos.15 and 48 were occupying the seats allotted to them namely 26A and 28D. It is probable that they may have shifted to some vacant seats further forward.

It seems possible from the injury analysis that the occupants of seats 8A and 8B have sustained injuries due to a hard object like a briefcase hitting the head/shoulder.

All occupants of the left side seats of rows 5 and 6 have sustained multiple injuries including head injury indicating the possibility of some forces causing severe damage in this area or causing failure of these seats.

The autopsies on the cockpit crew did not reveal any evidence of acute physical incapacitation. The cause of death in both cases were due to burns sustained. Histopathological and toxicological examination of both did not show any abnormality

24 bodies showed injuries to leg/ankle. The possible cause of such injuries could be the flailing of legs at the time of impact hitting against the bottom bar of the seat ahead. These injuries may have prevented some of these passengers from exitting the aircraft in time

before the fire engulfed the plane

If fire had not occurred, a large number of passengers would have survived.

The above observations would need action as under:

1) Wide dissemination and strict adherence to the contents of DGCA Air Safety Directorate Circular 3 of 1984 titled "Action required of police authorities in case of aircraft accidents" will greatly assist in the medical investigation of aircraft accidents.

Autopsy formats in compliance with the above circular should be prepared by the DGCA and should be available in adequate numbers with officials at all airports in India. These should be provided to the police authorities immediately in case of a fatal aircraft accident so that the autopsy reports would be as per aviation requirements. Wherever possible, availability of experienced pathologists connected with aviation organisations such as Indian Airforce/Airlines should be utilised to assist in obtaining proper autopsy reports.

2) Due to a considerable number of dead passengers having leg injuries provision of a foam pad around the bottom rear bar of the seat should be examined to reduce such injuries in future (wherever the pitch between the seats is

such that it could cause such injuries).

3) A large number of dead passengers and survivors had face, neck and head injuries. It is possible that quite a few of these may have been due to the passengers hitting their face/head against the back of the seat in front of them. Such injuries could be possible if the passenger does not tie the seat belts snugly or the seat in front is not kept in the vertical position prior to landing. It is advisable for instructions to be issued for all cabin crew to check and insist on the laid down procedure of seats to be upright, seat belts snugly fastened and the tray tables stowed properly.

2.17 ADDITIONAL INFORMATION:

2.17.1 ENGINEERING:

The aircraft had a night halt at Bombay on 13.2.1990. Prior to the subject flight on 14.2.1990 the aircraft had operated flight IC-669/670 Bombay-Goa-Bombay. The daily check schedule at Bombay, transit check at Goa followed by the transit check at Bombay before IC-605 took off was carried out by Indian Airlines engineers having security passes.

2.17.2 CLEANING OF THE AIRCRAFT:

On 14.2.1990 the Indian Airlines cleaning staff at Bombay cleaned the aircraft after its arrival from Goa. All these staff were checked and frisked before entering the aircraft.

2.17.3 CARGO AND UNACCOMPANIED BAGGAGE:

There was no cargo or unaccompanied baggage loaded onto this aircraft.

2.17.4 MAIL:

16 transit mail bags plus three covers weighing 52.7 kgs. had been loaded at Bombay on board this flight. A cooling period of 36 hours had lapsed before loading this transit mail on the aircraft. Two parcels and one cover of speed post weighing 1.4 kgs. in transit from Bombay airport was loaded onto this aircraft from Bombay. There were no courier bags on this aircraft.

2.17.5 CATERING:

M/s. Taj Air Caterers loaded the catering items for this flight. The equipment and food loaded had been isolated for anti sabotage check. The lift on which the articles were carried to the aircraft was also checked by the Bombay Airport Security Police at Gate No.1.

2.17.6 EMBARKATION OF PASSENGERS

All 139 passengers had been checked in and then boarded the flight IC-605. This was confirmed by matching the number of flight coupons and boarding card stubs, retained at Bombay. All passengers had gone through security checks in the Airbus side of the domestic terminal. All DFMD's (Door Frame Metal Detectors), HHMD's (Hand Held Metal Detectors) and X-ray machines were in working condition. Nothing objectionable had been detected during the frisking and baggage checking of passengers of IC-605. Prior to boarding all passengers identified their checked-in-baggage. There was no "Gate No Show Passengers" in respect of this flight.

2.17.7 OBSERVATIONS:

In view of the comprehensive drill carried out for the security check of the aircraft, passengers and baggage there is no evidence of any sabotage.

An examination of the airplane and engine, flight and maintenance log books did not reveal any discrepencies or malfunctions at the time of departure from Bombay which could have adversely affected the safety of the flight planned.

2.18 TESTS AND RESEARCH:

Salient observations from the field investigation of various systems and engines:-

2.18.1 FLIGHT CONTROLS:

(a) Primary Controls:

Sidesticks of pilot and co-pilot were damaged and burnt. Also the push buttons of various flight control computers on the overhead panels were burnt. A few related computers could be recovered from the wreckage trail. These computers had suffered impact damages. Rest of the computers are likely to have been consumed by fire.

(a.1) Ailerons:

Control surfaces on both the wings were found intact along with actuators. The surfaces could be moved freely and there was no apparent indication of any abnormality with these surfaces and actuators.

(a.2) Rudder:

Rudder control surface suffered no damage during crash. The surface was found free to move and there was no apparent indication of any abnormality.

(a.3) Elevators:

Port elevator surface was intact along with actuators. The surface was free to move and there was no jamming. However, the starboard elevator had suffered impact damage and the surface was broken. Both the actuators of starboard side were in the extended position for a length of about 11 to 12 cms. This was due to impact damage suffered by starboard trimmable horizontal stabilizer and elevator.

(a.4) Trimmable Horizontal Stabilizer (THS):

The position indicator of THS was reading close to 6 nose-up. Port THS surface was intact, however, starboard surface was damaged due to impact. THS motors and screw jacks were intact.

Trim wheel on the central pedestal was found jammed in approximately 5.2 nose up position.

(b) Secondary Controls:

(b.1) Trailing Edge Flaps:

Surfaces of trailing edge flaps were damaged during the impact of the aircraft. Examination of carriages revealed that flaps were fully extended.

This was also corroborated by the flap lever which was in configuration full position.

(b2) L.E.Slats:

Slats surfaces were damaged due to impact with trees on both the wings. Position of tracks of various slats indicated their full extended position. This conforms to the flap/slat lever position.

(b.3) Spoilers:

Spoiler surfaces were found retracted on both the wings. Spoiler lever was found in the armed position.

2.18.2 COCKPIT PANEL SWITCHES AND LEVER POSITIONS:

All the cockpit panels suffered impact damages and were exposed to intense fire. Following are the position of some of the switches and levers:-

i) On glare shield panel: (For LH and RH Navigational Display Control) VOR/ADF switches were in VOR 1 and VOR 2 positions, with Range Switches in 10 miles and Mode select in ARC mode.

ii) On overhead panel: Ext. light switches position were as following:
Strobe S/W - Auto
Beacon S/W - ON, Wing, Insp.Light SW-OFF.

NAV. Light/ S/W - OFF

Runway turn ON/OFF Light - ON.

Landing light (2) S/W - ON.

Taxi T/O Light - OFF.

These switches indicate preparation for landing. Engines Nos.1 and 2 and APU fire switches were found in normal and guarded position.

iii) <u>On Central Pedestal</u>:

- Ground spoiler lever in armed position.
- Thrust levers in TOGA position (Left lever was stiff to move, while right lever was less stiff to move).
- Trim wheel position is 5.2 Degrees Nose up and jammed.
- Both engines master switch lever - ON.
- Parking brake lever - OFF.
- Gravity gear ext. (handle had come out due to impact).
- Flap lever fully down.
- Radar select switch on position 2.
- Switches on both Radio Management Panels were ON.
- On both the Audio Control Panels INT/RAD switch was INT position.
- All the four Transfer switches of ATT Heading, Air Data, DMCs and ECAM/ND were found in Normal positions. All

controls correspond to a normal landing configuration.

2.18.3 <u>DOORS, EMERGENCY EXITS AND EXCAPE SLIDES</u>:

1. <u>Cabin doors and slides</u>:

Both the forward doors on port and starboard sides were found closed. Both the rear doors were open. The port side rear door was opened from inside, but the starboard side rear door was opened from outside. The emergency control handle on the port door was in armed condition. The escape slide for the rear port side door was lying detached from the door in un-inflated condition. Inflation reservoir attached to slide was found pressurised to 2500 PSI (in green band) indicating that it had not discharged and slide had not deployed. As the rear starboard door was opened from outside, it had not deployed the escape slide.

2. <u>Overwing Emergency Exits, Windows and Slides</u>:

Only 3 overwing emergency exit windows out of 4 could be located. Handle position of the two windows suggest that probably they were pulled. Other window was extensively burnt and no indications are available regarding position of handle.

Escape slide of port overwing was found lying out, but its inflation reservoir could not be seen as it was lying under the fuselage. It appears to have been burnt. It may be possible to confirm from the pressure reading of inflation reservoir, which might be under the fuselage, regarding the deployment status of this escape slide. The starboard overwing escape slide was found packed and partially burnt inside the fuselage indicating that it was not deployed.

3. Cargo Compartment Doors:

Both front and rear cargo doors were found closed. The front door was partially burnt and damaged. Nature of burns clearly indicated that the fire was initially outside the cargo hold on the cabin side and fire had travelled from cabin to the cargo hold.

2.18.4 STRUCTURAL DISINTEGRATION AND FIRE:

Major disintegration of the aircraft took place at the time of impact with the embankment when both the engines and landing gears were detached. When the aircraft impacted embankment it was in slight right bank as revealed by marks on the embankment and the broken trees. The lower side of forward fuselage had suffered severe crushing loads.

Immediately after separation of the engines from the wings, there was fire on fan casing of both the engines, as the fuel and oil system are located over it. In the wreckage trail, burnt pieces could be seen around 170 feet short of final rest position of aircraft. Major fire erupted in forward fuselage and fire travelled to rear side of the cabin.

Due to shearing of main undercarriage from the attachment points on the wings, front and rear spars ruptured more severely on starboard side. Fuel of starboard fuel tank supported the fire. Port wing tank fuel dripped out from the cracks of spar, but did not support the fire much.

2.18.5 ENGINES:

The Port Engines (SL.NO.V0021) and the starboard engine (SL.NO.V0040) were visually inspected in as is condition at the site of accident. The inspections were:

A. Port Engine:

1. Structural Observations:

(a) External:

The engine disintegrated into 3 major portions of Fan case, LP Fan along with booster stage and the remaining engine.

The Fan case was found ruptured around 6' O'clock position and left side of the case was exhibiting burn signs. The oil tank was found ruptured. Anti ice nose cowl valve was found detached, the valve was in closed position. EEC unit was found intact except some minor damages.

Five blades of LP fan were found displaced in disc slots. The blades were bent in a direction opposite to the direction of rotation. Booster stage of the compressor was attached to the fan shaft. Approximately 40% of the booster stages (1, 2 and 3) rotors and stator blades were intact. Visible booster stage rotor blades appeared to be bent in a direction opposite to rotation. The broken end of LP shaft was showing evidence of torsion failure.

LPT 5th stage rotors were found intact and there was evidence of shroud tip damage.

(b) Internal Boroscopic Observations:

Boroscopic inspection was carried out from the accessible boroscopic ports with the engine on ground in as is condition. The engine could not be rotated. During the inspection, damage was observed on the visible blades of 3rd stage HPC. Some IGCs (inlet to HPC) were also found bent. Damage was also observed on 3rd stage stator vanes leading edges. All visible 4th stage blades were found damaged and torn at leading edges. The blades bent in the circumferential direction, opposite to direction of rotation. 4th stage stator vanes were found damaged at leading edges.

Metal splattering was observed on the 1st stage HPT blades visible as well as second stage NGVs. Slight splattering (Metal) was observed on 2nd stage, HPT blades on convex sides. Slight splattering was also observed on leading edges of the 1st stage LPT blades.

Condition of visible fuel nozles were found satisfactory. Slight metal splattering was observed on the outer casing of combustion chamber. Condition of 1st stage visible NGV was found to be satisfactory.

2. Observation on variable stator vanes (VSV), Booster stage Bleed Valve (BSBV) and Active clearance Control System (ACC):

Variable stator vanes synchro ring runners links were found positioned approximately 10-15 degree from engine centre line. Active clearance control manifolds were found crushed. ACC actuator was partially intact and one of the butterfly valves was found in closed position. Booster stage bleed actuator was intact and slave actuator was showing impact damage.

B. Starboard Engine:

1. Structural Observations:

(a) External:

The Engine disintegrated into 3 major portions of Fan case, LP fan with booster stage and the remaining engine. The fan case was found ruptured around 6'O clock position. The left side of the module was exhibiting evidence of burning. Oil tank was also found ruptured. EEC unit was found intact except some minor damages. Two fan blades were found in disc slots and were found bent in a direction opposite to the direction of rotation. Approximately 40 to 50% of the rotors and stators of booster stages (1, 2 and 3) were found dislodged from their positions. The visible rotor blades of 1, 2 and 3 stages of the booster were found bent in a direction opposite to direction of rotation.

The broken end of the LP shaf was showing evidence of torsion failure. 5th stage LP turbine blades were intact and there was evidence of shroud tip damage.

(b) Internal (Boroscopic Observations):

Metal splattering was observed on the convex side T.E. of the 1st stage HP turbine blades. No damage was observed on 2nd stage HPT. Metal splattering was observed on the visible blades of the 1st stage LPT. Abrasions were also observed on the 1st stage LPT vane. Visible fuel nozzles were found to be satisfactory. Metal splattering was observed on the combustion chamber liners at 9 O'clock position, abrasion was observed on the visible 1st stage HP turbine vanes. At 10 O'clock position condition of visible fuel nozzles were found to be satisfactory. Slight metal splattering was observed on the combustion chamber liners. During visual inspection of HP compressor inlet, IGV were found detached from 10 O'clock to 4 O' clock position. Visible blades of 3rd stage were found broken from the platform. Third stage stator vanes were found damaged and blades were found dislodged at certain locations. 4th stage blades were found damaged and broken at tips. L.E.'s of the broken blades appeared bent in the circumferential direction opposite to the direction of rotation. 4th stage stator vanes L.E.'s and T.E.'s were also found damaged. 5th stage visible blades also exhibited damage.

Observation on variable vane (VSV) and Active Clearance Control (ACC):

VSV Synchro runners were found positioned 10 to 15 degree from engine centre line (similar to No.1 Engine). Bell crank of VSV was found slightly damaged and was in position.

ACC actuator was found displaced and damaged and the operating levers were found bent. ACC butterfly HP valve was found closed and LP valve was found opened.

C. Final Observations:

General pattern of damages to the compressor and turbine blades and other parts of both the engine as described above, are as a result of impact damage and as a result of disintegration of engines.

Torsion failure of LP shafts of both engines and bending of LP fan blades and compressor blades in the direction opposite to the direction of rotation indicate that both engines were devoloping power during the time of impact and the position of variable stator vanes on the engines are indicative of high power setting.

2.18.6 BENCH CHECK AND STRIP INVESTIGATION:

a) Elevator servo control actuators part No.31075-205 S/N 332, 362, 364 and 367.

The above servo control actuators were bench checked at the Maker's facilit (Lucas Air Equipment, Paris) as per Maker's specification and the test results were found within limits as specified and compared with the previous values recorded on each acceptance test report and found satisfactory. Eye end of actuator S/N 362 was found bent.

b) Flight Control Unit Part No.K217 AAM 7AB S/N.183:

The unit was examined at the Maker's facility (Sextant Avionique, Paris) and found exposed to intensive fire and impact damage. Altitude and vertical speed knobs were found jammed. 100'/1000' altitude selector was found in 100' position. Internally all cards and components suffered extensive fire damage. The Unit could not be tested due to impact and fire damage.

c) Centralised fault display interface unit (CFDIU) Part No.B401ACM0/303/S/N.149:

The computer was tested at the Maker's facility (Sextant Avionique, Paris) and found damaged due to impact. Reading of the memory from all display pages was done concerning last leg report, last leg ECAM report and previous leg reports. Since the printouts were bad, it was installed on AIRINTER aircraft F-GGEB on 18.6.90 around 22.20 hrs.GMT and clear print-outs were taken for last leg report dated 14.2.90 at 06:11 hrs GMT and last leg ECAM report upto

07:33 hrs.GMT on 14.2.90. In addition, printout for maintenance post flight report was also taken. Significant reading was noticed at 07:29 hrs.GMT on 14.2.90 on ECAM warnings reading "ENGINE 1 and 2 FADEC".

d) Electronic Engine Controls Part No.798300-8-027 S/N 2500-0126 and 2500-0157.

The functional test carried out on the two EEC at the Maker's facility (Hamilton Standard, Connecticut, USA) revealed:-

i) The Units were partially damaged due to impact.

ii) Channel B of S/N 2500-0157 passed production acceptance test which could be conducted on a single channel.

iii) Channel A processors of S/N 0157 and 0126 passed board level production test.

iv) E E P R O M data from S/N 0126 channel B and S/N 0157 channel were not valid.

v) Channel A of S/N 0126 and Channel B of 0157 had valid data. These two channels were in control of the engines at the beginning of February 14, 1990 and fault data did not indicate that a control channel switch over occurred during flight IC-605.

vi) The only fault stored in E E P R O M was D I S C F L (Instinctive Disconnect latched). The fault occurred at 07:29 hrs.GMT and was recorded in both EEC. DISCFL was a known recurring nuisance fault and this code/message has no operational effect on the engine or aircraft. This nuisance fault has now been eliminated by EEC specification changes in future software version.

e) FMGC part No.B 398 BCM102, Serial No.702:

The computor was tested at the Maker's facility (Sextant Avionique, Paris) and found front face damaged by impact. The board No.A54 and A71 containing FG bite information were removed. For extracting bite information bite components were further removed and mounted on new boards. These boards were then put in the serviceable FMGC and bite memories extracted. Printout of memory extracted for both command and monitor boards were taken. The details were in a coded form. The same were decoded by Airbus Industrie. Memory in cards of Flight Management

Portion could not be extracted. But the latest information recorded was at 04:57 hrs. GMT i.e. 10:27 hrs. IST on 14.2.90 which was before take off from Bombay on IC-605.

f) <u>Strip investigation of IAE V-2500 engine S/N V0021 (LH) and V0040 (RH)</u>:

Both engines were strip investigated at HAL, Bangalore facility by Maker's representative along with Indian Airlines and DGCA representatives. The detailed report is appended to this report separately. The salient features of the strip Investigation were as follows:

1. The engine break-up, due to ground impact of both engines were similar. But the No. 2 engine H.P.C. was found to have sustained more damage.
2. No pre-impact foreign debris was found in the engines (birds, trees, etc.).
3. Both engines had extensive (D.O.D.) detached object damage in the airstream due to detached hard body objects passing through the airstream while the engine was rotating.
4. Both engines had a substantial quantity of dirt ingestion. Also magnetic and

non-magnetic metal particles were found in the diffuser and high pressure turbine.

5. In the No.2 engine these pieces were fairly large and appear to be compressor blade and vane remains.

6. There was no evidence of any pre-impact onboard fire (other than normal combustion of fuel in the combustion chamber).

7. Both engines did not show any evidence of any pre-impact distress.

8. The break-up characteristics of both engines indicated high rotational speed under power at the time of impact. Some of the significant break-up characteristics were:

   i) Fan blade breakage at the blade root and bending of the blades opposite to the direction of rotor rotation.

   ii) Blade breakage and bending of the blades opposite to the direction of rotor rotation at various locations through the engine.

   iii) The L.P.C. stub shaft was twisted and separated due to torsion.

   iv) Substantial HPC blade and vane tip rub with HPC knife edge seal grooving into the seal lands.

   v) Metalization (Metal splatter) in

the combustor H.P.T. and L.P.T. blades.

g) Sub-Soil test at site:

The Court requested Geotechnical consultant M/s.Nagadi Consultant (P) Ltd., to carryout the work of Sub-soil testing near the first and second touch down points in order to obtain sufficient data regarding sub-strata conditions at site. The report No.B-1508, dated 15.5.90 revealed that:

i) The sub-soil at landing point 1 is predominently sandy whereas at the location of landing No.2 the sub-soil is clayey.

ii) The relative density/stiffness (hardness) of the sub-soil especially close to the ground level point No.1 is greater than that at Point No.2. This is confirmed both in the borewell investigation as well as from the results of the dynamic cone penetration tests.

N-Value at a depth of 0.30M at Point No.1 was 44 against 17 at Point No.2 and a depth of 2.25M was 53 at Point No.1 against 24 at Point No.2.

h) <u>Fuel sample test</u>:

Fuel sample collected from the accident aircraft was subjected to full specification test at approved Indian Oil Laboratory and found to meet the full specification.

i) <u>Engine acceleration/decelaration test as per Maintenance Manual</u>:

To know whether the engine acceleration/deceleration rates meet the requirements stipulated in the maintenance manual one time fleet-wise inspection was carried out on 26 engines fitted to 13 A-320 aircraft. The test was primarily based on ground test No.13. Pre-tested replacement engine test (Ref. TASK 71-00-00-700-011).

Actual engine acceleration time intervals of the engines tested varied from 4.56 to 8.35 seconds against maximum limit of 8.5 seconds. Actual engine deceleration time intervals varied from 3.8 to 5.0 seconds against maximum limit of 6.0 seconds.

All the engines have been found to satisfy the acceleration/ deceleration requirements of Maintenance Manual.

PART III

Re: INVESTIGATION

A. QUESTION OF LAW

1. The Court of Investigation is appointed under Rule 75 of the Aircraft Rules, 1937. The Rule states that where it appears to the Central Government that it is expedient to hold a "formal investigation", this investigation may be ordered irrespective of any other investigation or inquiry under Rule 71 or 74. The person appointed to hold the investigation is referred as the Court. The Central Government may also appoint one or more persons possessing legal, aeronautical, engineering or other special knowledge to act as Assessors. The Court shall hold the investigation in open Court in such manner and under such conditions as the Court may think most effectual for ascertaining the causes and circumstances of the accident and for enabling the Court to make the report stated in Rule 75. The Court shall have all the powers of a Civil Court for the purpose of the investigation. The Assessors are given the same powers of entry and inspection as the Court. As per sub-rule (7) of Rule 75 the Assessors shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and

they are to be forwarded to the Central Government with the Report.

2. The question is to what extent the Court can rely on a material which has not been brought in as evidence, formally. In the course of an investigation of this nature, the Court will have to seek clarifications apart from getting technical matters analysed. Similarly, the Assessors also may clarify their doubts and for this purpose, they may have to get technical matters analysed scientifically.

3. Under Rule 75, the investigation is referred as a formal investigation. This indicates the restrictive nature of the investigation in the matter of procedure. It is restrictive because the formalities of the Court are to be respected. No material can be considered as a piece of evidence without being properly proved and no disputed statement could be relied upon without the participants having an opportunity to explain the same, though there is no litigation amongst the participants and as such there is no 'lis' and the Court is concerned with finding out the real cause of the crash.

4. Sub-rule (2) of Rule 75 directs the Court to hold the investigation <u>in open Court</u>, though the manner and the conditions of the investigation are left to the Court to decide.

5. In the Report in connection with an accident to Air India Boeing 747 - Kanishka, Justice B.N.Kirpal of Delhi High Court realised that the investigation in open Court came in the way of collecting some material evidence and therefore the law was sought to be amended to enable incamera proceedings. Justice Kirpal however observes in para 1.4.3 of his report that the role of the Court under Rule 75 is essentially that of an investigator. In the report of Justice P.B.Sawant, Re: accident to Air India Boeing on 22nd June, 1982 I find some observations on this question in Part IV of the Report. Justice Sawant observed:

> "although the strict rules of the law of evidence do not apply to the present inquiry, it is axiomatic that the inquiry should be conducted in conformity with the principles of natural justice, and no material should be used for arriving at a conclusion against any person which he had no opportunity to meet."

At page 56 the learned Judge had to consider the complaint of a few participants that some correspondence was not given to them. In that connection it was observed:

"In any inquiry of this nature, the Court and the Assessors may have initially their own notions, ideas, doubts and views on matters having a bearing on the accident. Such views are purely personal to them and are not even meant for the audition of others. They are their inarticulate premises and no more than a loud thinking on their part. In order to satisfy themselves as to whether the views and notions, which they have, are right or wrong, they may collect the required information by various means including by addressing hypothetical querries to the concerned sources. The Court and each of the Assessors may further have different ideas and different lines of thinking originally and the information sought by them may even run in opposite directions. It is only after getting the required information that their views will be clarified. They may then elect to pursue some and abandon others. No one has a right to know what were their initial thoughts, views or notions or for what purpose a particular information was sought by them. The theoretical or factual information they may collect is only for their self-instruction and education. <u>It is only if they decide to pursue a particular line of inquiry and for that purpose use the information so collected, that such information will have to be placed before the parties and not otherwise.</u> So long as such information is not used in the inquiry, nobody has a right to ask for it and it need not be disclosed. To ask for such information is to try to probe the mind of the Court and of the Assessors by attempting to find out their initial reactions and the line or lines on which they were originally thinking. This is not only purposeless, but positively harmful to the spirit of enquiry. The Court and the Assessors may have initially views and notions which may be faulty or even fanciful. If, therefore, every information that is sought and collected by them is to be a matter of scrutiny by others, the spirit of enquiry itself will be thwarted. This is apart from the fact that every individual has a right to privacy which includes a right to keep his thoughts to himself."

6. Any material gathered by the Court or the Assessors, which is to be the basis for a finding on the main issue, should be tested for its correctness and acceptability; this is possible only if the participants have an opportunity to examine the said material. Basis for the conclusion is different from the conclusion itself. The basis has to come out in the proceedings in the open Court; it is only such a formality in the procedure that could save the Court from committing an error by relying on legally untested material. I am of the view that reliance on any rebuttable information without the same being placed in open Court, will be negation of the idea of an open Court investigation.

B. ASSESSORS

7. Rule 75 of the Aircraft Rules provides for the appointment of the Assessors; but their functions are not defined. Assessors are to be drawn from those who possess legal, aeronautical, engineering or other special knowledge. Rule says that they have to 'act' as Assessors. The Assessors shall have the "same powers of entry and inspection" as the Court. In other respects, they are not given any other power of the Court. As per sub-rule (7), the Assessors are given the liberty to dissent from the report and in such a case, their reasons for the dissent or any reservations shall be forwarded to the Central Government with the Report.

The functions of the Assessors will have to be understood from the purpose for which they are appointed and the qualifications required for their appointment. It is obvious that they have to bring in their specialised knowledge, in certain subjects, so that they can assist the Court in appreciating the technical questions. The Assessors are not an integral part of the Court of Inquiry. They are given the power to investigate in view of the powers of entry and inspection, obviously to enable them to understand the subject involved and to probe into the questions that are to be answered by the Court in which their assistance will be required. The Dictionary meaning of the word 'assessor' is "to sit beside, assist in the office of a Judge; an official to assist a Judge is called an assessor" - (vide Webstor's New Collegiate Dictionary). This aspect was considered by Justice F.B. Sawant in his report made in connection with the accident to Air India Boeing 707-437 Aircraft VT-DJJ. At p.57 of the said report, the learned Judge pointed out:

> "The purpose of the appointment of the Assessors, further, is to bring to bear on the proceedings their special knowledge, either legal, aeronautical, engineering, or from any other field helpful to the investigation. The role of the Assessors is, therefore, completely distinct from that of the jurors in a criminal or civil trial. The jurors are drawn from laymen and those with a special knowledge in any field which has a direct or indirect bearing on the issues' involved in the trial are discouraged. The purpose of the appointment of jurors is to temper the strict letter of the law by a more enlarged and liberal view according

to the morality and the equity of the case. The jurors are not supposed to discuss the evidence and merits of the case before the Court. Their discussions are to be among themselves and independent of the Presiding Judge. The jurors further are not required to give reasons for their verdict and the Court is bound by their verdict even if it is erroneous. The Assessors on the other hand are required to assist the court mainly on technical matters and to help bring on record and appreciate the technical evidence. The court and the Assessors are required to discuss the evidence together and given reasons for the views they take and the conclusions they arrive at. The Court is not bound by the views of the Assessors and the Assessor or Assessors taking a different view has to give his dissenting report. Since the role of an Assessor is to appreciate the technical evidence it is not necessary for him to watch the demeanour of the witnesses (unlike the jurors) to decide upon the veracity of their testimony. An Assessor may help the court bring the necessary evidence on record either by instructing the court in advance about the questions to be asked to the relevant witness or by forwarding the questions to the court by post. It is not necessary for him to remain present in the court for the purpose or even ask the question himself; even if present in Court. When evidence on a subject of which he does not possess experience is in progress, he may choose to remain absent if he thinks he will not be of any help to the Court. If an Assessor feels that some material which is useful has not come before the Court because of his absence, the witness can be recalled at any time at his instance. There are various modes in which the Assessors may assist the Court and discharge their function. There is no particular manner laid down anywhere for discharing their role."

In the course of the proceedings, I have enabled the Assessors to put questions to the witnesses and seek information whatever they thought as necessary, having regard to the above principles. Many of the questions were of high technical nature. Many questions had to be further developed for clarifications of the answers and therefore, I thought, instead of asking the Assessors to give me the questions in advance, time of the Court will be saved by permitting the Assessors themselves to question the witnesses.

The Assessors have visited the training centre at Aeroformation, Toulouse wherein pilots were trained. Similarly, the manufacturing centre of Airbus Industrie is also situated at Toulouse. Certain test flight was conducted by the Assessors. They had also visited NASA and Hartford, U.S.A.

C. PATTERN OF THE REPORT

8. On many questions there has been no unanimity amongst the Assessors. Since I have to consider those questions and arrive at my conclusions and as the two sets of views of the Assessors reflected the two rival cases projected by the participants, in the course of the proceedings, I have given their reasons elaborately in Part IV of this Report, before stating my conclusions. The main differences were in respect of the following questions:

(1) Whether the pilots followed the VOR-DME approach or adopted visual approach for landing and if visual approach was adopted, was there an omission to put off the flight directors (F.Ds), in time?

(2) The 0.133 'G' force (acceleration) recorded in DFDR pertains to which of the two impacts - the first or the second impact? or whether it was an erroneous recording by the DFDR.

(3) Whether the co-relation of CVR-DFDR timings furnished by CASB

requires modification as suggested by Capt. Rao and Capt. Gopal?

(4) What caused the idle/open descent mode of the plane at about T.F. 295 seconds and why the plane continued to be in the idle open/descent mode thereafter?

(5) Whether the FD 2 was switched off or not at about T.F. 313?

(6) Whether the pilots monitored the speed or not during the last phase of the landing and whether any display system in the cockpit misguided them by mal-functioning?

(7) Were thrust levers pushed in time or if there was delay in doing so, was there any reason for it?

9. The rival reasonings in support of parti-cular answers to those questions and my views are given in Part IV of this Report.

There were other questions to be considered and they are dealt in Parts V to VII.

10. The main contest, in the Court proceedings, was between the Airbus Industrie and the ICPA. - the former as the manufacturer of the aircraft, blamed the pilots for the crash. ICPA (which is

a representative body of the pilots) tried to establish that the systems in the aircraft caused the crash by their misbehaviour and that the pilots must have acted properly.

Indian Airlines has not projected any particular case, though its learned Counsel was highly critical of the role played by Airbus Industrie and the latter's attitude in trying to cut short the Court proceedings, in some aspects Indian Airlines supported the case of the ICPA. Aero Engines was interested only in its engines. No particular view point was projected by other participants. There is no lis in the investigation between the participants; therefore no participant need to have a particular case established. But, to enable the Court to find out the cause of the crash, different probable causes are to be projected so that no line of investigation would be left out. It is not enough for any participants to propound a theory; the participant should develop it and try to establish it. Open Court enquiry envisages evidence being gathered and tested in the manner of any other adversary litigation. The questions formulated by me above, do not create any burden of proof, on any one of the participants; they are the questions to identify the problems to be solved by the Court, generally. They are formulated for the sake of convenience at the time of writing this Report.

No point for consideration nor any issue was framed by the Court prior to the commencement of the proceedings since the object of the enquiry is to find out the cause of the crash. Each of the questions, like many other questions, arose in the course of the investigation and the Court's answer was invited to each of them, as relevant or leading to the cause/causes of the crash.

11. Several questions were technical in nature. A few, I have left open, having regard to the two sets of views supported by strong reasons for each of them; I felt it unnecessary to go into those questions such as the timing of 6.125'G' force and the co-relation between CVR-DFDR. I am of the view, the unanswered questions do not affect the ultimate conclusion arrived at by me on the basic question to be answered in this investigation.

PART-IV . ANALYSIS

CHAPTER-1

Descent and Approach

1. The aircraft VT-EPN operating flight IC-605 (Bombay-Bangalore) took off from Bombay at 11:58 hrs.(IST) on 14.2.1990. The aircraft contacted Bangalore approach control at 12:36 hrs.and informed its flight level 330 (33,000 ft.) and that it was estimating to reach Bangalore at 13:04 hrs. Bangalore approach control then passed on the prevailing weather information and informed that Runway 09 was in use. At 12:44 hrs. the aircraft requested for a descent and was cleared to Flight Level 100 (10,000 ft.). From 12:50:26 hrs. the pilots discussed between them about VOR-DME approach to Runway 09. At 12:53:39 the aircraft was identified by Bangalore Radar Control (ARSR - AIR ROUTE SURVEILLANCE RADAR with maximum range of 170 nautical miles) at 42 nautical miles on a VOR radial 31[illegible]. At 12:53:45 the aircraft was cleared to descend to 6000 feet on QNH 1017 and informed by Bangalore Radar that the aircraft woul be vectored for a visual approach to Runway 09. At 12:54:09 Capt.Gopujkar confirmed receiving the Radar instructions. At 12:57:16 Bang lore Radar control instructed IC-605 to turn to right on heading 150. At 12:57:22 the aircraft acknowledged and followed the instruction. At 12:57:37 approach check list started and completed at 12:58:10.

2. At 12:59:24 approach target speed 132 kts. indicated by the magenta triangle on the speed scale was confirmed by both the pilots and then flap was selected to No.1 position. At 12:59:48 the aircraft was cleared by Radar Control to descend to 4600 feet when it was 10 track miles to run to touch down. At 13:00:19 flap was selected to No.2 position and at 13:00:22 landing gears were extended. At 13:00:35 Radar Control informed the aircraft position at 7 miles west on left base leg for Runway 09 and asked IC-605 to report Runway in sight. At 13:00:38 the flap was selected to No.3 position. At 13:00:42 the aircraft reported Runway in sight. At the same time the Auto Pilots were disconnected as indicated by cricket sound 3 times in CVR. At 13:00:48 Radar Control asked IC-605 to resume its own navigation and switch over to control Tower frequency 123.5. At the same time flap was selected to No.4 position. At 13:00:51 the aircraft changed over to Bangalore Tower for further instruction. At 13:01:20 CM1 asked if landing checks were completed but CM2 wanted to complete the check at 1400 feet A.G.L. (above ground level). At 13:01:36 (DFDR second 228) CM2 announced alt.star and repeated that announcement at 13:01:40 (DFDR second 232). This speed alt.star indicated altitude acquisition mode for 4600 feet which was selected earlier. This time CM2 wanted to set go around

altitude but CM2 suggested vertical speed selection which CM1 finally agreed to. Had go around altitude of 6000 feet been selected the aircraft would have gone into open climb which was not desired at this juncture. Scrutiny of the DFDR data revealed that at DFDR second 225 the aircraft was in altitude capture mode when it was descending to 4600 feet and when alt.star phase was active the aircraft went into idle open descend at DFDR second 235 obviously due to a selection of lower altitude than 4600 feet. However, at DFDR second 247 the idle open descend mode was changed to speed mode again by selection of 1000 feet/min. rate of descent on FCU by CM2.

3. At DFDR second 260 CM2 asked tower for landing clearance when CM1 asked to set go around altitude again. At DFDR second 265, CM2 reported to be at "short final" which was acknowledged by the tower and landing clearance was given. CM2 seems to have not acted as requested by CM1 to set go around altitude. At 13:02:23 (DFDR second 275) landing checks were completed. Capt. Thergaonkar in his deposition stated that at this time (T.F.260) go around should have been set.

It was contended that this was a deviation from "Normal Procedure" under "Final Approach" check list detailed in FCOM Vol.3 Chapter 3.03.15 page 2 which states that

"(PNF) GO AROUND Altitude.......set.
Set go around altitude on FCU".

This is required to be done before completion of landing checklist. However this deviation was not a major error and did not contribute in any way to the accident.

From co-relation of CVR & DFDR data it is evident that at DFDR second 225 altitude acqui-sition mode for 4600 feet was activated. The chart showing the approach path indicated that it was about 600 feet higher than the normal path when altitude acquisition mode was acti-vated. Normally 700 ft./min. rate of descent is required to maintain the final approach path but in this case the aircraft was higher and CM1 asked for 1000 ft./min. rate of descent. Accordingly, vertical speed mode was selected with 1000 ft./min. rate. Actual rate of descent was, however, around 2000 ft./min. initially and then reducing gradually to about 1300 ft./ min. Due to higher rate of descent the aircraft speed increased to about 148 kt. whereas approach target speed of 132 kt. was required to be main-tained. However, when landing clearance was given, the aircraft was almost in the proper approach path but its speed was about 9 knots higher than the required speed.

4. Therefore, it can be said that the aircraft, more or less, descended properly and its initial approach profile, even though slightly higher, can be said to be normal. The aircraft was fairly in approach profile when it was 1000 feet AGL and obtained landing clearance. The aircraft was also in proper landing configuration. There was no controversy on this question.

5. At this stage, two conflicting views have been expressed. According to one view, the pilots though initially discussed about VOR-DME approach, later accepted the Radar's offer to be vectored for visual approach to Runway 09, and from 42 nautical miles to 7 nautical miles, Plane was guided by Radar and thereafter pilots adopted visual approach. This view is accepted by Sri Goswami, one of the Assessors and is given at Section 'A'.

6. The other view is that the approach adopted by the pilots was perfectly normal and even if it was visual approach other aids available can be availed of by the pilots. This view found favour with M/s. Capt. C. R. S. Rao and Capt. Gopal, is elaborated in Section 'B', below.

A. ONE VIEW:

A(1): Capt.Gordon Corps of Airbus Industrie in reply to questions by ICPA Counsel, explained in his deposition, "It is our considered opinion that having read the CVR transcript and heard the CVR many times in conjunction with the published procedure for a non-precision approach that, whilst as in normal practice the appropriate radio aids were tuned the actual flight path of the aeroplane was such that a non-precision approach as laid in the Jeppessen Manual was not actually being followed".

A(2): Perusal of the CVR transcript reveals that from 12:50:26 hrs.the pilots discussed between themselves about VOR-DME approach to Runway 09. But at 12:53:45 hrs.they were informed by Radar Control that the aircraft would be vectored for visual approach to Runway 09. At 12:54:09 hrs. Capt.Gopujkar confirmed receiving the Radar Control instruction and accepted visual approach to Runway 09. In this connection it is stated in para 10.1.4 page 2-11 of ICAO Dc.4444/RAC 501/12 "Rules of the Air and Air Traffic Servies" (12th edition, 1985) "If an air Traffic clearance is not suitable to the pilot in command of an aircraft he may request and if practicable, obtain an amended clearance". Having accepted Radar Control instruction for a visual approach at 12:54:09 hrs. Capt.Gopujkar never asked for an amended clearance for VOR-DME approach instead of being vectored by Radar to follow visual approach as offered by Radar Control. From the CVR it is apparent that after being spotted by Radar at 42 nautical miles at 12:53:39 hrs. the aircraft was under constant surveillance of Radar Control which was giving necessary guidance and instruction to the aircraft from time to time upto 7 miles west on the left base leg for Runway 09.

A(3): Further, it has been observed in the Jeppessen Manual that the chart dated 25.8.89 dealing with VOR-DME approach to Bangalore Runway 09 requires a minimum sector altitude of 6000 feet. Initial approach altitude is 6000 feet, initial approach fix is 13 DME and inbound of the approach is 089°. In other words from radial 316° the aircraft has to come upto 13 DME arc. At 13 DME the aircraft has to turn right to maintain

11 DME arc and 6000 feet to descend to 4500 feet. On crossing lead radial of 279° the aircraft has to turn left to intercept inbound 089° radial. 4500 feet altitude should be left at final approach fix of 7 DME and descend to MDA of 3270 feet. Missed approach will be at 2 DME as per procedure. If, only VOR is available the aircraft has to come over VOR at 6000 feet and then follow 269° radial outbound to 4500 feet and turn right at 7 DME to meet radial 089° inbound and then follow the procedure as stated above.

A(4): In this case the aircraft was vectored by Radar Control from 42 nautical miles to 7 miles and then the runway was in sight the aircraft was asked to resume its own navigation i.e., visual approach as already instructed by Radar. In this connection it is to be noted that as per Schedule IV of Aircraft Rules 1937 Section 3, para 3.5.1.1, "An aircraft shall be operated in compliance with air traffic control clearance received". "Operation Manual" Compiled by Indian Airlines under CAR Series 'O' Part I Issue I dated 31.12.1976 para 4 is a mandatory document to be carried on board for the guidance of the flight crew. It also stipulates in Chapter-I page 1.20 para 1.3.4.2 item 2 "ensure that the flight is carried out in accordance with the ATC clearance".

A(5): Thus, from 42 nautical miles to 7 miles the aircraft was under Radar Control and since then on visual approach. Therefore, the aircraft did not follow VOR-DME approach at all, although VOR radials were used during flight which is normally done.

A(6): Para 3.7. 3.3.1 in page 3.19 of Chapter III of the same Manual states in respect of stabilised approach:

> "The approach is said to be stabilised when the aircraft is flown at constant rate of descent, at correct speed and altitude in approach configuration and only minor power and heading adjustments, are needed. All approaches, irrespective of the weather conditions should be stabilised well before crossing the Runway threshold".

A(7): Normally an approach should be stabilised in landing configuration by a safe altitude above touch down. At this safe altitude if the aircraft is not on the correct glide path or approach profile in landing configuration with speed stabilised, then the approach must be aborted. The idea behind such a requirement is self evident. The inertia and forces acting on large commercial jet aircraft are such that alterations to approach profile and speed cannot be made at a late stage in the approach.

A(8): It is evident in the case of VT-EPN the aircraft did not stabilise at any stage during approach.

B: ANOTHER VIEW:

B(1): A jet transport aircraft is an aircraft which can become extremely critical within a few seconds during the vital phases of flight of take off and landing in case they are not handled correctly. This is due to various reasons.

(a) The heavy weight of the aircraft.

(b) Characteristics of a jet engine which takes quite a few seconds before the engine develops thrust if the power was at idle prior to acceleration.

(c) The high power to weight ratio due to present day modern technology, etc.

For example, under any particular conditions of flight, in case the engine power is at idle, if thrust lever is moved forward for engine acceleration at a particular speed, the aircraft would lose its speed by approximately 6 to 10 kts depending on the type of aircraft and the type of engines fitted provided the same flight profile is maintained. Similarly if an aircraft is descending with engines at idle maintaining a constant speed and if thrust levers are moved forward for accelerating the engines at a particular height, there would be a certain loss of height before the aircraft would level out and start climbing if the same speed is maintained.

B(2): During final approach, aircraft would be having the undercarriage down and wing flaps and slats extended. The undercarriage contributes to a lot of additional drag. The wing flaps and slats when extended provide a larger wing surface area and smoothen out the air flow over the wings at higher angles of attack. More lift is generated whereby the aircraft at the same weight can be flown at slower speeds when compared to flying without slats and flaps extended. These devices also help in improving the visibility available to the pilot because of the change of the pitch altitude available to the aircraft. The plane can be landed safely at a lower speed. From the A-320 quick reference handbook page 22, we observe that the approach speed, when the slats are lesser than one and flaps are lesser than one would be Vref+50 but for the aircraft at the same weight with flaps and slats at full position, the approach speed would be Vref. Extended flaps and slats increase the drag considerably and as a result reducing the margin of power available in case of encountering a difficult situation.

B(3): On final approach, when aircraft is descending even on the normal approach profile, for example, with a speed of about 20 kts above Vapp and the thrust is at idle for purposes of reducing speed, it would be necessary for the pilot to anticipate and increase thrust about 6 to 10 kts before target speed if he wishes to prevent the speed drop below Vapp, all the while continuing to maintain the normal approach profile.

B(4): If a pilot is high on approach and is at the correct approach speed, if he wishes to regain the normal approach path by increasing the rate of descent holding the thrust at idle, he should anticipate in advance of intercepting the desired profile by increasing thrust to prevent going below the approach profile, and losing speed below Vapp.

B(5): The range of height loss and the range of speed loss would vary with the weight of the aircraft, the engine characteristics and the flight environment prevailing.

B(6): Pilots fly into various airfields. The R/W's may be level, may have an upslope or may have a downslope. Normally the desired approach profile would be close to 3° to the horizontal. On the same approach slope, if the R/W has a downslope in the approach direction, the pilot would feel that he is on a lower approach slope. If there is a gradual sloping ground below towards the R/W it can cause severe problems to the aircraft, if for any reason a slightly lower approach profile is followed. An aircraft has crashed on approach to a south easterly R/W in Cairo due to such downslope of R/W and high gradually sloping ground below. If there is an upslope on the R/W in the direction of approach and landing like it was at Bangalore R/W 09, the pilot on approach would feel that he is high even if he is on the correct approach profile. This is due to the approach perspective he is used to, at a majority of airfields which are level. There could be a tendency for a pilot to come a little lower.

B(7): Considering all these above factors, pilot instructors have always trained jet transport pilots to use all aids available at the time of an approach to ensure safe approach and landing even whilst carrying out a visual approach. Normally there are various radio aids like NDB (Non Directional Beacon), Marker Beacons, VOR (VHF Omni Range), DME (Distance Measuring Equipment), ILS (Instrument Landing System), etc., To assist during the visual segment of any approach, we have VASI, PAPI, etc., which gives, by means of certain type of lighting on either side of the R/W or on one side of the R/W, a safe approach angle to the touchdown zone. Though at night VASI would be visible for a longer distance in good weather, during day light and sunshine the distance to differentiate the colours for interpreting a proper approach path would be very short. From personal experience of the two assessors, Capt.C.R.S.Rao and Capt.B.S.Gopal who have been on board the aircraft during approach to Bangalore on both, R/W 09 and 27 at times close to mid afternoon in bright sunlight, it was observed that VASI could be used meaningfully for an approach from 300/400 feet.

B(8): If an NDB is located at 1.7 nautical miles like "BB" at Bombay in line with R/W 14 at Bombay (which has a downslope) and a pilot even if on visual approach, crosses this NDB at 500 feet above threshold elevation, he would achieve a safe approach and landing by maintaining a correct descent rate and speed to the touchdown zone. Similarly if knowing the location of the DME transmitter of the airfield that is being utilised, if correct heights are maintained at appropriate distances from the R/W threshold, the pilot would have at all times an idea of how the aircraft is placed, whether high or low compared to the normal desired profile. For example, if a pilot is at 900 feet at 3 nautical miles from touchdown zone, he is on a good approach path. If higher or lower, corrections may be needed. Normally a safe approach always results in a safe landing.

B(9): All approach procedures are designed to cater for bad weather and low clouds over the airfield or low visibility. They also cater to different types of aircraft having different types of navigation equipment. It also caters to separation requirements between aircrafts, delay to aircraft where holding is required for any reason, failure of some navigational aids or ATC facilities available at the airport and communication failure between aircraft and ATC. Considering the VOR DME approach for R/W 09 at Bangalore, if ATC radar is not operative, an aircraft could join at any Initial Approach Fix (IAF) and come onto final using the VOR and DME. If DME is also unserviceable and only VOR is available and it is not possible for the aircraft to absolutely locate its position with respect to the airfield it would become necessary for the aircraft to come overhead the VOR and carry out the prescribed procedure of the VOR approach for R/W 09 by using elapsed time during the outbound leg. This is the reason why the same chart indicates VOR approach for R/W 09 also.

B(10): Normally all schedule operators file an IFR (Instrument Flight Rules) flight plan. The flight is conducted according to instrument flight rules. ATC would be responsible for ATC separation till the time the aircraft lands or cancels

IFR flight plan at an earlier stage. ATC radar knows the location of the aircraft with respect to the airfield at all times once the aircraft has been identified on the radar screen. Thus they would be able to guide any aircraft, both in good weather and in bad weather to a position from which the pilot can take over for continuing the approach, either by use of the radio aids serving that R/W or if conditions permit, a visual approach. Once a pilot sights the R/W and is willing to take over for a visual approach, the responsibility of the ATC radar to position the aircraft for a safe continuation of approach, ceases. If the radar is handling other aircrafts such a change over would assist the radar controller in reducing his workload.

B(11): Capt. Thergaonkar has deposed on page 5 that it is normal to carry out an instrument approach even if the weather conditions are good, when the pilot is under check. For other pilots under good weather conditions visual approach is permitted. For the purpose of route check, the tests are carried out by applying both kind of approaches.

B(12): One of the items to be filled by a check pilot during route checks in the DGCA proforma is "Type of Approach".

B(13): All available radio navigational aids as appropriate should be used even during a visual approach to establish a safe approach path. Even if an aircraft is cleared for a visual approach and an ILS is available for that R/W, it would be prudent on the part of the pilot to use that aid which would give the pilot a far superior flight guidance compared to his own judgment based on the R/W perspective. If anyone feels that it is wrong on the part of the pilots of IC-605 if they had used the VOR and DME and NDB that were available, then their opinion would not be in the interests of flight safety. In Bangalore even for a visual approach, DME would be an excellent aid to check heights at various distances for evaluating the correctness of the approach profile and to receive the DME, VOR should be selected. The final approach segment of the VOR DME approach in no way conflicts with the visual approach or any other aircraft in a visual circuit.

B(14): An ATC clearance is only a clearance. It cannot be mandatory. For example, if an aircraft is cleared to land, it does not mean that an aircraft should land. A pilot will carry out a go around if for any reason he feels that the approach becomes unsafe to continue, or if when he is on short final a vehicle crosses the R/W, etc. The pilot cannot be faulted for not landing during that approach. It is necessary to look at the spirit behind any of these clearances.

B(15): Capt.Fernandez was carrying out his first route check for PIC endorsement. The DGCA requires 10 satisfactory route checks of which at least 5 shall be by night for granting this endorsement. Generally during winter the weather all over India would be good. It is quite possible that on the sectors that A-320 was operating at the time of the crash, for the Bombay based crew, the weather could have been visual for all these 10 route checks. If a pilot is not checked for various types of approaches even under visual conditions and all these 10 route checks carry out visual approaches and landings, it would not be in the interests of flight safety to grant PIC endorsement and release him to fly as Pilot in Command both from the point of view of regulatory authority and the airline. It is necessary to check the competency of the pilot carrying out both visual approaches and instrument approaches prior to certifying him as fit for PIC endorsement. Policy of Indian Airlines as deposed by Capt. Thergaonkar would be very correct in the interests of safety of operation.

B(16): There were arguments regarding the requirements of a visual approach. The flight manual 2.01.00 page 1 permits VFR operations. Flight manual 4.03.00 page 7 permits use of auto thrust with or without AP/FD. During approach the use of FD is approved with use of NAV mode for VOR/DME, VOR, ADF approaches. The above statement is made based on the revision dated 16.3.1989 valid for A-320-231 aircraft which clarifies that use of both auto pilot and FD engaged is approved.

B(17): This.revision would appear to mean that in the three earlier lines under APPROACH the use of auto pilot or FD is approved. Nowhere in the flight manual we can find a prohibition of the use of FD during a visual approach. Use of available radio navigation aids during a visual approach is also not prohibited by the flight manual.

3(18): Airbus Industrie referred to FCOM 3.04.11 page 63B, revision 09, seq.001 under the heading 'Visual Approach with FPV'. They provided a copy of this page to the Court. However they did not provide the copy of the page 63A in respect of the same procedure. There was some confusion in the numbering of the pages of FCOM covering the same procedures between the copies with Airbus Industrie representatives and the copies made available to the court by Indian Airlines immediately after the accident. We would be quoting references from the manuals made available to the Court, which were the status of the Indian Airlines manuals on the date of the accident. On page 63A it is clearly indicated as below:

"The described visual approach is made with FPV only (for usually, there is no FIX to initialize target slope) (Both FD OFF)".

On page 63B for the visual approach with FPV, both FD1 and FD2 are required to be put off at the start of the approach.

This is not relevant to the approach of the VT-EPN at Bangalore.

B(19): FCOM 3.04.19 page 5, revision 03, seq.001, under heading 'Flight Patterns Visual Approach (one or two engines) does not state at any point, the requirement of flight directors to be put off. Similarly FCOM 3.04.19 page 7, revision 03, seq.001, for standard circuit pattern does not indicate the requirement of putting the FDs off at any time. FCOM 3.04.19 page 9, revision 03, seq.001, for low visibility circling approach does not indicate any requirement for the FDs to be put off. Any of these approaches would have the visual segment of final approach which VT-EPN had. Except for a visual approach with FPV as mentioned earlier, nowhere in the FCOM volume 3 under procedures and techniques have Airbus Industrie mentioned the prohibition of the use of FDs during a visual approach.

B(20): When we look at the full flight simulator profiles of the Aeroformation course (PF CM1 which we expect Capt.Gopujkar and Capt.Fernandez would have carried out), we find the following:

In FFS 1 there is one visual approach ILS supported.

In FFS 2 there is one visual approach ILS supported.

In FFS 3 there is one single engine visual approach raw data (which we again think is raw data ILS as raw data is generally used for ILS approach without FDs) and there is one visual approach and landing on 15R.

In FFS 4 we have one no slats visual approach 15R with FDs.

In FFS 5 and FFS 6 there are no visual approaches.

FFS 7 is a check session wherein there is no visual approach.

From all the above we see that there is only one visual approach without the assistance of any other approach aids indicated in these profiles, (i.e.), in FFS3.

Aeroformation have also carried out in FFS 4, a visual approach with FD (item 7).

The pilot has not been checked out for visual approach capability in his simulator check ride. Also FFS 4 shows that use of FD is permitted during a visual approach.

The above profiles also show that Aeroformation have trained pilots to use available aids such as ILS during visual approaches.

B(21): Capt.K.Shreshta on page 3 of his deposition has stated in connection with a VOR approach, "Only in case we are visual we can switch off the FD bar if we so desire". He is a very young pilot with limited experience and this statement indicates that FD bars can be used even during the visual segment of a VOR approach after the MDA. This would only be based on the training he has received.

B(22): The contention of the Airbus Industrie representatives who deposed before the court that FD bars should be put off for a visual approach cannot be accepted. Secondly, VOR DME usage by the pilots cannot be faulted. All this unnecessary controversy would not have risen if the pilot had just transmitted to the ATC that they would continue on a VOR DME approach after being positioned on final. No air traffic control unit in the world would say NO to such a statement.

B(23): The clarifying submissions on behalf of Airbus Industrie sent to the court vide

AI/DA L.No.115.0740 dated 5.10.1990, has enclosed in appendix C of one of the booklets, a JEPPESSEN approach plate for Bangalore VOR DME R/W 09 & VOR R/W 09 approach. This approach plate is dated 25.8.1989. On page 5 of that booklet under section 5 they have not made any mention of the MDA. It is observed that the MDA indicated in this chart is 3270 feet. Referring to CVR transcript page 8 in Exhibit 1, at crash seconds 730, CM1 has indicated MDA as 3280. Indian Airlines Aerodrome operating minima chart dated 22.12.1989 has given the MDA for VOR DME R/W 09 as 3280 feet. This has been used by the pilots in their discussion. On CVR transcript page 13 at crash seconds 162 Bangalore radar has indicated position of 7 miles west on left base R/W 09 for IC-605. The pink approach path indicated by Airbus Industrie on this JEPPESSEN approach plate has brought the aircraft to a position which is 4 nautical miles on the DME. VOR and the colocated DME are close to the beginning of R/W 27. Length of the R/W is 10,850 feet. At 4 DME the aircraft is just 2.4 nautical miles from the R/W.

B(24): The aircraft commenced a slow left turn from heading 150° from about 188 seconds as that was the time a left bank has been introduced. Aircraft was also having a tailwind component of nearly 14 kts. Aircraft would have had a wide turning radius with a slow increase in bank angle. The maximum bank angle put ih was close to 25° when the aircraft was just angle 15° from the R/W heading, most probably because the pilot felt that he may over shoot the centre line. If an immediate 30° bank angle had been put in at 188 for turning on to final, the aircraft would have been on final very much earlier. R/W was visible. So a pilot using both the VOR DME and his vision of the R/W has carried out a shallow turn which is quite natural. The slow correction can easily be seen from the way the headings have changed from DFDR time frame 225 from fig.1 of the revised data. Considering at ± 15° to R/W heading whilst turning visually on to final as being close to the final approach path, this aircraft would have been on final well before what has been indicated by Airbus Industrie. We should also remember that this aircraft crashed well before the R/W and we must allow for the location of the VOR.

The approach path indicated by Airbus Industrie on this JEPPESEN chart is inaccurate.

B(25): The pilots of VT-EPN were meticulous as they used the latest MDA of the Aerodrome operating minima chart and not the MDA given on the approach plate which was of an earlier date.

B(26): FCOM 3.04.11 page 62, revision 12 and page 63, revision 9 are for a non-precision approach. This does not call for FDs to be switched off. The bottom portion of page 62 and 63 would refer to the use of FD as the FD bars have been shown in the pictorial representation. In this approach which is the usual procedure that should be followed, Airbus Industrie have not indicated any point at which the go around altitude should be set. They have not prohibited selection of MDA on the FCU altitude selector. This FMGS procedure is described from the start of the approach. The only requirements indicated are: Reach final approach fix with configuration full and Vapp.

Passing fix select vertical speed = -1000 feet per minute.

Keep vertical speed down to MDA.

At MDA, if external visual conditions sufficient.... continue visual approach. Though on page 3.03.15, page 2, revision 12, during final approach they have indicated that go around altitude is to be set. If the non-precision approach procedure described earlier in this paragraph is followed, there is no requirement to set go around altitude.

B(27): At DFDR seconds 234 auto pilot altitude capture has gone off and the altitude of the aircraft was about 4600 feet. This was approximately 100 seconds from the touchdown zone. At that time the aircraft would have had approximately 100 to 105 seconds from the touchdown zone and the aircraft would have been approximately 4 to 4.1 nautical miles from the touchdown zone. For a normal approach aircraft should have been around 1200 to 1300 feet above the touchdown zone (TDZ) elevation. The aircraft was slightly high at this point of time but it was in a position to carry out a safe approach for landing. This was evidenced by the aircraft being at the correct height when at 500 feet above TDZ elevation.

B(28): Selection of 1000 ft/minute rate of descent upto the MDA and selection of MDA on the FCU have shown that these pilots were using the VOR DME approach procedure when the aircraft was on final.

B(29): Capt.G.Corps during examination on behalf of the court was asked a few questions about the Bangalore approach charts and the flight patterns in FCOM section 3.04.19. He confirmed that there was no specific chart associated with a visual approach at Bangalore in the charts that were made available to the court by Indian Airlines which are used by their pilots. He also stated this in his answer, "But I believe that it is standard practice to assume the go around altitude published on the chart for the appropriate R/W in case the go around has to be made for whatever reasons". It is only a belief and not a statement of fact. When visual approaches are carried out, an aircraft on a go around will continue on a visual circuit. Even the flight patterns in 3.04.19 for standard circuit visual approach, etc., show a height of 1500 feet above Aerodrome

Elevation as the circuit height. If that is considered the circuit height at Bangalore would work out to 4414 feet to 4500 feet.rounded off to the nearest highe hundred. Even Airbus Industrie's own theory of 6000 feet go around altitude to be set does not conform to a visual approach. It would only refer to a missed approach altitude for either the NDB approach or VOR approach for R/W 09.

B(30): Further, in his deposition, Capt.G.Corps has confirmed that there is no mention of FDs to be put off in the visual patterns on page 5, 6 and 7 in FCOM section 3-04-19. A-320 FCOM bulletin No.2 of April 1989, page 3, permits use of FD during visual approach but auto thrust should be in speed mode. Thus this also shows that there is no prohibition by Airbus Industrie to keep the FDs 'ON' during a visual approach. In that respect the pilots have not erred in keeping the FDs 'ON' even if it is considered that it was a visual approach.

B(31): A-320 FCOM bulletin No.9 dated April 1990 which was later revised by FCOM bulletin No.09/2 June 1990 on page 3 under recommendations item 1 states that

"Selected altitude in the FCU window should never be set below 1500 feet when in VMC".

It must be observed that Airbus Industrie have used the words "SELECTED ALTITUDE IN THE FCU WINDOW." Altitude is always used to refer to height above mean sea level. The Aerodrome Elevation of Bangalore at the ARP is 2914 feet. Altitude of 1500 feet if selected on the FCU window would be well below ground level at Bangalore. Airbus Industrie have not indicated that this 1500 feet in VMC should be above ground level. When this was pointed out to Mr. Guyot they have accepted the error. However this bulletin is current even now as we have not been informed of any cancellation or supplied with a revised bulletin. If we accept the Inspector of Accident's theory on page 55 and 56 and Airbus Industrie's opinion of a selection of a lower altitude to engage Open Descent mode, "was Capt. Gopujkar trained to set 1500 ft. on the FCU Altitude Window, and did he implicitly follow such a procedure". The Court cannot answer this question due to non-availability of FCU selection data on the DFDR.

B(32): Looking at the CVR transcript it is observed that the two pilots have been totally cordial through out the flight. Capt.Gopujkar has taken great pains to explain various aspects of this aircraft's handling to Capt.Fernandez as this was his first route check. All procedures have been followed, all check lists have been carried out. When CM1 asked for go around during Alt Star at DFDR seconds 232 it was not set by CM2 knowing the implications and he guided CM1 to select vertical speed. Landing checks were carried out after passing below 1500 feet as Airbus Industrie have provided the landing check list on the ECAM after passing below that height above ground. Even the call for 700 feet rate of descent by CM1 at DFDR seconds 292.5 was correct as aircraft had come to the correct approach profile. As mentioned earlier the correctness of their procedures has been indicated by not following the MDA on the VOR DME approach chart but using the later revised Indian Airlines' MDA of 3280 feet. They have followed heading instructions and come on to final closer than 7 DME. This is nothing abnormal as even in International airfields like London, Paris, Frankfurt, New York, etc. there are occasions when radar would guide an aircraft on to final closer to the R/W than normal to pick up ILS or final VOR radial, to expedite landing of this aircraft as well as those following.

B(33): Capt.Bhujwala during his cross examination had stated on page 2 that "Capt. Gopujkar adapted himself to the new technology very well and at no time he was critical of the same. Capt.Gopujkar was an instructor in Boeing 737 and a check pilot on A-320. He used to take a lot of pains to teach the trainees. His approach and attitude towards the trainees was quite helpful. The trainees used to be quite comfortable with Capt. Gopujkar".

B(34): It should be noted that this above statement has come from a long term close associate, who joined Indian Airlines in 1969 along with Capt.Gopujkar, trained on HS 748 when Capt.Gopujkar was his batchmate, later when being trained on Boeing 737 Capt.Gopujkar was again his batchmate. Both of them underwent induction course together and in July 1989 when they went to Toulouse for A-320 training they were again batchmates. There can be no doubt that the problems on this flight which led to the crash occurred only in the last few seconds.

COURT'S OPINION

(1) Whatever may be the controversy regarding the technicalities of the approach, whether it is visual or VOR-DME, I find this controversy has no substantial bearing to solve the problem before me which has arisen only after 292 seconds. The crash occurred because something happened between DFDR seconds 293 and 321. In fact all the participants substantially agree that the plane was in proper configuration, at about 294 seconds. It is also clear to me that after 321 DFDR seconds it was impossible for any one to prevent this crash having regard to the plane's situation at or about the time frame 320. The cause for the crash has to be found out in between these crucial seconds (294 to 320 seconds).

(2) The controversy was raised in connection with the switching off, of the FDs. The idea seems to be to show that visual approach was adopted, but in practice not properly followed; failure to switch off the FD is one such failure. The pilot witnesses have deposed before the Court that the plane can be landed safely either by non-precision approach or by visual approach even if FDs are on. If FDs are 'on', either the auto thrust should be disconnected and thrust controlled manually or auto thrust should be in speed mode. If

an emergency is foreseen the pilots can always push the throttles to increase the power of the engines. Even here, engines take 8 seconds to develop acceleration from idle; that is why I opine that it was beyond anybody's capacity to prevent this crash after TF.321.

(3) A strict adherence to the VOR-DME would have kept the plane at the proper altitude; the procedure followed by the pilots in the instant case kept the plane slightly at a higher altitude, which, did not create any problem by itself and had no bearing on the real situation that developed on or after, the TF.294; pilots, obviously followed a mixed up procedure. The plane should have moved along 11 DME arc (an imaginary arc around the Airport, indicating 11 miles to the Airport), till the 269° and then move straight towards the runway direction by crossing 7 DME at 4500 feet altitude. However, the plane moved almost straight and joined the runway direction near 7 DME arc, being vectored by the Radar. The fact remains that, by 292 or 294 seconds, the plane was in a proper situation and there has been no dispute, alteast, on this aspect and that, FDs could have been put off subsequently also if necessary. At 572 crash seconds (7:23:45 hrs.) the ATC had directed the plane to "descend to 6000 feet on QNH 1017 HP turn right on to heading 140 for

vector visual approach R/W.09". CM.2 had replied "Roger" and then repeated the words of ATC. This is a specific word indicating that CM.2 understood the instructions of the ATC. ATC had affirmed this again to which CM.2 had replied "Roger" (see - CVR transcription, for crash seconds 572 to 533).

(4) The two experienced pilot-Assessors have opined that, if the pilots are cleared for visual approach in clear weather conditions and if pilots follow an instrument let down procedure as a back up to the visual approach without deviating from the standard visual approach, the procedure is an acceptable procedure. This is so because in visual approach, the pilot has a greater discretion and may utilise any facility available to assist him in judging his approach path.

Discussion on this question is, therefore, unnecessary to find out the cause of this crash. I find no major deviation in the approach by the pilots.

PART IV

CHAPTER - 2

REGARDING: (1) Touch downs

(2) CVR - DFDR co-relation

DFDR data and the replay of the CVR tape has indicated that this accident was a result of certain events that happened during the last 35 to 37 seconds. On many aspects, such as co-relation of CVR with DFDR timing, the nature of the first touch down, the timing of the recording of 6.125 'G' force and as to the click sound found between the words recorded in CVR - "Hey we are going down", divergent views have been expressed. The two sets of views could be brought out exhaustively in the differing opinions on these questions, amongst the Assessors.

IV 2.A The reasoning of M/s.Capt.C.R.S.Rao and Capt.Gopal is reflected in the following:

1. On 29th June, 1990 after carefully listening to the last few seconds of the CVR recording repeatedly on a suitable equipment at NAL, a metallic click sound was noticed by one of the Assessors (Capt.Gopal) during the phrase "Hey we are going down" uttered by CM1. The sound was similar to the click sounds observed by the Assessor on the A-320 simulator of Indian Airlines at Hyderabad, an A-320 aircraft of Indian Airlines at Bombay and the A-320 simulator of Aeroformation at Toulouse.

The sound was between words 'GOING' and 'DOWN' very close to the beginning of the word 'DOWN' The sound was demonstrated to the Court and the Assessors on 2nd July,1990 and to the representatives of the participants on 4th July,1990. The representatives of Airbus Industrie indicated that the click sounds could be from any of the 4 items below:

(i) Cockpit door closing due to not having been closed but left free to move.

(ii) Pulling of sidestick controls to the full aft position to the mechanical stop.

(iii) Thrust lever movement and

(iv) Shaking of the pilot's or copilot's seat. As this had come from the manufacturers, further investigations were carried out.

2. The Assessors visited Hyderabad during mind July. On 17th July, the Assessors went on board an A-320 aircraft VT-EPJ and recorded the sounds generated by the above four items with engines running close to VT-EPN rpm and without engines running both on a hand held cassette tape recorder and on the CVR. The microphone of the cassette recorder had been held close to Area Microphone location. Capt.S.T.Deo, Director of Training of Indian Airlines assisted by Capt.Johnson and another A-320 pilot carried out various actions as requested by Assessors to obtain these records VT-EPJ was an aircraft which had been registered

earlier than VT-EPN. During the recordings, the pilots seats did not shake or generate any noise even when the pilots tried to shake the seats with a lot of force while sitting on the seats. The sidessticks generated a 'SWISH' sound when pulled fast to the aftmost position. No metallic sound was heard, let alone a multiple metallic click comparable to the click sound on the VT-EPN CVR. Capt.Deo mentioned that pull forces during flight in the air would be higher than that on ground by design. The clicks generated by the door being banged shut and thrust lever movement from Climb to TOGA were similar. The door had to be banged shut for it to go through both locking stops. Slow movement could not close the door fully. Also, a very good magnetic latch was available to secure the door in the open position and force was needed to release the door from this latch before banging the door shut. These tapes (CVR and audio cassette) were analysed by NAL and compared with the VT-EPN CVR recording of the clicks in question. At this time frame, there is no likelihood of anyone entering or going out of the Cockpit, as crew were directed to position themselves for landing by about 35 to 37 seconds earlier.

3. At one stage there was a doubt about the identity of the pilot who had uttered the phrase "Hey we are going down". NAL were requested to identify the speaker, if possible. However, at a later date, Mrs.Gopujkar, wife of Capt.Gopujkar,

visited Bangalore and after listening to the CVR tape confirmed that the voice was not that of Capt.Gopujkar but it was Capt.Fernandez who had uttered the said phrase. The methodology used by NAL was to determine the characteristic signatures associated with different sounds and to co-relate them with the signatures of known sources such as human voices, cockpit door closures, thrust lever movement from climb to TOGA etc. In respect of voices of Capt.Gopujkar and Capt.Fernandez the above signatures were obtained from an earlier part of the VT-EPN CVR recording which were later compared with the voice of the person who uttered the phrase "Hey we are going down". Similarly the cockpit door closure, thrust lever movement from climb to TOGA etc. which had been recorded on VT-EPJ at Hyderabad by the Assessors was compared with sounds available on the VT-EPN CVR tape.

4. The signatures were defined by the cepstrum of the signal. Using the shuttling feature of the RACAL recorded it was possible to extract different speech segments and sounds of the CVR or the audio tape and then separately recorded these segments on an audio cassette recorder with appropriate connotation. The separated segments were analysed using digital signal processing techniques particularly cepstrum analysis. Conclusions were based on comparision of the analysed cepstra plots.

The equipment used were:

(i) RACAL model STORE 4 DS 4 channel Instrumentation Tape Recorder with Transcription and Analysis Controller model TAC 4.

(ii) Rockland Multi channel Signal Processor model 804A.

(iii) National Portable Stereo Component System model RX CW55.

(iv) Masscomp 5600 Real Time Computer System.

(v) Honeywell Vicicorder model 1858.

The following were the observations during the analysis:

(1) The cepstrum corresponding to Capt.Gopujkar's voice was characterised by a distinct peak at 8.5 milli seconds.

(2) The cepstrum corresponding to Capt.Fernandez voice had a characteristic peak at 6.7 milli seconds.

(3) The cepstrum of the speech "Hey we are going down" revealed a distinct peak close to 7 milli seconds. This clearly identifies the speaker of the above phrase as Capt.Fernandez.

(4) Using the shuttling feature of RACAL recorder it was confirmed that the metallic click sound during the phrase "Hey we are going down" occurs between the words "going" and "down". The cepstrum of the above metallic click sound is characterised by two peaks at 3 and 7.2 milli seconds.

(5) The cepstrum of the sounds generated during the throttle lever movement from climb to TOGA in VT-EPJ at Hyderabad also shows two characteristic peaks at 3 and 7.2 milli seconds.

(6) The cepstrum of the sound generated during the cabin door closure of VT-EPJ has two characteristic peaks at 4.8 and 9.5 milli seconds. These were very clearly different from the pattern observed from the throttle lever movement from climb to TOGA.

(7) The cepstrum of the sound of cabin door closure at the beginning of the CVR recording of VT-EPN (most probably by the hostess who had come into the cockpit earlier humming "Ke sara sara whatever will be will be") shows two characteristic peaks at 5.2 and 9.3 milli seconds which is close to the cepstrum of the door closure of VT-EPJ indicated above.

NAL Scientists have drawn the following final conclusions:

(a) The speaker of the phrase "Hey we are going down" is Capt.Fernandez.

(b) The metallic click sounds in the phrase "Hey we are going down" occurs between the words "going" and "down".

(c) The metallic click sounds heard on the CVR between the words "going" and "down" is not due to the cabin door closure but is compatible with the sound made by the throttle lever movement.

5. From the nature of the multiple click sounds which closely resembled the sounds generated by either the cockpit door closure or by the thrust lever movement from Climb to TOGA and the above conclusions by the scientists of NAL that the metallic click sound between the words "going" and "down" corresponds to the moving of the thrust levers from Climb to TOGA by the crew of the ill-fated aircraft. From the DFDR data it is observed that thrust lever movement should have occurred between time frames 324.906 and 326.781 seconds. Airbus Industrie have indicated in their letter No.AI/E FS 420.0218/90 dated 25-9-1990 that the minimum and maximum time to process the TLA (Thrust Lever Angle) signal from the TLA transmitter to the instant it is recorded on the DFDR are 183 and 423 milli seconds. An average time figure of 0.3 seconds as indicated by them is considered good for use.

As the time for the sound of the thrust lever movement to travel from the thrust lever guadrant to the area microphone is almost instantaneous compared to 0.3 seconds delay for the thrust lever angle to be recorded on the DFDR, it would mean that on the CVR the click sounds referred above should be between the times of 324.606 and 326.481. These figures would be in terms of co-relation with the DFDR time frames.

6. To obtain a good correlation between the CVR and DFDR a continuous UV (Ultra Violet) recording for a little over 40 seconds from the end of the CVR recording was taken. It was recorded on Honey-well type Vicicorder after synchronising the tape speed using 400 Hz invertor frequency as the reference. Recording was done at a paper speed of 16 inches per second with a spacing of 0.1 second between the two vertical time divisions. The first identified phrase in this recording is "OK 700 feet rate of descent". For computation purposes a reference time 0 was given to the end of the CVR recording and the times were measured backwards with a negative sign.

Listening very carefully to the last few sounds of the CVR recording it is observed that the crash sounds exist for a period of 2.4 seconds before the CVR stopped recording. In addition it is observed that there is an audible sound as if something was breaking just prior to the termination of the CVR recording.

7. Coming to the physical evidence left behind during the second touch down of VT-EPN it was observed that all three gears of VT-EPN had left a deep indentation on the 17th green of the golf course prior to the impact with the embankment. The nose gear of the aircraft is very close to and below the pilots cabin. The nose gear deeply digging into the ground including the axle between the wheels also causing indentation would create severe noises inside

the cockpit. All three gears digging into the ground and the right engine nacelle also dragging on the raised ground on the 17th green would cause severe deceleration of the aircraft. From the nature of these indentations, it is evident that the aircraft has taken almost 2.4 seconds from the time of the second impact till the impact of the bottom surface of the fuselage or the nose gear with the embankment. Most probably, the noise which appeared to be of some component breaking just before the CVR stopped recording, could be the impact of the nose gear with the embankment whilst the fuselage of the aircraft went sliding on top of the embankment. At this time the power supply for the CVR must have failed resulting in the stoppage of the CVR recording. The DFDR has stopped recording after word No.23 of the time frame 331 has been recorded. Words No.24 and 25 would not have been recorded at Bangalore due to non-availability of localiser or glide slope. Word No.26 which was EGT engine No.2 has not been recorded. Hence it is estimated that DFDR has stopped working between time frames 331.375 and 331.406 seconds or 331.4 seconds.

8. The DFDR needs AC power supply for the bus. The CVR power supply is available from the battery through the invertor. The very heavy impact with the ground at the time the aircraft touched

the ground within the golf course just short of the embankment may have possibily cut out the power supply to the DFDR due to loss of AC power supply to the DFDR while the CVR could have easily continued working with power supply from the batteries. It is the opinion of the two Assessors (Capt.Rao & Capt.Gopal) that the DFDR stopped working at the time of the second impact with the ground and the CVR continued working for 2.4 seconds till the power supply of the CVR was cut when the aircraft fuselage under surface impacted the embankment and for a good co-relation of the CVR and DFDR they say that the commencement of crash sounds should be assigned the time of 331.4 seconds DFDR time and the end of CVR would correspond to the DFDR time frame of 333.8 seconds if DFDR had continued working. They further estimate that the click sounds between the words "going" and "down" in the phrase "Hey we are going down" has occurred from 9.18 to 9.13 seconds from the end of the CVR recording. This would correspond to the DFDR time frames of 324.620 and 324.670 seconds. Referring to the earlier computation of DFDR time for thrust lever movement on the CVR as between 324.606 and 326.481, the time of 324.620 to 324.670 falls within this range and hence it is considered to be correct. The reasoning given by the two Assessors are:

9.(i) There was a school of thought that the final sounds of the CVR, which is referred to as crash sounds earlier, was due to a very hard first touch down on the golf course causing 6 Hz vibration of the structure of the aircraft, which in turn gave rise to a high level of sounds in the cockpit and the CVR recording. As the CVR is a direct audio recover using microphones located within the cockpit, Indian Airlines was requested to send the specifications of the microphones and the CVR receivers. The data has been made available to the Court. The noise level in decibels originated by a 6Hz vibration of the structure would have to be so very high for it to come within the range of the specifications of the microphones and the CVR for recording purposes. Such audio noise generation from a very low frequency structural vibration of 6Hz is unimaginable. In addition, continuous crash sounds have existed for a period of 2.4 seconds. The aircraft after the first touch down has flown for a distance of nearly 234 feet which would take approximately 1.23 seconds at the speeds recorded on the DFDR. Air is a very good damper for any vibration of an aircraft structure when it is flying in the air. Severe turbulance during flight can cause very low frequency vibrations of the aircraft wings, oscillations of podded engines etc. and the two pilot Assessors with their cumulative nearly

4000 hours of flight experience have never experienced such high levels of audio recordable nose similar to that of VT-EPN CVR. Aslo there is no further intesification of the crash sounds after the second impact which was far more severe than the first touch down. If such noise levels could be generated by a 6Hz structural vibration in the cockpit, similar nose should have occurred in the cabin also. No survivor witness has indicated any high unusual noise after the first touch down. Further, if DFDR time of 329.937 which is the time at which 6.125 g has been recorded is considered as the time for commencement of crash sounds, the end of the crash sounds would correspond to 332.337. This would mean that the thrust lever movement sounds as determined earlier would have occurred at 323.157 to 323.207 DFDR seconds. This is well outside the DFDR recorded thrust lever angle at TOGA. Hence this opinion has to be discarded.

(ii) Though the DFDR time frame range for the TLA position at TOGA could be between 324.906 and 326.781, any movement of the identified thrust lever clicks towards the higher value cannot be considered because the radio altitude call outs would have a very big discrepancy. For example, if thrust lever movement time is given as 326 seconds, with the knowledge that the aircraft was on the ground at 329.8, the UV recording would show that the aircraft would be between the chime and the subsequent sink rate call. If the thrust lever movement is given the time of 325 seconds, the time of first touch down would occur during the sink rate thirty call. Thus it can be seen that the time of 324.620 to 324.670 seconds which has been indicated earlier as the time during which the thrust lever has been moved gives a very good co-relation between the DFDR and the CVR. The aircraft is on the ground at the time it should be on the ground as per DFDR data.

(iii) The phrase "Sink Rate Thirty" was used in the previous paragraph. From repeated listening of the CVR tape, it appears that it is "Sink Rate Thirty" and not "Sink Rate Fifty". However it is necessary to mention that this can only be observed by repeated shuttling of the tape on a suitable equipment with possibility of reduction in tape speed and frequency filtration. Also, it would correspond well within physical evidence of the first touch down and the radio altitude values on the DFDR.

(iv) Based on this time determination of thrust lever movement to TOGA and identification of certain important phrases during the last 40 seconds (using the UV recording) the co-relation of CVR and DFDR has been carried out. Even though the ground below the aircraft during the last 40 seconds was very uneven, giving rise to the recorded radio altitudes the auto radio altitude call outs do correspond well. The impcat time with the embankment corresponding to CVR stoppage would be close to 07:33:20 hours UTC or 13:03:20 hours IST. The aircraft has covered another 430 feet before coming to a final stop. At about 85 to 90 knots on leaving the embankment and to a sliding stop, the aircraft could have taken 4 to 5 seconds. Hence, aircraft is estimated to have reached final position at 07:33:25 hours or 13:03:25 hours IST.

(v) The Court and the Assessors proceeded to NAL on 6th November, 1990 to listen to the CVR tape again as there was a difference in the time indication of the radio altitude auto callout of "Three Hundred" and the CM2 call out of "You are descending on idle open descent ah all this time" in the CVR transcript from CASB and the transcript prepared by two pilot Assessors after co-relation.

In the co-relation from CASB, the call out of "You are descending on idle open descent ah all this time" is shown against DFDR time 304.9. The call out "Three Hundred" has been shown against time 305.3.

The pilot Assessors had shown the call of "Three Hundred" before the other CM2 call out. The call "Three Hundred" was against DFDR time 303.7 seconds and the CM2 call "You are descending on idle open descent ah all this time" was from 305.5 to 306.6.

After listening to the various channels of the CVR recording at NAL by the Court and the Assessors, it was established that the "Three Hundred" call was before the CM2 call "You are descending on idle open descent ah all this time". However "Hundred" in the "Three Hundred" appears to have overlapped the first two words of the CM2 call namely "you are". These two words "You are" are very clear in the CM2 call on the CM2 microphone channel. "Hundred" and "You are" which are overlapping are shown in brackets in the CVR-DFDR transcript below (It is necessary to note here the timing co-relation was not done by the NAL, but by the two Assessors).

(vi) Timing against important CVR phrases only, are indicated below. These timings indicate the start of the phrase or callout or occurrence. Where considered important the time taken for the full phrase or call out is indicated to nearest decimal of a second. Crash seconds are accounted for from the time of DFDR stoppage at 331.4 seconds which corresponds to start of crash sounds. This has been used as Inspector of Accidents also has taken crash seconds as 0 at start of crash sounds.

TIME		SOURCE	INTRA COCKPIT CONVERSATION	SOUND/ ALARMS
CRASH Secs.	DFDR Secs.			
39.4 to 38.1	292.0 to 293.3	CM1	OK, 700 ft. rate of descent	
36.5 to 36.1	294.9 to 295.3	CM2	Missed approach is ____	
32.8	298.6			Four hundred
27.7	303.7 to 304.8			(Three hundred)
25.9 to 24.8	304.8 to 306.6	CM2	(You are) descending on idle open descent ah all this time	
22.7	308.7	CM2	You want the FDs off now	
21.4	310.0	CM1	Yeah	
19.7	311.7	CM1	Ok, I already put it off	
17.9	313.5	CM2	But you did not put off mine	
14.8	316.6			Two hundred
10.7	320.7	CM2	You are on the auto pilot still?	
8.4	323.0	CM2	It's off	
7.35 to 6.6	324.05 to 324.80	CM1	Hey, we are going down	
6.0	325.4			One hundred rate
3.9	327.5			Sink rate
3.6	327.8			Chime
2.3	329.0			Sink rate 30
0.6	330.8			Sink rate 10
0.0	331.4			Crash sounds begin

10. REGARDING FIRST TOUCH DOWN:

The aircraft first touched the ground in the grounds of the Karnataka Golf Club approximately 2300 feet short of the beginning of R/W 09 of Bangalore Airport. The wheel marks on the ground during this touch down were for a distance of approximately 82 feet. Only the main gears had touched the ground and there were no wheel marks from the nose gear. The DFDR data has shown that the radio altitude at 329.953 seconds was 0 feet. The radio altitude at 328.953 seconds was 12 feet and the radio altitude at 330.953 seconds was 2 feet. The ground speed recorded at time frames 328.734, 329.734 and 330.734 is 116 knots while the CAS was 112.78, 113.03 and 110.28 at 328.234, 329.234 and 330.234 respectively. As the accuracy of ground speed recording is + 8 knots and the CAS recording accuracy is + 1 knot, considering an average CAS of 112 knots at these very low radio altitudes it would take .43 seconds to cover 82 feet after which the aircraft went up into the air. Also the DFDR normal acceleration at time frames 329.687, 329.812, 329.937, 330.062, 330.187 and 330.312 are 1.06250, 2.78125, 6.125000, 3.01563, 1.57813 and 0.01563 respectively. The maximum normal acceleration recording of 6.12500 has been at 329.937 seconds.

11. Mrs, Sadhana Pawar joined Indian Airlines in 1982 and is now a senior Airhostess with Indian Airlines.

She is one of the survivors of this accident. She was assigned duties at the rear of the aircraft during this flight. She was the airhostess who opened the rear left main door through which quite a few passengers were able to escape. She is an experienced cabin crew member and she has stated both in her affidavit and during her deposition that the first touch down was quite normal. In the affidavit she has stated:

> " The aircraft's first touch down there was nothing abnormal felt or heard. The first touch down seemed to be like an average landing".

In her deposition she has stated:

> " The first touch down of the plane did not give any impression that there was an abnormality and I thought it was a normal landing".

Mrs.Neela Sawant is another airhostess who survived from the accident. She was also seated at the rear of the aircraft when the accident occurred. She joined Indian Airlines in 1982 and presently she is a senior Airhostess. In her affidavit she has stated as below:

> "Before the first touch down there was nothing abnormal heard or felt in the aircraft and seemed to be an average landing".

In her deposition she has stated as below:

> "There were three impacts altogehter and the last one resulted in the plane stopping finally. However the first impact gave me impression that it was a normal landing".

Again during cross-examination she has confirmed as below:

> "The first landing gave the impression that it was a very normal landing".

A surviving passenger, Sri.Hemchand Jaichand, who is a bank official, occupying seat 21A (a window seat on the left side) has deposed as below:

> "Before the first touch down I saw barren fields and the plane was almost level to the fields but even then I thought it was a normal landing".

During cross-examination he stated:

> "The first touch down was not a smooth touch down but something like a landing in an airport situated at a higher altitude as in the case of Bajpe airport, even then I did not experience any unusual feeling while landing".

He also stated at a later time:

> " Though I thought it was a normal landing at the first touch down, still

it was rough. Most of the times I went to Mangalore I had experienced the same kind of landing".

Mr.E.S.Sridhar, a survivor, who is an Engineer, was occupying seat 27D (an aisle seat) is a frequent air traveller. He has stated:

"The first touch down was a mild one and I thought we had landed on the R/W".

During cross examination he has stated:

"The first touch down did not give me any jolt". Mr.Kumar Nadig, an Industrial Designer was occupying seat 12C (an aisle seat) at the time of the crash. He also held a private pilot's licence which has expired. During his deposition he has stated:

"It was quite a hard touch down in the initial stage. It was too quick and unusually hard impact. The second impact was much more severe than the first. After the second impact I think the plane came to a final stop".

The two surviving airhostesses have had 7 to 8 years experience as cabin crew. Flying has been their profession and they would have had plenty of experience to judge a normal landing or a very hard landing. Both have stated that there were three impacts out of which the first was a normal landing. Mrs.Sadhana Pawar has stated that the second impact was heavy and terrible and the third which was the final stop was on a marshy land. Mrs.Neela Sawant has stated that on the second impact she was thrown out of her seat and fell on the floor and she was still on the floor when the third impact occurred.

Mr. Hemchand Jaichand has stated that within a very short time after the first touch down the plane thudded against a hard surface. He has also observed the signs going off after the second touch down though he had been injured and was bleeding through the nose.

Mr.Sridhar has stated that at the time of second impact he had fallen forward and the seat belt had snapped and the plane stopped at the third impact.

The only person who has said that the first touch down was a hard touch down is Mr.Kumar Nadig but he has also stated that the second impact was more severe than the first and he suffered injuries only after the second impact. He has not deposed about any third impact and he felt that the aeroplane came to a stop after the second impact. The possibility of Mr.Nadig not having remembered the first touch down due to its smoothness does exist. He was sitting in an aisle seat with an adult lady by his side in the center seat and a child in the window seat and hence his vision through the window would be severely restricted.

12. The Court and the Assessors had visited the crash site a few days after the crash at the earliest possible opportunity after a formal investigation was ordered by Government of India. All telltale marks were fully evident at that time as nothing had been distrubed except to clear some debris at the embankment and on the road parallel to the embankment. Photographs taken by the team from Government of India, Civil Aviation Department immediately after the accident are available with the Court. These photographs have been filed as Ex.46 series. There are certain significant observations to be considred in respect of the ground over which the aircraft rolled during the first touch down. The photographs 46(1), 46(2), 46(3), 46(5), 46(6) and 46(20) which were taken immediately after the accident are very pertinent with respect to this portion of the area of the golf ground where the first touch down took place. Photographs 46(6) and 46(20) clearly show the undulating nature of the ground. Photographs 46(2), 46(3) and 46(5) clearly show that during the 82 feet roll the ground surface had considerable undulations in the mid part of the wheel marks. There was a sudden dip in the ground of approximately 3 inches

as observed by the Court and some Assessors on their numberous visits to the crash site. This depression was more predominant in the left wheel track area compared to the right wheel track area. The whole surface of the full 82 feet of the first touch down was grassy land which was fairly dry at the time of the crash. From Ex.46(2) we can make out the undulating ground even in the right hand wheel track marks. Looking at photograph Ex.46(1) which is a close up view of the initial touch down point of the first touch down, it is observed that hardly any indentation has been made by the wheels. It should be remembered that at this point the wheels of the aircraft would have been stationary and at the time of touch down the friction between the tyre and the ground would start the wheels rotating as well as create severe erosion of the top surface. Just before this touch down at right angles to the wheel marks we can also see a mark left by possibly a wheel borrow. This is our assumption as there is only one track that is observed in this photograph. In the same photograph it is apparent that the depth of the impression left by the aforesaid wheel barrow appears to be more than that created by the aircraft wheels. Also a careful observation of this photograph indicates grass being seen in the area of the tyre marks. Photograph 46(5) again shows a marking left by an equipment like a wheel barrow running parallel to the wheel marks indicating that the top surface of the whole area was similar in nature. One question that needs to be answered is whether an aircraft at a weight of 58 tons coming down and hitting the ground at a normal acceleration of 6.125 g or greater and at a speed of about 115 knots can leave a wheel mark wherein éven the grass of a soft top layer has not been removed by the friction created between the wheels and the ground when the wheels have to start rotation. This would only be possible if the aircraft touches the ground very lightly and the weight of the aircraft gradually settles onto the ground. Though soil testing which was carried out had indicated a fairly hard surface underneath the area of the first touch down compared to the soil strength of the area of the second touch down, it is evident from these photographs that the top surface of the ground in the area of discussion was fairly soft because of the wheel barrow marks. This type of impression, with the grass remaining at the point of intial contract can only occur if the contact between the stationary wheels and the ground is very light and there was no severe friction.

13. Ex.94 is a DFDR data of the landing of the same aircraft VT-EPN about 6 landings earlier.

The various recorded accelerations are in the data of the exhibit. This was filed before the Court by Airbus Industrie representatives. From the pressure altitude it appears that this landing was at Bangalore itself. After the aircraft had touched down, at a slightly later time during the landing roll, normal acceleration had shown a sudden increase. When this increase in normal acceleration was brought to the notice of Mr.Gerard Guyot his answer was:

> " I do not see other explanation than the aircraft could may be have been on a particular rough R/W because it could happen that R/W surface have significant irregularities".

He also confirmed that the same DFDR was on board VT-EPN at the time of the crash.

14. Though Mr.Guyot was sent as an expert by Airbus Industrie and was supposed to be competent to interpret the DFDR data, during cross examination by the learned Counsel of Indian Airlines, Mr.Guyot has stated that he expected fuel flow readings after the first touch down if the touch down had a vertical velocity compared to a normal landing (page 18). From the time after the first touch down, till the time DFDR stopped recording, by design there was no possibility of a fuel flow recording. The next recording of the fuel flow would have come for engine-1 at 331.781 and for engine-2 at 331.906 DFDR seconds. The DFDR

had stopped working at 331.4. During questioning by an Assessor, Mr.Guyot agreed that this was the first accident wherein he was interpreting DFDR data in respect of normal, lateral and longitudinal accelerations of the magnitude experienced in this crash (page 97). From this it has to be inferred that Mr.Guyot was not an experienced expert witness to give an opinion on the proper recording of the 'g', values.

15. The Court had requested the Airbus Industrie to carry out certain manoeuvres on an aircraft similar to those of Indian Airlines and fitted with V-2500 engines. DFDR data of that flight was requested for. The flight was carried out on 20-6-1990 at Toulouse. The DFDR data of the flight was made available to the Court. The duration of the flight was for a period of 1 hour.45 minutes. Only a few minutes data were requested for by the Court. Four profiles at very high angles of attack were carried out. One was a repeat of the Bangalore scenario. The second profile was under direct law initiating TOGA at the onset of stall warning and continuing flight at an angle of attack to get intermittent stall warning. The third was recovery at stall speed +12 Kts approximately. The fourth was engine acceleration at high angles of attack. The total duration of the DFDR data made available to the Court (which covered these four profiles)

was 9 minutes and 52 seconds. Eight seconds data from 15:10:36 to 15:10:43 UTC (inclusive) could not be retrieved from the DFDR. In the remaining 9 minutes 52 seconds, there were a total of 151 erroneous recordings on the DFDR. These included 26 erroneous readings of normal acceleration, 17 readings of longitudinal acceleration and 11 readings of lateral acceleration. Throughout the period this data was collected, the aircraft was in flight. One of the Assessors was on board this flight as an observer.

The acceleration values recorded during this flight varied from -7.37488 to +5.96992. Such values can never be achieved by this aircraft both by design or by even very violent manoeuvring. It is extremely surprising and significant to note that the errors in the acceleration values have occurred only after a profile at high angles of attack was carried out. During the part of the flight prior to initiating the profiles and getting in to the high angle of attack segment, no such acceleration errors occurred. Also, it was observed from the data that at certain times incorrect acceleration figures have been recorded in an isolated manner and sometimes in groups of 2, 3, 4 or even 5 consecutive readings of the same acceleration parameters. This does indicate that there is a definite possibility of incorrect acceleration readings being recorded by the DFDR after a flight segment at very high angles of attack.

This was the case during the last flight segment of VT-EPN till the first touch down. The possibility of the normal acceleration recordings in the VT-EPN DFDR data at the time of first touch down being incorrect cannot be ruled out. It would be necessary for the Airbus Industrie to carefully examine the design aspects of the accelerometers and the DFDR recording to overcome this problem.

Scrutiny of the VT-EPN DFDR data indicates that the radio altitudes recorded at 326.953, 327.953/328.953 and 329.953 seconds were 60, 30, 12 and 0 feet respectively. The pressure altitudes recorded against time frames 329 and 330 appears to be in error. The pressure altitude difference and radio altitude difference shown against 326, 327 and 328 seconds co-relate fairly well, but for 329 and 330 they do not co-relate even allowing for certain uneven ground observed in that area. At the speed that existed, the aircraft would have been about 195 feet horizontally behind the point of first touch down 1 second earlier to that touch down. There was no very significant high ground to consider the radio altitude against DFDR time frame 328.953 as erroneous. On the contrary, there was a slight depression in the ground in that area. There is a possibility that the radio altitude figure of 12 feet may not have been the height of the aircraft above the altitude of the point of the first touch down. It could have been less by a few feet. The same can be seen also by the comparison of pressure altitudes recorded against time frames 327 and 328. Hence it is possible that the aircraft was only about 10 feet (or even less) at the time 1 second prior to first touch down.

16. It is common knowledge that in these jet transport aircraft during take off on rotation a rate of descent is indicated on the VSI though the aircraft is on the ground and trying to get airborne. Indications become normal and correct after the aircraft gets airborne and stabilised in climb. Pressure sensing instruments cannot be relied upon at heights very close to the ground. This would include pressure altitude instruments and readings. For aircraft approaching the ground at even normal approach angles, the pressure altitude readings may not be correct both because of altimeter setting and possible higher pressure sensing due to ground effect. Mr.Guyot during his cross examination has concurred with the suggestion that ground effect causes errors in static pressure measurements. This is the reason why radio altitudes which are more accurate are used for Auto land and Category III landings. It is therefore necessary for us not to consider the pressure sensed measurements during the last 2 or 3 seconds, but rely upon the radio altitude data.

17. Looking at the pitch angles from DFDR times 324 to 329, it is observed that there has been a continuous increase in pitch altitude. At 328.641, the angle of attack has reached the maximum recorded value. This is just about 1 second from first touch down. The elevators have also started moving upwards in the last few seconds prior to the first touch down. Altitude loss per second has shown a reduction from 30 feet between time frames 326 and 327 to 18 feet between 327 and 328 and 12 feet between 328 and 329. If we consider what we have stated earlier whilst looking at the radio altitudes, then during the last 1 second, the altitudes loss would have been even less. This clearly shows that the aircraft was in the process of recovery from a very high sink rate during the last 3 seconds prior to the first touch down. It is possible that this aircraft did touch down fairly smoothly at the time of the first touch down with a very light contact at the point of initial touch down. The normal acceleration data that have been recorded cannot be relied upon because of the type of data that has been recorded in the Airbus Industrie test flight and because of non-co-relation with other parameters of flight during the last few seconds.

18. VT-EPN was experiencing a tailwind component during its final approach. At the initial stages

it was about 8 to 9 knots at time frame 296. The tail wind component continued during the flight with approximately a 7 knots component till about 321 seconds and increased to 9 knots at 323. From then on till the first touch down the tailwind component reduced. The photographs of the burning aircraft published by some of the magazines indicated the smoke travelling from the front towards the rear of the crashed aircraft and also towards the right of the crashed aircraft. This indicated a east north easterly wind direction. Hence it is evident that prior to the first touch down the aircraft had experienced a head wind component. A change from a tailwind component to a head wind component increases the performance under any conditions of flight. The CAS would increase and also the aircraft would tend to gain height at the same angle of attack. This would mean that VT-EPN which was having a high sink rate would have been assisted by this wind change in its performance by reducing the sink rate; this would have contributed to arresting the sink rate just prior to the first touch down.

19. Though 6.125 g has been recorded during the first touch down, it is necessary to note that no part or even a panel had been shed by the aircraft between the first and the second touch downs.

The first shedding of parts started only after the second touch down and the right engine cowling was riding the raised ground near the 17th green of the golf course. The photograph Ex.46(20) clearly shows where the shedding of aircraft components/parts commenced. Two of the Assessors had personally seen the type of damage that would occur after a high 'g' impact. In the Boeing 707 crash at Bombay in June 1982, the vertical acceleration recorded was a little over 5 g. The No.2 engine fell off after the impact and some other parts and panels of the aircraft had been shed before the aircraft came to a final stop though the aircraft had rolled for a short period on its landing gears and subsequently had a very short hop before the final impact. It is very difficult to imagine that this aircraft VT-EPN would not have shed any components if 6.125 g recorded was indeed the correct figure.

Mr.Ronald W.Weaver an accident investigator with International Aero Engines stated that it was common within the industry that DFDR data recorded after a 6 g impact cannot be valid. He quoted an accident to a DC 9 aircraft of Airborne Express at Philadelphia in 1985 wherein the aircraft had a 6 g impact and no parts of the aircraft had been shed immediately after that impact. The Court was able to obtain complete data of this accident and it was found that the maximum g recorded at the time of impact was only 2.76 g and the aircraft had shed lot of parts and components immediately after the impact (Ex.143) Mr.Weaver, however, after his return to USA realised his incorrect statement and sent a letter indicating the correct information in respect of this accident. It is not possible to agree with the contention that DFDR data would be invalid just because a normal acceleration in excess of 6 g has been recorded. The Court is not in possession of any documentation which can justify such a contention based on previous accident investigation records. As DFDR data recorded could be in error, every parameter has to be carefully evaluated against evidence available prior to accepting or discarding the data.

20. Mr.Gerard Guyot, in a technical note dated 10-7-1990 (Ex.95), has explained the reasoning for coming to the conclusion of the first touch down being in excess of 6 g. Only pressure altitudes have been utilised for this computation. Ground effect had not been considered as per his deposition during cross examination (page 24). We cannot agree to this computation as the other valid parameters, physical evidence and survivor statements do not tally with this opinion.

Mr.Gerard Guyot during his deposition on page 10 has stated that if the aircraft had touched down with a vertical acceleration of 6.125 g at the centre . gravity, the vertical acceleration would be 13 g at the level of the cockpit, 12.2 g at the level of the electronic bay and 17 g in the rear part of the fuselage. In spite of the estimated 17 g vertical acceleration, the two airhostesses occupying seats at the rear end of the cabin and Mr.Sridhar occupying seat 27D have stated that first touch down was a normal landing. Mr.Jaichand in seat 21A which is also towards the rear part of the cabin has stated that it was a normal landing. Even though one witness sitting over the wing close to the centre of gravity felt that it was hard, it must be remembered that the aircraft had touched down on a golf course with a shallow area in the middle part of the first touch down. Passage over this shallow area may have caused the impression of a hard touch down to this witness. An aircraft in flight is a moving object whose profile is continuously changing particularly under the conditions experienced by VT-EPN in the last few seconds before the crash.

21. Taking into consideration all the evidence before the Court, it is our considered opinion that this aircraft was in the process of changing its flight profile and arresting the sink rate when it touched down smoothly in the golf course for the first time before going up into the air again.

REGARDING SECOND IMPACT:

22. After the first touch down and rolling on the ground for a distance of 82 feet on the main gears only, the aircraft went up into the air and came down rather violently at the time of the second touch down. The aircraft had covered a distance of 234 feet from the end of the first touch down to the beginning of the second touch down.

23. This short flight was for a duration of approximately 1.2 seconds at the speeds recorded on the DFDR. There were a few small trees on the golf grounds between the two touch downs which were hit by the aircraft and cut during this short skip. One tree in line with the left engine was broken approximately 10 feet from the ground. One in line with the left main gear was broken approximately 9 feet from the ground and two trees on the right were cut at approximately 8 feet 4 inches and 7 feet 2 inches by the right hand engine and the gear. These trees had jagged edges at the top which would indicate that the impact point of the aircraft structure against the tree should have been higher than the remaining height of the tree. Also as a sink rate warning had been generated just before the second impact, by the design of the GPWS this aircraft must have attained a height greater than 10 feet before the aircraft came down and had the second impact.

24. Referring to FCOM 1.09.10 page 8, the flight mode changes to landing mode when radio altitude of 50 feet is passed. Considering the flight before the first touch down the aircraft would have been in landing mode on passing 50 feet radio altitude. This would have occurred about 2½ seconds prior to the first touch down. Reference FCOM 1.09.10 page 7, on the ground above 70 knots, the maximum deflection of the elevator is 20° up and down. During the first touch down both pilots were holding the sidesticks fully back. The moment the aircraft was no longer in flight but on the ground (during the first touch down), the angle of attack would have changed. The high angle of attack VT-EPN experienced during the last few seconds would change to a value close to pitch altitude at the time of touch down (angle of incidence of the wing has to be accounted for). The pitch angle at 328.125 was 8.79° . It is possible that the pitch altitude could have increased to about 9° to 9.5° in the period remaining before the first touch down. The angle of attack recorded at 329.641 was 15.65°. Immediately on touch down it would have changed to a figure close to 9° and the aircraft would be immediately out of alpha protection range (which starts at 12°). Under this condition the computers (ELAC) would no longer dictate the position of the elevators to maintain the maximum angle of attack. With

the side sticks had fully back by the pilots, the elevators would deflect upwards to the maximum permissible value under the present conditions of flight namely 20°. Such a violent movement of the elevators would create a very severe pitch up of the aircraft. At the speed of first touch down which was well above stalling speed, this would surely result in an immediate flight of the plane in a very steep nose high altitude. All this would have occurred in just 0.4 seconds. Elevator angle of -17.7° at 330.719 seconds confirms such movement.

25. Such movement of the aircraft does explain the hitting and breaking of the trees at such high measured heights even though, the aircraft was in the air for about only 1.2 seconds before it hit the ground again. It is most likely that this elevator movement which initiated the bounce could have taken the aircraft altitude to a very steep angle possibly beyond the stalling angle. The momentum of the aircraft would have taken it upwards to a certain extent after which the nose would drop and the aircraft would come down. This is evident from the way the ground marks are, at the second impact. We do not believe that any computer can stop the momentum of a 58 ton aircraft in about ½ to 1 second.

26. Most probably the pilots at that time realised that they would be coming down onto the embankment which they would have seen during the first touch down. It is possible that during

that short skip and the steep attitude after the first touch down they might have released their hands from the sidestick controls at almost the same time either to protect their faces or due to the realisation of the inevitability of a crash. It may be just a coincidence that both SSPPC and SSPPFO have recorded the same value against time frame 330.

27. The distance between the tree broken at a height of 10 feet and the end of the wheel marks of the first touch down is 118 feet. The distance between the tree and the beginning of the second touch down markings is only 46 feet. This shows that the aircraft came down very steeply at the time of the second impact after attaining a considerable height. This also explains the generation of the sink rate warning as well as the 10 feet auto call out.

28. In spite of all the factual evidence available, we are unable to understand how Airbus Industrie could have sent a technical Note No.AI/EE A441.082890 dated 13.9.1990 (it has been erroneously shown as 1989) wherein they have asserted that the maximum variation of altitude between the two main gear marks in respect of this accident would be 0.8 meters ± 30%. Even allowing the maximum limit as per their calculation it corresponds to 3 feet 5 inches. Airbus Industrie's explanation is unacceptable.

29. Some of the statements of survivor witnesses are quite relevant. Mrs.Sadhana Pawar during cross-examination has stated "I cannot say whether the plane was rolling or dragging after the first touch down and it is very difficult to describe as I have not paid my attention on that aspect". Mrs.Neela Sawant has stated during her deposition "There was a sort of movement which I cannot describe either as flying or rolling before the second impact occurred".

30. Mr.Hemchand Jaichand during cross examination stated "After the first touch down there was a jerky movement of the plane though nothing violent was experienced". Mr.E.S.Sridhar during his deposition has stated "Between the first and second touch down, though there was movement, I cannot describe the nature of the movement".

31. These statements do indicate that a movement of the aircraft, which they could not clearly describe, had taken place between the first touch down and second touch-down. An aircraft after touch down, going up very steeply and suddenly coming down would be a type of movement which they were only able to feel but could not see due to their seating positions. Though Mr.Jaichand was at a window seat, he has stated that he was not looking out of the window.

32. From the physical evidence of the broken trees, it is apparent that the aircraft had attained an altitude considerably higher than 10 feet with possibily a slight right wing low altitude. Due to the closeness of the trees to the second impact point, the aircraft must have passed the trees that were broken at a height greater than 10 feet either on the way up or on the way down. Most probably it would have been on the way down.

33. If a parabolic traverse is assumed the height attained at the mid point between the two touch downs would be very considerable to break the trees in the manner observed.

34. The sink rate of the aircraft just prior to the second impact should have been quite high reaching an approximate vertical acceleration value of more than 16 feet/second to generate the sink rate warning. Airbus Industrie have confirmed that the GPWS on board VT-EPN was a new version whose lower limit for generating the warning is 10 feet above ground. This also confirms that the aircraft should have attained a height greater than 10 feet during this bounce. The very hard impact reported by all the survivor witnesses corroborates this conclusion.

35. The 17th green of the golf course where the second impact occurred had a rising profile. All three gears have dug into the ground causing considerable decelaration of the aircraft as the engine power was still at a low level at the

time of the impact. However the engines appear to have continued accelerating to take off power and sustained that power, till the impact with the embankment. After a short distance, the right engine cowling was riding on the surface of a raised ground. This provided a support to the aircraft on the right side with the left main gear supporting the aircraft on the left or it is possible that the right main gear broke at this point due to the high forces of the second impact in the golf green and forces due to gear digging into the ground. (The right wheel marks had started before left indicating that right gear hit the ground first, may be due to slight right bank). This could be the reason how the right wheel marks abruptly ended when the right engine cowling marks commenced. Also, because of the type of rising ground, the nose wheels may have lifted off and later the under surface of the fuselage sliding on top of the embankment kept the nose gear clear of the ground. Though there was a depression between the 17th green and the embankment, the fast acceleration of the engines to take off thrust would have contributed to a considerable pitch up movement. This would have also assisted in getting the nose up whereby the fuselage went over the embankment instead of dipping down and hitting it directly. This is based on the very significant thrust change in the last 2 seconds of the 8 seconds during acceleration from approach idle to TOGA. (As indicated by the acceleration charts of the V-2500 engines made available to the Court).

The aircraft continued its forward movement assisted by engine thrust. When the nose gear, the engine nacelles followed by the main gears impacted the embankment, they were all broken off from the aircraft structure causing severe damage. A noise similar to something breaking is there in the CVR just before it stopped.

36. From the type of the imprints left by the aircraft in this area, it is quite possible that the aircraft has taken 2.4 seconds or even a little more before the impact with the embankment as indicated by the sounds recorded on the CVR before it stopped.

37. The aircraft fuselage and the wings chopped off a few small trees and bushes on the top of the embankment during its passage. The thudding referred to by one of the survivors is considered to be the impact of the aircraft structure against the embankment.

REGARDING THIRD IMPACT:

38. The fuselage with its damaged wings still attached to the body, with its under carriage and engines broken off, hopped over the nullah and a road parallel to the embankment and impacted

the ground for the third and a final time at approximately 260 feet on the other side of the embankment. The aircraft skidded on its belly for about 170 feet before coming to a final stop. During the hop, the disintegrated portions and various components of the aircraft lay scattered all over the ground between the road and its final resting place. The forward end of the aircraft was approximately 150 feet short of the boundary wall of the airport towards runway 09. The aircraft came to rest on its belly in an upright condition.

The aircraft did not stall prior to the third impact because of:

(1) The long skid marks for a distance of 170 feet caused by the belly of the aircraft before it came to a stop as reported by the Inspector of Accident.

(2) The right hand half of the cockpit which has survived the fire has shown the front sloping portion below the right hand front wind shield having a smooth surface as it would be on an aircraft.

(3) The post mortem reports of both pilots showed that they died of burns and not due to injuries sustained. Both the pilots had not sustained any fractures. Items (2) and (3) indicate that the aircraft did not come down on its nose

(4) The portion of the tail from the tail skid to the APU exhaust does not show any signs of damageleave alone serious crumpling of the structure to indicate that the aircraft hit the ground on its tail during the third impact.

(5) There were big stone boulders in the area of the third impact over which the aircraft had impacted which would have caused serious damage to the bottom part of the fuselage, during the 170 feet skid of the aircraft.

39. Mr.Laxmiah Reddy of Hindustan Machine Tools was witness No.22. From the evidence on record, he is the only person who has seen the actual progress of the aircraft from the embankment to the third impact point and final rest position. His statement about how the engines fell is corroborated by the position of the engines after the crash. During cross examination by learned Counsel, he stated that the cockpit was in normal position and that the front portion was not separated from the other part of the plane when he saw it. According to him, the plane landed on the marshy land as if it was a normal landing. He also deposed that there was an explosion in the front portion of the plane almost immediately after the aircraft came to rest.

40. We are of the view that the fuselage in one piece with the wings attached came to rest in an upright condition after the third impact. There was an explosion immediately thereafter along with a major fire.

IV 2.B (Mr.GOSWAMY'S VIEWS)

FIRST IMPACT ON GOLF COURSE:

1. At DFDR second 319 CM1 asked CM2 whether he was still on the Auto Pilot. At 321 second CM1 replied in the negative and CM2 also confirmed that Auto Pilots were off. At 322 second CM1 realised that the aircraft was sinking abnormally and explained "Hey, we are going down". At 323 second "Sink rate" warning from ground proximity warning system and Radio altimeter "one hundred" feet call out came. Then CM2 was alarmed realising that the matter was serious and said "O, shift". Immediately CM1 called "Captain" and at 324 second desperately repeated "Captain still going". It is implied that he lost all hope and was appealing to CM2 to do something to recover from the situation. At 325 second second "sink rate" warning came indicating that the rate of descent was abnormally high. At 326 second most probably CM2 disconnected the auto thrust depressing the instinctive push buttons on the thrust levers and moved them to TOGA position, which was confirmed by the "Chime" sound in the CVR and thrust lever full forward position in DFDR, vide page 4 of DFDR figure 10. But this action did not change the situation materially because engine power was already building up due to alpha floor activation at 323.9 second as indicated by gradual increase of aircraft speed from 106.53 kt. at

323 second to 111.28 kt. at 326 second. At 327 second third "sink rate" warning and RA call out "fifty" feet was voiced. At 328 second fourth and last "sink rate" warning and RA call out "Ten" feet was sounded. By this time engine built up some power as evidenced by actual EPR increase and speed increase to 112.78 kt. vide DFDR parameters. But power build up was not sufficient like any other jet engine due to slow response to acceleration from lower power. Finally, at 329.8 second the aircraft impacted the ground on the golf course of Karnataka Golf Association. Due to increased downward momentum (inertia) of the aircraft like any other jet aircraft and due to slow response to acceleration of the engine like any other jet engine the sink rate could not be arrested since the height available was not sufficient and the aircraft could not be recovered because action initiated, in this case, triggering of alpha floor was too late. Experiments carried out by Airbus Industrie, International Aero Engines and also by the Court indicated that if alpha floor could have been activated 3 seconds earlier i.e. at DFDR second 320 or thrust lever moved to TOGA position at that time, then only it was possible for the pilots to arrest the sink rate and recover the aircraft.

2. It may be stated in this connection that during replay of CVR at NAL, Bangalore, in presence

of all participants it was confirmed that there was a click sound between the words "going" and "down" when CM1 said "Hey, we are going down". It appeared that this click sound could be the sound of the thurst levers moving to TOGA (extreme forward) position. But Airbus Industrie felt that this was the sound for CM1 sidestick pull to full backward position. DFDR data shows that CM1 sidestick was moved to full back position between 322 and 323, second alpha floor was triggered at 323.1 and EPR command started increasing from 324 to 325 second. These parameters match Airbus Industrie thinking. But if it is considered that 1 second time is lost between uttering "Hey, we are going.... " and the thrust levers movement to TOGA position it can be presumed that the thrust levers were moved to TOGA at 323 second. But TLA position (Throttle lever position) parameter in DFDR figure 10 page 4 shows that it was moved to TOGA position at 326 second.

3. As per Airbus Industrie letter No.AI/E-FS 420.0218/90 dated 25-9-1990 it appears that there might be a time lag of maximum .4 second for the DFDR parameter to show the TLA position. Therefore, it can be said that the actual TOGA position movement could be at 325.6 second. If we further consider 1 second time difference for CVR-DFDR co-relation still 1.6 second could not be accounted for. However, if CVR-DFDR co-relation made by Canadian Aviation Safety Board, vide CASB document No.EP 36/90 dated 4.6.1990 is accepted then "Hey, we are going down" was

spoken at 323 second. If it is further considered that 1.5 second was lost in uttering the phrase "Hey, we are going down" and if a margin of 1 second time difference is allowed for CVR-DFDR co-relation then it can be said that the thrust levers were moved to TOGA position at 325.5 second. If the time lag of .4 second maximum is subtracted from actual recorded time of DFDR TLA parameter it indicates that the TLA was moved to TOGA position at 326 - .4 = 325.6 second which matches well with the thrust lever movement at 325.5 second as stated above. Therefore, as per the second analysis, although the TL was moved when CM1 said "Hey, we .... " it actually reached TOGA position at 325.5 second. It may also be construed that the thrust levers were moved by CM2 to TOGA position while CM1 was saying "Hey, ... " and moving his sidestick to full back position. Although the action was delayed, this theory does not materially improve the situation as the engine power was already in the process of building up since alpha floor was already activated at 323.9 second. This theory only supports that CM1 acted as he said "Hey, we .... ". But this theory does not explain when and how sidestick was moved unless it was presumed that both sidestick and thrust levers were moved simultaneously while saying, "Hey,........" and that sidestick and throttle movement sounds coincided. Also it does not explain the chime coming at DFDR second 326 in the CVR.

HARD LANDING vs. SOFT TOUCH DOWN AT FIRST CONTACT WITH GROUND

4. First touch down on the golf course left a continuous print of MLG wheel tyre marks for about 82 feet . At appropriate speed it was calculated and established that the aircraft remained in contact with the ground for about .42 second. Then it bounced as indicated by discontinuity of tyre marks for about 234 feet and touched the Golf Course near 17th hole for the second time. Time taken by the aircraft to reach this point works out to about 1.5 second from first touch down. Here first main wheel touched, then nose wheel touched. Main wheel contact with the ground was for 102 feet but nose wheel contact for 30 feet only. The soil was softer here and the tyre marks were deep. After the second impact the RH engine grazed a raised portion of the ground for about 40 feet. The aircraft thereafter jumped off the ground for a distance of about 43 feet till it collided with the embankment. According to Mr. Weaver of I.A.E, time between first impact and hitting the embankment is more than 2 second . At ground speed 118 kt. i.e. 201 feet/second time to cover the distance of about 475 feet works to 2.3 second vide page 6 of his deposition. The collision of the aircraft with the embankment was very hard and it caused the engines to drop down,

nose and main landing gear to shear off and front bottom fuselage to be crushed near electric and electronic compartment.

5. Regarding nature of impact at first touch down there were two divergent views. Indian Airlies, Indian Commercial Pilots Association and Air Passengers Association, Madras felt the first touch down was soft and cannot in any case cause a 6.125 g load. On the other hand Airbus Industrie - I.A.E. felt it was a very hard landing encountering a normal acceleration of 6.125 g.

6. Parties in favour of soft landing quoted two reasons:

1. Light tyre mark on the ground and
2. Passenger/airhostess statements.

Airbus Industrie and I.A.E. put up technical justification to prove their point of view of hard landing:

To decide whether a landing is soft or hard, the following points have to be considered:-

1. Strength of the subsoil
2. Ground marks
3. Rate of descent or vertical speed
4. Normal acceleration
5. Passenger witness
6. Matching of DFDR parameters.

(1) Strength of the subsoil:

Subsoil testing of the Golf Course near first and second impact was carried out by an independent Organisation and it has reported that the soil near first impact was much harder than the soil near second impact. Therefore, a hard landing would not make a deep impressions at the first impact point. Since the soil was softer, the second impact point registered deep groove mark which was not at all indicative of hard impact.

(2) Ground marks:

As stated above ground marks did not prove that first impact was soft.

(3) Rate of descent or vertical speed:

From Ex.95 it is observed that the rate of descent or vertical speed before first impact was in excess of 20 feet/second and from GPWS sink rate warning it works out to 16 feet/second to 25 feet/second. Therefore, it was definitely more than 16 feet/second. Capt.Guyot in page 9/10 of his deposition stated that as per Airbus Industrie design office the design limit load of A-320 aircraft corresponds to a vertical velocity on landing of 10 feet/second. Ultimate load is 1.5 x 10 = 15 feet/second. Therefore, vertical velocity of 16 feet/second was in excess of ultimate design load and so the first landing was very hard. He further stated that corresponding to a normal acceleration of 6.125 g at the C.G., the g effect near cockpit was 13g and in the rear part 17g. In page 73 of his deposition, he stated that even if hard landing at first touch down did not disintegrate the structure, it is considered that some internal damage is possible such as rupture of pipelines, disconnection of electrical wire in joints, damage to components and cracks in metal parts, etc.

To verify Capt.Guyot's statement "Aircraft Structure" by PEERY which is a standard book on aircraft structure was consulted. In page 52 it has been stated that if landing shock occurs for a short interval of time, it may be less injurious to the structure and less disagreeable to the passengers than a sustained load would be. This explains that even if the normal acceleration exceeds the design load it is not necessary that the structure will disintegrate. Nature of distribution of load over the structure has to be considered. In page 60 it has been shown in the same book that in the tail portion of aircraft the 'g' effect may be 10 even if the 'g' effect the the C.G. is 3.5. This explains that even if normal acceleration at the C.G. of VT-EPN was 6.125 it is possible that in the cockpit it could be 13 or in the tail portion it could be 17.

(4) Normal acceleration:

During normal flight envelope the 'g' effect is around 1. Scrutiny of Normal acceleration data of DFDR during last 5 minutes reveal that it was so. In their first letter dated 23-2-1990 to Mr.Khola, Deputy Director General of Civil Aviation, Canadian Aviation Safety Board informed for the first time that normal acceleration signal had experienced expansion and compression distortion after approximate 3/4th of the way through the subframe 329 second. This distortion was due to, they considered, as a result of vibrations induced by the aircraft impact with terrain. Therefore, it is clear that the first impact on the golf course was at the end of subframe 329 and the impact was heavy. CASB subsequently recovered this distorted signal through analysis of the DFDR wave form. Additionally, a portion of a second after reference time 331 was also recovered. Airbus Industrie, vide letter No.AI/EE-S MV/IG 447 0608/90 dated 19-7-1990 intimated that according to their calculation at first touch down impact at the Main Landing Gears was 4.14 'g' and corresponding normal acceleration at the C.C. is 6.125 g. Following the method enunciated in the text book 'Aircraft Structure' by PEERY it has been calculated and found that 'g' alue at the MLG and at the C.G. are matching the Airbus Industrie calculated 'g' values.

The value of normal acceleration recorded in last two readings of 329 second and first two readings of 330 second are 2.78', 6.12, 3.01 and 1.57. These readings recorded by the accelerometer seem to be perfectly in order, since it has gradually increased to a peak value of 6.125 and then reduced gradually.

(5) Passenger witness:

Two airhostesses in the rear and two out of three passenger witnesses stated that the landing was normal but one witness Mr.Kumar Nadig who was also a pilot (Private Pilot Licence Holder) and who regularly flies once or twice in a month stated in his deposition that it was quite a hard touch down, too quick and unusually hard impact. Therefore, passengers opinions are at variance on the issue. Considering the valued opinion expressed by the author PEERY of Aircraft Structure' in page 52 that if the landing shock occurs for a short interval of time, it may not be felt by the passengers, it may be stated that passengers witness did not project the correct picture.

(6) Matching of DFDR parameters:

CASB in the introduction to their document No.EP/36/90 dated 4.6.1990 stated in page 3 para 3.3 "The DFDR and the CVR was aligned such that the crash sound on the CVR occurred at reference time 329.8, the time at which an impact occurred on the DFDR as evidenced by the normal acceleration and the distortion of the DFDR wave form signal. This time matched well with the VHF keying and the radio altitude calls by the aircraft". It has also been stated that "the DFDR data, the distorted wave form signal in subframe 329 and the single crash sound on the CVR indicated that only the first impact was recorded and not the second. The recording continued for about one and one half second and then ended, on both recorders, without recording a second impact". This further proves that the first impact was at 329.8 second and it was a heavy impact. It also proved that second impact was not recorded. Additionally, it must be clearly understood that the severity of impact on second touch down following a bounce after first touch down can never be more than that on the first touch down because most of the vertical velocity will be lost after first touch down.

Further, Inspector of Accident during his cross examination clarified in page 34 that "now with the final DFDR data it appears that the 6g has occurred at a place which had been described as a soft touch down". "The impact occurred during last quarter of the seconds of subframe 329 of DFDR".

In this connection comments of CASB, in their reply No.142-1 dated 2-10-1990 addressed to the Court is very pertinent. It says

"As for vertical acceleration which was specifically queried, it appears to follow a believable trend and I think that it is therefore most probably valid, including the value of 6.125 g during the end of subframe 329".

7. Further, a site inspection of the initial touch down area in the golf course within a few days of the date of accident did not reveal much undulations. The surface appeared to be fairly even except for a couple of shallow depressions without sharp edges at the periphery. This was also confirmed by the continuous tyre marks. By any stretch of imagination normal acceleration cannot reach more than 6 g value as a result of flexible and large diameter tyre rolling over such a profile of terrain.

<u>Realiability of DFDR data after first impact :</u>

8. Airbus Industrie in their letter No.AI/E-fs 420.0103/90 dated 4-5-1990 in the last sentence in page 3 first intimated DGCA that "we think that any data retrieved after the first impact cannot be considered as reliable" since the impact with more than 6 g load was well out of any design objective. CASB, in their final report No.EP 36/90 dated 4-6-1990, while giving their assessment of DFDR data stated " the normal acceleration data after subframe 329 suggested that the aircraft was in a bounce, after the first impact, when the recording stopped. The first impact was therefore, considered sufficient to have

caused internal damage to the aircraft which affected the operation of both recorders. After subframe 329, the sidestick pitch controllers for both crew went to exactly the same number (-9.51^{o}). It would be highly coincidental that both sidesticks were moved to the same value. It is considered more likely that the aircraft was "broken" in some manner which caused the system to malfunction". Therefore, malfunction of DFDR recording system including wiring used to carry signals from pickup points (transmitters) of some of the components and systems cannot be ruled out. Under such circumstances some parameters recorded by the DFDR cannot give the true picture or status after initial impact which exceeded 6 g value. Capt.Guyot and Capt.Gordon Corps of Airbus Industrie and Mr.Weaver, Mr.Bolt and Mr.Sunder Venkat of I.A.E. had in their depositions rightly stressed this point. Thus, it is seen that after 329.8 DFDR second when the first impact occurred encountering more than 6g, the following parameters misrepresented the actual values:

(1) Parameter SSPPC and SSPPFO representing both sidestick movements in figure 4 of DFDR parameter listing, showing the same value -9.51^{o} which is highly coincidental and hence improbable.

(2) The engine parameters such as EPR actual which was steadily increasing from DFDR second 324 suddenly came

down at DFDR second 331 which were inconsistent.

(3) Engine 1 EGT came down at 331 second although fuel flow increased substantially.

(4) With correctly operating ELAC-1 transmitting same signal to both elevators, their movements because erratic at 330 second-LH elevator movement -8.89 and RH elevator -17.70 which is absurd.

(5) DFDR normal acceleration parameter did not show any significant g value for the second impact; in fact, after mid 330 second it recorded less than .7 g only.

(6) Hitting the embankment with severe impact did not show any appreciable longitudinal acceleration value.

9. With regard to reliability of DFDR data after first touch down the CASB, in their reply No.142-1 dated 2-10-1990 addressed to the Court stated "The data which follows trends should generally be considered valid, right through to the end of recording". Most of the data, in fact, appears to follow trends (it is not way off). While the data may be considered valid, it is important to realise that, after the impact during subframe 329, the source (signal from the transducer or electronic buzes) of the data may no longer be representing reality, even though the DFDR appears to record a valid word. Asit is likely impossible to determine absolutely, one can only judge the data by the trends it is following and

try to assess it as it relates to accident.

10. Therefore, DFDR parameters after first impact have to be considered with proper judgment and technical reasoning. Only those parameters which are found consistent and following the same trend before and after the impact should be considered acceptable.

Engine power build-up and acceleration:

11. Scrutiny of snag sheets of VT-EPN since its introduction into service did not reveal any significant, major or repetitive defect on the engines. Before take-off from Bombay on IC-605 on 14-2-1990 also there were no engine defects reported either by the pilot or the engineer. During flight no defect on the engine operation, performance or failure to respond to the pilots input were reported as evidenced by absence of any such communication from the aircraft to ATC as required by I.A. Operations Manual Chapter I page 1.20 para 1.3.4.2 item 3.

From the time alpha floor was activated at 323.9 all relevant engine parameters viz. EPR command, fuel flow, EGT, EPR actual and N2 responded properly and increased as recorded in the DFDR (reference to figure 11 and figure 12 of DFDR parameter listing may please be made).

A close agreement between engine simulation and DFDR data in respect of the above parameters demonstrated that the engines behaved normally during acceleration from 323.9 second prior to the first impact at 329.8 second [Please refer to Annexures (1), (2), (3) and (4)].

12. In respect of EPR actual it has been observed that 5 readings recorded in the DFDR before the first impact, when plotted in the acceleration simulation curve, matched well, rather, found better than expected. There was an abrupt deviation from the expected values after the first impact at 329.8 second. Values at 330 and 331 seconds were found inconsistent with the previous trend of the actual curve for which there cannot be any technical reasons other than unrealiability of the DFDR EPR actual data after first impact with more than 6 g loading which has already been discussed earlier in detail.

Even if it is presumed that the engines started malfunctioning for some reasons or the other, it is highly improbable that same type of defect will occur in both engines at the same time to give same type of poor performance i.e. failure to accelerate at the same time as per schedule.

Functional test of EECs at the Makers' facility revealed that the channels that were in control of the engines were functioning properly and test of fault memory dump showed that there were no fault that would have affected normal engine operation. In this connection deposition of Mr.Bolt of I.A.E. in page 7 and also strip investigation and functional test report of EEC may please be referred to.

13. Physical inspection in the crash site, boroscopic inspection and strip investigation of the engines revealed more or less same type of damage. Bent and broken fan and compressor blades in the opposite direction of rotation, metalisation in the burner and shearing of low pressure rotor stub shaft due to high torsion indicated that both the engines were operating at or near take off power before they were dropped after hard impact with the embankment. In this connection engine on-site and strip inspection report may please be seen.

14. Mr.Weaver of I.A.E. in his deposition stated in page 11 that based on the design criteria of the engines the calculated value of the torsional load required to shear the LPC stub shaft structure at full power is minimum 710,000 in lb. To cross check this statement the pertinent calculation sheet was asked for by the Court which was duly forwarded. It showed that the ultimate torque was 719,000 in lb. With the data provided the ultimate torque to shear the stub shaft was recalculated as shown in the text book named "strength of Materials" by Timoshenko published by Van Nostrand. The recalculation worked out to 719,396 in lb. which matched with figure forwarded by I.A.E.

15. Summarising the above it is stated that:

(1) There was no defect in the engines which operated satisfactorily.

(2) Engine parameters recorded by DFDR prior to the first impact at 329.8 second were absolutely normal commensurate with the expected performance.

(3) Relevant DFDR parameter figures concerning engine response to acceleration when plotted against the simulated nominal graph did not show any abnormality EPR actual value, in particular, was little better than expected.

(4) Both engines failing to accelerate at the same time due to any mechanical failure is highly illogical.

(5) Functional test of EEC did not reveal any defect or malfunctioning.

(6) Physical inspection, boroscopic inspection and strip inspection of the engines revealed that they were operating at or near full power when they dropped off the wings.

(7) Nature of damage to the LPC stub shaft of both engines indicated that ultimate design torsional force must have been applied to sheer off the shaft which is possible only if the engines were operating at full power.

From the above it is concluded that the engines responded properly to the acceleration schedule as per specification and were producing almost full power before hitting the embankment.

Second, third and fourth impact:

16. Although many witnesses have stated that the aircraft experienced three impacts, from ground marks it is established that the aircraft actually impacted four times

(1) First impact on the golf course with 6.125 g .

(2) Second impact after bounce near 17th hole on softer ground.

(3) Third impact with the embankment which was very hard and

(4) Fourth impact on the belly on the marshy area which was on the other side of the embankment, nullah and road finally coming to a halt.

In this connection, Capt. Guyot said in his deposition in page 11 "our estimation is that the time lapse between the first touch down and the point where the aircraft finally stopped is about 4 to 5 seconds. The aircraft during this 4 to 5 seconds was experiencing 3 very severe impacts before the final one". By simple calculation with the help of ground speed, the distance and time difference between first and second impact were found to be 316 feet and 1.5 second respectively.

Distance and time difference between second and third impact were 169 feet and .84 second approximate. Both CVR and DFDR stopped functioning just before second impact. Capt.Guyot in page 11 of his deposition said "In this crash both CVR and DFDR go off at about the time of second touch down". He also said in page 39 of his deposition, "on my knowledge the DFDR stops at 1.6 second after first touch down which corresponding roughly to be second touch down". CASB also confirmed this view in their report No.EP 36/90 dated 4.6.1990. It stated that the analysis of the DFDR data and the single crash sound on the CVR indicated that only the first impact was recorded and not the second. The recording continued for one and half second and then ended, on both recorders, without recording a second impact. The normal acceleration data after subframe 329 suggested that the aircraft was in a bounce after the first impact when the recording stopped. The recorder was determined to have stopped at 331

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17. After the second impact the aircraft hit the embankment very severely dropping both engines, breaking nose and main landing gears and crushing front bottom fuselage containing electric and electronic bay. It is most likely that the fire was initiated at this stage due to some short circuit in the electrical net work in the electric and electronic bay. In this condition the aircraft hopped over the embankment, nullah and the road and grazed on the belly over the marshy area before coming to a final rest. There were cracks on the front spar of the RH wing which allowed fuel from RH tank to rush forward due to inertia. This fuel mainly supported the fire. There was extensive fire damage in the front fuselage area ahead of the wings and practically the whole of the fuselage with other structure were consumed by fire.

Co-relation of DFDR and CVR :

18. Digital Flight Data Recorder (DFDR) records VHF keying parameters showing VHF transmissions by the aircraft. When the aircraft transmits this parameter is recorded on the DFDR. The actual transmission is simultaneously recorded on the cockpit voice recorder. DFDR records a time signal which is not available on the CVR. DFDR-CVR co-relation requires expertise. The normal practice is to have a copy of CVR tape was prepared with a time signal recorded on one of the channels. This recorded time will be simultaneously displayed

during the replay for transcription. Timings of the VHF transmissions recorded on CVR were matched with the timings recorded on the DFDR VHF keying to obtain the co-relation. There is absolutely no material to doubt that this method was not adopted either by the DGCA or by the CASB assisted by the American experts (NTSB). It was noticed during co-relation that the speed of the CVR replay was about two percent higher than the DFDR recordings and CVR timings were accordingly corrected.

19. Actual co-relation of CVR and DFDR timings achieved by synchronising the VHF No.1 keying parameter with the transmissions to the ATC showed that the transmissions by the aircraft fell within one second of the VHF keyings except one transmission which was synchronised by about two seconds. Sampling rate of the DFDR for the VHF keying parameter is once every second. The co-relation achieved between the DFDR and CVR, therefore, has an accuracy of about one second. This co-relation by the Inspector of Accident is within one second of the CASB's co-relation except for a couple of readings.

20. CASB in their report No.EP 36/90 dated 4-6-1990 stated in para 3.2 and 3.3 in page 3:

" The CVR tape provided by the Indian Government on Tuesday, April 17, 1990 was played back at the CTAISB Laboratory at its standard speed and it was determined that the 400 hertz aircraft power was displaying as 384 hertz. The CVR was therefore played back 4% faster and a copy tape was made while a simultaneous real time code was written to the copy tape. The time code, co-related to DFDR reference time, is shown on the partial CVR transcript provided in Appexdix 'D'".

21. The DFDR and the CVR were aligned such that the crash sound on the CVR occurred at reference time 329.8, the time at which an impact "occurred on the DFDR as evidenced by the normal acceleration and the distrotion of the DFDR waveform signal. This time matched well with the VHF keying and the radio altitude calls by the aircraft".

/COURT'S OPINION/

There has been a controversy as to the nature of the first touch down and whether 'G' force at that time was 6.125, or whether the said 'G' force is the result of the second impact at the 17th green of the Golf Course or whether the recording of 6.125 in the DFDR was incorrect.

(2) The rival view points are projected in the words of the respective Assessors.

(3) Mr. Goswamy prefers to hold that the 6.125 'G' force is attributable to the first touch down, while Capt. Rao and Capt. Gopal opine that the said 'G' force recorded by the DFDR cannot be referable to any of the touch downs and it is not a correct recording. Divergent views are also expressed regarding the co-relation of CVR-DFDR timings.

(4) I am of the view, whether the co-relation of timing is to be as furnished by CASB or as noted by the two Assessors, does not affect the ultimate conclusion, for the simple reason, that the timing as to the activation of Alpha floor and the movement of the thrust levers were within 8 seconds of the crash from whatever angle the timings are computed. The movement of the thrust levers at this point of time (whether at

324.05 seconds or thereafter at 326 seconds) would not have changed the course of the plane towards the crash. I am of the view that the controversy need not be technically resolved here, for the determination of the <u>basic cause</u> for this crash.

(5) There has been unanimity about the performance of the engines; the ultimate conclusion is that engines behaved satisfactorily. DFDR shows that throttle lever was at Toga position at 326 seconds (as 45°). When performance of engines has been found normal by other process of investigation, EPR values at TF.330 loose significance. A definite answer regarding the timing of 6.125 'G' in no way substantially aids the investigation. It may be an interesting subject for examination by the Scientists and technologists. No other significance of the timing of 6.125 'G' was pointed out during the course of the enquiry, nor in the arguments.

(6) No expert was examined by anyone to establish that the plane's first or the second impact resulted in 6.125 'G'; only certain suggestions were made to the witnesses, without eliciting technical data for investigation.

(7) However, it is necessary to make some observations:

(i) The triggering of Alpha floor is stated to be at 323.1 seconds; at the earliest its activation will be at 323.9 though one cannot be too sure of this time of activation; it might have been at 324.3 seconds also (considering a delay of 1.2 seconds for activation); if so, by TF.329.9, it will be 5.6 seconds from the time of activation of Alpha floor. The EPR value should be slightly more than 1.05. If, only movement of throttle levers is considered, then between TF.326 to 329.9, the available time was 3.9 seconds. EPR actual at TF.329 seconds for engine-1 is 1.05 and for engine-2 it is 1.06; at TF.330 it is recorded as 1.07 and 1.07 respectively. These figures substantially satisfy the acceleration curve (Ex.105), wherein it is indicated that at 5.5 seconds, EPR ought to be 1.05 and at 6 seconds 1.08.

(ii) In the written arguments submitted by Indian Airlines, the time taken to estimate the EPR value at 6 seconds is taken with effect from 323 seconds; this is clearly an erroneous basis. The Alpha floor triggering, at the earliest, will be 323.9 seconds (and I think it may perhaps be at 324.3 seconds or even later, in view of the uncertain knowledge as to this delay, exhibited by Airbus Industrie). Therefore, at 329th time frame, engine had not 6 seconds to develop acceleration.

(iii) A momentary impact of 0.42 seconds may not be injurious to the structure and that possibility cannot be ruled out in this case, especially when the plane was new and had not experienced metallic fatigue.

(iv) The passengers and air-hostesses did not feel the first touch down and this may support the theory that the first impact was mild and normal. On the other hand it is said that the first impact on the ground was only for 0.42 seconds, a momentary action and therefore these witnesses did not feel the experience so as to retain the experience in their memory; and that these witnesses have missed one of the touch downs, and have mixed up two impacts as one, which shows that their statements regarding the experience of the touch downs is faulty; they stated that there were only three touch downs in all. It is also said that if at the time of first touch down the plane was in the take off stage, the plane would not have again landed immediately within such a short time, with a heavy force; further, the EPR actual was only 1.05 for engine-1 and 1.06 for engine-2 at TF.329 and therefore engines had no sufficient power and speed to take off at the moment of the first touch down.

(v) Capt. Thergaonkar said in his deposition in page-14 in the last sentence that during normal landing normally 1.25 'G' normal acceleration is obtained. Therefore, if it is presumed that the first touch down was a normal landing, 1.25 'G' would have been recorded at-least twice, since the aircraft was in contact with the ground for 0.42 seconds; normal acceleration is recorded every 1/8th seconds in the DFDR. Thus, if second touch down was hard and experienced 6.125 'G', then 1 to 1.5 seconds earlier than this recording, 1.25 'G' would have been recorded atleast twice. But, perusal of 'G' recording revealed that there was no such recording; it was 1.06 or 1.07 which is normal when the aircraft was in air.

(vi) In the reasoning of Capt. Rao and Capt. Gopal, minute discussion is found as to why 6.125 'G' recording is unacceptable.

(8) Weighty reasons are found in the two sets of rival views.

(9) The touch downs are part of the crash. The cause for the crash developed earlier to the touch downs. In fact, the cause for the crash developed somewhere between DFDR seconds 294 to 321. Therefore, an exact finding on this controversial question of 6.125 'G' by itself cannot give any clue to find out the cause for the crash.

(10) It was pointed out that the first touch down was a soft one as spoken to by the

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passengers and the two air-hostesses; no damage resulted to the plane by the first touch down and by its own force, the plane moved forward climbing up after the first touch down; the plane must have gone up to about 14 to 20 feet, cutting a few trees just before it hit the ground severely near the 17th green of the Golf Course; the 6.125 'G' force was never there either at the first impact or at the time of second impact. This is so because, the plane had 'skip bounced' at the first impact. The relevancy of this question relating to 6.125 'G' force is stated to apply the DFDR readings after 329.8 seconds (i.e., after the first touch down, which was a soft impact); the idea conveyed was that 6.125 recorded by DFDR was spurious or incorrect and that any data given by the DFDR should not be accepted without being corroborated by other sustaining evidence. Arguments were addressed (in the written submissions) about the reliability of DFDR data after the first impact, but not of any earlier recordings. No DFDR recordings for the period 295 seconds to 329.8 seconds were challenged specifically in the Court. Airbus Industrie has sent an explanation dated 19th September, 1990 (after the arguments were over) as to why the DFDR recording for the initial 52 seconds showing auto thrust speed select mode as engaged, when the aircraft was still on the runway. The auto thrust logic, is stated to be in and remains in speed as long as the throttles are not pushed for take-off power selection. The doubt about the DFDR recording for the first 52 seconds was raised by one of the Assessors only for the first time at the time of questioning Capt. Corps and the witness had to get the answer only from Toulouse. In fact, Capt. Gopal has not persued his line of thinking after receipt of this letter as to the validity of DFDR recording during the initial 52 seconds before take-off at Bombay.

(11) The evidence on record explaining the nature of the 'G' force and the basis to infer the impact which resulted in 6.125 'G' is too sketchy; the principles applicable have not been placed before the Court by any of the witnesses. As Indian Airlines also has expressed doubt about this recording, a further research on this question may be conducted by the DGCA and the Indian Airlines, in the light of rival reasons found in the views expressed by the Assessors.

(12) ICPA contended that the reading for the last quarter of time frame 329 never came out in the normal manner even at the CASB; that CASB did not recover some circuits as disclosed from the letter of CASB; this last sub-frame was short of 6 bits. Admittedly the signal for

this time frame had experienced expansion compression and distortion after approximately three quarters of the way through the sub frame; this was assumed to be as a result of vibration and recording of 6.125 'G' had been therefore inferred, having been recorded after approximately 3 quarter of the way from sub-frame 329. In these circumstances, ICPA contended that recording of 6.125 'G' cannot be relied upon as the correct 'G' force exerted at that time frame, having regard to the fact that this acceleration is the 60th word of the second (TF.329) out of 64 words, and as there were distortions at this point of time, this value of 6.125 'G' cannot be relied upon for this time frame. ICPA also points out that CASB had revised the data subsequently, but not considered by the Inspector of Accident (Ex.115 is the letter of CASB dated 23-2-1990 written to the DGCA; the revised data and the relevant letter of CASB were not marked as an exhibit). Indian Airlines has referred to this controversy also to question the accuracy of the recordings by DFDR after the first impact and from this the EPR values recorded after TF.329.8 was questioned. At the same time, the Indian Airlines contended that if DFDR readings upto the plane's impact with the embankment (i.e., third impact) were to be accepted, EPR values shown are only 1.06 for engine-1 and 1.11 for engine-2 at TF.331; these show how poor and inadequate was the engine response in the engine acceleration in the last crucial seconds. The trend in the written submissions of the Indian Airlines casts doubt on the engine's performance, a very serious matter for the operator of the aircraft to make. During the investigation, its witnesses did not speak anything against the power-build up capacity of the engines; no expert was examined by the Indian Airlines to help the Court to understand this problem of 'G' force.

(13) Indian Airlines, as the operator of this aircraft, should have aided this investigation by examining some experts on this question rather than being satisfied by placing evidence to sustain its case that the aircraft was properly maintained and the pilots were properly trained. However, its learned counsel placed a very analytical and unbiased submissions, which has been quite useful to me to appreciate the various facets of the problems involved in this investigation.

(14) Capt. Gupta in his evidence has explained the nature of 'G' force thus:

> "At the time of normal landing the 'G' force could be anywhere to an extent of 1.0 to 1.05 value. At 1.5 'G' cannot be called a hard landing. I cannot say what could be the 'G' value on a hard landing. While approaching, the 'G' value in normal

circumstances should not be more than 1.5. Any time when 'G' value is more than 1.5 does not necessarily indicate that the aircraft is on the ground. The load factors on the aircraft at the time manoeuvring have direct relation to the 'G' values. The load factors are referred in terms of the pressure, the lift, the surface and the weight of the aircraft. The pressure means the air pressure. It is difficult to explain the concept of lift in simple terms. The concept of surface does not mean that it is on land, it will only conclude the surface area of the aircraft. So far in my experience I have not exceeded the 'G' limits during any of the approaches on A.320 aircraft. The values of 'G' force is only reflected in the aircraft if it exceeds out of the limits of 0.7 to 1.25. There will not be any indication of the 'G' force when it is between 0.7 and 1.25. This is reflected on the Ecam and where time is reflected will disappears and 'G' value will appear in amber. I repeat any 'G' force indication or value can never indicate whether the aircraft is in the air or on ground under all possible circumstances."

Cant. Guyot (witness for Airbus Industrie) has given his concept of this force:

"According to me the soft landing is landing with a vertical velocity I would say between 2 and 4 ft. per second. I have a record of the soft landing of the VT-EPN aircraft, which was recorded on the DFDR, during its flight No.6 prior to the accident. It is marked as Ex.94, where the normal acceleration was a maximum value of 1.10938 'G'. At the time of accident the vertical speed was atleast 16 ft. per second is revealed by the DFDR and the derivation is explained in the document now produced by me (Ex.95). Taking in account the pressure altitude evolution between time 324 to 329 we find an average vertical speed, which is in excess of 20 ft. per second and what is said in this document is that the value corresponding to time 329 cannot be taken into account because the pressure altitude is recorded in sub-frame 64 which means at the end of the second 329

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when the aircraft has already touch down. I experienced twice heavy landing earlier during my test flights. The second one I experienced was during A.320 flight testing. During this second flight testing the relationship between vertical speed and 'G' was 9 ft. per second related to 3.6 'G'. The CVR also independently indicates the high rate of descent at the time of touch down - vide: CVR page 17, 2 seconds prior to the crash there is the first sink rate warning, again on the next page there was further sink rate warning and in the note Ex.95 this is explained; the sink rate warning activation conditions are attached to the note Ex.95 are showing that very close to the ground, the vertical speed conditions were upto between 1000 and 1500 ft. per minute."

Again, he said:

"I think that the first touch down was between time 329.7 and 329.8. It is correct that the first impact was at 6.125 'G' force.

Q: Refer to DFDR flight parameters - it is not correct that at 329.8 seconds the impact was 2.78 'G' ?

A: Thefirst impact is immediately before the time corresponding to 2.78125 'G' that means corresponding to time 329.75 or 329.8.

Q: Explain why 3.01563 has appeared at 330 ?

A: After the peak of vertical acceleration which could have exceeded 6.125 'G' the vertical acceleration is decreasing as the aircraft is starting to bounce.

Q: The initial touch down of 6.125 'G' was in excess of the design limit of the aircraft ?

A: Yes. As I already stated.

Q: At such an impact even if it does not lead to the structure disintegrating, it is possible that internal damage such as rupture of pipeline, disconnection of electrical wire in joints, damage to components and cracks in metal parts might have taken place ?

A: Yes.

Q: What made the plane to roll for about 80 feet after the first impact instead of bouncing ?

A: It was rolling for about .4 seconds that means less than half a second which means that the bouncing was quite immediate."

Then, further, he was questioned about the possibility of first touch down being a soft one. The relevant questions and answers were:

Q: You have indicated that this aircraft would have atleast 16 ft. per second vertical velocity to record 6.125 'G' ?

A: Yes.

Q: This would be very close to a rate of descent of 1000 ft. per minute at the time of first touch down, Will this statement is correct ?

A: Yes.

Q: As explained earlier if there is a sudden rise of the ground of only 3 inches in a distance of 4½ ft. you can get a value of 6.125 'G' recorded on the DFDR. Could this not have happened in this touch down. Did you consider these factors when you confirm that the 'G' values were correct ?

A: We considered this factor but we did not think that the undulation of the ground was such that as the one you are indicating.

Q: Coming back to Ex.94 you have stated that a rough run way surface would give you increased 'G' values. Could not a definite fairly deep undulation as indicated in this photograph 46(5) caused a very high increase in the 'G' value ?

A: The only way to know how deep is that kind of depression is to have had after the crash a very accurate measurement by specialist people of the topographic measures of the ground in the Golf Course. Anyway, it is provident that the aeroplane had a very high vertical speed at the touch down which is consistent with the previous values of a hard landing which was recorded in Toulouse.

Q: Do you mean to say that the expert team from Airbus Industrie which visited the crash site did not take this into cognizance before coming to a conclusion ?

A: I do not say so.

Q: Please refer to fig. 4 page 28. Please look at the elevator's position commencing from the right elevator at time frame 328 till the right elevator at time frame 330. Both side sticks were held fully back, which was the maximum the

the pilot could do under the situation. I wish to suggest to you that this elevator movement has been absolutely correct has had proper effect and has arrested the rate of sink just before the touch down and the aircraft would have touched down at a very low rate of sink with the 'G' increase is recorded only due to the severe undulation of the ground. This has been confirmed by the surviving experienced air-hostesses and some passengers.

A: I do not agree with that.

Q: I would also like to suggest that any rotation of the aircraft will induce a positive 'G' and that is what has caused this aircraft to go up into the air again, after the first touch down and because of lack of speed and in addition the landing mode the aircraft hit the ground again hard just prior to the impact to the embankment ?

A: I do not agree with that. The aircraft due to the touch down at a high vertical speed, had probably very strong pitch down movements at the time of the touch down and its very low speed he had at this time, he was unable to compensate the pitch movements by a normal rotation and the aircraft was bouncing."

Here during the course of recording the evidence, for the first time on 26th July 1990 I find a suggestion by one of the Assessors in his questions, the reasons for his opinion that the first touch down was a soft one. Capt. Gopal disclosed his doubts and it was for the Airbus Industrie to clear it. A mere assertion by a witness is not proving any technological fact.

(15) This witness was further questioned by reference to photographs of the crash site by pointing out that from ground markings, it has to be inferred that landing gears did not suffer any distortion. Throughout the investigation I understood this controversy about 6.125 'G' force as relevant only to find out the accelerating characteristics of the engines; its relevancy otherwise was not known to me. If it has a bearing on any other question and has a significance in considering any other possibility, then I am of the view, it is too late to consider such a possibility.

CVR-DFDR CO-RELATION.

(16) The sheets depicting the graphic analysis of the click sound prepared at NAL were placed as part of court records. On 1st August, 1990 a letter was issued to all the participants in this connection. This analysis was through ultra-violet (U.V) recording. I expected, atleast, Airbus Industrie to take up the clues and get the sound analysed scientifically so that the Court would be provided with another opinion for comparison. Airbus Industrie have taken a negative attitude on this question, for reasons best known to them. No independent attempt was made by Airbus Industrie to have this sound analysed scientifically. The mode and manner of analysis done at NAL was made known to all by placing the papers as part of Court records. This analysis is relevant, mainly to identify the click sound.

(17) In case the thrust lever movement caused the sound, recorded in between the words "Hey we are going down", the timing given to the said expression by CASB will have to be slightly shifted by a second, but that in no way materially affects the ultimate conclusion, as is clear from the two rival sets of reasonings.

(18) According to the revised co-relation shown in the opinion of M/s. Capt. Rao and Capt. Gopal, CM.1 asked for "700 feet rate of descent" between 292 to 293.5 seconds. If CM.2 had

actually attempted to set the speed of 700 feet rate of descent, immediately thereafter, the timing of such selection will be 294 seconds, at a time, when the plane was in Alt* phase. In case CM.2 had not noticed the Alt* phase, or failed to follow the procedure applicable to the Alt* phase, his selection of 700 feet of descent rate would be a futile exercise. To this extent the revised co-relation made by the two Assessors has some bearing on the situation to be found out by the Court during the first phase of the crucial seconds. Similarly it has relevancy in the context of identifying the exact timing of the crash sounds.

(19) The revised timings made by the two Assessors were not before the Court at the time of the actual enquiry and the arguments; the mode adopted to dissect the timings and co-relate them could not be tested by the participants. Such an examination is possible only if the participants knew of it and had opportunity to challenge it. Therefore, I am of the opinion that this co-relation of the timings made by the two learned Assessors cannot be the sole basis for any decision by me.

PART IV

CHAPTER - 3

THE CRUCIAL SECONDS AND THE CRASH

1. Some of the controversial events are found after 292 DFDR seconds and it can safely be said that the problem of finding out the cause for the crash commences at or about the time CM1 said "O.K. 700 rate of descent". It is after this time the plane seems to have gone into idle open descent mode, which was noticed by CM2 at about 305 seconds. What made the plane to go into this mode? Why spped mode was not selected or attained; when and how did the pilots react and resorted to remedial action? are some of the questions to be answered. Here again, one view referred below as 'A' is preferred by M/s. Capt.C.R.S. Rao and Capt. B.S.Gopal and the other point of view 'B' is preferred by Sri.S.G.Goswami. Their respective reasonings reflect the views and the contentions advanced by the concerned participants also.

(1) At DFDR time frame 271, IC 605 was given clearance to land by the Bangalore tower. The wind direction and speed indicated was 120° at 5 kts. Thereafter CM1, (Capt. Fernandez) asked for landing checks and CM2, (Capt. Gopujkar) carried out the landing checks which has been indicated against DFDR time frame 275 seconds. CM2 instructed the cabin crew to take their stations for landing at 286 seconds.

(2) Against DFDR time frame 290 seconds the pressure altitude was 3392 ft., computed air speed 135.78 kts., a ground speed of 144 kts. and the magnetic heading was 88.24°. The engines were at idle and the SSPPC was 1.50 which was very close to the neutral position. The pitch altitude was 0.70°.

(3) The elevation of the threshold of R/W 09 at Bangalore is 2872 ft. The R/W rises steeply. The elevation of the Aerodrome Reference Point (ARP), which is near the apron 1 (where Indian Airlines aircraft normally park) is 2914 ft. This is an increase of 42 ft. above the 09 threshold elevation. Assuming that the elevation of the R/W at a parallel location to the

ARP as 2914 ft., it would mean an increase of 42 ft. in about 4000 ft. of R/W. Normally a narrow body jet transport aircraft like the A-320 is expected to touchdown between 1000 to 1500 ft. from the beginning of the R/W. Assuming the mean increase in height in this zone is approximately 18 ft. from threshold, the elevation in the touchdown area would be 2890 ft.

(4) The pressure altitude against DFDR time frame 290 would be at time frame 291 as it is recorded in word 64. At this point the aircraft was close to 500 ft. above the touchdown zone elevation. The speed was 4 kts. above the required magenta speed of 132 kts. and the heading was correct. The magnetic orientation of R/W 09 is 088°.

(5) Assuming an average ground speed of 130 kts. [(144+116)/2], the aircraft would have been horizontally about 6900 ft. before the second impact point. The impressions of the second impact point are approximately 1980 ft. from the threshold of the R/W. Considering the mean touchdown zone of 1250 ft. from the beginning of the R/W 09, the horizontal

distance of the aircraft from the expected touchdown point at DFDR time frame 291 would have been 6900+1980+1250=10130 ft. This would be equivalent to approximately 1.7 nautical miles. On a normal 3^{o} approach angle the rate of descent would be 300 ft. per mile which would correspond to 500 ft. at this distance from the touchdown point. The aircraft was at the correct height at DFDR time frame 291 seconds on a correct heading proceeding towards R/W 09 with a computed airspeed of just 4 kts. above the required approach speed of 132 kts. Aircraft was in a position to continue for a very safe approach and landing at this point of time; in fact there has been no serious controversy on this point.

(6) The revised DFDR data, (flight discretes 5) has shown auto pilot altitude capture from 292.766 to 294.766 seconds (i.e. Alt. Star phase). As per CASB (the corelated timings amended by CASB), at Time Frame 293.9, CM1 called out; "OK 700 ft. rate of descent" (According to M/s. Capt. Rao and Capt. Gopal, this time frame ought to be between 292 and 293.3 seconds). Thereafter CM2 has called "Missed approach is....."; CASB has allotted the timing of

293.9 seconds for this statement, while the two Assessors opine this to be between 294.9 and 295.3 seconds. CM2 did not continue the words regarding missed approach because of the ATC transmission giving airfield information, as it is a normal practice for a pilot to stop talking whenever there is an ATC transmission.

(7) From DFDR revised data fig.9, the auto throttle speed select discrete which was showing 1 against time frame 294 has changed to 0 against - T.F. 295. This is recorded on word 63. The change over of auto throttle speed select and the auto pilot altitude capture have to be analysed here:

Exhibit 111 was an affidavit by Capt. Gordon Corps of Airbus Industrie, this was filed on 25.7.90.

The theory of Airbus Industrie for this time frame, as indicated in pages 8 and 9 of this Exhibit from question 29 to answer 33, are reproduced below:

Q29. At time 35 to crash CM1 says "OK 700 feet rate of descent"; Why?

Ans. By reference to the profile shown in Annexure 'C' it is clear that he was just crossing a 3 degree slope at about this time. It was a correct change in the vertical speed mode to maintain a 3 degree slope.

Q30. But was the aircraft still in the vertical speed mode?

Ans: No, it had changed to alt star at time 36.

Q31. So could vertical speed have been reset?

Ans: Yes. but it was not.

Q32. What in fact happened?

Ans: At about the same time CM2 says "Missed approach is ah......h........h". As he says this, he takes the altitude knob and winds it up towards 6000, but because of alt star mode the system changes to Climb/Open Climb. The aircraft is commanded to climb. CM2 does not want that and so, in order to get the FD to show a fly down command again and to get the thrust reduced again, he again makes a "wrist flick" on the altitude knob, setting a level below ground level and reintroducing Idle/Open Descent. Now he has made a mistake and he realises it. The altitude knob was originally at 3200 feet. If he had wound it up a few hundred feet and then flicked it back down again, he could have set about 2000 feet in the FCU window.

Q33. Why do you know that this is what he did?

Ans: As explained by Mr. Guyot, this is the only way that the EPR command trace could be "humped" as it is between 38 and about 26 seconds to crash.

(8) EPR command of engines 1 and 2 at DFDR time frame 292 were 1.00 and 1.00. They are recorded on words 34 and 42. At 294 seconds it was 1.01 and 1.00 respectively. At 296 seconds it was 1.01 and 1.01. At 298 and 300 seconds it was 1.02 and 1.02. At 302 seconds it was 1.01 and 1.01. At 304, 1.00 and 1.00. At 306, 0.99 and 0.99. At 308 it was 0.98 and 0.98. The minimum command reached was at 310 and it was 0.97 and 0.97.

(9) DFDR gives both EPR command and EPR Actuals. EPR command is registered immediately as per the order given to the engines. Therefore if higher altitude had been selected by CM2, EPR command value should have registered a higher value, representing the climb value. EPR actual is registered only when engines develop power after acceleration in case of CLIMB and this will be subsequent to EPR command.

(10) If CM2 had dialed the altitude knob towards 6000 during ALT STAR mode, the system would

change to Climb/Open Climb. If this had occured, EPR command should have immediately registered the Climb-limit EPR. For example, at Bombay after take off during climb through 3000 ft. EPR command value was 1.29. Actual EPR of the engines would be slow to pick up and accelerate gradually. The thrust lever angle of engine 1 is in DFDR revised data fig.10 against word 50. The thrust lever angle of engine 2 is in the original DFDR data fig.11 and recorded in word 58.

(11) The Alpha Floor was triggered at DFDR seconds 323.1 and activated at 323.9. There has been no serious controversy of this point. This is taking into consideration the minimum of 0.8 seconds delay in activation. The delay could be upto 1.2 seconds also. EPR command of engine 1 and engine 2 at DFDR seconds 324.531 and 324.656 respectively have recorded 1.27 and 1.27. Alpha floor gives TOGA command and the next recording during time frame 326 has shown the figs. of 1.41 and 1.41. If Alpha floor activation is taken as at 323.9 seconds, then EPR command has registered a value of 1.27 in 0.6 seconds on its way up. If maximum delay of 1.2 seconds is considered, alpha floor activation would be at 324.3 seconds and

EPR command recording 1.27 would then be just 0.2 seconds later.

(12)(a) DFDR data of Indian Airlines A-320 VT-EPN which had carried out touch and go landings and a go around on 27-2-1990 has been made available to the Court by the office of the DGCA. The following were the inferences of the two pilot Assessors:-

Figs. 1 to 4 refer to touch and go No.1. The parameters being looked into, would be TLA engine 1 (word 50), TLA engine 2 (word 58) EPR command engine 1 (word 34), EPR command engine 2 (word 42), EPR actual engine 1 (word 2) and EPR actual engine 2 (word 10) against DFDR time frames. These are available in figs. 1 and 2. At time frame 2448 TLA engine 1 and 2, EPR command engine 1 and 2 and EPR actual engine 1 and 2 were all at idle. AT DFDR seconds 2450.781, TLA 1 was 11.95° and at 2450.906, TLA 2 was at 25.66°. This indicated a continued movement of thrust levers from idle to TOGA as the next recording at 2452 showed both TLA 1 and 2 at 45° which is TOGA. Looking at EPR command values, at time 2450.531 seconds EPR command engine 1 was at 1.33 and at 2450.656 seconds EPR command engine 2 was at 1.39. The increase of EPR actual of both engines was slower. EPR command has moved almost immediately to the maximum ordered thrust corresponding to thrust lever angles. Fuel flow increase has started at 2449 time frame only. Against time frame 2470, both thrust levers were at TOGA and EPR command was at 1.38. Against time frame 2472, both thrust levers have been brought back to MCT (maximum continuous thrust) position showing TLA angles of 34.8 for engine 1 and 34.1. for engine 2. EPR commands have dropped immediately to 1.32. As auto thrust control would be active in position MCT and below, the EPR subsequently have varied both in this position and the climb position. Considering touch and go No. 2 (fig. 5 to 8), similar immediate increase and decrease of EPR command corresponding to thrust lever position can be seen against time frames 2782, 2784, 2816, 2818 and 2820. Against 2818 it must be remembered that EPR commands 1 and 2 have been recorded before the thrust lever angles 1 and 2 hence the figures correlate. Considering the go around (figs. 9 to 12), it is noted that a simulated engine failure of engine No. 2 has occurred a few seconds after TOGA had been applied for the go around. The power was restored to climb power after about 20 seconds. At time frame 3150, TLA 1 and TLA 2 were in the climb detent recorded as 24.61°. As auto thrust was active during approach, EPR command and

EPR actual of both engines were at 1.07. At 3152 we see both TLA at 45° (i.e. TOGA) and EPR command has immediately recorded 1.39 on both engines. EPR actuals of both engines still remained at 1.07 at that time frame but showed an increase at 3153. TLA engine 2 which was at 45° at 3162 seconds has been moved to idle position (0.35°) as recorded at 3164. EPR command engine 2 has immediately dropped to 1.00. EPR actual which was 1.38 at time 3162 showed 1.37 at time 3163 and 1.24 at time 3164. Looking at fig.11 of the go around and comparing fuel flow of engine 1 and 2 at 3163 we find deceleration order has already been given at 3163. Considering time frames 3180 and 3182, TLA 2 has moved from idle (0.35°) to climb (24.96°). EPR command has jumped from 0.98 to 1.29. Actual EPR has remained at 0.99 at both these times and has increased only later. Similarly at time frames 3190 and 3192 seconds, TLA 1 has moved from TOGA to climb, the EPR command engine 1 has changed from 1.39 to 1.29 but EPR actual has remained at 1.40 and reduced later to auto thrust command.

(12)(b) The DFDR data of the flight test carried out by Airbus Industrie at Toulouse on

20.6.1990 show the following:-

(i) The T 1 series data are the repeat of the Bangalore scenario. Referring to page T 1.5.4, EPR command at 15.10.12 was 0.977 for engine 1 and 0.977 for engine 2. The next recording at 15.10.14 showed EPR command 1.305 for both engines and at 15.10.16, the TOGA command of 1.422 has been recorded for both engines. From page T 1.2.7 SSPPC was 13.27^{o} at time 15.10.12 and 14.94^{o} at time 15.10.13. Alpha floor would have been triggered between these two time frames. EPR command 1 has registered 1.305 at 15 10 14.531 seconds. An immediate EPR command increase has been recorded. A short while later at time 15.11.04 EPR command engine 1 was 1.430 in word 34. Immediately thereafter TLA engine 1 at word 50 has shown 36.92^{o} compared to 44.66^{o} two seconds earlier. This is from page T 1.12.5. At 15.11.06, the TLA engine 1 was at 24.97^{o} which appears to be the climb detent on that aircraft and EPR command engine 1 has shown 1.309. Again this has shown that EPR command's increase and decrease are almost immediate. The EPR command was 1.305 which has remained constant till 15.11.16 indicating that this was the climb EPR value under those conditions.

Later thrust modulation has started.

(ii) During the second profile under direct law referring to page T 2.12.2 at 15.16.44 TLA engine 1 was 0.32° indicating idle position. EPR command engine 1 was 0.996. At 15.16.46 TLA engine 1 is at 44.66° and EPR command has registered 1.422. This would be the TOGA power.

(iii) Looking at page T 3.12.3, TLA engine 1 was 0.32° at 15.23.32 with EPR command at 0.996. At 15.23.34 TLA engine 1 was 42.55° and EPR command engine 1 was at 1.324. The next recording at 15.23.36, TLA engine 1 was at 44.66° and EPR command engine 1 was 1.422. At time frame 15.23.34 the EPR command was recorded against word 34 which was earlier than TLA engine 1 at word 50.

(iv) Referring to page T 3.12.5 another engine acceleration has been carried out at time 15.24.40. TLA engine 1 was 0.32° with EPR command engine 1 at 0.996. At 15.24.42 TLA engine 1 was at 44.66° and EPR command engine 1 was at 1.418.

(v) In all these above engine accelerations the EPR actuals have responded slowly though EPR command has registered immediately. From the above it follows that whenever a limit thrust order is given EPR command reflects that order immediately. Climb/Open Climb is a thrust mode. Immediately this order is given, EPR command would register the value of Climb thrust. When aircraft starts climbing and altitude capture occurs the thrust modulation would commence. Similarily idle open descent is a thrust mode where idle thrust is ordered. The EPR command should register the order immediately though EPR actual may lag behind. EPR command would start modulating again on altitude caputre (or Alt Star).

(13) In case of VT-EPN, at 294 seconds altitude capture phase has ended and auto thrust speed select has shown zero at 295. If the theory that CM2 had moved the altitude towards 6000 during ALT STAR and Climb/Open Climb had engaged, EPR command should have registered Climb EPR under those conditions. This would have been close to 1.28 to 1.30.

(14) VT-EPN has shown a slow increase in EPR command which is matched by the EPR

actuals. EPR command which was 1.01 for engine 1 and 1.00 for engine 2 at DFDR seconds of 294 has only gone up to 1.02 for both engines at DFDR time of 298 and it has remained constant at DFDR time of 300 seconds after which the EPR command has slowly reduced. If a "wrist flick" had been done selecting a very low altitude as explained by Airbus Industrie after Climb/Open Climb, the EPR command should have immediately changed to 0.98 or 0.97 on both engines from the climb thrust EPR command. This has not occurred. The Airbus theory of these modes namely CLIMB/OPEN CLIMB and IDLE/OPEN DESCENT having occurred cannot be accepted.

(15) The change of auto thrust speed select discrete cannot be accepted with certainty.

Airbus Industrie in its letter AI/E FS 420.0208/90 of September 19th 1990 has shown Open Climb and Open Descent as thrust modes. On VT-EPN the thrust was modulating during the times in question. When you look at the entire accident flight data, whenever the auto throttle speed select has shown zero indicating a thrust mode, the EPR command engine 1 has been at a constant thrust value. This has been shown till time 2637 seconds after which the climb schedule has been changed. The EPR command is modulated during the cruise and during descent it held a fairly steady value. It must be remembered during descent until slats extension minimum idle would be the criteria and this value would depend upon the ECS demand. After slats extension, idle open descent will order approach idle.

(16) From fig.9 and fig.11 of the revised DFDR data of VT-EPN, auto thrust speed select discrete has changed from 0 to 1 at time 274 seconds. At 248 seconds EPR command of both engines have changed from 0.96 to 1.01 and at 250 the EPR command was 1.00 on both engines and later it decreased to 0.98 and 0.96. The EPR actuals increased to 1.00 at 250 and return to 0.99 at 254 on both engines. Similarly EPR command has shown an increase at time frame 278 and auto thrust speed select discrete was showing 1. All this was during the period when the aircraft was descending with vertical speed selected at -1000 fpm (rate of descent of 1000 feet per minute). From fig.2 we find that the rate of descent which was 1410 fpm at 246 was reduced to 1090 fpm at 248 after which it again increased to over 1600 fpm at 252. Similarly the rate of descent which was 1410 fpm at 277 was reduced to 1090 fpm

at 278 and again increased to 1410 fpm at 279. From the CVR we know that vertical speed had been selected and hence it is confirmed that during these time frames vertical speed was active. This is a thrust modulating speed/vertical speed mode and the thrust would adjust to maintain speed. If rate of descent is reduced, more thrust would be needed to maintain speed. Corresponding to the reduced rate of descent, the EPR command has increased followed by EPR actual and later when the rate of descent was increased, the EPR command and EPR actual have decreased. At time frame 282 though rate of descent had been decreased to 961 fpm, similar reaction on EPR command has not been observed, but fig.1 revised data shows that at that point the CAS had increased by a few knots whereby the thrust requirement was offset by the speed reduction requirement. The slight increase and reduction of EPR command and EPR actual correlates with auto thrust speed mode being active at the time frames mentioned.

(17) EPR command indicating either the climb value or the idle value at time frames

295 to 304 to indicate the engagement of Climb/Open Climb or Idle/Open Descent mode is not found. In case the auto thrust speed select discrete is considered faulty, and if 700 ft. per minute rate of descent is assumed to have been selected by CM2, inference is, during time frame 295 aircraft has left pressure altitude of 3300 ft. This would have been the altitude selected by the pilots as the MDA was 3280 as per the Indian Airlines aerodrome operating minima chart for Bangalore. ALT STAR would no longer be available. The slight increase in the EPR, both command and actual, to 1.02 would correlate with a reduced rate of descent to get on to the normal approach angle. At that stage the CAS was slowly dropping towards the target of 132 kts. Aircraft having a tailwind component would need a slightly higher rate of descent to maintain the normal approach path. This possibility can only be explained upto DFDR time frame of 298 or 299 wherein the CAS was close to the target speed (allowing for error of 1 kt. in CAS recording).

(18) After the auto call outs of Radio Altitude 400 and 300 ft, CM2 suddenly announced at about 305 seconds, "you are descending on idle open descent ah all this time." From

the tone it appears that it was a surprised type of remark. The tone does not indicate that it was a sarcastic remark. This call indicates the engagement of Idle/open descent around 304 or 305 seconds. CM2 at about time frame 308.9 asked CM1, "you want the FDs OFF now?" CM1 answered, "Yah" at 309 or 310 and again he said at 311.7 second "OK, I have already put it off." From this conversation it is natural to presume that CM1 put his FD off somewhere between this conversation. But FMGC used FD mode has already shown '0' at 307 seconds. This was one of the parameters used by Airbus Industrie to say FD 1 had been put off.
If CM1 had put off the FD earlier he would not normally say, "Yah " and "OK, I already put it off", but he would have immediately answered; "I have already put it off".
At about 313 CM2 finding that his flight director had not been put off by CM1 who had put off the FD on his side, called out "But you did not put off mine". This call appears to be natural because whoever puts off the FDs should put off both though normally during manual flight it would be the PNF to do so. (Capt.Fernandez had operated as co-pilot from the time he started line flights until this ill-fated flight where he was CM1). At this stage it was impossible to expect that CM2 would not have tried to put off his flight direc-

tor. If he had tried, there is a possibility that the FD may not have gone off due to proper contact not having been made on the FD push button.

(19) Normally any pilot would look at the mode annunciation on the FMA to look for the mode change that was anticipated. In this case the anticipated change was from Idle/Open Descent to Speed. As this did not occur on the FMA CM2 must have been perplexed. Even if FDs are "OFF" and if auto pilot is "ON" the mode annunciator would have remained. During these few seconds the 200 ft. call has come between 316 and 317 and CM2 must have looked at the auto pilot indications both on the FCU and on the FMA and instinctly called, while looking at these things to say, "You are on auto pilot still."

(20) With the type of low speed display that is available in the A-320 it is impossible to imagine that a pilot when he looks at the PFD can overlook the speed of the aircraft having gone below the magenta and the top of the VLS amber strip. Even if the engines were at idle and the pilot pushes the thrust levers forward when the speed tends to drop below V-app i.e., Magenta speed, by the time the thrust comes

on there would be a loss of about 6 to 10 kts.

(21) Capt. Rao and Capt. Gopal have an experience of nearly 40,000 hours of flying as Pilots; they are emphatic when they say that they never saw a pilot or a co-pilot in the airlines, ever dropping speed below V-app without reacting immediately on thrust levers.

(22) Questions were asked of Capt. Gordon Corps during his examination and his answers are as below:

Q: "From your experience as well as experience of other instructors of Airbus Industrie or Aeroformation have you ever come across or heard of a pilot whose airspeed monitoring was such that he could not identify the danger zone from the top of the VLS strip to the V Alpha Max. and permitted the speed to drop from 5 kts. above VLS to V Alpha Max?"

A: "No. I have not found any one who had difficulty in indentifying the low speed scale."

Q: "Do you agree that a pilot of any of these types would try to maintain the speed trend indicator at the absolute minimum, preferably unseen, to fly accurately when he is at the correct desired speed?"

A: "Yes."

Q: "Would you also agree that if the desired speed such as Magenta or V approach is lower than the actual speed of the aircraft and the speed is reducing towards the desired speed, the downward speed indicator would not be a cause for serious concern when auto thrust is on?"

A: "It depends on how long it is."

Q: "Would you agree that if the present speed is above the VLS amber strip there is no cause for serious concern?"

A: "In general, Yes. But it also depends on the sign and the magnitude of the speed trend."

Q: "Would that apply even when auto thrust is on"?

A: "Yes."

Q: "Would you also agree that on these modern glass cockpit aircraft with such speed indications a pilot does not read the speed figure but flies to achieve the desired speed indications?"

A: "I do not know what every pilot does. But I believe that they should be conscious of the indicated speed."

(23) Capt. Steve Last who is the Chairman of IFALPA Aircraft Design & Operations Committee (International Federation of Airline Pilots Associations) presented a paper for Aerotec 1989 at Anahiem, USA in September 1989 on the subject of "A-320 and B 757 on the line: a line pilots perspective." This paper was also discussed at the IFALPA Accident Analysis Committee meeting at London on 17th and 18th October 1989. This paper is Exhibit 144. Para 4 on page 4 is relevant here. It is quoted below:

> "I have to say that I have considerable reservations about the total airspeed/thrust control and monitoring concept on the A-320. This is due to the fact that there is so much reliance on the combination of auto throttle and FMS for speed management. As I stated earlier, the best feature of the airspeed indication is the trend

arrow, which is very compelling. Actual airspeed value is not. The normal operation is in reality to drive the speed trend arrow towards the selected airspeed triangle, and at that point to minimise the trend arrow. During approach with the normal "managed speed", the selected airspeed is driven by the FMS to values which are provided minimum ground speed, and are derived from values inserted by the pilot for surface wind, and actual wind at current altitude.

As a result, the pilot relies totally on the FMS output for approach speed information".

When this was shown to Capt.Gordon Corps during his examination, he said it was an individual opinion of a respected member of the community. However, Capt.Gordon Corps asserted that, with regard to the auto thrust system, at a recent conference at Toulouse, there was unanimous support for the auto thrust system of the A-320.

On 27th June 1990, representatives from IFALPA member associations which operate A-320 had met with Airbus Industrie to discuss the A-320 auto thrust system. Airbus Industrie captains Bernard Ziegler, Piere Baud and Nick Warner gave a presentation on the subject of A-320 auto thrust system and energy awareness. At the time of this presentation S/F/O Capt.Richard Pike, Chairman, New Aircrafts Study Group of British Airline Pilots Association made a presentation on the subject of energy awareness and control in the A-320 and future Airbus products. Later IFALPA pilots user group commentary on the Airbus Industrie presentation has been prepared and sent to various user airlines. These papers were circulated to the participants and these do not confirm Capt.Gordon Corps statement quoted above. Anxiety has been expressed about the auto thrust system and the speed indications. In spite of all this Capt.G.Corps seems to think that "For reasons that none of us will probably ever know it would seem that both of these experienced pilots made a similar mistake at the same time" as stated on page 118.

Two more questions and answers of the witness are necessary to be quoted here:-

Q: "You have been a certification test pilot having flown many different types of aircraft before coming on to the glass cockpit aircraft of Airbus Industrie. The two pilots of the ill-fated flight had flown on earlier technology aircraft safely and efficiently including monitoring speed properly as they were alive to convert on to A-320. Do you have any comment in respect of air speed indicator on the earlier and the present A-310/A-320 aircraft as speed is a primarily parameter of the flight?"

A: "I think that the speed indication on the A-320 is vastly superior to that of conventional aircraft because of the displaying things that were not possible with conventional instruments."

Q: "But still you think as stated in your affidavit the pilots are able to appreciate the loss of speed which they have never done before on the earlier conventional aircraft?"

A: "Aircraft systems are duplicated or triplicated to make them failure tolerant. With regard to the pilots we have two pilots and we have crew procedures which are intended to achieve the same for the human as we can achieve for the systems, for reasons that none of us will probably ever know it would seem that both of these experienced pilots made a similar mistake at the same time".

(24) During these happenings, certainly CM2 was looking at the FMA on the PFD and the FCU to check what has gone wrong, as the mode has not changed. Every time he has looked at the PFD in this period the speed has been well below the desired approach speed. The CAS went below 132 kts at DFDR time 296/297 seconds, 127 kts at 303 seconds, at 313 seconds it was 119 kts and at 329 seconds it was 106 kts. If the magenta speed was 132 the amber arc from VLS would have commenced at 127 and the red bar of V Alpha Max would have been around 111 kts. Normally, the pilots should have seen the speed fall below the magenta triangle and the VLS amber sector. V alpha prot speed as per 1.09.10 pg 9, revision 11, would have been between 115.5 and 118.5. The speed dropped below V alpha prot somewhere between 314 and 318. The range of V alpha floor from the same FCOM page was 112.3 to 115.4 but at

that speed the alpha floor was not triggered. Even if alpha floor had triggered at the lowest speed of the range, i.e., at 112.3 kts, it would have occurred between time frames 319 and 320 giving a margin of over 3 seconds earlier than the actual alpha floor triggering. Information given in this FCOM page is either incorrect or not according to aircraft design.

(25) The speed has dropped 26 kts. below the desired V-app of 132. The speed trend indicator, the VLS, V alpha prot. and V alpha max indications and the magenta speed which can vary depending upon the environmental conditions are so obvious and compelling. If the aircraft speed lubber line is above magenta triangle, the pilot may never read the absolute speed value. So long as the speed is at magenta or above there would be no sense of anxiety at any time.

Until the phrase "Hey we are going down" uttered by CM1 at 324.05 seconds there has been no anxiety and both the pilots have been very calm in all their expressions. Speed had dropped to 106 kts one second earlier and had increased to 109 kts at 324. It is impossible to believe that any pilot would be calm under these conditions. The speed drop from 132 kts to 106 kts has occurred from about 297 seconds to 323 seconds, a period of 26 seconds. A pilot during any approach would be looking at his air speed indicator very very frequently as every pilot would know that it is the parameter to keep the aircraft flying. In spite of nearly 10000 hours of experience each had on earlier technology planes both of them have overlooked speed on conversion to A-320. Again this is impossible to believe. The only way that this phenomenon can be explained is that something has occurred during these vital seconds from about 296 or 297 DFDR time frame which has changed the display of the low speed indications to a lower value. By the very nature of the low speed warning display if the lubber line has been above the Magenta and the Vls, there would be no anxiety. Only when CM1 realised the aircraft was going down he has started instinctively reacting on the side stick control pulling it aft to the full position relying on the alpha floor protection. When engine response was slow he has called out "Hey we are going down" and again instinctively pushed the thrust levers forward. By that time accident had already begun due to non-availability of speed, height and time. Subsequent auto call outs are a result and the concerned call outs have been explained earlier under heading "First Touchdown" and "Second Impact".

(26) Capt.G.Corps stated that he would not be able to tell the EPR readings for this engine or the N1 readings for the CFM 56 engine that would be necessary for an aircraft in configuration full descending at about 1000 ft/mt. with a tail wind of about 10 kts. when, -

(a) speed is established at V-app and

(b) speed is reducing to V-app.

Even though he is a test pilot, as a test pilot presently of Airbus Industrie he would be flying the two types of A-320. This gives room for suspicion that engine power awareness may not be there in a good number of A-320 pilots. May be this could be due to the very limited movement of thrust levers needed to be carried out by the pilots during the normal flight. The thrust levers not moving would be a disadvantage, as when thrust is at idle a pilot would never knew unless he looks at and reads the thrust figure from the engine EPR indication on the ECAM. From VT EPO circuits and landings and the previous landing at Bombay by VT-EPN (ILS approach onto R/W 27), it is learnt that the power of approximately 1.05 EPR is needed during approach with configuration full. 1.05 EPR would be very close to the lower limit. If due to any gusty winds if the speed increases, the thrust would come to idle under auto thrust control and it would not be abnormal. If they were 'moving auto throttles', the pilot would feel through the thrust levers that the thrust was at idle and no pilot would accept such a position on short final even if the speed was slightly higher than V-app.

(27) One side stick control movement is not reflected on the side stick control of the other pilot. Capt.Gopujkar could never have realised that Capt.Fernandez had started pulling the side stick aft from a time as early as 316 seconds. If conventional control column was available with dual control movement even with FLY BY WIRE system, Capt.Gopujkar would have realised this movement irrespective of what he was doing at that time. If

at that time of 316 or for that matter even unto 320 seconds, if the thrust levers had been moved unto TOGA this aircraft would have survived.

(28) From the data available, it is not possible to definitely conclude that IDLE/OPEN DESCENT was due to the selection of a lower altitude by the crew during Alt star . Even Airbus Industrie, when they had to explain the uncommanded CLIMB/OPEN CLIMB engagement during the bird hit incident at Delhi on 10-8-1989 have stated that "the exact reason for CLIMB/OPEN CLIMB mode engagement cannot be determined with available data. FCU selected altitude would be necessary to state definitely on the subject. This data is not available.

(29) We have the identical situation wherein IDLE/OPEN DESCENT mode is engaged at about 304 or 305 secs. and data is not available to identify why.

(30) Similarly there is no data available to explain the reason why two experienced pilots have not expressed any anxiety even though a speed loss of 26 Kts. below Vapp has occurred. We can give only a possibility to explain how it may have occurred. It would be for all concerned authorities to deeply investigate if this

possibility could occur due to a very remote computer malfunction.

(31) The commencement of the chime just before the crash is at DFDR of 327.8 seconds. Airbus Industrie have considered that this chime is due to disconnecting auto throttle by the pilots using the instinctive disconnect buttons.

(32) The time duration between the action of disconnecting auto throttle and the begining of the chime was checked by one of the Assessors, Capt.B.S.Gopal on VT-EPQ on 23-9-1990 at Bombay. The time varied between 0.9 to 1.2 seconds. Whether it was disconnected using the quick disconnect push buttons on the thrust levers or the auto thrust push button on the FCU, the period remained the same. From the co-relation of the CVR after scientific analysis it is observed that the gap between the thrust lever movement and the beginning of the chime on VT-EPN is little more than 3 seconds considering the completion of the thrust lever movement. This does not correspond to what happened on VT-EPQ.

(33) As explained earlier under 2.1 "CVR DFDR CO-RELATION", if thrust lever movement is moved from what has been established to a later time, the aircraft would still be in the air when DFDR has recorded that the aircraft was on the ground. There are many items which

can cause the occurrance of a chime below 800 feet and some of them are not recorded on the DFDR. These items have been indicated by letter No.AI/E FS 420.0102/90 of 3.5.1990 addressed to one of the Assessors, Capt.B.S.Gopal. We are unable to confirm that this chime was due to disconnecting the auto thrust by the pilots using the instinctive disconnect push buttons. Auto throttle would have automatically got disconnected even without any actions on these buttons as the thrust levers were moved from climb to TOGA below 100 feet radio altitude. FCOM 1.11.30, page 61 refers.

(34) The calls of Sink Rate 30, Sink Rate 10 the crash sounds have all been explained earlier under CVR DFDR co-relation, first touch down, second impact, etc.

(35) . From the DFDR data of the previous landing of VT EPN at Bombay, it is observed that the aircraft made a landing on R/W 27. The aircraft touched down, just after DFDR time 6679 seconds as the radio altimeter has shown 0 at that time but we have not seen thrust lever movement to idle against time frame 6679. It is possible that aircraft would have touched down just at the end of this time frame or slightly later. The pilots had used both the auto pilots in command mode. This is only possible if an ILS approach has been carried out. The auto pilots

were disconnected at 6644 just 35 seconds before touch down. The FD discrete has shown that it was "ON" throughout but FGC 1 FMA used has changed the status from 1 to 0 between 6658 and 6662 and FGC 1 used for FD has changed between 6659 and 6663. This is very similar to what has been shown on the VT-EPN data. But as this was an ILS approach there was absolutely no necessity for putting the FDs off by the pilot as the FDs would continue to give excellent guidance all the way to touch down. We do not expect a pilot to put off one FD on very short final during an ILS approach as it is neither a requirement nor a necessity.

(36) In the DFDR data of VT-EPO which carried out some circuits and landings most probably at Delhi airport on 28-9-1990 we find that the FD discrete has shown "ON" throughout the data from 2257 seconds to 3153 seconds. The FGC 1 BUS used (17) has remained "OFF" throughout. But the FMGC used FD mode was showing 1 indicating that it was in use from 2257 till 2547 after which it has gone off.

(37) From the explanation of the discretes given by Airbus Industrie it is rather difficult to explain as to what exactly has happened looking at the DFDR data of VT-EPO, VT-EPN landing at Bombay and VT-EPN crash. We are not sure that the only purpose of the discrete FGC 1 BUS used and the FMGC used FD mode is

to establish that the FD 1 is "ON" or "OFF". We have no means of answering if a certain failure has occurred in these busses of the FMGC which has caused these changes in the recordings.

(38) The engines were at idle when alpha floor triggering occurred at DFDR time frame 323.9 seconds. The engines did not have adequate time to accelerate to take off thrust before the first touch down of the aircraft at 329.8 seconds. The flight profile after the first touch down, as explained earlier, was such that the aircraft could not have survived even if engines had attained take off thrust at the time of the second impact.

(39) Assuming alpha floor activation at 323.9 seconds, this accident has commenced at 320.9 seconds. From that time onwards this aircraft had absolutely no chance of survival even if thrust levers had been moved forward. This is based on the performance under pitch normal law as evaluated both from simulator experiments and Airbus Industrie flight tests.

(40) Whether the first touch down was at 6.125 g or it was a smooth touch down, that would not have affected the fate of this flight in any manner. But it is very essential for the Court of Inquiry to establish what exactly happened before coming to any conclusion using whatever data and evidence that are available.

(1) After landing checks were completed CM2 asked cabin crew at DFDR second 286, to be at their stations for landing. DFDR data revealed that at Second 292 altitude capture phase started at 3358 feet altitude and lasted only for 2 seconds upto 294 second when altitude was 3326. It can be presumed that the aircraft was coming down towards Minimum Decision Altitude of 3270 feet which was selected earlier. At DFDR second 294 CM1 asked for 700 ft/min. rate of descent as revealed by CVR. CM2, in reply, uttered the words "Missed approach is....". His voice was not audible thereafter due to some ATC transmission. DFDR data further revealed that at DFDR second 295 the auto thrust speed mode, which was active since 1000 ft/min. rate of descent was selected, changed to idle open descent which is possible only if a lower altitude is selected on FCU during alt.capture phase. As a matter of fact such a selection, had cancelled the alt.star phase prematurely at DFDR second 294. Since no DFDR data are available to indicate the FCU selections, some possibilities have to be considered to know why and how the speed mode changed to

idle open descent mode which was not the desired mode at this stage. 3 such possibilities can be considered.

(1) As suggested by the inspector of accident, CM2, while making a selection for 700 ft/min. rate of descent as desired by the CM1 mistook the altitude selection knob on FCU as the Vertical speed selection knob and selected 700 ft. altitude. Since this was a lower altitude and the aircraft was in alt. star phase the aircraft went into idle open descent. Since the two knobs are side by side, Capt. Thergaonkar, Capt. Richard Steele, Capt. P.K. Gupta and Capt. Gordon Corps, have confirmed that such a mistake was possible. Capt. Thergaonkar had admitted that he himself committed such mistakes. He had seen a French Pilot committing the same mistake in Hyderabad simulator, vide page 6 of his deposition.

(2) Airbus Industrie suggested that CM2, at 294 DFDR second first selected a higher altitude towards missed approach alt. of 6000 feet and then realising that this was not the proper time for such selection as the aircraft

would go to the open climb since alt star phase was active, immediately reversed the alt knob to a lower altitude by a wrist flick. This caused the aircraft to go to idle open descent. To support their theory, it was stated that from DFDR second 294 the EPR command slightly increased for a short while (a hump in the EPR CMD graph) which was possible for a higher selection of altitude momentarily.

(3) Due to malfunction of computer or FCU reset or due to serious incorrect signal input to FCU from FMGC & FGC and FCU reset itself the altitude figure in altitude window of FCU changed to 100 feet which was a lower altitude than the aircraft altitude at DFDR second 303. This caused the aircraft to go to idle open descent, vide question by the Court to Capt.Gordon Corps in his deposition on Page 100.

(2) Since possibility (1) does not explain the slight EPR command increase from DFDR second 294, possibility (2) may be considered as close to reality. This

suggestion of Airbus Industrie is also in consonance with CM2's utterence of the words "Missed approach is......" indicating that he intended initially to set 6000 feet go around altitude.

In respect of possibility (3) Airbus Industrie forwarded a reply as promised by Capt. Gordon Corps in Page 101 of his deposition, vide letter No.AI/E-fs 420.0214/90 dated 19.9.90. It has been stated that "there were situations where the speed display in the FCU window has reverted to 100 kts. they are as follows:

- FMG, C1 CB action in flight
- FM reset.

With regard to unwanted change of FCU altitude there has never been a report of any such malfunction. It only occurs at FCU power up during start".

Moreover, the FMGC was functioning satisfactorily before DFDR second 303 and worked satisfactorily after this time also as indicated by triggering of alpha protection and increasing EPR command etc. Further, this hypothetical case of computer malfunction at 303 DFDR second does not explain why speed mode changed to idle open descent at DFDR second 294/295 which is about 8 seconds earlier to 303 second.

(3) Regarding FCU reset/failure reference may be made to FCOM Vol.3 Chapter 3.02.11 Page 4 Rev.10 (abnormal and emergency procedures) where FCU fault has been described. It is stated that with both FCU channels failed

- all FCU controls are inoperative
- Autothrust, AP 1+2 and FD1+2 are not available (except in land track or go-around mode where only auto thrust is lost).
- etc.

It is known from conversations in the CVR that FD1 and FD2 were working. Secondly, if auto thrust is lost there will be a single chime associated with ECAM warning FCU 1 + 2 fault and Master Caution Light. But in the CVR there was no chime recorded. Further auto thrust worked satisfactorily as indicated by alpha prot and alpha floor activation. These two things clearly indicate that both FCU channels did not fail. For a single FCU channel failure the other channel takes over and proper FCU function is not affected.

(4) Further 100 feet altitude indication would have immediately indicated to the

pilot that it was an absurd indication because Bangalore Airport elevation itself was about 3000 feet. From alt.star phase he should have known that the aircraft was approaching the last selected altitude i.e., MDA about 3270 feet. At DFDR second 301 RA call out "four hundred" should have indicated that the actual altitude was 400 feet AGL. Lastly he should have looked at the standby (conventional) sensitive altimeter to know the correct altitude and taken necessary corrective action.

(5) It is pertinent to quote here, para 3.7.3.3 of page 3.19 of Chapter III of Indian Airlines' Operations Manual which states "It is especially important that the Co-pilot will automatically inform the Pilot-in-Command of any abnormal deviations from the approach procedure, altitude, rate of descent, speed and timing or the points covered in para 3.7.1.3 above. In order to detect false communications in any of the Pilot's instruments systems, momentary cross checks should be made by the co-pilot". "Should a malfunction or any other situation occur or remain when below 1000 feet above airport elevation and be of such a nature as to

render a landing hazardous, the approach should be discontinued. During all approaches, the co-pilot has an important function as a safety pilot and must not hesitate to inform the pilot in command of any abnormality or procedural discrepancy." Therefore, if due to some reason or the other the altitude window of FCU changed to 100 feet it was CM2's duty to automatically inform CM1 and as RA call out "four hundred" has already come at 301 second the approach could have been discontinued to avoid hazardous landing, if considered so.

Therefore, there is no reason to believe that the FMGC or other computer could have malfunctioned only at DFDR second 294 or 303 just to change the speed mode to idle open descent only to justify calmness of pilots for 11 seconds or to be detected by CM2 at DFDR second 305 respectively.

(6) Regarding selection of vertical speed during alt.star phase Capt.Guyot and Capt.Gordon Corps of Airbus Industrie stated in their depositions that this selection is possible but the vertical

speed knob had to be pulled twice. This view was contested by ICPA who informed that one of the Indian Airlines Pilots carried out this exercise both in simulator and in flight and confirmed that vertical speed cannot be selected during alt.capture phase.

The procedure prescribed in FCOM Vol.1 Chapter 1.11.30 para B.5.1 Item (2) in page 32 will enable a selection of vertical speed. It states "Pull V/S-FPA knob (after selection of a new altitude). Engagement of the mode is made on current V/S - FPA. Window is synchronised on current V/S - FPA. Select a new V/S - FPA value, if needed. Selection may be made before engagement". First selection of a new altitude would have killed the alt.star phase and then pulling of V/S knob followed by a desired selection i.e., 700 ft/min. would have achieved the required V/S. Therefore, after selection of a new altitude (lower in this case) had 700 ft/min. rate of descent been selected by CM2 as stated above the aircraft would have gone to speed mode and the accident could have been averted.

(7) The CM2 never attempted to select 700 ft/min.rate of descent on the V/S knob

is evident from the following:

(a) He spoke about "missed approach" i.e., go around altitude. It is very unlikely that he would speak something and do something else, i.e., speaking about go around altitude and selecting V/S of 700 ft/min. which is not coherent.

(b) At that time, A/T speed select parameter of DFDR changed from speed mode to idle open descent mode due to altitude selection (changed from 1 to 0). If V/S was selected it would have remained in speed mode (i.e., 1). This parameter changed four times from DFDR second 225 according to Pilot's selection. Therefore, there is no reason to doubt this parameter.

(c) He confirmed thereafter that aircraft was descending on idle open descent (you are descending on idle open descent mode ha, all this time).

(d) In CVR there is no indication that CM2 even acknowledged CM1 request for setting V/S of 700 ft/min.

6 seconds later "RA (Radio Altimeter) call out - four hundred" - came at DFDR

second 301. At DFDR second 305 Radio altimeter call out "three hundred" came. Then CM2 realised that the aircraft was descending in idle open descent, and said "You are descending on idle open descent ha, all this time".

(8) It appears that immediately after selection of the lower altitude CM2 did not scan the flight parameters to see the result of his selection. It was his duty to see the mode change and announce. He also did not check the aircraft speed and announce the deviation of speed if it was less by 5 kts. than the required approach speed. In this connection reference is made to descent/approach and landing check list detailed in FCOM Chapter 3.03.16 page 1 rev.11 which states:

"(PNF) Flight parameters....Check.

PNF CALLS OUT A/S deviation of more than +10 kt. or -5 kt."

At DFDR second 305 the speed fell to 124.78 kts. which was about 7 kts. less than target approach speed. Indian Airlines Operations Manual Chapter III page 3.11 para 3.5.4. states "Co-Pilot shall keep a close and constant watch on flight instruments and engine parameters and report the discrepancies (that will jeopardise safety) to the Captain who will take appropriate action as per check list and issue command instructions". Therefore, CM2 deviated from the prescribed procedure.

11 second delay in recognising the idle open descent mode was however, explained by Airbus Industrie to be due to the fact that he was waiting for CM1 to watch and recognise the change and rectify the defect. It is evident that all this time CM1 was busy in flying the aircraft. Even he did not check the flight parameters including the aircraft speed which was falling down fast due to idle thrust.

(9) There might be another reason for the calmness in the cockpit from DFDR second 294 to 305. Prior to DFDR second 292 the aircraft was descending towards MDA with a vertical speed of 1000 ft/min. At second 292 the alt.star came in the FMA and at second 294 CM1 asked for 700 ft/min. rate of descent. CM2 realised that go around altitude was not set and so he started selecting 6000 feet when ATC transmitted weather information superimposing CM2's voice. In this process the alt.star phase escaped CM2's notice since the moment he rotated altitude knob the words "Alt.star" got erased from the FMA. At the same time 1000 ft/min.which was showing up in the V/S window of FCU changed to "dashed" indicating that the

V/S was being "managed" by FMGC. At this CM2 got perplexed, immediately reversed the altitude knob by instinct and started figuring out how V/S changed to be managed. This thought kept him busy and could be the reason for his calmness till he realised from FMA at 305 second that the aircraft had gone into idle open descent and said "you are descending on idle open descent ha, all this time".

(9A) Because of -1000 ft/min. rate of descent selection, the aircraft was already in speed mode from DFDR 247 second i.e., A/T (Auto Thrust) speed select parameter was 1. At 292 second Alt. star mode started (by flight discrete 5 page 3) and lasted for 2 seconds. So A/T speed select parameter remained as 1 from 292 to 294 seconds. At 294 second if -700 ft/min. had been selected this parameter would have remained at 1, whereas from DFDR we can see that at 295 second, this parameter changed from 1 to 0. This confirms that A/T changed from speed to thrust mode at 295 second. This may be due to either higher altitude selection with fixed idle power. From DFDR, it will be seen EPR command, EPR actual, Fuel flow, N2 increased from

294 second continuously upto 1.02 EPR and thereafter decreasing gradually to idle power 0.98 EPR.

A doubt may arise why EPR command increased from 290 second before alt.star came. It is because the aircraft was already in speed mode and therefore EPR command will increase to maintain the selected aircraft speed i.e., 132 kts. From 288 second aircraft speed reduced from 140.78 kts. to 137.28 kts. and then to 135.78 kts. To avoid the aircraft speed going below selected speed, EPR command increased at 290 second. Immediately at 291 second the speed increased to 136.03 kts. In the meantime the pitch of the aircraft was gradually increasing from 290 second. This washed away increase in aircraft speed and speed was again coming down from 292 second. This continued till 294 second when speed mode changed to thrust mode. Since higher alt.was selected in thrust mode, EPR command continued to increase. But because pitch altitude was gradually increasing corresponding speed was decreasing.

(9B) When a higher altitude is selected why the EPR command value did not immediately go upto 1.27 and it has gone only upto 1.01 or 1.02 at 248 second as well as at 294 second for the simple reason that, during open climb, EPR command is not expected to abruptly jump to the climb thrust EPR value from idle or near idle EPR. It rises slowly and smoothly keeping in view the passenger comfort during climb and to avoid cabin pressure surge.

During this period (seconds 294 to 300), due to a lower altitude selection the gradual increase of EPR command was checked midway (at EPR command 1.02) and again came down gradually from 302 second to idle thrust command at 308 second.

NOTE:- A reference EPR is computed by the EEC as a function of: Thrust lever angle (TLA), ambient termperature (Tamb), air inlet temperature (T2), altitude, Mach number and service bleed. The current EPR is then compared to the reference EPR and corrections are applied to the fuel flow in order to minimise the difference EPR ref-EPR: (FCOM Vol.I Chapter 1.18.30 page 1).

EPR Command is also computed by EEC using:- EPR Target coming from FMGC to EEC or directly from TLA (Thrust Lever Angle). This command is transmitted through DMC, then FDIU and then to DFDR. (Ref.Airbus Industrie letter No.AI/EE-A-441.0377/90, dated 12.4.90).

A comparison of the figures of EPR value obtained from a different flight, in the present case cannot give a correct picture; the flight and ambient conditions will be different. Further, those figures were not placed at the time of the investigation before the expert witnesses and these explanations were not sought.

STATUS OF FLIGHT DIRECTORS:

(10) After recognising and telling CM1 about idle open descent at DFDR second 308 CM2 advised CM1 "you want FD's off now". Obviously he was thinking of changing the idle open descent mode to speed mode again and he was aware that if AP's and Flight Directors are off the mode automatically changes to speed mode. Since AP's were already off, he wanted to put off the FD's now to rectify the situation. Next second CM1 put off his own flight director and intimated that he complied with the requirement. It may be stated here that Capt.Guyot in his deposition in page 36 stated that CM1 was wrong as normally he would have asked CM2

to switch off both FDs. The CM2 was the PNF, it was his task to have switched off both FDs. Further, in FCOM chapter 3.02.01 page 3 it has been stated that "procedures will be initiated on CM1 command. PNF - Pilot-non-flying is responsible for execution of required action or request for execution by PF, if applicable". Capt.Guyot's views were not contested by anybody. In this case CM2, instead of putting off both FDs merely asked CM1. At DFDR second 312 CM2 told CM1 "But you did not put off mine". It appears that even after saying that CM2 still did not put off his own (CM2) FD as revealed by the DFDR parameters. This is against FCOM procedure detailed in chapter 3.04.11 page 67 "under visual approach with FPV". It states:-

"At start of approach:

FD1 + FD2..........OFF".

On the issue of FD1 putting off and FD2 remaining ON many questions were raised by various Counsel and the court wanted full details of connected DFDR discretes viz., "FGC-1 bus used", "FMGC used FD mode" and "FD Off" - Capt.Guyot explained these discretes in page 2, 36, 37 and 75 of his deposition. Capt.Gordon Corps in his deposition in page 101 agreed to provide full details in this regard. In this connection, Airbus Industrie sent a letter No.AI/E-fs 420.0212/90, dated 19.9.90 forwarding a technical note No.AI/EE-A-441.0706/90, dated 7.8.90 on the subject of "A320 IAC - Bangalore EIS information displayed on PFDI".

Maintenance Manual chapter 22-10-00 page 39/40 also deals with the same subject. From all these informations it is understood that if FD1 is switched off "FGC1 bus used" which is actually called "FGC1 bus used for FMA" will no more provide FD1 information in the FMA of PFD1 i.e., the word FD1 will be removed from PFD1 when bit status is 0. But if FD1 fails DMC1 will gather the information from FGC2 bus (from FMGC2) and FD2 will be presented in the FMA of PFD1. Discrete "FMGC used for FD mode" which is actually "FGC1 bus used for FD" relates to FD order displayed on PFD. If FD1 is switched off FD1 orders will not be displayed on PFD1 i.e., command bars of FD1 will be removed when bit status is 0. But if FD1 fails, DMC1 will pickup the information from FGC2 bus (of FMGC2) and display it to PFD1. In other words, FD2 commands will be displayed in PFD1. Bit status 1 of discrete "FDs off" indicates dual failure of FDs and bit status 0 means FD1 or FD2 is displayed on PFD1 or FD1 is selected off. Therefore, this discrete does not definitely indicate whether FD1 or FD2 was being displayed on PFD1 or FD1 was switched off. But since bit status was not 1 it is true that there was no dual FD failure. Since the auto-thrust did not change to speed mode, by inference, it is to be concluded that at least on FD remained ON. Since it is known from CVR that CM1 switched off the FD1, therefore it has to be concluded that FD2 remained on. Status of all the above three discretes, therefore, indicate that FD1 word was no more displayed in FMA of PFD1, command bars of PFD1 were removed and FD2 remained ON. It may be stated here that discretes "FGC1 bus used for FMA or FGC1 bus used for FD2" going from 1 to 0 does not mean at all that the computors were no more electrically supplied. This does not mean either that the data bus failed or becomes disconnected.

(11) A question may arise in this connection that CM2 might have pressed the FD2 button on FCU to switch off his FD. But it did not work for some reason or the other and FD2 continued to remain ON. It can be said against this argument that whenever any person takes any action to achieve something, he always looks for the result of his action. In this case light on FD2 push button and display on FMA and command bars on PFD2 would have given him indication whether FD2 was OFF or not. Further A/thrust mode change from idle to speed in the FMA would also indicate if FD2 was OFF or not. But nothing was commented by CM2 at this time about malfunction of the push button as revealed by CVR and the aircraft continued to be in idle open descent. Thus the alternative action left to him now to come out of this situation was to disconnect auto thrust and take over manual control of thrust, which he did not. This action at this time also would have prevented the accident.

(12) It is considered pertinent to refer to FCOM Bulletin No.2 dated April 1989 page 3 of 3 in this connection. It states:

"B. Speed hold in Visual Approach"

To cope with the previous mentioned point visual approach is analysed. It is recalled that the visual approach is described in FCOM Vol.3 Chapter "Procedures and Techniques" FMGS Part. The described procedure recommends that both FD must be switched off. This causes the A/Thrust (if kept active) to be in speed mode (Thus preventing the crew from decreasing his speed inadvertantly)". It also states "If it is intended to maintain the FDs, two possibilities are offered.

------A/thrust is switched off: In this case thrust is manually adjusted to hold the desired speed (selected or managed).

------A/thrust is kept active: In this case it is recommended to use V/S on FPA mode which causes A/thrust to be in speed mode. The flight path is followed with the pitch tendance (either horizontal FD bar or altitude director bar) which may be adjusted with V/S-FPA knob on FCU".

Perusal of the approach procedures followed by the Pilots of VT-EPN, will reveal that the pilots were following none of the procedures as stated in above FCOM bulletin No.2. It is clear that they did not put off both FDs, as required by visual approach procedure in Chapter 3.04.11 page 67 Rev.11. They did not switch off A/thrust and took over manual thrust control; nor did they select vertical speed.

<u>Reduction of Speed and increase of rate of descent</u>:

(13) At DFDR second 312 the speed reduced to 121.03 kts.and the aircraft came down to 232 ft.AGL (Radio altimeter). Even at this stage the speed was not monitored by any of the pilots as required by the check list stated earlier and CM2 did not call out the speed, which was less than the target approach speed of 133 kts.by more than 10 kts.

Capt.Guyot was questioned by ICPA Counsel to explain how the speed was falling and the rate of descent increased. He explained it in his deposition (pages 55 and 56). He said that when the pitch attitude was increasing by CM1 sidestick input, angle of attack was also increasing to an extent till it was limited by alpha protection of flight control laws which prevented the aircraft to stall. When angle of attack increased, drag force also increased and became very high, since engine power was low (idle) speed had to fall and consequently, the aircraft had to sink further.

Capt.Guyot's explanation is in conformity with the contents of Chapter 7. "TAKE OFF AND LANDING HIGH SINK RATE ON THE APPROACH" in Page 171 & 172 of the authoritative book "Handling the Big Jet" by Capt.D.P.Davies published by the Civil Aviation Authority, U.K. He highlighted three important points among others in respect of jet aircraft:

(1) Poor acceleration time of jet engine from low RPM.

(2) Increased momentum of jet aircraft making sudden change in flight path impossible, and

(3) Drag increases faster than lift producing high sink rate at low speed.

To arrest sink rate he suggested two ways:

1. By increasing incidence (angle of attack)- but only if air speed and sink rate are otherwise acceptable. In this case the thrust must be increased to counter the

drag from extra incidence or the resulting sink rate will be higher.

2. By increasing air speed. This can be done by increasing thrust. A heavy aircraft takes a lot of acceleration, so when this option is exercised a lot of thrust will be needed.

(14) In this particular case the thrust was fixed at idle (low)and speed was low, so by increasing the angle of attack the drag, which increased at a faster rate, was not counteracted by augmentation of thrust and hence the speed fell down and rate of descent increased further. Thus efforts of CM1 to pitch up the aircraft to bring it up to the normal flight path by increasing angle of attack at idle thrust deteriorated the situation. In this connection, the comments of Inspector of Accident in Page 53 and 54 are very pertinent. "The DFDR data clearly shows that at this stage, nose of the aircraft was being pitched up, and its speed was steadily falling below 130 kts. The nose up change of the pitch angle was probably as a direct result of the sidestick input being given by Capt. Fernandez to keep the aircraft in profile but as the engines were maintaining only idle power due to open descent mode, the speed of the aircraft was being washed away and the

aircraft started coming below the profile required for a normal landing".

(15) At DFDR second 315 Radio altimeter call out "Two Hundred" was announced. This was the time when the pilots should have acted fast without wasting time. After a gap of 7 seconds the CM2 asked CM1 at DFDR second 319 "you are on A.P.Still?" To explain the silence of 7 seconds at this stage Airbus Industrie felt that CM2 was still testing CM1 to recognise the reason for idle open descent. If it is presumed that due to some reason FD2 did not go off inspite of CM2's efforts to put it off and CM2 was busy in investigating the reason for the last 7 seconds and that is why he wanted to know if the A.P. was still on, then it has to be commented that below 200 feet AGL there was no time to be lost in investigation. It was the time for the check pilot to act and to take over control of the aircraft which was steadily losing speed and height unmonitored and to apply TOGA power manually by deactivating A/thrust keeping in view the high downward momentum of the aircraft and slow acceleration response of jet engine. Had CM2 applied TOGA power at

this time manually the aircraft could have been saved.

(16) A question has been raised by the Court as per OEB No.37/3 dated April, 1989 where malfunction of FMGC has been described. A theory was put up that at approximately 294 to 296 seconds if such a failure occurred resulting in wrong gross weight information in ECAM which could have given the pictorial data of V-app., VLS, V Alpha max well below the actual speed of the aircraft and this could be the reason why both highly experienced pilots did not consider the aircraft to be below the minimum required speed. This explains the total calm atmosphere in the cockpit till the phrase "Hey, we are going down" was uttered by CM1 at DFDR second 322.

Capt.Gordon Corps in his deposition in page 99 and 100 considered this as a highly improbable scenario since two independent channels of calculation could not have same failure of the same magnitude at the same time. Secondly, other items that depend on this information of FMGC like onset Alpha-floor, Alpha-prot, etc., operating at the nominal value did not support failure of both FMGC. However, he agreed to provide detailed information later. Accordingly, Airbus Industrie se letter No.AI/È-fs 420.0211/90, dated 19.9.90 explaining this aspect.

Gross weight and C.G.are computed by FMGC on the basis of data entered by the pilot before take off and displayed in lower ECAM. But from the time 10 seconds after lift off until CAS=255 kts. or altitude= 15000 feet till the aircraft stops on ground, weight of the aircraft is independently computed by FAC aerodynamically from informations of angle of attack, actual aircraft speed, altitude, mach, slat/flap position. C.G. is also independently computed by FAC which is a function of stabilizer position, elevator position, actual aircraft speed, altitude and FAC computed weight. VLS is computed by FAC from FAC weight, FAC C.G. and slat/flap position. Similarly, V-Alpha-prot and V-Alpha-max are also computed by FAC in slat out configuration from angle of attack, actual airspeed and slat/flap position. The DFDR traces show that incidence (angle of attack) and speed measurements obtained from ADIRS-1 were accurate. This ascertains that IAS, VLS, V-Alpha-prot and V-Alpha-max were correctly displayed on PFD-1 which was independent of

FMGC functioning.

It has been concluded by Airbus Industrie that on PFD the following are presented:

1.(a) Actual airspeed coming from corresponding ADIRS.

(b) VLS, V-Alpha-prot & V-Alpha-max computed by associated FAC

(c) V-app computed by associated FMGC.

2. On MCDU the V-ref and V-app computed by FMGC. Thus (a) and (b) are independent of FMGC functioning.

The above information is already given in FCOM bulletin No.1 dated February, 1989.

(17) Therefore, improbability of the hypthetical FMGC failure can be rejected on the following reasons:

(1) FMGCs was correctly functioning before 294/296 DFDR second as the target approach speed of 132 kts.computed by FMGC and indicated by magenta triangle was confirmed by both pilots earlier.

(2) If FMGC 1 fails, FMGC 2 takes over immediately without changing the speed indications computed by FMGC.

(3) Failure of two independent FMGCs at

the same time to give a wrong indication of same amount is highly improbable.

(4) Even if both FMGCs fail at the same time, VLS information computed independently by FAC will be still correct and available (In DFDR flight discrete 8 page, it is shown that FAC 1 never failed). As per FCOM Vol.3 Chapter 4 Page 2 Rev.11 V-app = VLS + 5 kt + wing correction. Therefore, even if V-app figure is wrong due to both FMGC failure (actually in case of both FMGC failure V-app figure will disappear) pilots are taught and supposed to know that V-app can never be less than VLS + 5 kt. In other words, the actual aircraft speed should always be 5 kts. above VLS speed.

Implications of both FMGC failure

As a mater of fact, to understand the implications of both FMGC failure it is to be recalled that FMGC covers several functions:

(a) Flight Management which is mainly navigation including display in the NDs.

(b) Autopilot

(c) Flight Directors

(d) Autothrust.

ai) In case of both FMGC failure there will be no more navigation display on the MDs. But DFDR shows that CM1's MD selection was arc mode/1D NM range. CM1 or CM2 did not comment on loss of such display.

aii) On both PFD V-app will no longer be displayed but CM1 or CM2 did not comment on this.

b) Both Autopilots fail. Both autopilots were put off at DFDR second 174.

c) Both Flight Directors fail. But from CVR it is clear that both FDs were on till DFDR second 309 when CM1 put off FD1 and FD2 still remained on. It is impossible to have both FMGC failure and one FD engaged.

d) Both autothrust computors fail. This will give a single stroke chime which is not inhibited below 800 feet. In addition there will be "Master Caution" and ECAM warning. But there was no single stroke chime in the CVR till DFDR second 326. From the above analysis it is considered that both FMGC failure did not occur.

(5) Further, flight manual requirement of approach and landing speeds which is binding by Aircraft Rules is specified in page 5.06.00 page 2 dated 20.4.1989 as follows: "Approach speed is atleast 1.23 V-slg" "Approach speed upto 1.41 V-slg is permitted". On the day of accident at Bangalore during the accident V-slg works out to 104 kts. in landing configuration at 3000 feet AGL. Therefore minimum approach speed works out to 127.92 kts.

(6) That the FMGC was working satisfactorily after DFDR second 294-296 was indicated by correctly triggering of alpha prot and alpha floor, EPR command increase after activation of Alpha floor, etc.

(7) There was no comment of pilots regarding wrong V-app indication computed by FMGC and displayed on speed scale of PFD.

(8) The hypothesis of FMGC failure giving wrong indication of gross weight can only shift the V-app in the speed scale to a lower value.

(9) Actual aircraft speed computed by ADIRS was correct.

Aircraft speed information in PFD speed scale was correct:

(18) Aircraft speed is computed by three independent Air Data Computers incorporated in three ADIRU (Air Data and Inertial Reference Unit). In normal condition, Air Data Computer 1 (ADR 1 - Air Data Reference No.1) supplies speed information to Pilot's PFD and ADR 2 supplies the same to co-pilots PFD. If any one of these fails (known by ECAM warning "ADR 1 or ADR 2 fault"), standby ADR 3 can be transferred to the faulty side by the Air Data transfer switch. This switch has three positions - Normal, Captain and F.O. If Captain's (CM1's) side ADR 1 fails, this switch should be transferred to "Captain position so that, the ADR 3 will supply speed information to pilot's PFD. In this connection, reference may be made to FCOM Vol.1 Chapter 1.16.01 Page 1 and 9 and FCOM Vol.3 Chapter 3.02.16 Page 2. But from the crash site investigation it has been found that Air Data transfer switch was in normal position. This confirms that none of the ADR 1 or ADR 2 fails.

Further, following an ADR failure,

if there is a speed disagree between two remaining ADRs, flight control alternate law becomes active and protections are lost. FCOM Vol.3 Chapter 3.02.16 Page 7 may please be referred to. In that case Air speed has to be cross checked and faulty ADR has to be identified by checking air speed information with standby (conventional) air speed indicator. The faulty ADR is to be put off. In alternate law "cricket" sound and "stall" synthetic voice message would have come in the CVR as the angle of attack was increased towards the stalling angle in this particular case, vide FCOM Vol.1 Chapter 1.09.10 Page 13. Further, in case double ADR failure, auto thrust would have been lost recording a "chime" in the CVR which was not so.

Therefore, it is confirmed that neither there was a single ADR failure nor double ADR failure.

Therefore, reason for the calmness in the cockpit for not doubting the so called incorrect aircraft speed is not sustainable. The fact remains that the aircraft speed was not monitored and the fall of speed was not announced by CM2 as required.

FCOM Vol.1 Chapter 1.16.10 Page 9.

states that in case of a single ADR failure also a single chime would have come and recorded in the CVR which, in this case has not happened.

TRIGGERING OF ALPHA FLOOR

(19) At DFDR second 322 CM1 realised that he would not be able to continue the flight and make a landing on the runway 09. He said "Hey, we are going down", at that time aircraft speed was 108.78 kts. and aircraft height was 136 feet AGL. In this connection, first two paras of page 3 of 3 of FCOM bulletin No.2 dated April, 1989 is quoted below:

"Further more, and this must be underlined, each time AP/FD acquires or holds SPD/MACH on the pitch axis (via the elevator) the A/THR is engaged in thrust mode. Thrust is fixed (max climb or idle) and cannot vary. In open descent for example, with A/thrust active thrust is idle and fixed to idle.

If the FD orders which show the way to keep the required speed, were not followed, then due to the fixed idle thrust, speed might decrease upto Alpha-floor activation. This remark particularly applies in visual approach (with A/T engaged) where the FD orders may not be followed (in order to adjust the flight path) thus leading to a speed decrease upto Alpha-floor activation.

This is exactly what happened in this particular case. From about DFDR second 295 onwards the aircraft was falling below the normal flight path. The speed started falling and aircraft was coming below the flight profile. CM1 was trying to maintain the flight profile with the help of elevator to increase angle of attack. But as explained earlier the speed was steadily falling and ultimately at DFDR second 323.1 Alpha-floor was triggered as the aircraft already entered in the alpha-protection zone at DFDR second 319 and the CM2 pulled his sidestick more than 14°. It may be stated in this connection that Alpha floor function becomes active when,

1. angle of attack is more than 9.5° in configuration 0, or
2. angle of attack is more than 15° in configuration 1, 2 or 3, or
3. angle of attack is more than 14.5° in configuration full.
4. It is also active when sidestick is more than 14° nose up and if pitch

attitude is greater than 25° or if the angle of attack protection is active.

It is the fourth condition that had triggered the alpha floor function. It is pertinent to mention here that when CM1 was struggling to pitch up the nose of the aircfaft to come upto the normal flight path as he was falling below, the aircraft entered the alpha protection zone (stall protection) and with side-stick pull beyond 14° operated Alpha-floor triggering as per specification of the aircraft. This stall protection and alpha floor activation does not appear to have been invoked by the pilot; these protections came on their own on meeting the stipulated conditions.

It is further stated that there is a delay between triggering of Alpha-floor function and activation of Alpha-floor protection due to channelling of the signal through a number of computers. Capt.Guyot confirmed in his deposition in page 77 that Airbus Industrie was aware that there was a delay but only on raising queries they conducted detailed investigation and inform vide letter No.AI/EE-A-441.0378/90 dated

12.4.1990 that the delay could be 0.758 second min. and 1.203 seconds max. For practical purposes it was suggested that a delay of 0.8 second could be accepted. It is pertinent to mention that this delay of 0.8 second was not published earlier in any of the aircraft document supplied to the operator.

(20) Therefore, at DFDR second 323.1 the Alpha-floor protection was triggered and activated at 323.9. The engines normally started spooling up as required. At that time Radio altitude was 110 feet AGL and speed was 106.53 kts. which was min. in the DFDR recording. It may be stated that the triggering of Alpha-floor function is inhibited below 100 feet radio altitude.

COURT'S OPINION

(1) The day was clear, cloudless and sunny. From a height of 300 feet, the pilots could have seen the runway being far ahead of the plane's location. Atleast when call out of 200 feet radio altitude was heard, the pilots could have seen that the plane was prematurely going down.

(2) Situation at this crucial second (about TF.318) was:-

(i) plane was in idle open descend mode;

(ii) FD.1 was off:

(iii) CM.2 thinks either FD.2 was on, or if it has been put off, auto pilot was on and this has caused confusion in his mind;

(iv) plane was already at an altitude of 200 feet above the ground;

(v) speed was falling; and

(vi) if thrust levers had been pushed, the engines would develop power in 8 seconds which would have given speed to take up the plane and landing would have been postponed and thus crash would not have occurred.

(3) There is a 'chime' recorded. Its timing is stated to be at 326.5 seconds (revised as 327.8 seconds by the two Assessors); Airbus Industrie attributes 'disconnecting of auto

throttle by the pilots using the disconnect buttons, to this sound. It is unnecessary to examine this question, as the plane was by that time at a situation wherein the fate of the plane could not have been altered by any human power.

(4) As a Court of investigation, I have to express an opinion about the basic cause for the crash. The crucial period commenced roughly at about 293 seconds, when CM.1 asked for 700 feet rate of descend. The entire period ending with the crash could be divided into three stages. The first stage is between the time when 700 feet rate of descend was asked and the time when CM.2 spoke the words "you are descending on idle open descend ha, all this time." The second stage is between the words "you want the FDs off now" till RA call out of 200 - i.e., between TF.307 to 315. The third stage commences with the words "you are at the auto pilot still ?" This timing given as 319 seconds was revised as 319.8 seconds by CASB, which the two Assessors have taken at 320.7 seconds. During this time-frame plane had moved into the death trap at 321 seconds and no action by the pilots would have saved it.

(5) The cause for the crash has to be seen in the first two stages.

(6) A few alternative possibilities, can be

thought of, during the first stage. They are:-

(i) CM.2 selected the vertical speed of 700 feet rate of descend as requested by CM.1, without noticing the Alt*; hence selection became otiose.

(ii) CM.2 thought of, first complying with the earlier request of CM.1 for "go around altitude" and therefore stretched his hand to dial the altitude knob, but while doing so, was guided by the just spoken words of CM.1 and thus, by mistake dialed for 700 feet (instead of 6000 feet of altitude). This resulted in the plane adopting the idle open descend mode.

(iii) CM.2 wanted to select the vertical speed of 700 feet but committed the mistake of selecting the wrong knob (as happened to several pilots, including Capt. Therogaonkar).

(iv) Even though CM.2 saw the Alt*, while selecting the vertical speed, he did not resort to the required procedure, of dialing and pulling the speed knob.

(v) CM.2 had his own ideas and therefore did not select the vertical speed, nor go around altitude.

(vi) CM.2 selected the "go around" altitude which resulted in the plane climbing up and so immediately by a "flick" of the wrist, reversed the knob, without realising, that while reversing, a low altitude got selected.

(vii) A complete failure of the systems in the aircraft - for this, I do not find any evidence whatsoever. The plane reacted to the side stick movements and the pushing of the throttle levers within a few seconds. Hence this possibility has to be ruled out.

(viii) The probabilities were, CM.1 did something which he never imagined as a wrong one and was quite certain of his action. If he stretched his arm to select the correct knob, but while acting on the knob, mechanically selected the wrong figure, he may not notice it and he will be sure of his action.

(7) If CM.2 had proceeded to select "go around" altitude while speaking the words "missed approach", the plane would have started climbing up. The theory of Airbus Industrie is, CM.2 selected "go around altitude" and immediately realised that plane was climbing up and therefore reversed the selection of altitude by a wrist flick resulting in selecting a very low altitude, which he failed to notice, which in turn resulted in the plane going into 'idle open descent . For this theory, Airbus Industrie refers to DFDR readings. This is elaborately discussed under two rival sets of views.

(8) This theory assumes that CM.2 selected a

higher altitude at about TF.294 and immediately reversed it. If so, he must be aware of the action taken by him. He cannot be surprised by the idle open descend mode of the plane; Capt. Gopujkar (CM.2) attributes the 'idle open descend mode' to CM.1, by saying to CM.1 "you are descending on idle open descent aa all this time". If CM.2 had selected a higher altitude and then reversed it, without realising that reversal resulted in the selection of a lower altitude, his expression would have been quite different, something like "oh! this is on idle open descend, why ?" When CM.2 uses the phrase "aall this time", it is clear that according to CM.2, plane was in idle open descend mode for a long time. At any rate, he would immediately realise that his action in selecting the altitude by turning the knob by flicking the wrist must have caused some change in the plane's mode and therefore he would have checked the altitude selection once again. It is not possible for me to infer that Capt. Gopujkar, if he had actually dialed any one of the knobs and then reversed it, would have failed to examine the effect of it after realising that plane was in idle open descend mode.

(9) The hump theory (same as the wrist flick theory) propounded by the Airbus Industrie does not explain one more factor. CM.1 asked for 700 feet rate of descent at about 294

from 0.98 to 1.00 at 290 seconds and became 1.01 at 294 seconds, and then got increased to 1.02 at 298 seconds till 300 seconds and then reduced to 1.01 at 301 seconds and at 303 seconds came close to 1.00 and at 306 seconds became 0.99. The EPR actuals correspondingly changed later, but never got below 1.00 at any time thereafter. The suggestion implicit in the 'hump theory' was that CM.2 selected higher altitude after CM.1 spoke the above words, and the selection was made by CM.2 while talking "missed approach is...". This can only be after 294 seconds; may be at about 295 seconds, by which time, already EPR command value had started going up at 290 seconds.

(10) The witnesses examined by the Airbus Industrie have not explained the circumstances under which normal increase in EPR value would go up from idle (i.e., from 0.98), as happened earlier also at 248 seconds. In fact, Capt. Guyot and Capt. Corps, the two main witnesses examined by Airbus Industrie were not able to explain many aspects of this aircraft; when questioned, they repeatedly replied that they would send the reply after getting an answer from the 'design office'.

(11) As, this hump theory is propounded by the Airbus Industrie, it is for this participant

to lay the foundation for the theory by placing proper technological reasons before the Court. The recording of oral evidence was concluded on 9-8-1990. For the preparation of the arguments, several Advocates requested time; the Counsel for Airbus Industrie, at that time opposed the move to adjourn the proceedings for arguments for more than two weeks. However, having regard to the questions involved and the vast material on record, Court proceedings were adjourned to 17th September, 1990. Written arguments were to be filed by 12th September 1990; thus participants had over four weeks to prepare and file written submissions. On 12th September 1990 the counsel for the Airbus Industrie came up with a request for another six weeks to file written arguments, which I declined to grant. When the Court assembled on 17th September, 1990 A-irbus Industrie filed its written submissions, which is not exhaustive of the facts, and there has been a complete go-by to the analysis of the material on record. On the same day oral arguments commenced. The written submissions filed by the Airbus Industrie disclose only, its defensive attitude.

(12) In the written arguments filed, it is stated that Airbus Industrie had no access to several exhibits filed in the Court. This is incorrect and is an unfair

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statement. At the very beginning, participants were told to look into the exhibits at any time and the Secretary of the Court was instructed to permit the participants/their Advocates to inspect the documents and wherever possible copies sought for were furnished. A substantial number of exhibits were the publications of Airbus Industrie or of Aeroformation.

(13) If I am to apply technical rules of evidence, on many of the contested issues, I have to draw adverse inference against the stand taken by the Airbus Industrie. It failed to cross-examine most of the witnesses who spoke about the functioning of the systems of this aircraft and other subjects such as, activation of Alpha floor protection and selection of vertical speed during Alt* phase. The witnesses examined by Airbus Industrie were ignorant of many aspects pertaining to this aircraft and diversionary answers were given by these witnesses (Capt. Guyot and Capt. Corps). On many questions, left unanswered by its witnesses, answers were sent after the arguments were over. Other participants had no occasion to read these answers and test them for their correctness. Airbus Industrie seems to have treated the Court proceedings as if it is a private investigation, ignoring the provisions of Rule 75(2) of the Aircraft Rules, 1937.

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(14) Another probability is that CM.2 dialed the wrong knob (thinking that he dialed the correct knob) resulting in the selection of a lower altitude (a possibility spoken to by Capt. Thergaonkar) It is also, probable, that he wanted to select go around altitude first and therefore selected the altitude knob, but, while dialing it, the words just told to him by CM.2 regarding vertical speed, influenced his action and thus he selected the altitude of 700 feet without even realising that he selected the wrong altitude. There are occasions when an action taken with a particular object in view, gets confused because of another object influencing it. If CM.2 had acted at TF.294 to dial V/S knob at a time when plane was in Alt* zone, he might have failed to follow the requisite procedure. This is also quite probable because having thought that he selected the vertical speed of 700 feet at the most appropriate time, he was surprised to find the plane in idle/open descent mode a few seconds later and therefore he expressed to CM.1, by stating "you are descending on idle open descend aa, all this time".

(15) CM2 (Capt. Gopujkar) certainly knew that while at landing approach, idle open descend mode was not proper. Alt* phase continued throughout TF.294. If CM.2 had dialed the speed knob without

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the appropriate steps applicable to Alt* phase, as stated above, it will be a futile exercise.

THE SECOND STAGE:

(16) At TF.305, CM.2 spoke the words "you are descending on idle open descend as all this time". Just prior to that there was RA call out of 300. The call out occurred in the course of CM.2 telling "you are descending..." When call out of the radio altitude is 300 (for three hundred feet) and the plane is found to be in idle open descend mode, the instinctive reaction of the experienced pilots ought to have been to accelerate power, unless they were certain of the safety of the plane in spite of its situation. Capt. Gopujkar asked CM.1 at about TF. 308.9, "you want the FDs off now" and Capt. Fernandes responds by saying "ya" and immediately he (Capt. Fernandes) puts off his FD because he says further, "OK, I already put it off". There can be no doubt that switching off of the FDs at this point of time also would have converted the idle open descent mode into speed mode and in all probability crash would not have occurred. For about 2 to 3 seconds, CM.2 does not talk, but then says, "but you did not put off mine". This indicates that CM.2 wanted CM.1 to put off both the FDs. Evidence on record (both oral and documentary) show that it is the function of Non-Flying Pilot (CM.2) to put off both the FDs. Here, CM.2 expected CM.1

to put off his FD; probably CM.2 thought as pilot in command he was there to check the pilot flying (CM.1) and he need not act strictly as CM.2, or because CM.1 had put off FD.1, CM.1 also should put off FD.2. It is not possible to find out any other reason for CM.2, here, to expect CM.1 to put off the FDs. This statement is made at TF.312.9 (17 seconds before the crash) At TF.314 [stated as 316 seconds by the two Assessors] there was a call out of radio altitude as 200. At TF.319.8 CM.2 asks CM.1 "you are on the auto pilot still?" By that time plane must have descended further down. CM.1 says 'No In fact, it is admitted by all the participants that auto pilot was put off far earlier at TF.174 and the sound was clearly recorded. That was when CM.2 had told "runway in sight" and after ATC had transmitted the message "605, position 7 miles west, on left base for R/W 09 check wheels and report R/W in sight", and CM.1 spoke of "flap 3". Capt. Gopujkar certainly must have noticed the disconnecting of the auto pilots earlier. But the words he spoke at TF.319.8 indicates that in spite of FDs being put off, the panel displayed the functioning of FD.2. CM.2 had told CM.1 that the latter did not put off former's FD, after CM.1 had told CM.2 that he had put off his FD. CM.2 realised that his FD was not put off. Having realised that CM.1 had not put off FD.2 of CM.2, the normal reaction of CM.2 ought to be to put off FD.2 himself. Therefore, either he pressed the switch in an attempt to put off the FD or saw CM.1 pressing the said switch to put it off by stretching his arm towards FD.2 switch. Thereafter, both the pilots were certain that FDs were off, but CM.2 found the panel showing otherwise. This is possible only if auto pilot was not disconnected; therefore CM.2 asks CM.1 whether he was "on the auto pilot still". (However, if FD.2 is switched off, there would not be the display of the letters 'FD.2'). Since auto pilot was disengaged and there is no dispute on that question, inference is that FD.2 was not off, in spite of CM.2 or CM.1 pressing the switch to put it off. Having pressed the switch off, both were certain that FDs were off, without realising that the act of switching off of the switch failed to put off the switch. To put off the FD, the switch had to be pressed. It is quite possible that in the instant case, sufficient pressure was not imparted while pressing the switch and the pilots did not watch the push button light, FMA and the vanishing of FD command bars. It is also probable that the FD.2 switch had failed for some reason and did not respond to the pressure put on it, to put off FD.2. The query made by CM.2 about the auto pilot being still on at TF.319, according to

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me, is indicative of the fact that FD.2 was still 'on' in spite of an action to put it off.

(17) CM.1 takes about 2 seconds to answer CM.2 and to say 'No', i.e., to convey that auto pilot was not 'on'. CM.2 repeats the words "it is off". This answer indicates that he was surprised by the information that auto pilot was off. He was wondering about the continued situation in spite of auto pilot and both the Flight Directors were being 'off'.

(i) I cannot agree with the contention that FD.2 switch was not at all pressed. The previous conversation between the pilots clearly brings out that they wanted FDs to be off. It is inconceivable that a person of Capt. Gopujkar's experience would not have pressed the FD.2 switch to put the FD.2 to off, after Capt. Fernandez told him that FD.1 was put off; it is also inconceivable that Capt. Fernandez would not have stretched his arm to put the switch off, after CM.2 enquired of him that his switch was not put off by CM.1; one of them certainly must have pressed the switch, but, for some reason, it did not go off. The question of Capt. Gopujkar "are you on the auto pilot still ?" was at about TF.319; by the time CM.1 replied 'No', which was at about TF.321, plane had entered the death trap. The revised timing furnished by CASB to this answer 'No' is 321.4 seconds; the repetition of the words "it is off" by CM.2 was at about 322 seconds, and it was too late to retrieve the plane. Capt. Gupta in his affidavit (which is treated as part of his deposition) clearly stated that it was a tricky affair to put off FDs and it is for the pilot Not Flying to stretch himself to reach the FD in front of the Pilot Flying. [Similarly, for CM.1 to put off FD.2, he will have to stretch himself as could be seen from its location].

(ii) The DFDR does not provide for recording the FD.2. Capt. Guyot stated that as auto thrust was remaining in thrust idle mode, FD.2 must be on.

(iii) These switches are not "feather-touch" sensitive; they require to be pressed to put them off.

(iv) After CM.2 told CM.1 that the latter did not put off former's FD, the next words came out about 7 seconds later. For 7 seconds, there was no conversation. Pilots would not have been idle during these 7 seconds. In all probability, one of them pressed the FD.2 switch off in the meanwhile, but the result was confusing. That is why CM.2 asks CM.1 (after 7 seconds) "you are on the auto pilot still". The circumstances are such that it is impossible for me to conclude that pilots did not press the FD.2 switch; therefore the inference has to be that it did not go off for some reason or other.

(18) In the course of ascertaining as to whether auto pilot was on or off, crucial seconds were lost. Thrust levers were not pushed at that moment. It is quite evident that plane would not have crashed only if any one of the pilots had pushed the throttles by TF.321 seconds. At that stage no pilot should pause to examine and find out the cause for the wrong displays, if any, or for the cause as to why the plane was in idle open descend mode. The approach profile for landing and the duties of pilots while landing a plane are explained by a few witnesses who are themselves pilots in A.320 aircraft. But the contributory role played by the FD.2 switch in this case also cannot be ignored.

(19) Capt. Thergaonkar pointed out that whatever mode is selected, - whether of speed mode, or of idle descend mode - it is displayed on Flight Mode Annunciator (FMA). The FCU is quite clear and large. While approaching landing pilots are expected to manage the speed. The witness added:

> "It is true the speed Alt* referred against 13.0.1.03 hrs. and the next one was achieved just above 4600 altitude. Thereafter obviously the FCU altitude was set for a lower altitude. The setting of the altitude once again below 4600 was contrary to the said

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procedure.....on the second occasion i.e., at 13.02:08 hrs, go around of 6000 ft. should have been set, but apparently it was not done; because he was on the vertical speed at that time the plane would not have climbed up again by setting the height at 6000 on the second occasion. Eventhough there were two deviations from the procedure referred already I do not think that it was inevitable that the plane should have landed at the Course. At 3341 height when Alt* came again (about 292 DFDR seconds) the pilot could have taken action to convert the mode into speed mode. If at 13.02.42 hrs. (i.e., 293.294 DFDR seconds), 700 ft. rate of descent had been selected the aircraft would have gone into speed mode and auto thrust would have maintained the engine power and thus aircraft speed. The last 35 seconds before the crash was the most crucial stage in the flight. I am quite comfortable and always felt comfortable while flying A.320. I do not think the aircraft is too sophisticated..."

He also stated that route checks are always conducted on passenger flights all over the world and that is the prevailing practice.

(20) Capt. Sathye spoke of the need to scrupulously follow the check list by the pilots and that plane has to be in the speed mode at the time of approach; maintenance of speed is very important at the time of landing.

(21) Capt. Gupta (witness on behalf of ICPA) said that the normal practice during approach for the pilots is to maintain the speed and agreed that in the last 35 seconds to the crash there is no reference to speed on the CVR. He agreed that as per Ex.78, it is the specific task of pilot Non-flying to monitor speed and advice if it goes outside the limits of plus 10 or minus 5 knots, above VPP and then said:

> "I am surprised myself and after all my efforts I have not been able to judge the state of mind of Capt. Gopujkar who was so very meticulous why he has failed to call the deviation of speed."

A few sentences later, this witness said:

> "Possibly the crash could have been avoided if the deviation of the speed was pronounced at the time frame of 312."

(22) Capt. Gupta never landed this aircraft in idle open descend mode in the course of his 300 flying hours and states that while landing one has to be in a proper approach profile. An

appropriate speed is very important, which is called V. approach and that the speed will have to be monitored by both the pilots. According to him,--

> "....if the plane is in the normal approach profile, where plane cannot afford to lose height the throttle will have to be moved for increasing the speed."

(23) Capt. Bhujwala is another pilot who was Capt. Gopujkar's batch-mate throughout. He also states that idle open descent is not the correct mode for approach and it ought to be speed mode and that while approaching it is necessary to monitor the speed. He stated:

> "If the speed goes below V.approach or Majenta triangle the pilot will have to normally increase the speed by operating the throttle. This is necessary for proper landing of the aircraft."

(24) Capt. Shresta, though young and a recent trainee also says that "the aircraft speed must be maintained at V. approach speed till you come close to the runway and that speed will have to be maintained."

(25) It was argued that such a fundamental and basic requirement of maintaining approach speed would not have been ignored by Capt.Gopujkar and therefore, 'something in the speed

indicator must have misled him.

(26) With the frequent announcement of radio altitude from 400 feet and below, when plane was found to be in idle open descent mode, the first reaction ought to have been to resort to the throttle; obviously Capt. Gopujkar was perplexed by the idle open descend mode and the display of FD.2; this diverted his mind in not noticing the speed.

(27) DFDR shows that at 293 seconds, speed was 134.53 knots. Magenta was set at 132 knots at TF.96. At TF.296 the speed was 131.78 as per the DFDR. Speed had fallen to 130.78 by TF.298. Therefore, the speed was certainly below magenta at TF.298 and can it be said that this was not noticed by anyone of the pilots till CM.1 exclaimed:

"Hey we are going down", which was at about TF.323. At TF.324 speed was 109.78 knots. By that time about 7 seconds earlier radio altitude call out of 200 had been made. At TF.302 the speed was 127.53 and at 303 seconds it was 126.28; speed was continuously falling even thereafter.

(28) Do these indicate that the two experienced pilots failed to notice the falling speed ? Is it likely that both the pilots were in a confused state of mind and they did not realise the speed fall ? Or any of the displays misled them ?

(29) One more hypothesis has to be referred. A.320 has an unique system called Alpha Floor Protection, which essentially protects the plane from wind shear. By moving the side sticks, it is possible to trigger Alpha floor protection; when activated this system activates the engines and engines' develop full acceleration in 8 seconds from activation. CM.1 has moved the side sticks and Alpha floor was triggered at TF.323.1, and it must have been activated at TF.323.9? At TF.321, side stick was moved to 8.89° ; if this was the action taken by CM.1 in the direction of triggering Alpha floor, it indicates that CM.1 had realised the gravity of the situation. If only he did not rely on Alpha floor system, he would have acted on the throttles by pushing the levers; if he had pushed the throttles by TF.321, there was every chance of this plane surviving the crash because by TF.329 engines would have developed full power. Therefore, can it be, that, the pilots relied on this Alpha floor protection which delayed their action on the throttles ?

(30) Whatever be the probabilities attributable to the pilots, the fact remains that they saw the plane being in idle open descend mode, which is not an appropriate mode for descending at that phase of the flight and the requisite corrective action was not taken. There may be many explanations; it may be said that such

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experienced competent pilot like Capt. Gopujkar would not have failed to notice the speed and would not have failed to remember the requisite action to be taken. It is quite possible that for some reason the pilots believed the plane to be in proper speed and there was no cause for panic; they must have felt that they can check the FDs and the auto pilot, before taking the next step.

If FD.2 is 'on', the FMA in front of CM.2 would display the letters 'FD.2'; but it will not be displayed in the FMA of CM.1. If FD.2 is off and auto pilot is 'on', the FMA in front of CM.2 would display the words 'A/P'. Therefore it is surprising as to why Capt. Gopujkar asked CM.1 as to whether auto pilot was 'on'. If FD.2 did not go off and if he had looked into the FMA in front of him he should have questioned as to why FD.2 was still 'on'. Unless the display system misbehaved, the other inference could only be that Capt. Gopujkar did not concentrate and did not look into his FMA. Some doubt has been cast about this display system and it has been suggested that the display system must have misled the pilots, regarding speed. It was contended that, at this stage in the absence of the FMA being available for examination the suggestion made that there must have been wrong display should not be ignored. The systems in the cockpit are backed by alternatives. Normally, the reaction of CM.2 ought to have been to look into other displays as well, to check and find out whether FD.2 was 'on' or not. Similar is the case with the speed displays.

(31) The two pilots are no more and their version of the situation has to be inferred from the various circumstances. All the various probabilities are on the assumption that the display systems in the cockpit functioned perfectly. In case there were wrong displays, for whatever reason and the pilots were misled by such displays, resulting in their failure to note the speed fall, none could attribute any error to the actions taken by these two pilots. Due to the fire, these systems are not available for examination to find out their behaviour during the early crucial seconds. Just as the manufacturers are proud of their product (the aircraft) and attribute infallibility to the display systems, ICPA is certain of the unimpeachable perfection of the two pilots. ICPA repeatedly questioned as to how it is possible to infer that the pilots might have

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committed the mistake of not following the basic principle of flying, and ignore the speed fall; why not attribute the error to the display systems ?

(32) This is a case where various answers can be given for each disputed question, as could be seen from the two sets of rival views summarised by me already. It is not possible to infer what the pilots must have done during the first two stages of the crucial seconds. But, it is possible to say what they should have done and what a properly trained prudent airmanship should have prompted them to do.

(33) It is clear that, the pilots failed to convert the idle open descend mode to speed mode (for whatever reason) even when they saw that the plane was in idle open descend mode and the plane was already in the crucial phase of landing. After runway was in sight, short finals announced and landing checks completed, pilots diverted their attention to find out the reason for the idle open descend mode, rather than reacting to the situation by acting on the throttle levers. Crucial seconds were spent in checking the FDs and the auto pilots. The entire crash is the result of what the pilots did not do between 295 to 320 seconds - during 25 seconds (i.e., less than half a minute) and not what they did.

(34) The pilots should know that every second is valuable and no moment should be unnecessarily spent on avoidable investigations during the last phase of landing. Craftsmanship, sincerity and intelligence will be of no use when over-confidence clouds these qualities and the instinctive reflex fails to act.

THE CRASH

(35) At 329.9 seconds there was the first touch down. This was with a heavy 'G' force is the theory putforth by Airbus Industrie and others. Another theory is, this was a soft touch down and the next impact with the ground was quite heavy and the crash sound recorded pertains to this; therefore, as per this second theory, crash sounds were recorded at TF.331.4 and that thrust levers were moved between 324.05 and 324.80. Even then, it is seen that the time lag between these two points is within 7 seconds.

(36) The plane impacted the ground at the golf course, bounced for about 234 feet and then impacted the golf course once again; thereafter, it dragged further for about 100 feet before impacting the embankment. The

was no sufficient running ground space available. It could not fly over the embankment (which is at about 12 feet height) of the golf course; the engines impacted against the embankment and got disassociated from the plane, resulting in fuel leakage and fire erupted to consume a few and caused irreparable burnings in others; the forward momentum of the plane carried it for a while to land the plane on the marshy land, about 150 feet away from the airport boundary wall. Examination of the engines revealed that they were fully active and almost gained full power by the time the plane impacted against the embankment.

(37) A discussion on the events during these crucial seconds leads to one inevitable conclusion, that, the pilots in spite of noticing the plane in idle open descend mode failed to react immediately at the final phase of landing; instead, they tried to find out the cause for the idle descend mode and in this they spent some valuable moments. The continuous functioning of FD.2 inspite of an attempt to put it off might have confused them and diverted the attention of these pilots or, a false sense of security that this plane is capable of looking after itself, because of its special features like Alpha floor protection might have misled them.

(37) Discussion on the question of crew training

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and the peculiarities of Alpha floor protection and Alt* phase would indicate the insufficiency in the training imparted to the pilots, on these questions. Reflexes to act in a particular manner, during an emergency or during unforeseen situation, can be developed only by intensive training and forewarning against relying on systems in the aircraft meant to meet some other contingency. For example, when pilots are trained to pull side stick first and then use the thrust lever as back up, at the time of demonstrating Alpha floor exercise, the reflex action also would be the same, when an action is necessary to increase the thrust, under adverse conditions. In fact, CM.1 has resorted exactly to the said procedure. If he had been trained to move thrust levers first and he had pushed them by TF.320 seconds, most probably crash would not have occurred. It is necessary to repeat here that, overemphasis on the special features of this aircraft, such as envelop protection, Alpha floor protection and that the plane would not stall at all, must have created a false sense of security in the pilots and postponed the realisation of the gravity of the situation, till about TF. 321 seconds. The words of CM.1 "you are on the auto pilot still" ? almost ended with the time within which the throttle levers should have been moved. There was no sense of urgency, or of panic in these words, a factor which indicates complacency with which the pilots were functioning.

(38) Earlier I have said, while considering the approach selected by the pilots that there was no major deviation by following a mixture of VOR-DME and visual.

(39) However, a minor deviation may sometimes contribute to the development of a major disaster. When auto pilot was disconnected earlier at DFDR seconds 174, if CM1 or CM2 had called for switching off the FDs and FDs had been switched off, the subsequent confusion arising out of idle descent mode would not have happened. At least, while landing checks were being done (between 271 to 275 seconds or immediately thereafter) FDs should have been switched off. Evidence, no doubt, shows that landing with FDs 'on' is possible; but that is an exceptional mode of landing. If the FD is used during visual approach, procedure described in last para of Page 3 of 3 of FCOM Bulletin No.2, should be followed. The "two crew-member philosophy" requires any action taken by one pilot to be monitored by the other.

(40) According to Capt.Gupta, the pilot who puts off one FD also should put off the other FD and that CM1 was wrong in not calling for switching off the FDs and only putting off his FD. Subsequently, Capt.Gupta deposed that,

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"Looking into the circumstances he (Capt. Gopujkar) definitely made an attempt to switch off the FDs himself and persistent indications on FMA created a doubt in his mind whether auto pilot was'on'or not. All these actions under these circumstances were not called for any normal conversations but positively for a corrective action, I fully understand if FDs had not gone off by his effort Capt. Fernandez's effort could not have been achieved anything better and <u>this could have attributed to the loss of time</u>."

The witness (an experienced pilot), who was the sole witness for ICPA, further said:

"The normal practice during approach for the pilots is to monitor the speed"

and agreed that during the last 35 seconds to the crash there is no reference to speed on the CVR; in the instant case, at DFDR 312 seconds CM.2 ought to have called for the deviation, from the speed; he said -

"Probably the crash could have been avoided if the deviation of the speed was pronounced at the time frame of 312".

Capt. Gupta felt that the showing of Alt* capture mode for AP.2 from time frame 225-235 while for

AP.1 it was 225-234, indicates spurious signals to the DFDR and he attributes spurious signals at TF.292 to 294 seconds also.

(41) This witness has attributed pressure in the mind of Capt.Fernandez because he was under his first Route-Check. Capt. Gupta opined that:

> "During the last 6 seconds nothing could have been done to prevent the crash".

He repeatedly said of the using of throttles to maintain speed while landing:

> "The speed can be increased either by moving the throttle or by increasing the rate of descent. In case at shortfinal if I am at height I will convert my height into speed by increasing the rate of descent (that is the second method). However, <u>if the plane is in the normal approach profile where plane cannot afford to loose height the throttle will have to be moved for increasing the speed.</u>

(42) The learned counsel for ICPA brought out from his witness (Capt. Gupta):

> "The tolerance in the computer is very small; any small deviation in the working parameters at that particular time in the system gets latched due spikes in the system and

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remains faulty in the system till such time the computer is re-loaded after a self test the DFDR during this time if represents any of those systems readings will automatically remain unreliable till such time the computer is back in order. This is what we call the reflection of spurious signals on the DFDR. <u>The DFDR readings are definitely reliable it is only unreliable during the course system remains faulty</u>."

(4 3) I have referred to the deposition of Capt. Gupta elaborately for more than one reason; he is the sole witness for ICPA; he is an experienced pilot in A.320; he has not hesitated to point out some of the mistakes committed by the two late pilots in the instant case and he has not asserted that display systems in the cockpit must have failed or misbehaved. In the statement of the case filed on behalf of the ICPA, there is a suggestion that -

> "in all probability, there was malfunctioning in the flight directors resulting in the air-crash not coming into speed mode inspite of best efforts of Capt. Gopujkar and Capt.Fernandez."

(44) I have opined that attempt must have been made to switch off FD.2 at TF.313 seconds, but

most probably there was no sufficient pressure put on the switch, or for some reason, switch did not go off. If CM1 had attempted to switch off FD2, he has to stretch his arm across towards the switch, unlike the switch of FD1 which is nearer to his seat and CM1 would not notice whether the switch had gone off or not by looking at his FMA. But this cannot be the real cause for the crash, because, there was still some time left for the pilots to resort to manual operation of the throttles.

(45) Possibility of display systems misleading the pilots was not highlighted in the evidence by anyone of the participants.

(46) Doubt about the systems and their functioning not being highlighted in evidence erases such a doubt raised only in the arguments. Possibility of an event having occurred, certainly has to be investigated, provided such a possibility is suggested as a line of investigation. The Court cannot act only on the basis of a mere hypothesis; for example, a remote possibility of 'black out' of human mind always exists; from this, is it possible for the Court that such

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a possibility must have occurred and can I say that its non-happening has not been established ?

(47) While investigating for the cause of a crash of this magnitude, no line of investigation legally suggested should be ignored; these ideas are to be discussed in the open Court for consideration. The Court and the Assessors should examine only such suggestions dispassionately; in the absence of proper evidentiary material on record, answers to these questions are to be deduced from the probabilities of the circumstances.

(48) Indian Airlines has examined several witnesses; some are competent pilots and a few engineers also. It was not elicited from anyone of them the possibility of wrong displays or misbehaviour by instruments. No pilot stated that the speed displays are not conveniently placed for speed monitoring. Atleast three pilot witnesses (Capt. Thergaonkar, Capt. Sathya and Capt. Bhujwala) did not complain of any difficulty in monitoring the speed while flying this aircraft.

(49) In these circumstances, I am constrained to conclude that material on record is insufficient to cast any doubt about the functionings of the cockpit instruments and their behaviour, except, regarding the doubt about the sensitiveness

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of FD2 switch.

(50) I am of the view that there was an unnecessary diversion of attention to check the cause for the idle/open descent mode of the plane and the instinctive reaction to resort to the thrust levers did not come out at the crucial moment.

(51) It is quite probable that a false sense of security was created by a wrong understanding as to some of the systems of the aircraft and inadequate knowledge of these systems, which retarded the growth of proper reflexes in the pilots.

(52) A possibility of idle/open descent mode getting engaged for an unknown reason, as happened in the case of 'Delhi Bird Hit' incidence, has been referred; such a suggestion was made by a few participants also. There is no evidence, here, of any hard impact against the plane at TF.295 or thereafter (or earlier), till the crash.

(53) There is nothing to indicate that pilots were aware of the speed falling; these are two experienced pilots out of whom one is on his first route check in this aircraft. The calmness of cockpit atmosphere indicates that their mind was elsewhere; if not at that point of time, pilots should have resorted to manual operation of the

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throttles, instead of searching for the cause for the idle/open descent mode. The check pilot did not even acknowledge when the pilot under check (CM1) asked for 700 feet rate of descent; instead he spoke of "missed approach...."; Why ? Did the interruption to the talk by the ATC transmission, interrupted the line of thinking ? Purpose of the investigation in finding out the cause and circumstances of the crash, is to take remedial measures from a practical point of view, to prevent recurrence of such an accident. In the words of Shakespeare:

"Wise men ne er sit and
wail their loss,
But cheerly seek how to redress
their harms".

PART-V

ENGINES:

5.1 A detailed discussion on the engines is not called for in this case. Aero Engines examined 3 witnesses on their behalf. Mr.Ronald Weaver is an Accident Investigator at IAE and he has spoken to the boroscope inspection conducted by the Deputy Director of Air Safety and others, when he was present. There was also some questioning of this witness regarding vertical 'G' force at the time of the impact. Mr.Graig Bolt is another witness who is the Manager of Airworthiness at IAE. He gave evidence regarding the certification proceedings and the certificates obtained for the engines. He was also questioned about the timing of the first touch down and about the DFDR readings. There were several questions regarding N2 and the proposal to improve it. The last witness was Mr.Sundar Venktat, who is a Customer Support Manager at IAE. He is also highly qualified in technology and other allied subjects and has gained good experience in the subjects. He has pointed out that there was no complaint about V-2500 Aero Engines at any time by the Indian Airlines.

5.2 These three witnesses examined by IAE were quite forthright in their answers and I do not find any hesitation in any one of them to meet any of the problems placed before them at the time of questioning. In this problematic case, I found unanimity amongst all concerned about the performance of the engines. Some of the technical aspects are found in the note which I have appended to this report, separately, which may have a bearing on further research.

5.3 Though DFDR data had indicated a reduced actual EPR value on left engine during the bounce between first and second touch downs, strip examination of the engines, type of failure of LP rotor stub shaft in both engines similar in nature, calculation of LP rotor RPM needed to develop torsional forces capable of shearing the stub shaft compared with design loads indicated by IAE and deposition of expert witnesses of IAE convincingly established that the engines were at Take off Thrust or close to Take off Thrust at the time of impact with the embankment.

PART VI

DEVELOPMENT OF FIRE

6.1 When the aircraft hit the embankment, the fuselage went sliding over the embankment causing severe damage to the under surface of the fuselage and the wings centre section. The engines and the main undercarriage being ripped off the structure, would have caused serious damage internally to the wings and the fuel tanks. During this impact there is a definite possibility of rupture of the fuel tanks at the forward end. There was still 3500 kgs. of fuel remaining in the tanks based on the flight plan fuel. During the severe deceleration of the aircraft at the time of impact with the embankment and possible rupture of the fuel tanks, and also the severe deceleration at the time of the third impact before the aircraft came to a final stop, due to inertia, the fuel in the tanks would have moved forward through the ruptures of the tanks and spread all over the inside bottom portion of the front fuselage. After the aircraft came to a stop, fuel would spill onto the ground. There were a large number of stones in the area where the aircraft came to rest. Rubbing of the structure of fuselage against these stones could easily cause a spark to start the fuel fire.

Survivor witness (No.17), Mr. Kumar Nadig has stated that the fire was coming out of the cabin floor near row 10 or 11 in front of him. This area would be near about the leading edge of the wing root. He had occupied seat 12C.

6.2. Mr. Hemchand Jaichand, survivor witness (No.6), who was sitting on seat 21A has stated that he saw fire leaping out near about the 17th row, right side. This area would be close to the aft end of the wing root.

Mr. Sridhar, survivor witness (No.7), has stated that he saw the fire in the front side covering the entire front portion before he exited the plane through the rear main door.

The two hostesses who survived have also stated that there was fire and smoke in the front portion spreading towards the rear.

Mr. Laxmiah Reddy, witness (No. 22), who saw the plane coming down onto the marshy land has stated that he heard a big sound like an explosion from the front portion of the plane and heavy blocks of smoke coming out of the plane.

The crew oxygen cylinder containing oxygen under high pressure is located underneath the floor of the forward fuselage. Portable oxygen bottles are located in the cockpit and cabin crew seat positions. These would have assisted the fire tremendously.

From these statements, location of crew oxygen bottle and portable oxygen bottles and the photographs it seems that a fairly intense fire started somewhere between the cockpit and the leading edge of the wing root.

6.3 The passengers seated in row 3E and 4D have survived. Similarly passengers seated in 7C, D and F, 8D and F have survived. From the statements of the witness Mr. Laxmaiah Reddy, it does appear that an opening may have been created by either the crash or the explosion somewhere around that area for them to survive the fire. From the seating charts, 46 passengers out of 53 seated in rows 1 to 10 have died, indicating the severity of the fire when it started from underneath in that zone.

6.4. Most probably the large number of oxygen generators distributed through out the aircraft to provide emergency oxygen supply at the time of decompression, would have assisted in increasing the intensity of the fire. The very fast spread of the fire rearwards is also indicated by the fact that 20 passengers out of 25 seated in rows 14 to 19 have died. From rows 11, 12 and 13, all the 9 who were seated on the left side of the aisle survived and one who was seated at 11D also survived. 6 passengers seated on the right side in these rows have all died. We do know that the left hand side emergency exits were opened and these 10 people would have survived coming out of those exits. It is most probable that either the right hand emergency exits were not opened by the passengers sitting next to them or they were burnt after exiting the plane, as intense fire had been observed on the right hand side wing root area. Also, from the post mortem report it was observed that the passenger seated at 12F had injury to his forearms/hands and abdomen. May be he was incapable of opening the exit next to him before being burnt to death.

A large number of deaths upto row 19 indicates a very fast spread of the fire from the front to the rear.

6.5 From the fuel tank architecture the wing tanks capacity is 12487 kgs. and the centre tank capacity is 6600 kgs. This would be usable fuel and there would be some fuel left in the tanks at the bottom which cannot be used. With 3500 kgs. remaining on approach we would anticipate that this would have been evenly distributed in the wing tanks. The centre tank would have had only the unusable fuel.

6.6 From the inspection report of the Airbus team there was a 10" x 6" hole in the forward spar, apparently caused by some force from inside the tank is indicative of a post crash explosion from inside the tank. Even though some fuel was retrieved from the left hand wing tanks, the fuel which had spilled out onto the outside ground would have contributed to the fire from the bottom. 30% of the forward roof of the centre tank had been completely destroyed and all the remaining fuel in the centre tank would have assisted the fire.

6.7 It is not possible to know the duration during which the aircraft was burnt and the time that was available to the passengers inside the plane to escape. From the intensity of the fire the occupants of the forward seats had just a few seconds before the fire engulfed them. As 10 passengers have escaped through the left hand exits, assuming that 5 of them got out through each exit, we may roughly estimate that the fire would have engulfed this region in about a minute or slightly less from the time of the third impact.

6.8 As a large number of passengers from row 20 to 28 and possibly the two passengers from row 17 to 19 have passed through one rear exit, it would appear that this above estimation could be correct. Subsequently, the fire has spread out to the rear section of the aircraft also. With the comparatively low amount of fuel that was available it is rather difficult to explain how the rear passenger cabin was fully burnt upto the rear galley. In all probability, the impact with embankment and the passage of the fuselage over and rubbing against the embankment, may have caused a serious rupture to the bottom surface of the fuel tanks including wing tanks. This would have started spilling the fuel when the aircraft came onto the ground on its belly and slided forward to come to a stop. Such fuel might have contributed to the damage caused to the floor structure and burning of all internal furnishings, baggage in the overhead bins and under the seats, etc., again assisted by oxygen generators.

6.9 As only 3300 kgs. of fuel has caused this fire to spread to the entire aircraft and evidence of fire has been recorded in the right wing root area and forward and aft spars, the intense fire due to the fuel may have lasted for a very short period of time which was subsequently supported by the furnishing, clothes, baggage, oxygen generators and portable oxygen bottles, etc. From passenger survival point of view it is not possible to estimate exactly as to the time factor that was available for them to escape.

6.10 The airport fire station is located in the middle of the airport below the control tower. Even if the engines are kept running, for the crash fire tenders to proceed from the fire station to the end of R/W 09 and then onto the boundary wall from where the first fire fighting actions were launched, would have taken a minimum of 3 minutes because there are turns, bad road, hump across the crash barrier etc, to be negotiated.

Re: HAL.

6.11 The fire fighting operation conducted by the fire tenders at the Airport came under severe attack by a few participants.

Actually two questions arose concerning the Hindustan Aeronautics Limited (for short HAL) Airport.

6.12 The Airport is under the control of HAL which is an incorporated Company. HAL belongs to the Government of India in its entirety. The Inspector of Accidents in his report - Ex.C1 remarked that this Airport was not licensed so far even though under the aircraft rules licensing was essential.

6.13 The second question pertains to the fire fighting operation conducted immediately after the crash.

On the first question I do not think, it is necessary for me to give a definite opinion. However, a few points are indicated hereafter.

6.14 The Aircraft Rules, 1937 are the Rules framed by virtue of the power given to the Government of India by the provisions of the Aircraft Act and to some extent by virtue of Section 4 of the

Indian Telegraph Act and these Rules provide the general conditions of flying, general safety conditions, registration and marking of aircraft, etc. Part-XI of the Rules govern the Aerodromes. Rule 11 states that none shall use any place for landings and departures of any aircraft other than an aerodrome licensed or approved for the purpose in accordance with the provisions of Part-XI of the Rules. Part-XI contains Rules 78 to 87. As per Rule 78 a Government aerodrome shall not be open to use by any member of the public save to such extent, if any, and subject to such conditions as the Central Government may determine. Rule 79 states as follows:

> "79. Places other than Government aerodromes - A place in India other than a Government aerodrome shall not be used as a regular place of landing and departure by a scheduled air transport service or for a series of landings and departures by any aircraft carrying passengers for hire or reward unless;
>
> a) It has been licensed for the purpose, and save in accordance with the conditions prescribed in such licence; or

b) It has been approved by the Director General subject to such conditions as he may deem fit to impose, for the purpose of giving joy-rides for hire or reward".

Rule 80 provides for licensing of the aerodromes and Rule 87 provides the conditions governing the grant of licence. It is clear from Rule 79 that licence is not required for a Government aerodrome.

Rule 3(27) defines Government aerodrome as "an aerodrome which is maintained by or on behalf of the Government and includes an airport to which the International Airports Authority Act, 1971 applies or is made applicable".

6.15 Mr. Satendra Singh opined that the Bangalore Airport belongs to HAL and therefore it is not maintained by or on behalf of the Government and if so licensing under Rule 79 is mandatory. The HAL however has contended that HAL itself is entirely owned by the Government of India and is basically under the control of Defence Department and on several occasions even the DGCA inspected this airport and so far at no time this airport was licensed except for one year during 1961. It was pointed out that this airport has been functioning from about the year 1940 and so far no authority insisted that it has to be licensed under the Rules and no authority found any fault for non-licensing of the airport. It was pointed out that the Inspector of Accidents himself is an official of the Department of DGCA and DGCA never insisted that HAL airport requires licensing. This airport was established primarily for the defence purposes and therefore has been under the control of the Ministry of Defence, but at the same time it has also been serviced for Civil Aviation. Three documents were filed on behalf of the HAL to point out that the authorities of DGCA carried out inspections earlier and the report in the prescribed form have been submitted. In these circumstances it was contended that no licensing was necessary. It is further pointed out that the timings for the landings and take off of various aircrafts are to be approved by the Government of India and any user of the airport by aircraft of other countries are also subject to the approval of the Government of India.

6.16 For the purpose of finding out the cause or the causes of the aircrash in question I do not think this question of licensing of the airport has any bearing. The facilities available in this airport will have to be seen for the purpose of finding out whether immediate action was taken to minimise the effects of the crash; but for this, no other question would arise because the investigation does not disclose that in any manner either the ATC or any other facility available in this airport has contributed in any manner for the crash in question. Investigation reveals that the airport has satisfactory facilities for the landing and take off of the planes. Though some question was raised that I.L.S. should have been there, that question was incidently raised.

6.17 Mr. Satendra Singh in his deposition stated that this airport falls within the category-7 and the requirements in respect of category-7 airport are satisfied in this case. He also admitted that the DGCA inspected this airport as is seen from Exs. 57 to 59, during the years 1982, 1983 and 1984 and that he is not aware of any complaint made by the DGCA against this airport, which has not been rectified or attended to. He also stated that the use of this airport by different aircraft are based on the approval of the Central Government and that whenever there is change in the schedule or timings regarding flights, approval of the Central Government was being obtained and Ex. 60 is one such document containing certain telex messages. For category-7 airport, as per International standards and recommended practices, the number and type of rescue and fire fighting officials for this category has been specified. For category-7 one R.I.V. and two crash fire tenders (CFTs) are required.

6.18 In his deposition, the third witness Mr. P.M. Rao, who is the Senior Manager (Aerodrome)

HAL has stated that this airport is primarily for the use of military aircraft produced or serviced by HAL but subsequently after it commenced functioning in the year 1940 it was approved by the DGCA for public use. Airports at Pune, Srinagar, Jorhat etc. also similarly are under the control of the Defence Department. The fire fighting equipments and the personnel maintained at this airport, according to him, are in accordance with the standards prescribed by ICAO. The capacities of the 2 CFTs maintained at this airport and their discharge rates fully satisfy the ICAO standard. However, he admitted that the DGCA does not carry out any inspection of the airports under the control of the defence. He also stated that there was a proposal to install ILS in this airport.

6.19 The views of the Government of India on this question of licensing are not disclosed to the Court. Similarly, DGCA also has not placed any material to assist the Court on this question of licensing this airport. In the absence of a direct participation by the Government of India or by the DGCA, on the question whether the airport requires licensing or not an expression of opinion by the Court would be incomplete.

6.20 The fact remains that the facilities available in the airport should be perfect as far as possible and some supervisory authority should be there to inspect the airport periodically and see that proper facilities and services are provided and rendered. An inspection of the airport by an outside authority would guarantee that the airport is maintained properly. Complacence on the part of the personnel who are entrusted with the various functions at the airport can be prevented or at least reduced to a large extent if such inspections are carried out by a higher authority.

6.21 Some of the participants taking the clue from the report Ex.C1, urged that there has been laxity in the operation of the fire fighting force. It was contended that the CFTs and the RIV moved into the crash site after some delay. This apart, the gate of the boundary wall could not be opened in time, resulting in further delay in the movement of the men and vehicles. By the time the fire fighting operation became active, the fire has already taken its toll. It was contended that if there had been a prompt action on the part of the fire fighting personnel, several lives could have been saved.

6.22 At page 24 of Ex. 1 the Inspector of Accidents noted the facilities available at HAL airport to fight fire and render rescue services. Among other things the Inspector has observed that the gate was not opened in time even though power cutter was used to remove the lock. Therefore, the spraying operation was conducted from the boundary wall and spray could not reach the entire burning part of the aircraft. There was no facility to refill the vehicles immediately. The report also states that the communication between the tower and the fire fighting personnel was not direct and similarly there was no provision to directly contact other fire fighting stations in the city.

6.23 HAL has taken strong exception to these criticisms and asserted that there was no laxity at all on their part and in the circumstances the fire fighting personnel operated with utmost promptness. Mr. Satendra Singh's opinions expressed in his report were based on the report he in turn obtained from others who were assisting him in his investigation after the crash. Therefore, his opinion could not be justified by him directly (i.e. by his personal knowledge) in the course of his deposition.

6.24 Witness No.1, Mr. Sharma is the Deputy Manager, Fire Service, HAL. He stated that there are four fire stations under his control belonging to HAL. The HAL aerodrome fire station is the one which is involved in the present situation. He speaks about the various facilities, vehicles and water sources available. He states that whenever there is an aircraft activity such as landings or take off, there is a procedure prescribed for the fire crew. The crew is alerted by the tower by pressing a button, which shows amber light in the fire station area. The firemen report back to the tower to confirm receipt of the message. Thereafter they position themselves in the vehicle, the engines are started and kept running. There is a walkie-talkie for inter-communication between the tower and the crew apart from an internal telephone. If there is any emergency the tower gives audio-visual signal which includes lighting of the red light and buzzer. In such a situation the vehicles proceed to take their position on the ramp. The red light and the crash bell are put into use in case of an aircraft accident/fire. On this the vehicles proceed towards the runway collecting relevant informations enroute. On the date of the aircrash in question these vehicles which were in alert position turned out from the fire station on hearing the crash bell and on the way they could see a column of thick black smoke at the western end of the air-field. Therefore, they proceeded in that direction. According to this witness absolutely no time was lost by the vehicles and they proceeded to the scene of the crash immediately and within two minutes the vehicles must have reached the end of the runway. This witness states that he was in his office on the date of the accident. He heard shoutings in the ground floor about the fire and immediately he came down, jumped into a jeep; by that time he saw one of the CFTs and a jeep rushing out of the said building. He instructed to call fire engines from other divisions of the HAL. He also flashed back a wireless message asking for the fire engines from other stations including a message to inform Karnataka Fire Force for help. At the end of the runway he crossed over to the access road which led into the emergency gate. He says by that time two CFTs were already at the boundary wall and discharging foam from their minotors. The gate was not yet opened and therefore he issued instructions to the Fire Officer to get the power cutter and to open the gate and to bring the fire engines out. However, he climbed over the gate and rushed to the crash spot. This officer states that he opened one of the doors of the plane and in this regard there was a help by some one else also, but no passenger was there inside the plane. But, smoke was coming out. After this witness entered the plane and moved towards the port side he heard people crying for help. About 3 or 4 persons including a lady were rescued behind the port wing next to the fuselage. This witness went to the port door and shouted for any survivors, but there was no response. By that time CFT by name Godavari came to the site and positioned behind the star board wing and started discharging the foam. The RIV also arrived and started discharging the foam. He says another vehicle Krishna also arrived, which was positioned behind the tail and another vehicle

Thunga also came. Thick smoke was coming out and fire was spreading towards rear of the plane and it was burning at the top. After sometime the CFT returned after replenishment and positioned at the nose of the aircraft and started dousing operations. By this time the fire engine of Karnataka Fire Force also arrived and engaged itself in fire fighting.

This witness is a Fire Engineering (B.E.) Graduate and has been trained in fire fighting operations. According to him the time within which rescue work is possible, is about 148 seconds after the crash because the temperature at the end of this period will raise to about 390°F to 400°F, which is the survival limit. Similarly the melt through of the fuselage will occur in about 15 to 30 seconds. The flash point of aviation gasoline is of the order of - 30°F to -50°F with flammability range of 1.4 to 7.6% and spontaneous ignition temperature of 824°F to 880°F. The fire spread rate is about 700 to 800 ft. per minute. The witness has produced an issue of 'Fire Engineers' journal in support of his statistics.

From the boundary wall where the CFTs were positioned initially, the burning portion of the aircraft was well within the reach of the monitors and the direction of the wind at that time was from the front of the aircraft to the rear and therefore the foam spray could move faster to a longer distance because of the wind assistance. The normal reach of the foam spray from the CFT will be 60 meters, but in this case the wind aided the foam to reach another 5 to 6 meters. According to this witness, but for the prompt action of the fire fighting force the fire in the aircraft could not have been brought under control and damage would have been still more. The witness also states that even though RIV need not be compulsorily required as per the latest ICAO recommendation, still here, it was being used. He denied that there was any delay for the CFTs to reach the site. He also asserts that the equipments and the facilities maintained at this airport were according to the standards, internationally recognised. This witness was thoroughly cross-examined by various participants. According to him the RIV and two CFTs were already there at the boundary wall and were pouring the foam towards the burning site, by the time he reached the gate. However, the gate was locked and therefore none of them could immediately go out towards the crash site. The key was not kept with the fire station and he was not aware as to where the key was kept. He also deposed to the mock trial monitored by the tower once in a month. But he admitted that no exercise was conducted in respect of a crash occuring outside the boundary wall. The key was not with him and it was not necessary for him to know where it is kept because he had the authority to break open the chain of the gate. According to him it was the responsibility of the security personnel to have the gate locked and preserve the key. However, he has not given any satisfactory answer as to why the personnel who were in the RIV and in the two CFTs did not break open the gate. It is the assertion of the HAL that the gate was opened with a power cutter and such a power cutter was available in one of the fire tenderers. If so, it is un-understandable as to why there was delay in cutting open the chain of the gate. It is clear from the deposition of this witness that RIV and CFTs had reached the boundary wall earlier to him. When such a dense smoke was coming out and fire was already spreading I do not think that any reasonable person would have waited for any other authority to order the cutting open of the gate chain. The normal human behaviour in such a situation will be to open the chain with the power cutter available. Therefore, there seems to be some strength in the contention of a few of the participants that the power cutter was not available at all with the fire tenders. Neither the key nor the cutter being available, the gate could not be opened at the earliest point of time. Added to this, probably the gate had rusted and could not be opened smoothly. It has also come in evidence of this witness No.1 that no exercise whatsoever was being conducted to keep oneself ready for the eventualities of the crash occuring near the boundary wall. Obviously the gate was never opened after it was fixed for a long time. This inference is inevitable in the circumstances of the case not only because of the statements contained in the deposition of this witness, but as will be presently seen from the deposition of a few more witnesses.

6.25 At one stage in the cross-examination this witness stated that the gate was opened about 2 minutes after the CFT reached the boundary wall and he admits that at least a minute could have been saved to reach the crash site if the CFT had used the power cutter at the earliest point of time on reaching the boundary wall. Having regard to the nature of the fire and the preparedness required to extinguish it, even a minute counts and most probably this minute would have saved some years of life time, of a few in the plane.

6.26 It is not known clearly as to whether the power cutter was available in the vehicle and if so the personnel in the vehicle failed to act immediately for want of specific authority. It is not known as to who were the other persons who were in the other CFTs and the RIV, who could have acted immediately before this witness reached the boundary wall. A broad impression is inevitable that there was some laxity on the part of someone in the matter of opening the gate.

6.27 In fairness to HAL it will have to be noted one more aspect at this stage. The fire could be controlled provided the rescue work is done within 148 seconds after the crash. This will be 2 minutes 28 seconds. The plane had fallen into a marshy area about 150 ft. beyond the boundary wall. The time that will be taken for the fire fighting vehicles to reach the end of the runway from the fire station is stated to be 2 minutes (vide para 9 of Mr. Shama's affidavit, made part of his deposition). If so, the fire must have developed in intensity and must have achieved great burning power, by the time the CFTs reached the end of the runway and by the time they were positioned at the boundary wall further spreading of the fire must have taken place. Positioning at the boundary wall would itself require at least half a minute. In these circumstances, whether the fire fighting operation would have succeeded in reducing the damage, even if the gate had been unlocked or opened immediately, is a matter of doubt. After the gate, to reach the plane, one had to pass through a marshy land and it is in evidence that one of the vehicle in fact could not be moved and had to be pushed. Having regard to these factors, for any vehicle to reach the plane at the site in which it has fallen would have taken at least 4 to 5 minutes from the fire fighting station. The damage by that time must have been complete; those passengers who could save themselves or who were saved by the rescue operation of others must have been saved already. If the situation is viewed from this angle, it is possible to hold that the delay of a minute or so in opening the gate in the instant case has not mattered either way. The deposition of this witness discloses that CFTs reached the boundary wall earlier to the RIV obviously because the RIV did not accelerate itself to the expected speed. This witness also explains that those who were in the vehicles had reached the boundary wall earlier, concentrated on the aspect of extinguishing the fire immediately by discharging the foam from the said place, instead of considering the question of breaking open the gate with the aid of the power cutter. When a grave accident occurs how a human mind reacts is beyond one's comprehension. This explanation of the witness also is quite possible. The lack of exercise to meet the situation of this nature occuring outside the boundary wall must have caused the men concerned to forget about the power cutter.

6.28 Most of the accidents occur at the time of landing or take off. The accidents at the time of landing need not be always inside the airport area. It may be near about as happened in this case. Though the fire fighting vehicles are primarily meant to meet a situation caused by the accident within the airport area, it will be necessary to note that the concerned personnel also should be trained to act promptly at the time of the accident that may occur near about the airport also. Some periodical exercise in this regard would train the personnel to meet the situation.

6.29 Witness No.2 is an Assistant Aerodrome Officer in HAL. He has undergone the requisite training. He is also a M.Sc.(Tech.). He speaks about the functioning of the tower in the airport. He was the person who received the short finals report from the aircraft and issued the landing clearance. He saw the aircraft suddenly going down and dust and smoke were observed by him. Immediately he sounded the crash bell to despatch the CFTs. Normally it takes about one and half minutes for an aircraft to land after short finals are reported. This however depends upon the other factors and usually short finals are reported when the plane is about 400 ft above the ground. There are binoculars in the tower having a range of about 10 miles. His colleague was using the binoculars to check the runway, but he does not think that his colleague was watching the aircraft flying towards the air-field. Till the moment he pressed the alarm bell whatever conversation was recorded between the ATC and the aircraft was of this witness. After pressing the alarm bell the further communication recorded was of his second officer because this witness immediately started initiating emergency procedure.

6.30 Witness No.3, Mr.P.M.Rao, who is the Aerodrome Officer is not certain whether the gate at the boundary wall was opened during the last 20 years. He admits that the key is to be with the security personnel and they are also involved in implementing the emergency plan. But he is not aware whether any security personnel made any attempt on the date of the crash to open the gate. This witness asserts that the gate was opened by the fire fighting personnel by using the power cutter. The fire station is just below the tower and the distance between the gate and the tower is about 6 to 7 thousand feet.

6.31 Witness No.13 is Capt.Vijay S.Sathaye. He was to fly IC 604 on the day of crash from Bangalore to Bombay and he was seated in his plane. His radio was on and therefore he heard the landing clearance given to the ill fated IC 605. He saw the aircraft coming in. He was a close friend of Capt.Gopujkar. He saw huge dust beyond the boundary wall and instantaneously there was flame. He saw the aircraft going up slightly and settling down again. Realising that there was a crash he transmitted to Bangalore ATC and told them about the crash. Thereafter he ran towards the flight despatch and from the flight despatch he went towards the crash site along with Mr.Manjunatha Ural (Witness No.16). On reaching the boundary wall he found the gate closed and one fire tender was spreading foam across the wall. He jumped over the gate and ran towards the aircraft along with Mr.Ural and another Mr.Murthy. He was prevented from going closer to the plane by others and he felt helpless particularly since both pilots of the ill-fated plane were his close friends. He remained at the crash site for approximately 10 to 15 minutes. During that period HAL fire tender kept on spraying foam to the aircraft. But the foam was not reaching the aircraft completely because the fire tender was not near the aircraft. According to him, when he was there, no other tender had come near the aircraft. He returned thereafter and operated IC-604 to Bombay. During the period he was at the crash site the fire was not under control. He also states that some attempt was going on to open the gate by some people when he reached the gate, with the help of something like a crowbar, but he did not notice any power cutter being used. In view of the anxiety he jumped over the gate which was 7½ ft. height. According to him he reached the boundary wall about 10 to 15 minutes after the crash and at the time he was jumping over the gate attempt was still going on to break open the gate lock.

Witness No.16, Mr.Manjunatha Ural, is the Flight Operations Officer at Indian Airlines, Bangalore. Mr.Murthy is another such officer.

Mr.Ural says that Capt.Sathaye rushed into his office and informed of the aircrash. Immediately along with Capt. Sathaye and Mr.Murthy he rushed to his jeep and drove towards the site of the accident. On the way he was over taken by one fire tender at the end of the runway. He saw one crash tender already spraying water from inside the periphery wall towards the plane. Thereafter the second tender also reached the place. Three of them jumped over the gate and ran towards the crashed plane. According to him some persons were using ordinary fire axe to cut open the chain of the gate. The gate was opened only by the time he returned after about 10 minutes. Till he returned from the site fire tenders had not come to the spot at all. He was at the spot for about 10 minutes.

6.32 There are a few more witnesses who have referred to the fire extinguishing operations. They include the Airhostesses, a passenger and a person who witnessed the crash, but none of them is able to speak definitely about the movement of the vehicles and the time taken for these fire fighting vehicles to reach the crash site. From a consideration of the entire evidence and the circumstances as already observed by me it is not possible to accept the case put forth by the HAL that the gate at the boundary wall was opened immediately. Certainly there was some delay and the delay could have been avoided if the key was available to open the lock or if the power cutter was immediately used to cut open the chain. Though Mr. Sharma had given some explanation as to why the power cutter was not probably used by the fire fighting personnel who reached the boundary wall, the depositions of Capt. Sathaye and Mr. Manjunatha Ural shows that the delay in opening the gate was not marginal by 1 or 2 minutes, but it took several minutes before the gate was opened. It may be, that even if the gate had been opened at the earliest point of time and the rescue operation had started immediately, the intensity of the damage would have been the same. But, that is not a valid reason to explain away the delay in opening the gate and rushing towards the crash site. None can foresee at that time whether immediate operation at the site was required or not. When large fire had broken out the person concerned with the rescue operations should rise to the occasion. His profession and his training should mould him not to get confused or deviate from the required action on the ground of being confused by the intensity of the fire. These personnel should be trained to act not only promptly, but also diligently. Their mind should be alert towards the situation and act to prevent the spreading up of the fire. These persons cannot infer that it was too late for them to take any action and therefore they can proceed to the crash site after attending to some other preliminary rescue operation. This is a matter for the HAL to seriously ponder over and take an appropriate action to train its fire fighting personnel properly.

6.33 One more fact requires to be noticed. Ex.1 (page 24) under sub-head 'Ambulance' it is mentioned, "On the day of the accident, the medical attendant was not present". During the cross-examination of Mr.P.M.Rao, Senior Manager (Aerodrome) (Witness No.3), he admitted that, "Even though the medical attendant was not on leave on the date of the crash, I understand he was not present in the ambulance. I understand that he went to the office in connection with his personal work."

6.34 Absence of medical attendant at the time of this crucial hour when planes arrive or take off indicates another sense of complacency on part of the concerned personnel. The administration of HAL should alert itself against such complacency. Accidents occur unexpectedly. Those who are to provide relief measures are expected to be always vigilant and to be in readiness for action.

7.A FLIGHT CREW TRAINING

A-320 is a commercial jet transport aircraft designed to be operated by 2 pilots. It is equipped with Fly By Wire controls operated by sidestick controls replacing the conventional control columns. The FBW system controls both the primary and the secondary surfaces. Computers which receive electrical command signals from the flight deck, process the information and transmit the commands to the appropriate hydraulic actuators operating the flight control surfaces. The movement of Horizontal Stabiliser for trim purposes is automatic based on computer commands only without any direct input by the pilots. The movement of one sidestick control is not reflected on the other.

Flight Management and Guidance System (FMGS) on the A-320 provides Auto Pilot Control, Flight Director Commands, Auto Thrust Control, Rudder Commands, Flight Envelope Computations, Information Display Management etc.

The Auto Thrust System is designed in such a way that the Thrust Levers do not move when the system is active.

The aircraft is equipped with Full Authority Digital Electronic Control (FADEC) to provide a full range of engine control. 6 Cathode Ray Tube (CRT) displays are used to replace conventional instruments.

Majority of the pilots sent by Indian Airlines for training on to A-320 were previously flying Boeing 737 type of aircraft. The Indian Airlines Boeing 737 aircraft is an early generation aircraft with basic Auto Pilot and Flight Director Systems. It does not have an Auto Throttle system. There are no FMGS or FADEC or any similar systems. There are vast differences in the FCU panel of the A-320 and the panel ~~is~~ in similar location on the Boeing 737. The Flight controls afe conventional and cable operated using conventional control columns. Any movement of one control column is reflected on the other pilot's control column.

Movement of these pilots from Boeing 737 to A-320, needed to bridge a very great technology gap from the 1960's to the late 1980's. Great care is needed to achieve a good transition for ensuring flight safety.

Indian Airlines had planned to induct 19 A-320 aircrafts during the period May, 1989 to March, 1990. This was a massitve task needing a large number of pilots to be trained in a short period of time to launch all these aircrafts into service. A-320 was a new type of aircraft being inducted into Indian Airlines. It had neither the competency nor the equipment and associated materials to carry out the training themselves prior to the induction. It was therefore essential for them to depend on the manufacturers to carry out the training of a large number of the pilots.

One of the requirements for PIC endorsement, as per the Indian Aircraft Rules, is 100 hours experience as a co-pilot before commencement of 10 mandatory route checks as PIC under supervision. If this were to be satisfied, it would have been impossible for Indian Airlines to induct these 19 aircrafts without hiring a very large number of pilots from abroad qualified on A-320 to fly these planes till the time their own pilots were trained. Their licences had to be validated for flying Indian aircraft, and a large number of these hired pilots had to be check pilots or instructors to carryout route training of Indian Airlines pilots.

When a new aircraft is inducted, it is normal practice to request for exemptions (including the above 100 hours co-pilot requirement and 10 mandatory route checks) from the DGCA in favour of experienced personnel to overcome this difficulty. Such exemptions have been granted earlier by the Ministry of Civil Aviation and the DGCA at the times of introduction of A-320 into Indian Airlines, Boeing 747, A-300 and A-310 into Air India.

On 31-1-1989, Indian Airlines wrote to DGCA, vide its letter HOP/25 8502/223, requesting for various exemptions for training 152 pilots (12 examiners/instructors, 103 captains and 37 co-pilots) in 16 batches at Toulouse. 2 DGCA examiners on A-300/Boeing 737 were to be trained in February/March 1989 after which, they were to formulate and execute induction courses at CTE Hyderabad for the remaining pilots before proceeding to Toulouse for training.

Along with this letter, Indian Airlines had enclosed copies of various training courses for pilots, operations personnel and cabin attendants.

On 6-2-1989 Deputy Director Flight Crew Standards of DGCA, prepared a note wherein he has given his comments regarding the exemption requests from Indian Airlines. Briefly they are:

1. Course contents of technical and simulator training appear to be quite elaborate and adequate.
2. Simulator capability has not been indicated by Indian Airlines to ascertain the extent to which the training thereon can be considered for acceptance.
3. Airbus Industrie does not maintain a cadre of its own instructors. Pilots with experience on type are mustered on contract from all over to impart conversion training.
4. Experience and licence details of pilots to be engaged by Aeroformation for imparting training should be provided by Indian Airlines to consider their suitability and validation of their licences.
5. Simulator and flight checks for type endorsement may be carried out by French DGAC examiners as also technical examinations rather than being checked by pilots engaged by Aeroformation.
6. Required forms signed by French DGAC examiners is acceptable.

7. Indian Airlines to indicate minimum number of crew for whom exemptions are required to enable them to introduce aircraft without any difficulty and without compromising safety standards. It would not be correct to allow exemptions of 100 hours co-pilot experience and 10 mandatory route checks to all 103 captains.

8. Direct examinership/instructorship could be considered on receipt of their performance and check reports from Aeroformation/DGAC France.

9. Carrying out of CA 40 B/A checks on aircraft after successful completion of their A-320 simulator training can be considered only after the capability of the simulator is intimated to DGCA India.

10. Indian Airlines to provide biodata of Aeroformation instructors along with security clearance for validation of their licences.

11. As course contents submitted by Indian Airlines for A-320 conversion appears to be quite exhaustive, there may be no objections in accepting course completion certificate from Aeroformation.

12. Indian Airlines to have a discussion on all points rather than have protracted correspondence.

A meeting was fixed for 9-3-1989 after consulting DDG (K).

On 15-3-1989 Aeroformation sent a telex to Indian Airlines confirming that their A-320 courses have been certified by French DGAC and their pilot instructors were approved.

On 30-3-1989 Indian Airlies requested the DGCA for approval of 21 Aeroformation instructors to fly Indian registered aircraft and to act as examiners and instructors. Details of their experience including experience on the A-320 had been indicated. It should be noted that some of these 21 pilots had very low experience on A-320 on 30-11-1988. Against two names, namely, Sylvester and Lorenz, no A-320 flying experience had been indicated, but there was a remark TBC.

On 24-4-1989 Indian Airlines wrote a letter to the DGCA giving some details of the A-320 conversion course at Toulouse which included paragraph (iv) on page 2 reproduced below:

> "Flight training which will include 6 landings by day and 6 landings by night for captains and 3 landings by day and 3 landings by night for first officers. This will consist of :
>
> (i) go around with one engine.
>
> (ii) one instrument approach
>
> (iii) one full stop landing ".

They have also indicated that as this course has been approved by the French DGAC , they were requesting DGCA to accept the certificates of course completion, simulator, flight and route checks carried out by Aeroformation instructors/examiners, CA 40 A/B forms signed by them, etc. Direct examinership had been requested for Director of

Training, Director of Operations and Operations Manager Training after completion of the course and two route checks.

They also submitted a list of 70 pilots with a request that the first 50 captains who successfully completed A-320 conversion course be granted PIC endorsements after 4 route checks. In this list of 70 pilots, Capt.Gopujkar was Number 38.

On 28-4-1989, Deputy Director Training and Licencing, prepared a note for Director of Training and Licencing and Deputy Director General which briefly indicated the following:

1. Acceptance of Aeroformation training and checks by Aeroformation instructors/examiners approved by DGAC, France, towards grant of command/type endorsement.
2. Approval of Aeroformation instructors/examiners and approval of ground and simulator courses.
3. After examination the syllabus of ground technical course, simulator booking and exercises, submitted by Indian Airlines appeared to be adequate.
4. As list of 21 pilots of Aeroformation submitted by Indian Airlines could be approved as examiners, as they are approved instructors by DGAC, France after their security clearance is obtained by Indian Airlines. Their licences also may be validated to fly Indian registered aircraft.

The note was counter signed by DTL on 1-5-1989, DDG on 2-5-1989 and Mr.P.C.Sen, Director

General, approved the validation of the licences of the list of pilots enclosed on 5.5.1989.

The preliminary meeting between DGCA officials and Indian Airlines was held on 29-3-1989 in connection with A-320 training. As per Indian Airlines letter Number HOP/27 10085/762 of 13/17th April, 1989, the decisions taken were that the Director of Operations, Director of Training and Operations Manager Training would be granted PIC endorsement on A-320 after carrying out two route checks instead of 10 route checks. The requirement of 100 hours P2 experience will be waived.

The above three would be granted examinership after grant of PIC endorsement. The other decision was, for 40 additional pilots 100 hours P2 experience would be waived and PIC endorsement would be after 4 route checks and 20 of these pilots would be allowed to act as examiners/instructors on A-320.

On 4-5-1989, security clearance of the 21 Aeroformation/Airbus Industrie Pilot instructors was intimated to Indian Airlines by the Ministry of Civil Aviation.

On 8-5-1989, Indian Airlines forwarded to DGCA the flying experience of 70 pilots slated for training on A-320.

On 6.6.1989, a note was prepared by an officer of the DGCA to the DDFCS that Ministry of Civil Aviation had informed Indian Airlines of the security clearance of the 21 Aeroformation/Airbus Industrie pilot instructors. If approved their licences could now be validated for a period of 6 months as Indian Airlines had intimated the Ministry that their stay in India was likely to be 6 months. On the same day it was approved by DDFCS and later vide letter No.F.No.81/89/L(I) dated 6-6-1989 to the Director of Operations, Indian Airlines, the DGCA validated the licences of all 21 Aeroformation/Airbus Industrie Instructors under Rule 19 of the Indian Aircraft Rules, 1937.

On 7-6-1989, the DDFCS prepared a note for the attention of Mr.S.K.Gupta, Junior Analyst in the Ministry of Civil Aviation quoting DGCA U.O. No.81/89/L(I) dated 5-6-1989.

The above note was on the subject of exemption for pilots of Indian Airlines from flying A-320 aircraft. Some of the contents of this note are briefly indicated below:

(a) Indian Airlines pilots are being trained in batches at Toulouse on Indian registered aircraft. According to the arrangements arrived at the pilots of Indian Airlines who are deputed for training will be subjected to thorough technical ground/simulator and inflight training on completion of the training period, they will be subjected to a flight test by the examiners of the Airbus Industrie in accordance with the laid down standards. The examiners will submit the required reports and if satisfactory after scrutiny by this department they will be accepted for the grant of endorsement on A-320.

(b) For grant of PIC endorsement it was recommended that the first 53 pilots of the enclosed list may be exempted from the requirement of 100 hours co-pilot experience on type and they would also be exempted from the requirement of 10 mandatory route checks but shall carry out 4 route checks with approved examiners. However, Director of Training and Operations Manager of Training shall carry out two route checks with Aeroformation examiners.

(c) Licences of Aeroformation examiners have already been validated.

(d) Exemption of technical exams in aircraft and engines on A-320 conducted by DGCA can be granted, provided the pilots trained at Airbus Industrie have been assessed by examiners of Airbus Industrie as having adequate proficiency in their technical knowledge.

The note has quoted that exemptions had been granted to Indian Airlines and Air India, in the earlier years at the time of introduction of other aircrafts. This note had been issued by the approval of DDG.

On 3-7-1989, vide AV 11013 9/89 A, the Government of India, Ministry of Civil Aviation and Tourism issued an order granting exemption from 100 co-pilot hours on A-320 to 53 pilots of Indian Airlines with a proviso that they should carry out 10 mandatory route checks before PIC is given. Capt.Gopujkar was included in this list. After some earlier correspondence on 16-1-1990, the Managing Director wrote to DGCA vide his letter No.HOP/ 25 8502/121 indicating difficulty in the introduction of the fleet and requesting exemption for a further 22 pilots.

On 25-1-1990, DDFCS prepared a note on the subject of exemptions from 100 hours co-pilot experience for grant of PIC on A-320 Indian Airlines pilots quoting all earlier correspondence. The case had been discussed with Director of Operations, Indian Airlines. 90 Commanders were needed by February,1990 to operate 18 aircraft at 5 sets of crew per aircraft.

The note also indicated the status of exempted and non-exempted pilots slated for A-320 command as on that date.

Based on the earlier criteria of 2500 hours PIC experience on Boeing 737, the note requested approval for 14 more pilots to be recommended to the Ministry for exemption under Rule 160 of Indian Aircraft Rules,1937. The exemptions shall be from compliance with the requirement of 100 hours co-pilot experience for PIC. However, mandatory 10 route checks have to be carried out. This note was signed by DDG(K) on 25-1-1990 and DG on 1-2-1990.

Government of India, Ministry of Civil Aviation issued an order vide their letter No.AV 11013/9/89 A dated 12-2-1990 exempting 14 more pilots of Indian Airlines from the requirement of 100 hours co-pilot experience on A-320. However, 10 mandatory route checks should be carried out before PIC rating was given. Capt.C.A.Fernandez was included in this list. There are a few very important observations from all the above proceedings in respect of granting exemptions and acceptance of Aeroformation training.

(a) Though DDFCS had made a note on 6-2-1989 that simulator capability has not been received to ascertain the extent to which the training thereon can be considered for acceptance, he has prepared another note on 7-6-1989 for the attention of the Ministry of Civil Aviation which indicates that pilots who are being trained at Toulouse could be subjected to a flight test after thorough technical ground/simulator and inflight training. From the files provided by the DGCA, the Court has not observed any material regarding the capability of the Aeroformation simulator.

(b) DDFCS had made a note on 6-2-1989 that experience and licence details of Aeroformation instructors was needed to consider their suitability prior to their validation. But, it is observed that no attempt had been made to obtain the flying experience on A-320 aircraft in respect of two pilots namely Capt.Sylvester and Capt.Lorenz. The records had only shown TBC against their A-320 flying experience and TBD against their Airbus A-320 type rating.

The basis on which these two pilots were approved as examiners to train Indian Airlines pilots is not forthcoming.

(c) Though the reference to flight training has been made on 24-4-1989 by Indian Airlines in their letter to the DGCA (No.HOP/25 8502/817) and inflight training had been indicated in the first paragraph of the note of DDFCS dated 7-6-1989 to the Ministry of Civil Aviation there is no evidence of flight training having been imparted to Capt.Gopujkar and Capt.Fernandez before their flight test by approved examiners on the aircraft.

The A-320 training records of Capt.Gopujkar shows that after his simulator check during session FFS7 with Capt.Phillips, he has been taken directly for CA 40 B(J) day check on aircraft VT-EPF on 19-7-1989 and for his CA 40 B(J) night check on the same aircraft on 21-7-1989. Capt.M.Fillion has carried out both the day and night checks. In the case of Capt.Gopujkar two forms have been filled up for each of the flight tests which are Aeroformation format and CA 40 B(J) of DGCA. There is a discrepancy in the date in the two forms of the night check. In the Aeroformation format, the date of 20-7-1989 has been indicated and at the bottom it has been shown that Capt.Gopujkar was qualified for type endorsement. On the CA 40 B(J) the date of 21-7-1989 has been indicated with chocks off time as 00:45 hours and/on chocks time as 01:55 hours.

The night check assessment was above standard. It does appear that as the crew went for the night flight on the 20th night, the Aeroformation format may have the date of 20-7-1989 and because of the actual local times being indicated, the date has been shown as 21-7-1989 (which would be correct).

Similarly the training file of Capt.Fernandez has shown that he has satisfactorily completed his simulator check with Capt.Steele on 19-11-1989. The CA 40 B(J) check by day which was done in India on VT-EPG was on 3-12-1989 with Capt.Thergaonkar between 08:30 and 09:30 hours. The night check was on the same day and on the same aircraft with Capt.S.T.Deo between 18:15 and 19:40 hours.

Mr.O.P.Ahuja, Deputy Director Flight Crew Standards, gave evidence before the Court on behalf of the DGCA. During cross examination he deposed that:

Whenever a new aircraft is inducted into an airline, initially the pilots are trained by the manufacturer's training centre.

The instructors of the training centre are approved if they meet the criteria of approval as laid down by the DGCA. However, the DGCA is empowered to relax these requirements.

Under Rule 41A(2) the DGCA accorded approval to appointment of examiners for carrying out flying tests and technical examinations. Rule 41A(3) was also complied with.

Indian Airlines approached the DGCA for according approval to instructors/examiners of Aeroformation for imparting training and to carry out assessment checks of their pilots undergoing training at Aeroformation.

Mr. Ahuja also stated that the proposals made by the Airlines are examined by a Board of Officers dealing with the subject in the DGCA. The Board comprises Deputy Director of Training and Licensing, Deputy Director Flight Crew Standards, Director of Training and Liceneing and if need be the Deputy Director General is also associated with the examination of such proposals.

There are no documents regarding the formation of such a Board to examine the proposals made by Indian Airlines in the files submitted by the DGCA. Similarly Court did not find any recorded notes of an internal meeting between the various officers mentioned earlier forming the Board. Some notes being prepared and sent for approval to the next higher official as a normal administrative practice, were seen.

The Court is of the view that in future, it would be a safer practice to form a Board, members of which would sit together and carefully examine every aspect of training before recommending exemptions to the Ministry as well as the DGCA for granting exemptions.

During the cross examination by learned Counsel on behalf of Consumer Association a question was raised whether Air India in the year 1986-87 had sought permission to send pilots for proficiency checks and recurrent training in A-310 simulator at Singapore. The witness stated that he did not know anything about the case and that whether Air India had indicated that the Singapore simulator data was different from the GE engines on the Air India aircraft.

Later the correspondence on the above subject between Air India and DGCA was sent to the Court by the office of the DGCA. It was observed that a request had been made by Air India in the letter of October, 1986 for the use of A-310 simulator facility at Singapore wherein Air India had clearly stated that the simulator at Singapore was fitted with PW engines which were not compatible with Air India aircraft combination as their aircrafts were fitted with GE engines. There were a few letters exchanged between the DGCA and Air India on the subject till the third quarter of 1987. Air India in its letter of 11-4-1987 had confirmed that for initial conversion training, only Aero-formation simulator fitted with GE engines would be used; though only for recurrent training, use of A-310 simulator at Singapore had been requested. However, no letter from the DGCA granting approval was placed before the Court.

During the Court proceeding it has come out that the Aeroformation A-320 simulator used for training Indian Airlines pilots did not have the V-2500 data or the instrumentation during the training of quite a large number of Indian Airlines pilots. The simulator had been programmed with CFM 56 engine data and had the associated display. Full flight simulator training of both Capt.Gopujkar and Capt.Fernandez was conducted using CFM 56 engines. This was stated by Capt.Richard Steele, an Airbus training captain during his deposition.

The basis as to how the concerned department of the DGCA accepted training of Indian Airlines pilots on an A-320 simulator fitted with CFM 56 engines without any reservations and special stipulations is not clear:

(a) Though they had expressed apprehension about the use of a simulator with a different engine configuration even for proficiency checks and recurrent training during 1986-87 in the case of Air India.

(b) Though DDFCS had noted on 6-2-1989 that simulator capability is necessary to ascertain the extent to which the training thereon can be considered for acceptance.

(c) Accepted the simulator training on the Aeroformation simulator which was not compatible with Indian Airlines aircraft engine combination without obtaining further data and carrying out analysis. ...

From the training files of Capt.Gopujkar and Capt.Fernandez, it is to be noted that a part of CA 40 B(J) check has been carried out on the Aero-formation simulator which was not compatible with Indian Airlines aircraft engine combination.

For the future, when new aircraft would be inducted by any airline it would be prudent for the DGCA to prepare a format which should be answered by the organisation concerned obtaining complete basic data, along with the requests for various exemptions etc. The Board as indicated earlier could then evaluate the proposal in toto if necessary with concerned officials of the airline before formulating and approving the complete training programme.

During the cross examination of Mr.Ahuja, it has come to light that for a considerable time the post of the Director General of Civil Aviation had not been filled by a full time incumbent. Post of DGCA is a sensitive post and his responsibilities are both statutory and administrative. Important and delicate questions are to be met by the DGCA. Any Adhocism in the appointment of DGCA is not in the public interest. It is doubtful whether a temporary incumbent holding a higher responsible post would discharge his functions independently, at all. I am of the firm view that practice of making temporary appointments or placing some one incharge of this responsible post and thus extend the adhocism to such an appointment should be given up.

Capt.V.P.Thergaonkar, Operations Manager Training, Indian Airlines, who is qualified and also an approved examiner on A-320, deposed before the Court on behalf of Indian Airlines. In his affidavit dated 7th May,1990 he has stated that during training at Toulouse:

1. There was 1 hour with full flight simulator and 7 fixed base simulator sessions (phase I) of 2 hours each (1 hour per pilot per session) during the ground phase of 2 weeks.

2. 7 sessions of fixed base simulator (phase 2) of 3 hours each (1½ hours per pilot per session) and

3. 7 sessions on full flight simulator of 3 hours each (1½ hours per pilot per session). The 7th session was a simulator check.

The affidavit also states that the training at Toulouse covered flight training which will include 6 landings by day and 6 landings by night for captains and 3 landings by day and 3 landings by night for first officers which would include go around with one engine, one instrument approach and one full stop landing.

Passing marks for ground score examination was raised by Indian Airlines to 80% from the Aeroformation and DGAC requirement of 70%.

Training at Toulouse was entirely carried out by Aeroformation instructors.

Capt.Gopujkar's route checks had been carried out by Capt.Fillion, Capt.Deo and Capt.Baud.

DGCA had approved 5 Indian Airlines pilots as examiners, of which one has resigned. DGCA also approved 7 pilots as check pilots out of a list of 10 pilots. Capt.Gopujkar was one of the approved check pilots. All these were released as check pilots after satisfactory completion of local flight check and 2 route checks from the right hand seat.

Annexure-1 and Annexure-2 which were attached to the affidavit of Capt.Thergaonkar are the two versions of the training conference held in Toulouse in November, 1987. There are a few differences in the two annexures in the understanding of the composition of flight crew training course. In Annexure-1 the 7 sessions of FBS phase-1 and 7 sessions of FBS phase-2 and the 7 sessions of FFS training have all indicated clearly the amount of training per pilot as half the duration of the session. This Indian Airlines report has also indicated that the last session of the FBS phase-2 will be a sort of assessment of the pilot for having reached the required standard before commencement of FFS training. Similarly this Indian Airlines report has indicated that the 7th FFS session would be a check ride carried out by an approved flight instructor.

Indian Airlines has used the word "flying training" in its report. It has indicated that it would consist of CA 40 A and B checks. Though all this would have been discussed during the training conference, in Annexure-2, Aeroformation has not indicated that the 7th FFS session would be a check session. It has used the word "flying training phase". The training records of Capt.Gopujkar shows that the instructor has carried out a flight check only and filled up the CA 40 B(J) report by day and night and also the IRC and LRC on the aircraft in the pilot proficiency check report.

In Annexure-2 under heading "Documentation" Aeroformation has indicated that "Each trainee will be provided with appropriate training documentation at the beginning of the course including ...

Flight Crew Operating Manual (FCOM)

FCTM for 12 instructors (FIF)".

Under course organisation, Aeroformation has indicated in paragraph 4.2 "Since all courses will be given in English, trainees will read, write and speak English fluently".

Capt.Thergaonkar during his deposition stated that Capt.Gopujkar had 28 hours of training on simulator and about 3 hours of actual flight and Capt.Fernandez also had similar training and he had also one remedial session. Capt.Gopujkar had been exempted from the 100 hours co-pilot requirement. He had done 11 route checks. This additional route check was because of the requirement of being examined by one more examiner. Capt.Fernandez was not exempted initially but later he was exempted of this 100 hours co-pilot experience; by that time he had gained 68 hours of experience as a co-pilot in A-320.

Capt.Fernandez was on his first route check on the ill-fated flight. Though none could personally assert as to who was in charge of the controls on 14th February,1990, entire take off and landing including cruise should have been done by Capt.Fernandez because he was under route check. From CVR/DFDR transcript, it is clear that Capt.Fernandez was CM-1. Capt.Thergaonkar deposed that vertical speed knob and altitude knob in A-320 cockpit are in close proximity. There are some differences between the two knobs. He had also committed mistakes in selecting the knob by mistaking one for the other on two or three occasions. Other pilots also may have made similar mistakes and he had seen a French pilot committing the mistake on the A-320 simulator at Hyderabad. At page 10 of his deposition he has stated that the training course makes the pilot familiar in most respects in respect of A-320. Later he stated "only in general terms, at the time of training at Toulouse, we were told that the acceleration timing of V-2500 engines are larger than other engines".

At page 11 he stated as below:

> " The Indian Airlines entirely relied on the Aeroformation for the training. However, before the training started they had discussions and certain modifications resulted in the training to suit Indian conditions. Indian Airlines had to rely on Aeroformation for training because it was the only place where training in A-320 was available with the simulators. Further, Aeroformation is a subsidiary of the Airbus Company and the programmes were developed by the manufacturers. The training course of Aeroformation is also approved by DGAC of France".

Capt.Richard Steele (witness No.19) during his cross examination has stated that each pilot has undergone about 57 hours of simulator training and he thought that Capts.Gopujkar and Fernandez had 3 hours of base flying training. He has also stated on Pages 3 and 4 that in the case of Capt.Gopujkar VACBI was for V-2500 engine and the FCOM in his position was related to V-2500 engine. Capt.Fernandez was required to do a remedial session after his FFS 7 check and in the recheck thereafter he was found fit for command endorsement. On page-11 he has stated that the training imparted at Toulouse strictly complied with the syllabus of the DGCA and agreed by Indian Airlines. He also stated that European certification authorities have certified the A-320 simulator with CFM 56 engines for training pilots for A-320 aircraft with V-2500 engine and they included UK CAA and the authorities of Cyprus and Yugoslavia. In this connection Appendix may be referred.

Capt.Steele in his deposition indicated the modifications to the course by Indian Airlines, such as to increase pass mark from 70% to 80% in technical examination, modify simulator 7 session to meet requirements of Indian Airlines and DGCA, increase the number of non-precision approaches in the syllabus and increase the amount of base training to double the standard course level.

Capt.Steele confirmed that Capt.Gopujkar had undergone simulator training, base training and line training at Aeroformation. However he did not undergo flight instructor's familiarisation course. If he had undergone this training he would have been trained to handle mishandled approaches including at low speed at idle thrust in close proximity to the ground. A line pilot however would know how to handle the plane at a low level and low speed and low thrust. This witness further stated that his own training on A-320 lasted for about 6 months. At that time the aircraft was under development. He was also responsible in part for the creation of the A-320 course.

Again Capt.Steele stated:

"The instructors are given training to recover from low speed at the low level. I do not expect a line pilot or the check pilot to get into a situation of low level with a low speed. I expect them to recognise such a situation and take a prompt recovery action. The line pilots and check pilots are instructed as to how to recover from such a situation. This is different from an instructor taking recovery action following an error made by another pilot. I did not have an occasion to get into an approach which Capt.Fernandez got into in this case. I have not also seen such a situation in the simulator. Whenever such an error is made by a trainee in the simulator he has been taught to recover from it".

Later he has stated that he has come across trainees during training making wrong selections of the knobs on the FCU but he has not come across any certified pilot committing such an error.

He has also stated that in the case of Capt.Fernandez ground training, FCOM and VACBI related to V-2500 engines. All FBS sessions with exceptions of section 11 and 14 and all FFS training was conducted utilising all CFM 56 engines.

Capt.Steele deposed that he had flown the aircraft fitted with both type of engines. From experience he could say that operationally there was no significant difference.

Capt.P.A.Bhujwala (witness No.24) was the co-pupil with Capt.Gopujkar, He has clarified that if the training in FFS was for 3 hours, 1½ hours training would be for Capt.Gopujkar and the other 1½ hours would be for him. While one actually operates as a trainee,the other will be participating as a co-pilot. At Toulouse he had 28 hours of conversion simulator training from Boeing 737 to A-320.

Capt.Bhujwala explained that items 16 to 19 in FBS 8 were demonstrations and pilots were asked to notice alpha floor indication on FMA and upper ECAM and then TOGA being registered on ECAM. Under item 18 he did not notice the time taken for the engine to develop full power and it was CFM 56 engine. Capt.Fillion carried out his flight checks. He also stated that he was not told that the engines required atleast 8 seconds to pick up full power and he had also not realised the same at any time. However, it was pointed out to him that it was a high bypass engine and therefore spool up time was appreciably more. He did not recollect whether anyone told him that acceleration from approach idle to TOGA would be longer with alpha floor compared to thrust lever movement to TOGA. According to Capt.Bhujwala Alpha floor should always be backed by thrust lever movement to TOGA. Here it is necessary to refer to the deposition of Capt.Gordon Corps as below:

Q : Would Airbus Industrie expect a customer to have complete and thorough knowledge of the aircraft like themselves with respect to the customers for them to design profile training for their air crew when they introduce a new aircraft to the field?

A : I would imagine that the customers use their experience from other training programmes to assist them in making these decisions.

Q : Do you think that there could be such serious omissions in the A-320 profile training given to Indian Airlines A-320 pilots in respect of demonstration of certain system operation and their critical nature under certain specific flight condition for example inadvertent idle open descent engagement during manual flight on short finals?

A : I am not involved in the detail of the training programme at this level.

Q : Do you know that the page of FCTM you have attached with your affidavit of 5-5-1990 are dated January, 1990 and did not exist on the dates Capt.Gopujkar and Capt.Fernandez were trained at Toulouse?

A : It is correct that the FCTM itself had not been issued at that stage.

The witness agreed that Airbus Industrie is responsible for the FCOM. When he was shown certain pages of the fully updated volumes of FCOM supplied to the Court after the crash and the same pages in the manuals which had been issued to late Capt.Gopujkar during his training he concurred that they pertained to CFM 56 engines.

On page 87 Capt.Gordon Corps agreed to the suggestion that if any pilot shows a serious deficiency of not monitoring speed on final approach wherein he drops his speed by 20 to 25 kts. from desired minimum approach speed he would not be approved as a captain by any right thinking instructor.

Training records of Capt.Gopujkar shows that he has been assessed as above standard during his flight check by night after satisfactory simulator check. He has been issued with a type rating on A-320 as captain and certificate of course completion of CAT II training on A-320 by the President of Aeroformation. He was considered "above standard" by Capt.Baud of Airbus Industrie during one of his route checks.

Similarly Capt.Fernandez was checked by Capt.Richard Steele on the simulator after a corrective training session had been completed and had been certified fit for command endorsement on one of the DGCA formats. He was also issued certificates of course completion of both EFC II upto and including simulator and CAT II training by the President of Aeroformation.

Capt.Steele was the only witness who stated that each pilot was given 57 hours of simulator training by Aeroformation. Capt.Thergaonkar had a total flying experience of 11600 hours in May,1989 of which over 8500 hours were as captain. He has been a DGCA approved instructor and examiner for quite a few years and he has trained a large number of pilots of Indian Airlines on various types of aircraft. Indian Airlines also possess quite a few simulators which are used both for full flight simulator sessions and whereever applicable for CPT (Cockpit Procedure Training) sessions also. He has differed totally in respect of the number of hours of simulator training given to Capt.Gopujkar and Capt.Fernandez . Capt.Bhujwala has also clearly explained that during the full flight simulator session of 3 hours, each of the pupils got 1½ hours and for one half of a session the trainee participated as a co-pilot. It has to be concluded, therefore, that 57 hours of simulator training is shared by two pilots and that each pilot did not experience the actual training for the full 57 hours, each experienced 28½ hours of simulator training and the other 28½ hours his experience was of a co-pilot in the simulator. With the improvement in technology, more and more training establishments are using either a fixed base simulator or even a full flight simulator for what was earlier known as systems training and cockpit procedures training. Aeroformation may use fixed base simulators presently for the purposes of systems training and procedure training. Examination of the various fixed base simulators phase-A does indicate that after every stage of VACBI the pupil is exposed to the detailed performance of those systems in that stage in the FBS. This system exposure cannot be considered as simulator training. The profile of FBS phase-B are a demonstration of various exercises and how they should be handled. Capt.Bhujwala has explained the exercises from 16 to 19 in FBS 8, which clearly shows it was a demonstration. This would correspond to what was termed cockpit procedure training a few years ago. Only 'Hands on' flight simulator training would give a pilot the feel of the aircraft performance under various conditions of flight. He can get this only on a full flight simulator when he is acting as a PF. Further the 7th FFS session is not a simulator training session. No check session can ever be considered as training. This would further reduce the amount of simulator training a pilot has received during his conversion.

Though Capt.Steele gave evidence as representing Airbus Industrie in training matters, it was felt that the simulator training has not been properly presented before the Court by him. Therefore, all the exercises during the simulator session and flight session given to Capt.S.T.Deo and Capt.L.Manchanda for their instructors training were examined.

There was no exercise which dealt with handling a mishandled approach at low speed at idle thrust in close proximity to the ground. Similarly none of the FBS or FFS profiles have an exercise wherein a line pilot has been instructed to recover from a situation of low level at low speed and low thrust. Capt.Steele himself never had an occasion to get into an approach similar to VT EPN and he had also not seen such a situation on a simulator. Airbus Industrie was not quite candid and failed to present a correct picture of the training in the evidence adduced on their behalf.

In Annexure-2 of Capt.Thergaonkar's deposition, Aeroformation has indicated the requirement of trainees to know English well. One of the Assessors during his visit to Aeroformation in June,1990 had specifically requested for a French Instructor for his FBS/FFS sessions. During the session it was observed that, when clarifications were sought the Instructor had difficulty in explaining. The Court had desired that Airbus Industrie should produce certain instructors who had taken part in training Capt.Gopujkar and Capt.Fernandez to obseve as to how they would explain certain procedures before the Court and the participants. Unfortunately Airbus Industrie indicated that this would upset its training programmes if these persons have to be called to depose before the Court. The possibility of a certain lack of understanding on the part of the pupils because of the difficulty in the explanations in clear English language by the concerned instructors has to be posed and left as such.

In the same Annexure-2 it is mentioned that Aeroformation would provide the trainees with appropriate documents including FCOM. The documentation provided to Capt.Gopujkar during his training had certain pages which were not appropriate to the aircraft he was being trained for. Similarly Airbus Industrie which is responsible for FCOM's, also had not provided correct and appropriate documentation to Indian Airlines till the date of the crash, as evidenced by the fully updated documents provided to the Court, but which had pages, not appropriate to the Indian Airlines aircraft.

Similarly Aeroformation should have provided a copy of an FCTM at the beginning of the FIF course to Capt.Deo and Capt.Manchanda. They had done their simulator session on 5-6-1989 and 18-7-1989 respectively. As per Capt.Gordon Corps FCTM itself had not been issued when Capt.Gopujkar and Capt.Fernandez were trained at Toulouse. Capt.Gopujkar did his simulator check on 18-7-1989 and Capt.Fernandez did his check on 19-11-1989. Proper documentation as per training conference had not been made available to the two instructors named above during their training.

The approval of the A-320 course by DGAC France was furnished by Airbus Industrie. Aeroformation had written to DGAC on 8-12-1987 giving the training programme (ground and flight instruction) that will be followed by A-320 trainees. On that date it seems A-320 aircraft with V-2500 engines had not even started flying. The approval based on the above programme was conveyed to Aeroformation on 7-4-1988. Aeroformation wrote to DGAC on 25-7-1988, indicating a modification particularly to the following training sessions:

FBS 1 to 14 and FFS 1 to 7

Approval was granted on 2-8-1988.

There would have been many changes in the original data supplied to the DGAC, France in December, 1987. As indicated in Airbus Industrie letter No.AI/E FS 420.1051/90 dated June 28th, 1990 the configuration of Indian Airlines aircraft is different to those fitted with CFM 56 engines. Indian Airlines aircraft are the first aircraft with 4 wheel bogie main gears. The performance of the aircraft would have changed which means the contents of the course would have changed. Further, the aircraft fitted with V-2500 engines seems to have been certified only in the year 1989. Approval of DGAC, France to train pilots on simulator with CFM 56 engines for flying later on aircraft fitted with V-2500 engines, is not placed before the Court (also see Appendix).

In the interests of safety of operation Indian Airlines should carefully monitor the pilots when they operate the altitude and vertical speed knobs or for that matter any other knob on the FCU and take corrective action immediately if by chance Aeroformation instructors have taught Indian Airlines pilots to operate these knobs in the manner of a 'wrist flick' referred by Capt.Gordon Corps in his deposition.

A-320 is a new technology Fly-By-Wire aircraft. Airbus Industrie has sold this aircraft to Indian Airlines which did not possess any aircraft similar to this earlier. Capt.Gordon Corps observation (at page 84) that customers use their experience from other training programmes to design profile training for their crew, cannot be correct. Capt.Thergaonkar who has experience of training a large number of pilots has stated that Indian Airlines entirely relied upon Aeroformation for the A-320 training. Mr.O.P.Ahuja, who had experience in approval of courses on behalf of the regulatory authority has also deposed that no organisation other than the manufacturers would have the necessary know-how of the aircraft whenever a new aircraft is inducted into the airline.

From the statement of Capt.Bhujwala it follows that he was not aware of the additional delay in the engine acceleration when Alpha Floor gave the acceleration order. Even Capt.Gopujkar being his co-pupil would not have received this information. From the report and deposition of the Inspector of Accidents it can be inferred that this information was not available with the DGCA until a query was raised after this crash. Even the initial response of Airbus Industrie (Ex.55), on which the Inspector's report was based, was incorrect. After further analysis, Airbus Industrie wrote to DGCA on 12-4-1990 revising their estimate of the Alpha Floor trigger/activation delay range. This did indicate that even Airbus Industrie did not have a clear knowledge of the extent of this delay on the date of the crash.

It is evident that Capt.Gopujkar and Capt.Fernandez were ignorant about the time delay of 0.8 to 1.2 seconds beyond the normal acceleration time if alpha floor gave the thrust increase order. Evidence of Capt.Gupta who was also trained at Toulouse stated that there was no difference between alpha floor triggering and its activation. The depositions of witnesses on behalf of Airbus Industrie clearly indicate that they were not quite aware of the delay between triggering of alpha floor and its activation. In fact, at an earlier stage, the time difference between the two was stated to be 0.5 seconds (vide Ex.1 -page 57). But during the course of the present investigation it came out that the delay may be between 0.8 to 1.2 seconds.

It is obvious that Aeroformation was not aware of this delay at all and consequently the trainees would not have been made aware of this delay. The engine takes 8 seconds to develop full power on receipt of the command. The pilots seem to be under the impression that alpha floor would activise the engines fully in 8 seconds, now it is found that it would take about 8.8 seconds to 9.2 seconds for the engine to develop acceleration after alpha floor is triggered. It is absolutely necessary for the pilots to know this important feature.

From the DFDR data it can be seen that CM1 has moved SSPPC from -5.20^{o} at time 320 all the way to -16.29^{o} at time 323 and -16.47^{o} (full aft limit) recorded at time 324 seconds. Thrust lever back up movement has come only later. This corresponds to the explanation of FBS 8, item 16 regarding demonstration and observation of alpha floor. He has also used the words 'backed up by the pilot moving the thrust levers to TOGA. If this was the way pupils have been trained, CM1 pulling the sidestick first and later moving thrust levers, appears to be normal. "If Capt.Fernandez had known about this delay, would he have moved thrust levers earlier to TOGA when he started pulling the sidestick control to full aft position?" is a valid doubt that arises because this would have probably saved the aircraft from the disaster. If thrust has been given by moving the thrust lever at 320 seconds by 328 seconds, engines would have certainly developed full power/acceleration, thereby lifting up the plane at 328 seconds, instead of allowing it to touch the ground by 329.9 seconds. It is also quite possible that Airbus Industrie or Aeroformation had never visualised the situation wherein the mode of idle/open descent gets engaged at a very low altitude on short finals (for whatever reasons) creating a serious safety hazard, as it occurred in this aircraft. If they had ever imagined this situation, organisations like Airbus Industrie or Aeroformation would have introduced this situation in a profile during simulator training or they would have taken action to see that this mode engagement could never occur on short finals. Though a modification has been launched, Indian Airlines should ensure that all their pilots are given a demonstration of the disastrous consequences of this mode engagement at a critical stage on the simulator and check for their reaction on every proficiency check or recurrent training till such time all the aircrafts are modified. Future conversion training may consider this profile.

Indian Airlines should also very carefully evaluate with the manufacturer and DGCA the advantages of introducing manual thrust operation whenever manual flight is conducted on the A-320.

The Government of India, constituted a special committee in February, 1990 to evaluate the state of preparedness of Indian Airlines for the safe operation of Airbus A-320 aircraft. The Chairman of the committee was Air Marshal S.S.Ramdas AVSM, VM, VSM of the Indian Air Force. The committee has examined among other things:

(a) Adequacy of the norms, the training programme of the flight crew and its efficient implementation having due regard to the changed technology required for safe operation of A-320 aircraft.

(b) The system followed by Indian Airlines for a qualitative evaluation of the flight crew.

(c) Adequacy of training imparted to the aircraft maintenance personnel for efficiently maintaining and servicing the new technology A-320 aircraft.

(d) System followed by Indian Airlines for a qualitative evaluation of the aircraft maintenance personnel.

This expert committee has already submitted its report and recommendations to the Ministry of Civil Aviation and it is entirely unnecessary for this Court to go into the matters considered by the said expert committee.

7.B <u>EXEMPTION FROM 100 HOURS FOR P.I.C. ENDORSEMENT</u>

1. One of the incidental questions came up pertained to the exemption granted by the DGCA for the Command Endorsement of a pilot. Normally a co-pilot with an experience of 100 hours in the particular type of aircraft only will be considered for the Command Endorsement. Whenever new aircrafts are introduced it is not possible for the operator to have with it , such pilots with 100 hours of flying experience in that type of aircraft. In such a situation experienced pilots in other aircrafts and who are trained as co-pilots in the new aircrafts are considered for Command Endorsement upon the exemption being granted by the DGCA in this regard. That ~~such~~ an exemption was granted to several pilots when A-320 was introduced has been questioned as improper. The suggestion implied in this objection was that lack of 100 hours experience as a co-pilot in A-320 resulted in an insufficient experience for the pilot to become the Pilot-in-Command (for short 'PIC'). In respect of several pilots Indian Airlines sought the exemption from the DGCA having regard to the shortage of the experienced pilots to fly A-320. It is in evidence that this is an usual practice followed certainly in India but elsewhere also. However, the DGCA while granting exemption would consider the advisability of granting PIC endorsement after dispensing with the

requirement of 100 hours flying experience. Mr.Ahuja, witness No.26, was examined on behalf of the DGCA. This witness stated that Indian Airlines sought exemption for 72 pilots. But actually exemptions were granted only to. 53 pilots. This exemption was granted based on the flying experiences of the pilots. The witness stated that "It was granted only to 53 pilots based on their flying experience and pilots and PIC experience on Boeing 737 aircraft. Pilots having a total flying experience of more than 8500 hours, total PIC experience of 5500 hours and a total PIC experience on Boeing 737 aircraft of more than 2500 hours were exempted from the requirement of 100 hours" (page 258). When similar exemption was sought for another 41 pilots DGCA asked the Indian Airlines to re-examine the request taking into consideration the available number of PIC rating who have complied with the requirement of 100 hours of co-pilot experience and 10 consecutive satisfactory route checks. Only 14 more pilots were exempted. The DGCA also examined the performance of the pilots during training at the Aeroformation before considering the exemption question; that is why 5 pilots were denied the exemption. Capt.Fernandez was granted exemption by the order dated 12-2-1990 along with 13 others. By that time Capt.Fernandez had already gained experience of 68 hours of flying as a co-pilot in A-320. Before the grant of PIC endorsement every co-pilot will have to undergo mandatory 10 consecutive route checks. Mr. Ahuja also has explained the manner in which the exemptions were granted on earlier occasions also.

2. Capt. Gupta, who deposed on behalf of ICPA, himself is a pilot in A-320. At the time of deposition he had an experience of 300 hours of flying in A-320. Earlier when exemption was sought for him from the requirement of 100 hours of flying to enable him to obtain PIC endorsement it was not granted. He is aware of the reaon. He stated that he had only about 2460 hours of flying experience and not 2500 hours of flying Boeing 737. According to him that was the main consideration while granting exemption. Capt. Gupta earlier held PIC endorsement for Boeing 737 also.

3. It is clear that DGCA and the Government applied uniform standard while granting the exemption. The experience gained in other aircrafts, even though certain systems may be different, cannot be held to be irrelevant. The flying experience certainly counts whether in one aircraft or the other. However, when new aircraft is introduced the pilots will have to be trained in the new system. That does not mean that whenever a new aircraft is introduced and the pilot on being trained should necessarily undergo the experience of 100 hours of flying as a co-pilot irrespective of the background of the concerned pilot.

7.C REGARDING SNAGS

In his report Ex.1 Mr.Satendar Singh has referred to an unattended snag regarding PACK-2. According to the Inspector this snag was being carried forward from 12th February,1990 till the date of the accident and no action seems to have been taken. It was observed by the Inspector that carrying forward of those snags required that the aircraft should not be flown above 31,000 feet. But on the date of the accident, while cruising the aircraft was at 33,000 feet. The other complaint about some seat lumbar vertical adjustment was not highlighted at the time of investigation by the Court.

Charles D'Souza was examined by the Indian Airlines. He is a Flight Manager. He was examined in the place of Capt.Tandon who was ill. This witness however stated that he fully endorsed the statements in the affidavit of Capt.Tandon as he was personally aware of the facts stated therein. The snag referred in the report Ex.1 arose during the flight IC-669 and 670. This witness states that he had met the pilot who was in charge of those flights and he did not complain of any snag referred in Ex.1. The snag was also not communicated on the company channel. There was no special report about it. The company was not at all aware of the snags. The snag sheet will go to the Engineering Department and if any incoming pilot finds the snag he would pass on the information in the company's channel, which in turn would pass it on to the Engineering Department. Mr.G.Venkateshwar Rao, Superintending Aircraft Engineer, was also examined by the Indian Airlines. According to him no snag was found in the aircraft in question from 13th Feburary. His job was to do the transitional checkings. The aircraft was in Bangalore on 13th February and he had checked it. Mr.Ramachandran Raghunathan was examined as witness No.27. He is a Superintending Aircraft Engineer stationed at Bombay. He had checked VT-EPN on 12th February personally. As he was required to do the transit check he went through the pilot's defect report (for short 'PDR') and noticed the snag reported as "PACK-2 unserviceable". He got it confirmed from ECAM page. Thereafter he rectified the snag by re-setting the computer by re-cycling the circuit breakers. Thereafter he checked the operation of the PACK-2 system and found it serviceable. This he confirmed also by setting the ECAM page. Thereafter he counter signed the PDR page. He has identified his initials. According to him the Clerk inadvertantly stated in the computer sheet by making the entry that this snag was carried forward. There was no serious cross-examination of this witness at all. In fact it can be held that he was not at all cross examined by any one seriously.

In the circumstance it is clear that the material on record establishes that PACK-2 was serviceable and the Inspector of accidents was not properly informed of the situation and obviously he was misguided by the computer sheet.

7.D ALPHA FLOOR PROTECTION

The witness for the Airbus Industrie (for short AI) Mr.Guyot deposed that the purpose of installing alpha floor system was to protect the aircraft against the wind shear condition and that alpha floor system was not a mandatory item for certification purpose. The witness also stated that it is not included in the minimum equipment list because it is not mandatory. This witness, however, stated that in the instant case the delay between 0.5 to 1.2 seconds in the triggering of alpha floor protection was of no consequence because it had to be applied at least 3 seconds before the effective triggering of alpha floor. This system is part of the auto thrust system and according to him in the instant case it triggered at time frame 323.1 seconds. According to him the time available between the triggering of the alpha floor and the first touch down was about 6.7 seconds. At a later stage he indicated that there will be a delay of 3.8 seconds for the alpha floor to become effective because 3 seconds will have to be filtered to give an accurate value of the angle of attack to trigger alpha floor. He clarifies that the advantage of the full power is provided. This is obviously because the angle of attack gets automatically varied during wind sheer conditions.

Capt.Gordon Corps, a Test Pilot of AI, stated that"this system which is fitted uniquely to all airbus aircrafts automatically applies full thrust when activated. It was activated in the Bangalore accident by a combination of angle of attack and the pilots stick position which caused the advanced the operation of the system".

Mr.Satender Singh, the Inspector of Accidents, who held preliminary enquiry stated before the Court that he was informed by the AI that the delay in the triggering of alpha floor was only 0.5 seconds but subsequently he was informed that the delay may go upto 1.2 seconds.

Capt.Gupta, in his evidence, suggested that the pilots were under the impression that this alpha floor protection would be available to them and therefore they did not react to push the thrust levers on the date of the crash even when they realised that the plane was going down. He indicated in his deposition that this protection was not available below 100 feet altitude. He gave the impression that there was no difference between triggering and activation of alpha floor.

From the material on record two inferences are possible:

(i) Generally the pilots reposed faith in the alpha floor system and that they were not specifically told not to rely upon it and that it was meant mainly for'wind sheer protection.

(ii) The delay in activation of alpha floor after its triggering was not known to the pilots. In fact AI itself was not quite certain about the time factor governing the functioning of this system. If pilots had been specifically told and warned that this system requires a minimum of 1.2 seconds before it transmits thrust increase order to the engine, the pilots probably would have directly used thrust by pushing the thrust levers rather than acting on the sidesticks. Just before the crash CM1 tried to activise this system instead of pushing the throttles to increase power of the engines. This again indicates the erroneous faith developed by the pilot in this system. From Mr.Guyot's evidence one cannot be certain of the time required to activise this system. The operator of this aircraft and the pilots should be properly instructed and advised about this system and its limitations.

7.E COCKPIT ATMOSPHERE

CVR conclusively establishes that the two pilots have been totally cordial through out the flight. Capt.Gopujkar has taken great pains to explain various aspects of this aircraft's handling to Capt.Fernandez as this was his first route check, All procedures have been followed, all check lists have been carried out. When CM1 asked for go around during alt star at DFDR seconds 232 it was not set by CM2 knowing the implications and he guided CM1 to select vertical speed. Landing checks were carried out after passing below 1500 feet as Airbus Industrie has provided the landing check list on the ECAM only after passing below that height, above ground. The call for 700 feet rate of descent by CM1 at DFDR seconds 294 (or near about) was correct, as aircraft had come to the correct approacn profile. They have also followed heading instructions and come on to final, closer than 7 DME which is not very unusual. Capt.Bhujwala during his cross examination had stated on page 2 that " Capt.Gopujkar adopted himself to the new technology very well and at no time he was critical of the same. Capt.Gopujkar was an Instructor in Boeing 737 and a check pilot on A-320. He used to take a lot of pains to teach the trainees. His approach and attitude towards the trainees were quite helpful. The trainees used to be quite comfortable with Capt.Gopujkar". It should be noted that the above statement has come from a long term close associate, who joined Indian Airlines in 1969 along with Capt.Gopujkar, trained on HS-748 when Capt.Gopujkar was his batchmate, later when being trained on Boeing 737 Capt.Gopujkar was again his batchmate. Both of them underwent induction course together and in July,1989 when they went to Toulouse for A-320 training they were again batchmates.

Capt.Gopujkar and Capt.Fernandez were conversing about their personal food habits, medical check up, etc. (between crash seconds 1439 to 1353) and at 07:17:46 hours CM2 asks whether CM1 had matches (obviously to smoke, which is not prohibited at that time frame). The theory propounded by Capt.Gordon Corpns that the relationship between the two pilots was stiff and CM2 was conducting himself as an examiner of CM1 and cockpit atmosphere was not smooth is totally unacceptable. It was pointed out that CM1 (Capt.Fernandez) did not insist that some of his requests for selections, such as , go around of 6000 feet were complied with by CM2 and thereby he failed in his task as CM1. But it has also come on record that most of such requests were out of time and when CM2 reminded CM1 of the correct procedure, CM1 must have accepted the suggestion. As the selection of go around 6000 feet sought by CM2 at 260 DFDR seconds (7:32:08 hours), it is seen that immediately thereafter CM2 was busy with the ATC and the action to be taken for landing.

One factor, however, requires to be noted. At no point of time there was a reference to the speed except at DFDR seconds 96 when Magenta was checked. Though speed call out is not mandatory, a reference to the fall in the speed is not seen as having been called out at the subsequent stages, specially after 294 seconds when idle/open descent mode was noticed. This is one of the points on which I have earlier noticed the divergent views in Part IV.

7.F ALT STAR

There is a peculiarity referred as alt star phase in the course of the flight by A-320. Whenever the aircraft is about to reach the selected altitude, the aircraft will enter alt star zone. This is also called altitude capture phase. The aircraft would not change its mode from this phase unless the pilot takes certain action, if necessary, to change the vertical speed or the further altitude to be attained by the plane. It is said that during alt star phase, to revert from speed/vertical speed mode to climb open climb or idle open descent mode pilot has to take only one action, namely, selecting different altitude. In case pilot wishes to change from idle open descent to speed vertical speed during alt star phase, two actions are necessary:

(i) selection of vertical speed by dialing V/S knob and

(ii) pulling the V/S knob.

During alt star phase FMA would display alt star. During this phase vertical speed cannot be selected as the aircraft is already in the course of capturing the selected altitude. Therefore, to select a fresh vertical speed, the FCU altitude will have to be re-selected to get out of alt star phase and then select vertical speed. Broadly this is what I learnt about this phase.

No publication of the Airbus Industrie explains this alt star phase clearly. According to the ICPA and its witness Capt.Gupta, Airbus Industrie has no convincing answer regarding the problem posed by alt star phase. According to ICPA, during the alt star phase if the vertical speed knob is pulled, there would be a momentary or transitory change of mode showing vertical speed. This will not result in a permanent selection of V/S knob and it immediately disappears. After V/S knob is released this alt star phase once again gets engaged. ICPA asserts that during alt star phase selection of V/S knob can only be achieved by the functions of two knobs by operating both the speed knob and the altitude knob of FCU.

The following questions and answers in the deposition of Capt.Guyot are relevant here:

Q. During alt star could vertical speed be reset?

A. Yes it is possible but it was not so.

Q. I put it to you that vertical speed cannot be reset at alt star zone?

A. I do not agree with the suggestion.

Q. The vertical speed cannot be selected directly during alt star without resetting the altitude in FCU?

A. That is not so. When you are in alt star if you pull the vertical speed knob you synchronise the indicated vertical speed with actual vertical speed of the aeroplane then thereafter dial the knob to the vertical speed descend. If you are not in alt star and if you are in vertical speed then to alter the vertical speed the knob will have to be turned without pulling it.

Q. I am suggesting to you that if the aircraft is in the alt star mode the only way in which vertical speed selection can be made effective is to ensure that aircraft goes out of alt star mode i.e., by changing the altitude on the FCU?

A. I do not agree with this. When you are in alt star mode you can select vertical speed without changing FCU altitude.

Again when this subject was posed at a later stage the witness said:

Q. Refer to photos 2 series and please explain as to how vertical speed can be selected when the aircraft is in alt star?

A. According to the FCOM reference No.1.11.30 page 36 equivalent to page 39 it is said on the top of the page "disengagement" that ALT ACQ can be disengaged by selecting another longitudinal mode. The vertical speed mode is a longitudinal mode. What you to do to reengage the vertical speed mode when you are in ALT ACQ mode is to pull the vertical speed knob and at this time the vertical speed mode will be synchronised with the actual vertical speed of the aeroplane and the value will appear in the vertical speed selected window. As the aeroplane is on the way to capture the selected altitude, after a few seconds, the aeroplane will revert again in ALT ACQ and you have to pull again the knob if you want to re-engage the vertical speed, then you will keep definitely the vertical speed when the aeroplane will achieve the altitude HOLD and you can continue in vertical speed without reselecting lower altitude on the FCU. During the approach of VT-EPN in Bangalore when the aeroplane was in alt star at time 292, 293 and 294 on the DFDR, the aeroplane was in alt star and speed mode. If the crew had been trying to reselect vertical speed during these 3 seconds, we would have seen on the DFDR that the auto thrust speed select parameter would have remained at 1 value, that means in speed mode instead to go to thrust idle mode.

This witness admitted that the explanation offered by him about the vertical speed selection during alt star was not found in any of the publication of the Airbus Industrie. Capt.Guyot was not prepared to rely on the test that may be conducted in the simulator since he was not aware of the simulator at Hyderabad.

Capt.Gordon Corps was also examined at length on this question. The following extract from his deposition would speak for itself:

Q. Please explain how vertical speed is set when the plane is in alt star?

A. The vertical speed knob is pulled perhaps more than once before the mode remains engaged.

Q. Please refer to photographs, collectively marked as Ex.114 - 2 and 2L. How do you set the vertical speed when the aircraft is in the situation described in the PFD in the said photographs?

A. When the vertical speed knob is pulled the window will read the instantaneous vertical speed and after a short period of time the mode will revert to speed alt star.

Q. How long does alt star normally last?

A. It is a function of rate of descent. It may be 12 to 18 seconds. But if the rate of descent is very low it could be still shorter.

When the knob is pulled for example in the very first second of alt star, the vertical speed will be set and will then revert to alt star. The alt star will continue until the height is captured. When the aircraft reaches the altitude it will hold that altitude and it will be in the alt hold mode. The vertical speed will not be set though it would have been set earlier for a short period.

Q. So, by setting the vertical speed during alt star you are referring to the movementary and transitory phase?

A. Yes.

Q. Have you personal experience of setting vertical speed during alt star?

A. Yes.

Q. Do you remember how long the setting remained?

A. For a few seconds.

Q. I put it to you that this can never be construed to be setting of vertical speed during alt star at all and that you are unfortunately reduced to justify a stand which is not really justifiable?

A. I do not agree with that.

As the learned Counsel Mr.Vahanvati suggested the mode explained by Capt.Gordon Corps is not a mode at all to select the vertical speed, this witness admits that during alt star phase the process of selecting vertical speed will have to be a repetitive action till the end of the alt star phase. His answer reflects an element of obstinancy to establish that vertical speed can be set during alt star phase even though it is movementary. What is the purpose of such a selection to regulate the flight in ununderstandable.

It was argued on behalf of the Airbus Industrie that alt star phase will be in display on several occasions during any training period and therefore the pilots will b fully aware of it. But there is no single piece of evidence to establish that the trainee pilots were instructed as to how vertical speed can be selected during alt star phase. Even the expert pilots of the manufacturer are incapable of giving a precise answer to the problem. Nothing was elicited by the learned Counsel for the Airbus Industrie from the Indian pilots who were in the witness box as to their knowledge about this alt star phase.

It should be a matter of grave concern to the Indian Airlines and it should closely examine this question and find out whether its pilots have fully understood the implications of alt star phase. It is also a matter for the DGCA to examine whether the trainees were properly instructed on this question. The manufacturer should take care to explain this alt star phase in greater detail to impart precise knowledge on this question to those who are concerned with the matter.

7.G STALL WARNING

1. In conventional aircraft, whenever the angle of attack increases and approaches the stall, a warning called the "Stall Warning" is provided. A pilot would instinctively push the throttle levers forward to increase engine thrust on the onset of such warning.

Airbus Industrie has taken a definite, unequivocal stand that this aircraft A-320 does not require a stall warning because it would never stall.

2. On occasions when computer system protections get degraded to an extent wherein aircraft flight control operation would be on par with a conventional aircraft Airbus Industrie have provided an audio 'STALL' warning. At this time such a warning is mandatory.

3. Crash of VT-EPN has demonstrated that in spite of all protections against stalling, an alarming loss of speed well below the approach speed (normally magenta speed) would be disastrous. Some warning system, such as the stall warning, which would bring an instantaneous corrective reaction by the pilots would be useful towards accidents prevention.

4. At present pilots are required to watch the low speed display in the airspeed scale in this aircraft. As auto thrust is normally active pilots have to take remedial action if speed drops

below V approach. Speed trend indicator also has to be observed. There is no special warning to remind the pilot about a dangerous loss of speed below the required approach speed. Low speed display is not recorded on DFDR.

5. In the instant case, serious allegations were made that the pilots failed to monitor speed during approach. Those who have reposed faith in the pilots contend that these pilots would not have failed to monitor speed and the low speed display in the cockpit. They attribute the fall in the speed to the display system. If for any reason, the pilots were in a state of confusion, the possibility of the pilots ignoring the movement of the low speed colour display indicating speed loss cannot be ruled out. But this needs that both pilots are confused enough for the low speed display not to register in their mind. Calmness in the voices of the pilots recorded by the CVR does not show such confusion. A warning similar to stall warning if was available between DFDR seconds 312 to 320 would have woken them up even if such a confusion had existed. If the warning between these time frames had resulted in the pilots pushing the thrust levers forward, most probably the crash would not have occurred.

6. It was pointed out that too many varieties of warnings may lead to confusion by themselves. The question is which kind of warning is more

important during the critical stages of a flight. The manufacturer and others interested in the subject and safety may consider this aspect.

7. Capt.Gordon Corps, however, states that if the conventional aircraft is compared to the situation of this VT-EPN, the stall warning would have occurred when air speed was about 106 knots. This would have been only after 323 seconds DFDR time and no useful purpose would have been served, as it was within 8 seconds of the crash. One possible answer to this is, to prevent such future accidents, prepone the timing of the stall warning to an earlier stage when the speed falls below 120 knots, when magenta speed is at 132 knots (as in the case of VT-EPN). In this case it would have been at DFDR time frame 312 to 313 seconds. Incidentally, in the flight test carried out at Toulouse with Capt.C.R.S.Rao, one of the Assessors on board, stall warning had occurred at 120 knots under direct law operation with the aircraft weight and C.G. close to VT-EPN and altitude close to Bangalore elevation.

This is a matter for the researchers of the manufacturer and the regulatory authorities to consider and locate the exact timing for the warning against speed fall to occur, in the light of experience gained from this crash.

7.H REGARDING INSPECTOR OF ACCIDENT

Ex.1 is the report of the Inspector of Accident. Immediately after the accident the DGCA appointed Mr.Satendra Singh, Director of Air Safety, as the Inspector of Accident under Rule 71 of Aircraft Rules, 1937. He immediately took the inspection work. On 17th February, notification was issued directing a formal investigation of the accident under Rule 75 and the Court was appointed with the Assessors.

Under Rule 71(2) the investigation by the Inspector is to be private, while Court's investigation under Rule 75 is a formal investigation to be held in open Court.

Under Rule 74(4) any person desirious of making a representation concerning the circumstances or causes of the accident may do so in writing to the Inspector. Inspector has certain powers to summon any person and examine such a person as per Rule 72. His report is to be submitted to the DGCA.

The manner of the investigation held by the Inspector was criticised before me by one or two participants; it was contended that he prepared his report in a hurry and submitted it by 31st March,1990 (within six weeks of the accident) and that it was incomplete and he failed to discharge his functions as per the Rules. This criticism is unwarranted. Within a few days of Inspector's appointment, the Court of Inquiry was announced. The Court's powers are wider and certainly its status required the Inspector not to come in the way of Court's investigation. He had to avoid a parallel investigation. Moreover, as is usual in such circumstances, he sought my permission to continue his investigation and agreed to complete it within the time specified by me. An open inquiry by a Court is always favoured than a private investigation, especially when the Court is presided over by a sitting Judge. I was anxious to complete the investigation early. Having regard to the limited scope of the Inspector's investigation, in the context of Court's appointment, I asked the Inspector to file his report by 31st March,1990.

He has adhered to the time limit imposed by me; he had not even full six weeks time to complete his investigation. He based his report on the available material. It is to be noted that even if the Inspector has power to summon and examine any person, the relevant Rules do not provide for an open enquiry and cross-examination of the persons whom he examines. Therefore, his inquiry is in the nature of an informal investigation.

The Inspector was examined as witness No.23 and he was cross-examined. He was questioned about the propriety of his taking the assistance of manufacturer of the aircraft, the Indian Airlines and of Aero Engines and he replied that no proper investigation was possible without the cooperation of those who are connected with the manufacture and operation of the aircraft. His report was based on the investigations conducted by him, assisted by several teams of officers and some of his findings were based on the opinions given to him by others, as in the case of his opinion regarding fire fighting operations conducted by HAL after the crash. I have based my conclusions on the evidence placed before be. The report of the Inspector, in fact, enabled some of the participants to focus their attention to some aspects which, but for his report would not have been noticed by many.

A few criticised him for venturing into adding his "findings" and "recommendations" in his report, when Court is already seized of the subject. Under Rule 71(5), the Inspector is empowered to add any observations and recommendations which he may think fit with a view to preservation of life and avoidance of similar accidents in future. Therefore, it cannot be said that the Inspector overstepped in adding "recommendations" as part of his report-Ex.1 He did not actually investigate on behalf of the Court, but while investigating abided by the Court's directive to expedite his investigation to avoid parallel proceedings - one in private and another in open Court. His conclusions and his recommendations found in Ex.1 in no way binds the Court; Court may consider them just like any other material placed before the Court.

Whenever a Court of inquiry is appointed under Rule 75, the purpose of continuing the investigation by the Inspector under Rule 71 is not clear to me. A parallel investigation ought to be avoided. As a practical solution, if the Inspector in a particular case seeks Court's permission to continue his investigation, that cannot always avoid the embarrassment to the Court. The findings of the Inspector were published widely, even before the Court had an occasion to consider the issues; Airbus Industrie, one of the participants, in this case even suggested that investigation by the Court was unnecessary in view of the Report.

Aircraft Rules 1937 should be amended to solve this anamoly, so that in future, conflicting proceedings - one in private and another in open Court, could be avoided.

The Inspector has not considered many relevant questions such as the nature of the training imparted to the pilots and the procedures for grant of exemptions while the new aircraft was inducted, the effect of the revised co-relation of CVR-DFDR done by CASB, the knowledge of the pilots as to the peculiarities of alt star phase and the limited nature of alpha floor protection.

May be, he was short of time.

Statutory investigation of this sort should be conducted by an independant Authority and not by an Officer of DGCA. An Officer of DGCA may not be able to point out the mistakes committed by his own department. Investigation should be entrusted to a high powered body consisting of those possessing knowledge in the relevant subjects and who, at the initial stage of the investigation itself, are in a position to know the areas of investigation.

An open Court enquiry to find out the cause of the crash of this magnitude cannot be concluded early. The initial fixation of a short duration of three months to complete the inquiry while constituting the Court, is an empty prescription. Such a limitation itself is a burden on the Court's working; a tendency to hurry up may develop in such a situation. If a Judge is appointed to be the Court of inquiry there should not be any prescription of time limit to complete the inquiry; the Judge himself should be trusted to complete the inquiry expeditiously.

7.I **D.G.C.A.**

During the course of the investigation of this unfortunate accident, the functioning of the Directorate General of Civil Aviation also came in for close scrutiny. The Directorate General of Civil Aviation is a statutory body like the Federal Aviation Administration (FAA) of U.S.A. and the Civil Aviation Authority (CAA) of the U.K., responsible for exercising regulatory control on aviation activities to ensure all round safety of Operations. In the year 1971, the International Airports Authority of India was carved out of the DGCA to look after the four International Airports. Subsequently, in the year 1986, National Airports Authority was carved out of the DGCA to look after the remaining domestic airports and also to exercise Air Traffic Control.

While the Government carved out the N.A.A. from the DGCA under the National Airports Authority Act, it left the powers of the DGCA in tact under the Aircraft Act and Rules. Nevertheless DGCA was neither reorganised, strengthened or modernised to cater to the regulatory role it was expected to play. Under the Aircraft Act and Rules, DGCA is expected to licence all Aerodromes. But it has come to the notice of the Court that the licence of the Bangalore Airport, which is under HAL was not renewed since 1961. It is not known whether DGCA is licensing other Airports in the Country and renewing them after properly ensuring their safety requirements.

The DGCA is apparently ill equipped to undertake the vital responsibilities entrusted to it under law. The truncated DGCA is now left with regulatory functions relating to Airworthiness Control, Licensing of Flight Crew and Engineers, Investigation of Accidents and Incidents, Air Transport Control and R & D activities. As is obvious, while the Government has been attentive to and spent huge sums for the growth of air carriers and airport authorities, hardly any attention seems to have been focussed to improve the functioning of the Directorate General of Civil Aviation. Modern sophisticated fly-by-wire technology A-320 aircraft had been inducted in the airline operations but the strength and capability of the DGCA to exercise regulatory control on operation of such sophisticated aircraft has hardly seen any improvement; it has remained a totally neglected organisation with adhoc arrangements to discharge its functions. While all the regulatory functions continue to be with the DGCA, there is no infrastructure with the DGCA to discharge some of the functions. As a result, the Directorate General of Civil Aviation which is supposed to be a watch dog of aviation activities and ensures safety of the air passengers and aircrafts, is unable to 'exercise independent control on very vital aspects of its functions like training and licensing of pilots and engineers.

Only after the unfortunate crash of the Airbus A-320 at Bangalore on 14-2-1990, the Government seem to have posted a full fledged DGCA which post was kept vacant for long. There is practically no control of the DGCA on Air Traffic Control matters, which although regulatory in nature, is being exercised by the National Airports Authority. Air-travel safety should have top priority. Safety of air-traffic includes safety of all those who are likely to be affected on the ground also by a major accident. The concept includes the post-crash operations like rescue operations and medical treatment. The Government should reorganise, strengthen and modernise the DGCA immediately by providing it with proper personnel, funds and other wherewithal. All regulatory functions relating to air safety including air traffic control and licensing of aerodromes should be exercised by the DGCA. The DGCA should play an effective role in the selection of pilots for training in advanced aircraft, preparing the syllabus for training, monitoring the training and finally in the evaluation and clearance of pilots for line flying and for command endorsement. There should be no relaxation of any regulation or discipline in this regard .

Whenever a sophisticated aircraft in large numbers, is inducted, a corresponding sophistication of the airfields is also necessary, such as installation of ILS in all Airports. This should have been considered by the DGCA, it being the regulatory Authority for air safety in India.

Similarly, the approach roads leading to the parameters of the Airport should have been visited to see that they are maintained properly to enable the vehicles move fast during an emergency During the court's visit with the Assessors, it was found that the approach roads at HAL Airport were not maintained properly and one is reminded of kutcha village roads.

In the course of his deposition, the Senior Manager (Aerodrome) HAL was not able to tell with whom the keys of the gate were kept. Similar ignorance was betrayed by the Deputy Manager, Fire Force, HAL. This shows that those responsible Officers did not care to find out the custodian of the keys even by 7th May, 1990, though the crash occurred on 14th Feburary. It was their responsibility to find out the cause for the delay in opening the gate. Obviously, lack of a proper control and supervision of these Officers seem to have lulled them to complacency.

Need to have an independent Authority to enforce regulatory measures should be met at the earliest.

PART - VIII

FINDINGS

1. The aircraft had a valid certificate of Airworthiness and was maintained in accordance with the approved maintenance schedules.

2. There was no defect reported, on the airframe, engines and their systems prior to the ill-fated flight nor any defect, abnormality or emergency reported during flight by the pilots, till it crashed.

3. There was no apparent indication of any abnormality of flying controls.

4. Investigation of the engines revealed that the engines were developing power and were at or near full power when they sheared off from the wings after hitting the embankment.

5. DFDR data reveals that there was no failure of aircraft electrical, hydraulic, yaw damper and cabin pressurisation and communications systems. There was no smoke of fire warning. The GPWS activated Sink Rate warning four times from DFDR seconds 324 onwards.

6. The wreckage examination revealed that the slats were extended, flaps were in full down position, spoiler lever armed and landing gears were down thereby indicating landing configuration of the aircraft.

7. Weather conditions were clear.

8. All security procedures prior to commencement of the flight were carried out and there is no evidence of sabotage.

9. The pilots were appropriately licensed to undertake the flight.

10. Capt. C.A. Fernadez was flying the aircraft from the L.H. seat as CM.1 and it was his first route check for command endorsement under supervision of Capt. Gopujkar, Check Pilot of A.320 aircraft.

11. Although VOR-DME approach was discussed between the pilots, it is not clear whether VOR-DME let down procedure as per Jeppessen Manual was followed. From 42 NM to 7 NM the aircraft was under surveillance of Bangalore Air Route Surveillance Radar and from 7 NM onwards indications are that visual approach or a mixture of visual with Non-precession approach was being followed.

12. The aircraft reported R/W in sight when it was 7 NM west on left base of R/W 09 and was cleared to land by Bangalore Tower at 13:02:17 hrs. which was acknowledged by the flight crew.

13. Landing checks were completed but go around altitude was not set. Similarly, Flight Directors

were not put off at the time of landing checks.

14. The aircraft was slightly higher and also having higher speed when landing clearance was given but thereafter it came to proper profile for approach to land.

15. At 13:02:42 [295 DFDR Time Frame - i.e., about 35 seconds before the time of first impact with the ground], the aircraft was at a height of 512 feet AGL. Since then it started coming down below the profile and aircraft speed was falling below the target approach speed. There is no specific indication that the crew monitored the speed and height since then.

16. The relationship between the pilots was quite cordial.

17. When Capt. Fernandez (CM.1) was pulling the side stick control off to pitch up the nose and arrest the sink rate, the aircraft entered the Alpha protection zone (high incidence protection) at 313 seconds and finally at 323.1 seconds Alpha floor (thrust protection to increase thrust to take off power) was triggered and in all probability at 323.9 seconds (or at 324.3 seconds), Alpha floor was activated by Capt. Fernandez taking the side stick movement to full back position.

18. Airbus Industrie was not aware of the exact delay between Alpha floor triggering and its activation due to signal transmission through a number of computers and the delay seems to

have been investigated only after the accident. Even now there is no definite knowledge of the exact delay which may vary from 0.8 to 1.2 seconds. None was aware of this delay factor so far.

19. Basically Alpha floor functioning is built as a protection against wind shear, but the pilots seem to be under the impression that the protection from this system will be available to increase power of the engines in any emergency without any time delay and a false sense of faith has been reposed on this system.

20. This crash would not have happened.

(a) if the vertical speed of 700 feet as asked for by Capt. Fernandez at about DFDR 294 seconds had been selected and aircraft had continued in speed/ vertical speed mode;

(b) if both the flight directors had been switched off between DFDR seconds 312 to 317 seconds; or

(c) by taking over manual control of thrust i.e., disconnecting auto thrust system and manually pushing the thrust levers to TOGA (take off - go around) position at or before DFDR 320 seconds (9 seconds to first impact on golf course).

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21. In all probability one of the pilots acted to put off FD.2 by about TF.313 seconds, but FD.2 failed to go off resulting in confusion in the mind of Capt. Gopujkar.

22. There is nothing to show that the pilots realised the gravity of the situation even after the Radio Altimeter Synthetic call-outs of 400 feet, 300 feet and 200 feet.

23. Whatever be the exact timing of the throttle movement, it was too late an action to prevent the crash.

24. Alpha floor protection was triggered at 323.1 seconds and got activated at 323.9 seconds (or 324.3 seconds) which again was too late to develop sufficient power in the engines to prevent the crash.

25. At DFDR seconds 329.8 the aircraft first impacted the golf course. At what point of time 6.125 'G' was experienced and whether its recording by the DFDR was correct, are not decided. No expert witness was examined by anyone to explain the nature of 'G' force and the manner in which DFDR records the said force.

26. Soil testing report indicated that the first touch down area was harder as compared to the second touch down point.

27. The aircraft bounced for nearly 1.194 seconds after first impact of about 0.42 seconds.

28. The impact against the embankment caused the detachment of both engines, landing gears and crushing of lower front fuselage.

29. Thereafter the aircraft hopped over the nullah' and parallel road and landed on a marshy land about 320 feet from R/W 09 boundary wall and came to rest about 150 feet short of the boundary wall after dragging on the ground.

30. Forward portion of the aircraft was engulfed in a huge fire in the beginning. The fire propagated later towards the rear.

31. The rear left door was opened by an air-hostess and most of the surviving passengers escaped through this door. A few passengers escaped by opening emergency exit windows.

32 The percentage of survivors in the front, middle and rear zones of the aircraft were around 16%, 27% and 73% respectively of the passengers occupying the seats in these zones.

33. RA emitted auto call-outs of 400, 300, 200, 100 and 50 (or 30) till the first touch down.

34. CVR-DFDR correlation reveals that at about 38 to 40 seconds prior to the first touch down the aircraft was in proper auto thrust speed mode

and was descending in vertical speed mode. At DFDR seconds 292 altitude capture mode was activated indicating that a selection on the FCU panel close to MDA of 3300 ft had been made at an earlier stage of the flight.

35. Prior to 305 seconds, the aircraft went into idle open descent mode. A conclusive finding as to what pilots did at this point of time is not possible.

36. DFDR recording shows that auto thrust speed select discrete changed status from '1' to '0' at 295 Secds. There is no doubt that plane was in idle open descent mode by 305 seconds, by which time the plane was at an altitude lower than 400 feet Radio altitude.

37. The aircraft could not sustain the height and speed in the approach profile because of fixed idle thrust in idle open descent mode.

38. The aircraft never went to speed mode thereafter, though it was the most proper mode for landing.

39. In all probability, for some reason the pilots did not realise the gravity of the situation of idle/open descent mode and being at a Radio altitude below 300 feet at DFDR TF. 305 seconds.

40. The ATC tape at Bangalore Airport was found recording the tower and approach frequencies only and time was not recorded.

41. The crash fire tenders of HAL Airport must have reached the boundary wall of the airport at the earliest point of time but, subsequently there was delay in opening the gate and reaching the fallen aircraft.

42. Capt. Fernandez had occupied L.H. seat after more than 2 months of operating as CM.2 from RH seat without any simulator or aircraft training prior to change over.

43. The aircraft touched on its main wheels for the first time in the Golf Course of Karnataka Golf Association approximately 2300 feet short of the beginning of R/W 09.

44. During the short flight between first and second touch downs four trees, in line with the two main gears and the two engines were broken by the aircraft at heights from 10 feet to 7 feet 2 inches and the aircraft hit the ground on its landing gear in a slightly right wing low altitude.

45. There was an explosion when fire commenced and there was also a major fire, forward and aft of the right wing.

46. RH rear door had been opened from outside by airport fire services personnel when they reached the aircraft.

47. Few passengers escaped through overwing exits and through fuselage openings created by crash/explosion.

48. 86 passengers and 4 crew lost their lives at the time of the accident. Two more died later in hospitals. 21 passengers and one crew suffered serious injuries.

49. 81 of 90 passengers who died at the time of the accident have died due to shock as a result of burns sustained.

50. 32 victims had injuries to lower limbs, 20 to the head and 7 had thoracic injuries causing possible physical inability to escape the fire in time.

51. Cause of death of Capt. Gopujkar and Capt. Fernandez was due to shock as a result of burns sustained. Autopsy reports indicated no fractures.

52. Tail section behind rear galley housing CVR and DFDR and APU showed no signs of damage.

53. Though major part of fuselage was destroyed by fire the RH portion of cockpit structure which had the front wind shield, No.2 sliding window (Direct Visiion window) and No.3 window survived the fire though partially burnt.

54. The RH No.2 sliding window was in an openable condition at the time of the crash.

55. A witness had seen a person hitting against the cockpit RH side window before fire engulfed the plane.

56. All computer units had suffered extensive damage.

57. Speed drop from 132 Kts. to 106 kts. has taken 26 seconds from DFDR times 297 and 323 seconds.

58. Computers have not held the actual angle of attack at design limit of 15° or at speeds of Alpha max as indicated in FCOM. Actual angle of attack has gone beyond and speed has dropped below the appropriate values.

59. Movement of left and right elevator towards maximum allowable up position as indicated against DFDR time frame 330 is according to design and condition of flight (without expressing anything about the reliability of DFDR recording at this point of time).

60. The times of change of FMGC used FD mode and GFC 1 bus (18) discrete status do not correspond to the time of CVR conversation of FDs to be put off and putting them off.

61. Idle/open descent mode of auto thrust system has engaged some time after DFDR time 295 seconds. The exact reason for this mode engagement cannot be explained or proved because of non-availability of FCU selected altitude data or FCU controls selection data on DFDR.

62. Right bank has been induced when CM.1 pulled side stick fully aft and Rudder has been used to lift wing at DFDR times 323 and 327. Loss of about 7 feet has been attributed to this cause by Airbus Industrie.

63. CVR has shown no sign of panic or anxiety about

speed loss till CM.1 spoke - "Hey we are going down". There were no calls of speed deviation though speed was 106 kts. at DFDR time 323 seconds.

64. Low speed display on PFD on A-320 is excellent and they are computer generaated. If correct they cannot be mistaken and speed trend display is compelling. There is no digital read out of value of current speed. PFD Air Speed display data is not recorded on DFDR.

65. Power awareness may be deficient in A-320 pilots when auto thrust is active, as even an Airbus Industrie test pilot was not aware of power required during final approach at 1000 FPM rate of descent.

66. There is no warning if auto thrust brings thrust to idle for whatever reasons during approach.

67. Idle/open descent on short final though corresponding to an aircraft in dangerous configuration leading to limit flight condition, is indicated in 'GREEN' on PFD and not in 'RED'.

68. Movement of one side stick control is not reflected on the other.

69. Static thrust levers when auto thrust is active have removed the feel of thrust lever movement and

and visual indication of position corresponding to actual thrust or thrust change trend. Only way to know the thrust is to read the value on ECAM.

70. Use of VOR/DME during visual approach is in conformity with Indian Airlines and Aeroformation procedures. Use of FD during visual approach is not prohibited by Airbus Industrie. The pilots in the instant case, followed a visual or a mixture of VOR/DME with visual procedure in all probability.

71. CM.1 pulling side stick backed up by moving thrust levers to TOGA is in conformity with training imparted to pilots by Aeroformation.

72. Information in documentation provided by Airbus Industrie to pilots during training and to Indian Airlines has not been very clear and sometimes not appropriate to Indian Airlines aircraft.

73. The very grave consequences of IDLE/OPEN DESCENT mode engagement either inadvertantly by the pilots or automatically due to a system mal-function is not part of the simulator profile training. This indicates that no one may have visualised such an occurrence to ever take place.

74. The flight control computers seem to have permitted the aircraft to maintain the minimum speed of 106 kts. which had been reached at DFDR time 323 seconds. The speed increase to 113 kts. before the first touch down and conversion of this

kinetic energy into potential energy was prevented. Was this prevention due to the computers is a matter to be considered.

75. Landing mode of the flight controls may have contributed during the last 3 seconds in the prevention of conversion of kinetic energy into potential energy.

76. It seems that Aeroformation simulator training on simulator fitted with CFM 56 engines has been accepted by the concerned department of the DGCA without obtaining full data on the simulator capability even though this had been thought of and concern had been expressed earlier during 1986-87 regarding use of an incompatible simulator even for recurrent training and proficiency checks. No additional stipulations had been prescribed after this acceptance.

77. Part of the CA.40.B (J) check in case of both these pilots was carried out on a simulator with CFM.56 engine data.

78. Recommendation for approving Airbus Industrie/ Aeroformation instructors has been made and approval granted without receiving confirmation of A.320 PIC rating and A.320 PIC experience in the case of two pilots.

79. The subject of Bangalore HAL Airport holding a licence or not was not relevant and would have in no way affected this crash.

80. All primary and secondary flight controls appeared to have operated normally.

81. Increase of N2 RPM on slats extension on VT-EPN was less than those recorded on Airbus Industrie aircraft and two other Indian Airlines aircraft.

82. The engines have operated normally throughout and have not contributed towards the cause of this accident.

83. Under conditions prevailing and based on the DFDR data and CVR transcript, the accident commenced at approximately DFDR time 321 seconds. The aircraft had no chance of survival thereafter.

84. If ILS was available at Bangalore for R/W 09 most probably, this accident would not have occurred.

85. But for the severe fire, the loss of lives would have been considerably less.

P A R T - IX

/ PROBABLE CAUSE OF THE ACCIDENT /

Failure of the Pilots to realise the gravity of the situation and respond immediately towards proper action of moving the throttles, even after the Radio altitude call-outs of "Four Hundred", "Three Hundred" and "Two Hundred" feet, in spite of knowing that the plane was in idle/open descent mode. However, identification of the cause for the engagement of idle/open descent mode on short final approach during the crucial period of the flight is not possible.

PART X

RECOMMENDATIONS

1. Accident/incident investigation authority should be totally independent of the DGCA and all organisations connected with aviation in India. Only this can ensure an impartial and unbiased investigation looking into the role of every organisation connected with the accident/incident including the DGCA.

2. Whenever an investigation is ordered under Rule 71 of the India Aircraft Rules, 1937 and later a formal investigation is ordered under Rule 75, automatically the Inspector of Accidents should only indicate the finding based on factual evidence and no interpretation or recommendation should be made to avoid embarassment to the formal investigation.

3. A highly experienced pilot should always be associated with the Inspector of Accidents officially if he is from an engineering background and the pilot's report should be recorded whenever an airline accident is to be investigated.

4. DGCA should formulate procedures and develop information formats which has to be completed in all respects every time a new aircraft is introduced into the airline to cover all training aspects and exemptions/validations to be granted.

5. DGCA should form a board of officers competent to deal with all aspects of training with if necessary senior experienced training personnel from the airline to assist such a board officially to evaluate the proposed training programmes prior to acceptance whenever a new aircraft is introduced into the airline in the future. Minutes of meetings of such a board should be properly recorded.

6. DGCA should develop a machinery in coordination with the Ministry of Defence for supervision of Government aerodromes including Ministry of Defence aerodromes in respect of facilities offered to civil aircraft operating through those aerodromes on scheduled flights to ensure adequate safety standards.

7. DGCA should insist that on the first route check, be it for release as a co-pilot or for training towards PIC endorsements, should be with an approved flight instructor or examiner.

8. It would be advisable to have at least a category I ILS installed at every airport in India and for every R/W used by jet transport aircraft on scheduled services.

9. Time recording should always be available on ATC tapes and regular checks should be carried

out to ensure proper recording.

10. HAL should have proper communication facilities with the airport emergency services and all communications between the ATC and the emergency services should be recorded on one of the ATC channels.

11. A crash siren at Bangalore airport should be installed which could immediately alert all fire stations of HAL. They may look into having two different types of sirens, one to indicate an aircraft emergency and the other to indicate a factory emergency.

12. The crash fire bell at the airport fire station should be of good quality and should be louder and similarly the red light should be larger and brighter.

13. The bushes on either side of the road and ramp should always be kept cut to a low level so that visibility is not impaired at any time even for a person sitting in a low level vehicle.

14. HAL should develop good roads leading to all exit gates of the airport on which all fire and rescue vehicles could move at high speed. One set of keys to the locks of every locked gate should be available with every airport fire services vehicle.

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15. Mock exercises should be carried out by the airport fire services for fighting an aircraft fire outside the airport boundary wall.

16. HAL should evaluate the VASI at Bangalore to improve its colour identification from longer distances during hours of bright sunlight.

17. All audible sounds generated by movement of various' controls and levers which could be recorded on the CVR tape should be carefully analysed to obtain a corelation with the DFDR as accurately as possible particularly during the most critical period of the flight. The excellent capabilities that are available with various premier establishments in India should be properly documented for use in future.

18. As the DFDR data can have highly erroneous recordings, a very critical analysis of every critical DFDR parameter in comparison to factual evidence should be made for acceptance or rejection of such data.

19. Similarly a very careful analysis of CVR transcript is necessary to look at all possibilities before it could be used towards any conclusions.

20. Due to considerable number of dead passengers having leg injuries which may have prevented them from escaping, a provision of a foam pad around

the bottom rear bar of the seat should be examined wherever the pitch between the seats is such that it could cause these types of injuries.

21. As large number of passengers and survivors had faced neck and head injuries possibly du to the seat ahead not being vertical, it is advisable to issue instructions to all cabin crew to check and insist on the laid down procedures of seats to be upright, seatbelts tightly fastened and tray tables stored properly. Seatbelts sign could be put on earlier for them to carry out this function.

22. DGCA should distribute a large number of printed autopsy formats corresponding to their air safety circular 3 of 1984 to all airports in India. They must be available in adequate numbers depending on the passenger capacity of the aircraft using the airfield and these should be made available to police authorities in case of any fatal accident with a request for strict adherence to its contents.

23. Experienced aviation pathologists either from Civil or Military Aviation should be made use of in an advisory capacity. A large number of copies of the above circular if sent to various hospitals around airports could assist in wider

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dissemination of information among the doctors of the hospitals.

24. In the light of the test flight conducted at Toulouse in the presence of an Assessor Airbus Industrie needs may examine the design aspects of the accelerometers and the DFDR recording system as used on the A-320 to improve accuracy of recordings particularly after a flight at high angles of attack.

25. Some slides did not display when door exits were opened from inside. It is recommended that slide activation mechanism should be evaluated for improvement.

26. Installation of a conventional airspeed indicator unconnected with any computers with a speed bug which could be manually set at the desired V-app, generating an unmistakable audio warning (again unconnected with any computers) fitted on all aircrafts when speed drops more than 5 knots below the bug, which have computer generated display of airspeed to be used as the primary speed display may be considered. A provision should be available to check this warning, during the pilots pre flight check. Such warning should be serviceable, for release of the flight. Airbus Industrie and Indian Airlines to evaluate retrofit such a feature in place of their present standby airspeed indicator on the A-320.

27. Expanded indication of the value of the current against the lubber line in the PFD is recommended for better appreciation of current speed value.

28. A provision of low a/speed warning even under pitch normal law should be examined by the certification authorities at about 1.14 to 1.15 Vs 1g for this type of FBW aircraft to prevent a similar accident in future.

29. Due to possibility of mistaking altitude and vertical speed knobs one for the other, a modification is recommended where vertical speed knob would have a wheel to be operated vertically up and down instead of the present clockwise and anticlockwise direction of movement of the knob.

30. A very serious human factors evaluation is necessary using ordinary line pilots regarding the loss of direct physical and visual cues by the type of sidestick controls in use in A-320 when compared to dual control wheels operating in unision of the earlier aircraft to determine the adverse impact it may have under critical conditions of flight like that of VT-EPN. Human factor evaluation of moving auto throttles giving feel of thrust increase or decrease versus the static thrust levers of the A-320 auto thrust system using line pilots is recommended to establish advantages and disadvantages.

31. Option of moving auto throttles is desirable in all future aircrafts if static auto thrust system similar to A-320 is to be installed in such aircraft.

32. After gear down and below 2000 feet radio altitude it is recommended that idle/open descent mode should be indicated in flashing red on the FMA associated with a single stroke chime.

33. Airbus Industrie should evaluate the provision of a feature, by which low thrust level occurring, during final approach, even on speed mode due to gusty wind conditions, would attract immediate attention of the pilots; if it occurs very close to the ground it could lead to unsafe situations.

34. It is recommended that the low range scale of the EPR gauge upto 1.10 should be expanded to give a better indication by the needle of a low thrust condition.

35. Airbus Industrie may look into providing a range in red colour upto 1.02 EPR to attract pilots' attention of a low thrust situation when on final approach.

36. Similar features as above could be evaluated and provided for operation in N1 mode.

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37. It is recommended that the emergency exit sliding window in the cockpit (direct vision window) should have the operating handle in the forward end to give a better leverage than at present, so that it could be easily opened by a comparatively frail lady pilot using any one hand only. Indian Airlines may check with Airbus Industrie if a retrofit modification is possible for their present fleet and future aircraft.

38. Safety of operations would demand that Airbus Industrie execute the proposed modifications of increased approach idle by 2.5% N2 and auto thrust mode changing to speed mode when aircraft speed drops to VLS, as top-most priority modifications. Indian Airlines should pursue the matter vigorously with Airbus Industrie in co-ordination with DGCA.

39. Installation of a single master switch conveniently located to switch off both FDs when required is recommended; slave switches could be used to switch them 'on' individually or repositing of both switches centrally be considered.

40. A modification to prevent auto thrust mode change from speed mode to thrust mode during Alt* just by change of altitude selection is highly desirable. The mode change should occur only by pulling the altitude knob after change of altitude selection.

41. Airbus Industrie should clearly define in their procedures and flight patterns the position at which they need the flight directors to be put off.

42. Airbus Industrie should immediately amend A-320 FCOM bulletin No.09/2 of June 1990.

43. Indian Airlines should introduce simulator training session whenever a line pilot is required to change his seat from the co-pilot seat to the captain seat after a long period of operation from the right hand seat even when this is for obtaining 100 hours experience prior to PIC route check.

44. In the interests of quality of training and safety, it is recommended that DGCA accords approval for all the 100 hours co-pilot experience to be obtained by a pilot slated for direct PIC training on to any type from the left hand seat only under the supervision of an approved check pilot/flight instructor/examiner. If airline needs to use these pilots from RH seat during this training period pilot should be given simulator training as PF from RH seat also.

45. Operation of the cockpit emergency exit windows (direct vision windows) either during pre flight check by pilots prior to commencement of their first leg of their series of flights or during daily certification of flight by aircraft

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maintenance engineers would ensure easy operation of the window by preventing the seals from sticking to the framework causing higher force requirements to open when need arises.

46. A re-emphasis regarding a 3 seconds delay in alpha floor activation by angle of attack in case of windshear should be made to all A-320 pilots and Indian Airlines should recommend that pilots should not wait for alpha floor but react on thrust levers immediately if an adverse situation is encountered.

47. It is recommended that Airbus Industrie and certification authorities to carefully re-evaluate the limit of 15° angle of attack (alpha max) was both simulator experiment and Airbus Industrie flight test under direct law going to slightly higher angles of attack have shown better performance and reduced altitude loss.

48. In view of the results of the test flight at Toulouse it is recommended that, certification authorities including DGCA should carefully evaluate acceleration characteristics of an engine at high angles of attack to give better information to pilots as Airbus Industrie test flight has demonstrated different acceleration characteristics by the same two engines in the four profiles.

49. With the drastic change in high bypass

turbo fan engine designs from the 1960's to the present day and the acceleration characteristics and net thrust developed during various stages of acceleration of present day engines it is recommended that certification authorities may re-examine the existing engine acceleration certification requirements.

50. Indian Airlines should include inadvertant engagement of IDLE/OPEN DESCENT on short final at heights very close to the ground as a profile during simulator training of pilots being converted onto A-320 and also during recurrent training and proficiency checks till such time all their A-320 aircrafts are modified with the new proposed modifications.

51. As documentation supplied by aeroformation to a large number of Indian Airlines pilots during training did not fully correspond to the Indian Airlines aircraft (which was not according to the minutes of the training conference) it is necessary for Indian Airlines to update these documents in co-ordination with Aeroformation.

52. Indian Airlines should include recovery from a situation of low speed at idle thrust in close proximity to the ground in their check pilot training and instructors training on the simulator.

53. It is recommended that all pilots in India operating automated aircraft be advised that in case of any malfunction of any auto pilot or auto thrust systems or any engagement of undesired mode occurs at altitudes below 1000 feet above ground level manual control should immediately be taken over and if considered necessary a go around should be carried out. No critical investigation or correction on the automated system should be carried out at critical altitudes prohibiting the idle/open descent mode below 1000 feet radio altitude should be seriously considered.

54. Indian Airlines should very carefully evaluate with the DGCA and Airbus Industrie the advantages of introducing manual thrust operation when manual flight is being carried out on the A-320.

55. Indian Airlines should carefully evaluate with Airbus Industrie the auto thrust behaviour during gusty wind conditions when speed suddenly increases beyond V-app and decreases at altitudes below 200 feet AGL and adverse implications if any to determine the limits of use of auto thrust system. This may have to be evaluated in both cases of Magenta speed or selected speed.

56. The U.V. recording and sound cepstrum analysis would help to identify the voices, as well as various other sounds; research and study of the

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science may be undertaken, so that in future its benefit would be available whenever necessary.

57. A 'Human Factor Research' centre may be established to study and analyse Human Factors in Aviation.

58. A careful study be made to evaluate the advantages of having backward facing passenger seats with a shoulder harness towards improved passenger survivability at the time of accident. Such backward facing seats may prevent the type of head injuries, injuries to legs and hands, arms etc., that occurred in this accident.

59. Due to severe fire developing with hardly 3000 to 3300 Kgs., fuel, burning completely the interior furnishing, top of the fuselage and the floor of the cabin, DGCA should carefully evaluate along with other certifying authorities and manufacturers, the feasibility of providing oxygen cylinders for crew and for passengers in the least fire risk areas (well away from the fuel tanks namely front and rear of the fuselage), with a provision of a valve close to the cylinders which would be closed at levels below 10000 feet. This may help in delaying the spread of the fire in comparison to the oxygen generators distributed throughout the aircraft and may contribute to saving more lives.

60. DFDR should record the selections made by

the pilots in the FCU; at present it is not possible to infer many of the actions taken by the pilots during the last phases of the flight. Practicability of getting DFDR recordings of instrument displays such as speed display also should be considered.

61. All Airports used for civil transport aircraft operation should be inspected, assessed and certified as fit for such operation, by a competent authority.

62. The DGCA shall be strengthened in all its aspects to meet the growing technological requirements, as indicated in Part-VII of this Report.

K. Shivashankar Bhat
30.XI.1990

(JUSTICE K. SHIVASHANKAR BHAT)

1. CAPT. B.S. GOPAL		
2. CAPT. C.R.S. RAO		ASSESSORS.
3. Sri S.G. GOSWAMI	30/11/90	

APPENDIX I

In the course of the investigation, the assessors had occasions to study literature on Human factors inflight; they also had the benefit of holding discussions with Human factor experts at NASA (USA). Based on their knowledge a useful note is prepared, which I have included in this part of the Report.

Similarly, certain simulator experiments were conducted and flight tests held to collect relevant data. These could not be directly used in evidence due to practical difficulty. Therefore the inferences drawn by the assessors cannot be applied to arrive at a definite finding. These data were indicative of certain 'trends', and may be useful to continue the study regarding matters stated therein. It is hoped that the concerned persons like the manufacturers and the Regulatory Authorities would undertake further research on these matters in the interest of future flight safety and improved performance.

A. HUMAN FACTORS IN FLIGHT (by Frank H.Hawkins)

Page 26

The errors made by pilots are in principle no different from those made by everyone else. The use of the words "pilot error" has suggested that somehow the nature of the errors made by this kind of operator is unique, that once an accident could be attributed to this "cause", then the problem was solved and the case be filed. To many, this may not have been a wholly inconvenient procedure.

Page 27

The pilot error concept also focuses rather more on what happened than why it happened and so for this reason, too, it has been unhelpful in accident prevention activity.

Page 36

It is also possible to predict, as proposed in what has been called Murphy's Law, that if equipment is designed in such a way that it can be operated wrongly, then sooner or later, it will be.

Page 44

Training for a particular task will reduce the incidence of errors, though it will not totally eliminate them. Overlearning, which is discussed has a notable effect in making a skill more resistant to stress and error.

Page 124

Traditionally, accident investigations have been primarily concerned with determining what happened and who carried legal liability. This involved confirming that all those concerned were licensed properly and that they had at the time of the accident conformed to company and state regulations. Once this had been determined, it was usually assumed that those concerned had the capacity to perform their allocated task and if they did not do so, then blame could be allocated, punishment and penalties inflicted, claims settled and the case filed.

But increasingly, intelligent people are asking, why. Why a properly qualified, highly trained, medically fit, well paid person, failed to perform his task as expected.

Page 244

Direction of movement of the control relative to the display is another aspect requiring Human Factors attention. Human performance can be improved by assuring correct design in accordance with human expectation and physiology. The matter is not always as simple as it may seem. Normal of the accident conformed to company and state regulations. Once this had been determined, it was usually assumed that those concerned had the capacity to perform their allocated task and if they did not do so, then blame could be allocated, punishment and penalties inflicted, claims settled and the case filed.

But increasingly, intelligent people are asking, why. Why a properly qualified, highly trained, medically fit, well paid person, failed to perform his task as expected.

<u>Page 244</u>

Direction of movement of the control relative to the display is another aspect requiring Human Factors attention. Human performance can be improved by assuring correct design in accordance with human expectation and physiology. The matter is not always as simple as it may seem. Normal expectation is that a control Knob should rotate clockwise to increase the value and vice versa.

<u>Page 248</u>

The very reliability with which automated systems normally perform provides the foundation upon which over confidence and complacency are built.

<u>Page 316</u>

Inadequate Human Factors input in the early stage of system and equipment design may finally necessitate the use of complex normal and emergency operating procedure which in turn may increase the risk of human error. While the true responsibility for the error in such cases may go back to the original design, it is the operator who is usually left "holding the baby".

B HUMAN FACTORS IN AVIATION (Edited by Earl L.Wiener & David C. Nagel)

Page 19

Accident investigators have moved away from the position or regarding the phrase "pilot error" as an appropriate explanatory cause. It is necessary to ask why the error was made and why it was not detected and corrected.

Page 159

Safety depends upon reducing human error. Human error depends upon both the amount and the stability of workload. Since the jet aircraft presents variable amounts of workload at variable times, there is ample opportunity for pilot error.

Page 183, 184

But when the human is primarily along just for the ride, the chances for a human induced error greatly increase. Pilots have already reacted to automation by voicing fear of loosing their manual flying skills. There will be future accidents due to pilots trying to program their way out of trouble, instead of deactivating automation and flying under manual control.

Page 266, 267

The problem of human error in aviation has turned out to be a difficult one both to understand and to solve. Accidents are often catastrophic; typically, little information is available from which to piece together a complete or comprehensive picture of causality. Errors are neither random nor mysterious. They seem to be lawful in the sense that they are predictable and that more humans (even experts) tend to make errors that follow certain patterns under a variety of circumstances.

Page 272

To develop solutions to the problem of human error, whether they be better equipment, better selection policies for flight crews, or better training, we must be able to predict with some certainty what conditions in flight are the most likely to cause the types of errors which contribute so disproportionately to aviation accidents and incidents.

Page 291

With modern flight simulators capable of reproducing a wide range of operational conditions, such training can be extremely effective in alerting the crew to deal effectively with unlikely events (Lauber & Foushee, 1981).

Page 296

The ability of a pilot to manually control an aircraft is fundamentally limited by the handling qualities and characteristics of the aircraft as well as basic neuromuscular capabilities of the human. The provision of information of the right kind can greatly reduce control errors made even by the most highly skilled pilots. Conversely, without the proper information, even the most highly skilled pilot may be helpless to effect adequate control.

Page 297

Different classes of actions should have dissimilar command sequence; this will make capture and description errors less likely. Actions should be reversible whenever possible; whenever the consequences of an action are particularly significant, the action should be made difficult to do, thus tending to prevent unintentional performance.

Page 300, 301

Automation, which as we have seen can have a very positive effect on both efficiency and safety, can also have a depressing effect on safety. As pilots are removed from an active role in flying the aircraft, more and more incidents that can only be termed "loss of situational awareness" are reported.

Page 434

On the negative side, the digital systems seem to invite new forms of human error in their operation, often leading to gross blunders rather than the relatively minor errors which characterize traditional systems.

Page 445

Designers responded to pilot error by attempting to remove the error at its source. that is, to replace human functioning with device functioning in their view, to automate human error out of the system. But there were two flaws in this reasoning; (1) the devices themselves had to be operated and monitored by the very humans whose caprice they were designed to avoid, thereby relocating but not eliminating human error; and (2) the devices themselves had the potential for generating errors that could result in accidents.

Page 453, 454

Many airlines have attacked the blunder problem as a training matter. The importance of training for the conduct of automated flight cannot be overemphasized, but all too often training departments become dumping grounds for problems created by cockpit design and management.

If human factors engineering is done properly at the conceptual and design phase, the price is high, but it is paid only once. If training must

Page 458

The rapid pace of introduction of computer based devices into the cockpit has outstripped the ability of designers, pilots, and operators to formulate an overall strategy for their use and implementation. The human factors profession is struggling to catch up. The devices themselves are highly reliable, but therein may lie the problem: they are also dumb and dutiful.

Page 522

If an automated system does not provide adequate feedback to keep the pilot informed of an action taken, reason for the action, and present status, these become additional concerns for the pilot.

Page 525

It is of utmost importance that crew systems and human factors design engineers play a strong role in the development of new systems. If left to their own devices, avionics and software engineers will mechanize systems in the most economical or convenient way for themselves, and in ways that may be completely logical to engineers. The results, however, may be illogical to the pilots who must later operate the systems, or worse yet, they may be unsafe or not meet mission requirements.

Page 549

The large majority of accidents or incidents occur as a result of errors that are commonplace; many appear to be system induced.

Most of the serious errors that crew members make are not first time occurrences. If error data could be captured through a system which encouraged crews to describe all errors in a timely fashion, with the understanding that the information would not be used in any manner to reflect on their record, a valuable tool for accident prevention would be found-

Page 558

The control of the autopilot system, termed auto-flight control system (AFCS), is the most complicated and troublesome system from a pilot's standpoint. The AFCS can automatically control airspeed, altitude, descent and ascent, and track (ground path) following through the autopilot, autothrottles, vertical navigation system (VNAV), and lateral navigation system (LNAV). The problem that pilots have with this new system is that there are apparently too many options or modes of operation. For instance, climbing to a higher altitude can be made in three different ways automatically through VNAV, vertical speed, or flight level change. Each of these modes has different characteristics and possible sources of error.

Side Stick Controller. Airbus Industrie will introduce the side stick controller in its A 320.

Thus far pilot reaction to the side stick controller has been lukewarm because of the fear of losing the "feel" of the aircraft. To the experienced pilot, this feel is critical, as much sensory information is gained from changes in the aircraft attitude or airspeed, even before it becomes evident on airspeed or attitude instruments. The design of the side stick controller permits the other pilot to override control of the aircraft by using higher stick forces. Many pilots are concerned that movement of one of the controls might not be evident to the other pilot. One advantage of the system is that it allows the pilots an unobstructed view of the instrument panel.

C. THE POWER OF AN OPEN MIND (by Ellen Langer)

(Extracts from an article by the noted Harvard University Psychologist published in the July 1990 issue of the Reader's Digest Indian edition pages 57 to 60).

The consequences of operating on automatic pilot, range from the trivial to the catastrophic. The examples that follow, demonstrate how we cut off our commonsense when we treat information as though it were true regardless of circumstances.

Unfortunately, once people set their minds on a single solution, they often fail to look for others.

Whenever you face a new problem, question all your assumptions before mapping a course of action.

The consequences of becoming so used to one way of doing things that we block out the present world can be dire.

By forcing yourself to look more carefully for the specific source of your dissatisfaction, you will increase your potential for solving the problem.

2. HUMAN FACTOR AND THE PRESENT CRASH:

2.1. The subject of Human Factors have played an extremely important role in this accident. Capt.S.S.Gopujkar had over 10300 hours of total flying experience of which nearly 7200 hours were as Pilot-in-Command. He had flown as commander on both HS-748 and B-737 of Indian Airlines prior to his conversion onto A-320. He was also an instructor on B-737. Similarly, Capt.C.A.Fernandez had over 9300 hours total flying experience with nearly 5200 hours as Pilot-in-Command (which included command experience of HS-748 and B-737).

Though these pilots had flown individually as commanders of their earlier aircraft to amass great wealth of experience, after recent conversion onto this new A-320 aircraft, the aircraft has been allowed to crash. The CVR has indicated a total absense of panic till about 7 to 8 seconds prior to the crash.

The assessors to the Court of Inquiry visited NASA AMES at San Francisco during June, 1990, where the assessors had discussions regarding Human Factors Research, conducted by NASA after the introduction of Glass Cockpit airplanes. This meeting was co-ordinated by Dr.R.Curtis Graeber of the Aerospace Human Factors Research Division of NASA on behalf of that organisation. Among the other participants during these discussions were Dr.Charles E.Billings, Dr.Everett A.Palmer, Dr.Barbara Kanki, Ms.Barbara Townsend, Ms.Sheryl L.Chappell, Mr.Asaf Degani and Capt.H.Orlady.

Dr.Greaber and Dr.Billings are world known figures alongwith Dr.Wiener in Aviation Human Factors Research. The other personnel who attended the meeting have conducted research in various aspects of Aviation Human Factors in respect of flight crew operating modern technology aircraft. Capt.H.Orlady is a retired airline captain with a lot of jet transport flying experience in various types of aircrafts who is assisting NASA in their studies.

The broad outlines of discussions were:

(i) Response time of visual information presented when:

(a) it is straight forward.

(b) when some confusion may exist.

(ii) Reflex actions.

(iii) Pilot reaction when exposed to totally new technology after extensive experience on earlier technology aircraft.

(iv) Effect of certain peripheral cues being removed in new technology aircraft which were available in earlier technology aircraft etc.

Valuable guidance was given during discussions and certain documented materials were also given to the Assessors. NASA indicated that they had so far not conducted any specific tests in respect of A-320 aircraft and its static Auto Thrust system.

The Assessors during their visit to Toulouse, France in June, 1990, had the opportunity to meet Mr.Jean Jacques Speyer who was introducted as the Airbus Industrie Human Factors specialist.

2.2. A few questions to be considered are:-

(i) Why two highly experienced pilots have permitted the speed to drop below the required managed speed of 132 knots viz., an extent of 26 knots (i.e.) upto 106 knots without either of them observing the loss of speed or commenting about the loss of speed.

(ii) Why was there no anxiety or panic till 7 to 8 seconds prior to the crash.

(iii) If conventional (earlier technology) air speed indicator had been provided with a selectable V-app bug (as in A-300), would the pilots have permitted the speed loss without observation.

(iv) If a stall warning like a conventional aircraft was available and had come on at approximately 119 knots (as it had occured on the A-320 aircraft MSN001 FWWAI during a flight carried out for the court by Airbus Industrie at Toulouse on 20.6.1990), what would have been the reaction of the pilots and would this flight have crashed.

(v) If the aircraft had conventional type of dual control wheel would the movement of the control wheel corresponding to the SSPPC movement have attracted the attention of Capt. Gopujkar a few seconds earlier to the situation that was developing and if so, what would have been his reaction. Would he have reacted on the thrust levers earlier.

(vi) If moving auto throttles were available would the pilots have accepted auto throttle position at IDLE, at low altitude during approach.

(vii) What would be the effect of the type of speed display that is available in A-320 in respect of the monitoring of the correct indicated airspeed value by the pilots. Whether the speed trend indication and the type of warning indications in respect of VLS V alpha prot and V stall warning, could generate mistaken sense of security/safety.

(viii) What is the effect of static Auto Thrust system in the monitoring of the actual power existing during approach.

(ix) Would IDLE indicated in red or flashing red at low altitudes during approach have made any difference.

(x) Cockpit sliding windows.

2.3. <u>REMARKS & ANSWERS</u>:

(i) When two highly experienced pilots have permitted the speed to drop below the required managed speed of 132 knots by an extent of 26 knots (i.e.) 106 knots without either of them observing the loss of speed or commenting about the loss of speed.

(ii) Why was there no anxiety or panic till 7 to 8 seconds prior to the crash.

From the first day of commencement of flight training any pupil pilot is made aware of the great imoortance of speed to achieve flight of an aircraft and to keep the aircraft flying. Among the assessors there are two pilots who have between them more than 63 years of Airline flying experience wherein, they have operated as a crew with another pilot. In their whole career none of them have ever observed a pilot dropping his speed below Vapp without immediate reaction to correct the dropping speed. Capt.Gorden Corps in his affidavit has stated that he has 30 years of experience as a test pilot. He has been a CAA test pilot for concorde flight certification. He has been a test pilot with Airbus Industrie for the last 8 years and has also been an instructor. During his deposition Capt.Gorden Corps was asked the following question:

"From your own experience as well as experience of other instructors of Airbus Industrie or Aeroformation, have you ever come across or heard of a pilot whose air speed monitoring was such that he could not identify the danger zone from the top of the VLS strip to the V alpha max and permitted the speed to drop from 5 knots above VLS to V alpha max?"

The answer was "No, I have not found anyone who had difficulty in identifying the low speed scale".

Airbus Industrie and Aerodormation have a large number of pilots with plenty of jet transport background as well as transport aircraft background requiring flights with other pilots as part of the crew. The pilot assessors of the court have enquired with other experienced pilots if they have ever found any pilot who has dropped the speed below Vapp by over 20 knots. The answer has always been NO. The cumulative background experience of all these pilots would extend to hundreds of years. If this enormous wealth of experience has never found a pilot who had dropped the speed to the extent that had occured in this crash, was there any other factor which did cause this speed drop go unnoticed. The DFDR cannot give us any proof in this regard. It is our opinion that this is a serious possibility that should be very carefully evaluated by Human Factor specialists. The court had desired conducting of certain special exercises in the Indian Airlines A-320 simulator at Hyderabad.

The Indian Air Force was requested to spare the services of their Human Factor specialists alongwith some of their newly acwuired equipment for use during these tests and evaluations. This had been agreed to and the Indian Airlines had made arrangements to provide the simulator for Court's use. One of the exercises that had been planned was a discrete change of airspeed indications particularly the low speed display of Magenta Vls, V alpha max etç., by feeding in a lower gross weight when the pilot's attention was drawn to another item in the cockpit. This test could have given a clue as to whether the absolute speed is monitored by A-320 pilots. The court had requested the assistance of 20 line pilots from the ICPA but unfortunately the ICPA for their own reasons did not wish to co-operate with the court for conducting these tests.

2.4. Taking into onsideration all factors as above, a valid doubt arises as to whether something may have occured which could have given wrong speed limit indication on the low speed scale which generated a sense of security and safety to the pilots whereby they did not monitor the drop in speed of the absolute value of CAS. If Vls is below current speed and the speed trend indication is showing downwards with Magenta speed selected, which moves under varying conditions of flight with the Magenta being above Vls, there is a possibility that both pilots were comfortable with the speed of the aircraft. That could be the reason why no speed calls have been given by any of the pilots even though the loss of 26 knots has been recorded on the DFDR which occured over a period of 27 seconds from DFDR time frame 296 to 323.

Airbus Industrie have issued an OEB No. 37/3 in April, 1989, on the subject of FMGC malfunctions which has been admitted as exhibit 134 wherein a possibility of loss of gross weight memory has been indicated. This OEB has been issued on the basis of reported FMGC resets/ malfunctions.

Two FAC's individually compute and feed the data for display on the two PFD's. However, if due to FMGC malfunction, if the correct gross weight memory is lost or it changes to a lower value, the indications would also correspondingly change.

If a conventional airspeed indicator had been fitted in the normal airspeed indicator position namely to the left of the PFD with a speed bug which could be set at the desired Vapp, would this have attracted the attention of the pilots when the speed went below the desired approach speed. This should be a matter of serious consideration by the Human Factor Researchers of all manufacturers who have the type of display such as is available in the A310 and A-320.

There can be no doubt that the A-320 speed display format is good. However, after this crash, no area should be left unconsidered. It would be prudent to carefully evaluate the possibility of installation of a conventional ASI with a manual speed bug setting which could also be used as a standby airspeed indicator if necessary. A provision could also be made for an audio warning whenever the speed drops more than 5 knots below the selected bug speed on the conventional ASI.

Such a feature may prevent a crash in the future due to computations resulting from incorrect gross weight at any time. Looking at the DFDR data it is also observed that during the last few seconds, an FGC bus and FMGC bus have changed their modes which is also too much of a coincidence to accept, though, Airbus Industrie have taken great pains to explain that from these change of status of the busses they have deduced that FD 1 had been switched off. In addition to FD1 being off, was this also indicative of an internal failure in the FMGC, cannot be answered as both the FMGC's have been burnt after the crash and their memory data is not available. It is also observed from the FCOM that FMGC is not an item that is monitored by the warning system either aural or visual of the ECAM.

(iii) If conventional (earlier technology) airspeed indicator had been provided with a selectable Vapp bug (as in A300) would the pilots have permitted the speed loss without observing the same?

The late two pilots have obtained their nearly 10000hours of experience on previous conventional aircrafts with conventional air-speed indicators. Each of them have flown independently as captains. One of them has even been an instructor, training pilots wherein he would have been insisting on maintenance of correct speed. If any of the two pilots had shown any tendency of dropping speed below the minimum acceptable speed of Vapp or Vref, no instructor would have certified them to even hold a co-pilot's rating on any of the passenger transport aircraft let alone Pilot-in-Command rating. This was also agreed to by Capt.Gorden Corps during his deposition.

A commercial pilot on a public transport aircraft is required to carryout a profeciency check twice a year, an instrument rating check once a year and route checks twice a year as per the requirements of the regulatory authorities. Added to the above he would have done extensive simulator refreshers and detailed conversion training on the simulators whenever he undergoes conversion on to a different type of aircraft.

Flight training is also prescribed on some of the aircraft. All these would be carried out under the supervision of a check pilot or an instructor or an examiner. Both the pilots Capt.Gopujkar and Capt.Fernandez had never shown serious deficiency to any of their check pilots or instructors throughout their career, the majority of which has been on conventional aircrafts. If a conventional airspeed indicator was the one which had to be followed instead of the present display of the A320, it is the opinion of the two pilot assessors based on their own experience as both as the line pilots and examiners that this loss of airspeed would not have occured.

(iv) If a stall warning like in a conventional aircraft was available and had come on at approximately 116 to 119 knots (as it had occured on the A-320 aircraft MSN001 FWWAI during a flight carried out for the assessors by Airbus Industrie at Toulouse on 20.6.1990), what would have been the reaction of the pilots and would this flight have crashed?

On A-320, the pitch normal law which we believe existed at the time of the crash on VT-EPN, there is no stall warning available. Stall warning has been discussed at great length during the deposition before the court. Capt.V.P.Thergoankar, a very senior instructor examiner of Indian Airlines who is also qualified on A-320 has clearly stated during his deposition: "Whenever there is a stall warning the pilots instinctively go in for full power".

This court concurs with the opinion expressed by Capt.Thergaonkar, as that is the way a pilot is trained to react on any type of aircraft whenever a stall warning occurs.

It has become necessary to discuss the subject in greater detail due to the controversy that has been generated with regard to absence of stall warning in pitch normal law. Mr.Gerard Guyot, (Director, Test and Development of Airbus Industrie) is stated to be an expert technical witness. He is also a pilot qualified on A-320. During questioning (on page 33 of his deposition) he indicated that stall warning would have come at 105 knots on VT-EPN at the time of the crash if this aircraft had been compared with a conventional aircraft with a stall warning. (as per certification requirements).

A few minutes later when asked as to the speed at which audio stall warning would have come Mr.Guyot answered:

"The audio stall warning would have come at 110 knots in the conditions of the Bangalore accident (Page 34)".

Capt.Gorden Corps in his affidavit dated 25.7.1990 (Page 13) has stated that stall warning would have occured at 105 knots if it were a conventional aircraft and the previous evidence of stall warning speed of 114 knots was incorrect.

The Court had requested Airbus Industrie to carryout a flight on a A-320 aircfaft with V-2500 engines certain profiles both under pitch normal law and pitch direct law with the weight close to the weight of VT-EPN at the time of the crash. The flight was carried out on 20.6.1990 at Toulouse, France. One of the requested profiles was to initiate TOGA at the onset of stall warning under pitch direct law and maintain speed close to stall warning speed by having intermittent audio stall warning. It was also carried out close to 3000 ft. pressure altitude. From the DFDR data supplied to the court it was observed that stall warning had initially come on at approximately 119 knots. As this was a requested profile, it is accepted, that thrust levers were moved to TOGA by Capt. Gorden Corps who was the Commander of the flight when the audio stall warning, was first generated which as per the DFDR was at a CAS of 119 knots. One of the assessors who was on board also confirmed that during the exercise there was intermitant audio stall warning. The lowest speed recorded during this profile was close to 116 knots for a period of 3 seconds. When we look at the DFDR data of VT-EPN a CAS of 119 knots was passed at 313 DFDR time frame. If a stall warning as observed on the Airbus Industrie aircraft during the special flight was available on VT-EPN at 119 knots, going by the instinctive reaction of a pilot to apply TOGA at that DFDR time of 313 seconds, there is no doubt in our minds that this aircraft would have survived. Even if we consider the lowest speed recorded during the special flight test profile of 116 knots, VT-EPN passed this speed between time frames 317 and 318. Even if TOGA had been applied at that time this aircraft would not have crashed. The above statements are based on even Airbus Industrie's acceptance that VT-EPN needed a period of 4 seconds of application of TOGA for its survival compared to the actual alpha floor activation which occured at 323.9.

The deposition of the experts from Airbus Industrie when compared with the actual occurance of stall warning during the test profile carried out by Airbus Industrie indicates a lack of good understanding of the actual design features. A difference in speed between 105 knots and 119 knots is quite considerable.

It would be prudent for all concerned to seriously evaluate the requirement of stall warning and audio stall warning to alert the crew well in advance of impending disaster.

(v) If the aircraft had conventional type of dual control wheel, would the movement of the control wheel corresponding to the SSPPC movement have attracted the attention of Capt.Gopujkar a few seconds earlier to the situation that was developing and if so what would have been his reaction. Would he have reacted on the thrust levers earlier?

One side stick movement during manual

flight does not have any reaction on the other side stick. As per the VT-EPN DFDR, the CM-1 started pulling the side stick towards the maximum from approximately time frame 319. If it was a conventional control column, definitely Capt.Gopujkar would have noticed this movement at either time frame 320 or 321, because of peripheral vision as well as the co-pilot's control column physically moving backwards. If TOGA had been applied at that time, would the aircraft have survived would be matter of debate. Possibilities of its survival cannot be ruled out. Definitely the aircraft would have touched down within the golf course itself, but, a little later than the present touchdown point; if during the bounce, after the first touchdown the aircraft had cleared the embankment it would have survived. This court does not wish to express anything further on this subject except to indicate that further Human Factor studies in this area may be advisable for consideration in the design of future aircraft.

(vi) If moving auto throttles were available, would the pilots have accepted auto throttle position at IDLE at low altitudes during approach:

This is also an item that has generated a serious controversy both during the enquiry as well as in the international pilot community.

On this aircraft when auto thrust is being used, the thrust levers do not move. They are placed in certain specific detents or positions. The auto thrust system has been designed for use during the complete flight profile from takeoff to landing. It is very pertinant to note that the only time a pilot moves the thrust levers during a flight are so limited, as ennumerated below:

(a) During takeoff move thrust levers from IDLE to either flex position or TOGA.

(b) Move thrust levers from the above position to the climb position at acceleration altitude.

(c) Move thrust levers from climb position to IDLE at the time of flare for landing when the call "RETARD" is generated.

The above are the only movements which are carried out as far as forward thrust is concerned during a normal flight.

During the deposition of Capt.Gordon Corps, when a question was asked regarding the thrust needed (in terms of value of EPR) during an approach in landing congiguration at a descent rate of 1000 ft/mt and with a tail wind of about 10 knots when:

(a) speed is stabilised at Vapp.

(b) speed is reducing to Vapp,

he could not give an answer. He indicated that he has got out of the habit of memorising power settings due to flying various types of aircrafts and he stated that he is of the tupe that uses power to achieve what he wanted. The court has to bear in mind that this statement has been made by a test pilot who is very actively flying Airbus A-320 aircraft at present and who was also approved as an examiner by the Indian DGCA to train Indian Airlines pilots.

It would also be necessary to consider the type of display available for the engine parameters.

The EPR display has both needle and digital indications. Under conditions indicated EPR would be very close to the lower limit and a look at the EPR guages may not indicate anything abnormal. If a test pilot himself has indicated his non observation of power settings needed during approach, it would be incorrect for us to expect line pilots to look at power settings when auto thrust is active.

Airbus Industrie themselves in their earlier models namely A 300 and A 310 where they have moving auto throttles have built in safe guards of thrust levers not retarding below 10° position from IDLE during approach in landing configuration as indicated by the A 300 FCOM 7.03.04. This was read and confirmed by Capt. Gordon Corps and he also stated from memory that it is similar in A 310 and A 300-600. Such design had ensured IDLE thrust levers beyond flight IDLE (corresponding to approach IDLE of A 320 aircraft) which would have automatically resulted in faster engine acceleration. However in the A 320 with no thrust lever movement, this safe guard is not available and the thrust can go to approach IDLE without the pilot's knowledge even in speed mode when speed is higher than the desired speed namely Magenta or selected speed. Capt.Gorden Corps also confirmed that in A 300, speed cannot drop below Vapp with auto throttles engaged when the Vapp has been correctly set and the systems are functioning nomally. Though this was recalled by him as an exercise in memory, it was a correct statement.

But with the improved technology of A 320 it is possible for the thrust to go to IDLE and the speed to drop below Vapp at any time during approach by means of a change of mode whether it is broughtabout intentionally or unintentionally. Such mode change did occur on VT-EPN wherein engine was at IDLE and the speed did drop below the desired speed.

It is a well known standard procedure that is taught and followed by all pilots flying aircraft with moving auto throttles never to permit auto throttles to be in IDLE position during the final stages of approach to landing at low altitudes or at heights close to the ground. Pilots would always accept even a slightly higher speed by over powering auto throttle movement backwards as they would be aware of the dangers involved if thrust is permitted to go to IDLE during critical phases of the final approach even though the above mentioned safe guards of thrust lever angle is built in by the manufacturers. A very valuable cue of feel has been removed from the pilots by the design of the static auto thrust system in the A-320. IFALPA have expressed their anxiety in respect of this design. When Capt.Gordon Corps was shown a paper by Capt.Steeve Last, Chairman, IFALPA Aircraft Design and Operations Committee, presented for Aerotec 1989 at Anaheim in September, 1989 (Exhibit 144), it was brushed aside as an individual opinion. Capt.Gordon Corps also stated that the same IFALPA have required other manufacturers on their latest aircraft to adopt the Airbus philosophy. Unfortunately this was incorrect. Airbus Industrie themselves held a conference with A-320 qualified representative of IFALPA member associations at Toulouse in June, 1990, wherein the auto thrust system of A-320 came in for a lot of critisism. They have Capt. Richard Pike, Chairman, New Aircraft Study Group of BALPA, who made a presentation of this meeting. He has clearly indicated the serious anxiety regarding some of the systems of A-320 aircraft. The IFALPA pilots user group commentary on the Airbus Industrie presentation does not reflect the views expressed by Capt.Gorden Corps as indicated above in his deposition on Page 93 though this was on 6.8.1990.

IFALPA users group have clearly indicated in their conclusions as below:

(a) Proposed modification do not simplify the the interface.

(b) The proposed modifications do not resolve problems.

(c) Operators have concerns about overall desirability of static levers.

(d) SAE S 7 has concerns about desirability of static levers.

(e) A 330/340 will have same problems but

(i) more critical inertia/momentum due to greater size.

(ii) less frequent crew exposure.

(f) A 330/340 should be offered with option of moving throttle allow operators choice.

Capt.Guyot during his deposition stated that the concept of A-320 throttles was to avoid the fitting of a dedicated electrical motor for auto thrust as the engines are fully eletronically controlled. Nevertheless the thrust control through the levers is conventional (Page 34). When a question was asked as to whether any specific Human Factors research was conducted in respect of this auto thrust system vis-a-vis the advantages gained by reduction of certain components, the question was not covered in his long answer. It is necessary to note that Capt.Guyot has given his designation as Flight Test Engineer/Director, Test and Development of Airbus Industrie. Even in the documents sent to us by Mr.Jean Jacques Spayer, the Human Factors specialist of Airbus Industrie, we have no information regarding any Human Factors research carried out by Airbus Industrie in respect of Auto Thrust System of A-320 with its static thrust levers.

It is a matter for further consideration by all concerned, that a very vital cue for safe operation of ... flight with auto thrust system active has been removed by the static thrust levers.

The assessors had planned to carryout a test of the eye movements of the pilots during their simulator test program indicated earlier for determining the eye points of regard during an approach on an A-320 aircraft by using eye mark recorder cameras. This equipment was available with the Indian Air Force Institute of Aerospace Medicine Human Factor experts. This court could have obtained very valuable data regarding the monitoring of the actual power setting from the EPR guage during final approach with auto thrust active. Unfortunately due to non availability of volunteer pilots from the ICPA who refused to co-operate, this court would only indicate that a very serious Human Factor study should be undertaken by specialists to prevent any future accidents of this nature.

It would also be pertinant to note that when a pilot is not at all used to operating thrust levers during a normal flight, there could be a slight delay in a pilot's reaction when certain deviations are noted. This time delay could be extremely serious in its consequence under conditions that could lead to dangerous situations as that which occured in the case of VT-EPN.

(vii) What would be the effect of the type of speed display that is available in A-320 in respect of the monitoring of the correct indicated airspeed value by the pilots. Is the speed trend indication and the type of warning indications in respect of Vls V alpha prot an d V stall warning could generate mistaken sense of security/safety:-

This is a matter which has been discussed to a certain extent under item (i) and (ii). However further elaboration may be appropriate. One of the assessors has had considerable training experience on A 310 aircraft when these were introduced into his organisation. The other assessor when he was given the opportunity to fly the A 320, indicated that the speed trend indication was so compelling that he was very closely monitoring the trend indicator and trying to achieve flight with no trend indication without observing the absolute value of the indicated airspeed. This had also been observed by the assessor qualified on A 310 during his training of pilots on that type of aircraft. For this reason on the A 310, instructions had been issued from the very beginning that during approach the double bug had to be set at the desired Vapp on the standby airspeed indicator which was just next to the PFD on the left hand side. It would not be very difficult to imagine a pilot with a display as in the A 320 not to get purturbed when the present speed of the aircraft is above the amber region of the Vls and above the desired Magenta speed. Capt.Richard Pike in his presentation has recommended the inclusion of a digital box on the speed scale indicating the actual speed of the aircraft after a careful discussion of the subject in his presentation.

Though this is a very good recommendation, would this be enough to prevent a future accident in case of incorrect indications as mentioned earlier in items (i) and (ii). A standby ASI in the correct position with a selectable speed bug giving an audio warning when speed goes below 5 knots of the selected speed would ensure safety at all times.

(viii) What is the effect of static auto thrust system in the monitoring of the actual power existing during approach.

This item has already been discussed.

(ix) Would IDLE indicated in red or flashing red at low altitudes during approach have made any difference.

It is a general philosophy in every sphere of activity or engineering to associate red colour with danger and green with normal or satisfactory operation. Even Airbus Industrie have clearly defined their philosophy under the headings "COLOUR CODE AND WARNING HIRARCHY" in FCOM 1.06.20 (Pages 1 and 2).

Under colour code, red warnings are used forconfiguration or failure, needing immediate action. Under warning hirarchy, red warnings are indicated as level 3 which are for situations needing immediate crew action, aircraft in dangerous configuration or limit flight conditins (example stall, overspeed), system failure altering the flight safety (example engine fire etc.)

These warnings are associated to an

Aural warning : repitative chime sound or specific sound.

Visual warning: Master warning red light flashing until crew clearing action, warning message on CRT (some exceptions).

On VT-EPN Capt.Gopujkar observed IDLE open descent annunciated on the FMA a few seconds before the crash. As per the CVR transcript of exhibit 1, it is shown against crash second 24. The crash of VT-EPN has fully demonstrated that IDLE open descent on short finals and at low altitudes is a flight situation which did cause the aircraft to get into a dangerous configuration and limit flight condition which needed immediate crew action. IDLE open descent is indicated in green under all conditions of flight. Capt.Gordon Corps had accepted during his deposition that red warning will attract immediate crew attention. However for the suggestion that the colour of IDLE should be changed from green to red after gear is selected down as a lesson from this crash so that in future under such conditions, during approach immediate warning is passed onto the crew, his answer was evasive. This is a matter to be seriously considered by the manufacturers, operators of Indian Airlines and our regulatory authorities. Preferably it should be associated with an aural warning also, as explained under Warning Hirarchy.

(x) Cockpit sliding windows:

These windows slide rearwards and can be used for crew emergency exit. The court and the assessors during their visit to the crash site during February,1990, a few days after the crash, had observed that a portion of the cockpit including the RH cockpit sliding window appeared to be intact. No wrinkles or deformation had been observed in the framework of the fuselage surrounding the sliding window. The front window was still in place. The rear window aft of the sliding window was also in pleacebut the laminates were burnt to a certain extent A small portion of the sliding window laminate towards the rear had shown damage due to fire. The internal framework of the sliding window appeared to be intact. The upper and lower tracks of the sliding window appeared to be intact except for the rearward last few inches of the top rail which had shown fire damage. The push button on top of the control handle had been observed in the pressed position. The handle itself did not show any serious fire damage and could be turned around its axis. The post mortem report of the pilots indicated that they had died of burns. This started the court thinking about the reasons why the pilots were not able to use the emergency exit before they were burnt to death. One of the witnesses Mr.Laxmaiah Reddy had stated during the deposition that he had seen someone hitting the cockpit window with his fists before the fire engulfed the region. From his position and explanation to the court it was surmised that this might have been Capt.Gopujkar hitting against the RH cockpit sliding window. One of the assessors went to a parked aircraft at Bombay with two engineers of Indian Airlines for observing the operation of the cockpit sliding window when the pilot's seat is moved forward to allign with the eye markers. It was observed that the handle of the sliding window was almost in line with the seat backrest when it is vertical which would normally be the position of the backrest and the seat at the time of takeoff and landing.

The position of the handle in the earlier Airbus aircraft namely A 300 and A 310 was at the forward end of the sliding window. In any crash it is possible to expect deactivation of the electrical seat movement or even prevention of seat movement mechanically backwards due to impact damage. In a severe crash like that of VT-EPN it is also possible to expect injury to a hand making it unusable to open a window. With this in view the assessor tried to open the window of the aircraft in Bombay using only one hand with the pilot's seat correctly positioned using the eye markers.

The LH window could not be opened by the use of one hand either left or right. However it could be opened by using both hands with the use of the forward assist handle. As far as the RH window was concerned, the window could not be opened by using one hand or both hands also. During the period the assessor was in the aircraft, the engineers could not also open the RH window while sitting in the pilot's seat.

It is advisable that the design of this window should be re-examined. The window should be operable by the use of one hand at times of emergency. In the A 320 it does appear that proper leverage is not available to open the window at the position where the locking handle is situated because of the angle at which this handle would be, when the seat is correctly positioned for flight using the eye markers.

There is also the possibility that the windows of VT-EPN may not have been opened from the time it was inspected at Toulouse prior to acceptance till the date of the crash due to winter conditions prevailing in India and also due to the air conditioning efficiency of the APU. This could have caused the beeding to stick to the outer frame needing additional force to open during emergency. Most probably all this would have been overcome if the handle had been at the front end of the window similar to A 300 or A 310 for reasons of affording better leverage.

On 29.8.1990, two of the assessors visited
rash site alongwith the secretary to the court.
n Airlines provided an Assistant Engineering
er to assist in opening the VT-EPN sliding
w. After slight tapping on the outside glass
using water as a lubricant to clear the little
s around the bottom tracks, the window was
d fairly easily even though 6½ months had
since the crash and this portion of the
e was lying in open air and rain. The
ould slide back to about 4" of its aft limit.
due to fire damage of the upper track at
end. The mechanism was observed to be
normally. This indicated that the RH
ing window was in a fully operable
when the aircraft came to its final rest
n and for some reason the pilot who was
ted to be seen alive by a witness was not
le to open the window. The LH cockpit window
had been totally burnt though Capt.Fernandez in
CM 1 position also died due to burns, hence it
could not be examined.

Did aesthetics determine the location of the sliding window handle? Did Airbus Industrie consider human engineering aspects at the time of this window design? Are there any lessons to be learnt from this crash towards the design of cockpit emergency window exits? These are all matters for consideration by experts in the field for use in future designs.

However it would be advisable for Indian Airlines to establish a procedure wherein these windows are operated frequently during certair ground checks to prevent the seals sticking to the structure.

It is also necessary to keep in mind th there are women pilots who may fly these aircra and who may not be physically as strong as men

2. SIMULATOR EXPERIMENTS:

Airbus Industrie have in their technical Note No.AI/E A 441.0377/90 dated 12-4-1990 have confirmed that the angle of attacks corresponding to Alpha Prot is 12°, Alpha Floor is 14.5°, Alpha Max is 15° and Alpha Cz Max is about 19°. They have indicated that weight and altitude have no effect on these values. Alpha floor value is subject to a correction term depending on horizontal wind gradient.

FCOM 1.09.10, page 9 under heading "PROTECTIONS" in the Flight Controls chapter have indicated high angle of attack protection as below:

"In pitch normal law, when angle of attack becomes greater than alpha prot, the elevator control is switched from normal mode to a protection mode where angle of attack is proportional to side stick deflection. The Alpha max cannot be exceeded even if the side stick is pulled fully back. If the side stick is released the angle of attack returns to and maintains alpha prot.

This protection, which provides protection against stall and windshear, has priority over all other protections.

Valpha prot varies between about 1.11 Vs(conf 0)
1.14 Vs (conf full)
and ∠ Valpha floor varies between about 1.08 Vs (conf 0) and 1.11 Vs (conf full). Valpha max varies between about 1.07 Vs (conf 0) and 1.06 Vs(conf

1.09.10 page 10 under note 1 states "At take off alpha prot is equal to alpha max for 5 seconds."

By design, this aircraft is not supposed to exceed the alpha max of 15° angle of attack at any time even if the side stick is pulled fully back under pitch normal law. But under pitch direct law vide FCOM 1.09.10 page 15 there is a direct stick to elevator relationship and no protections are operating.

During the last few seconds of the flight, when CM1 started pulling the side stick to the fully back position from time frame 322, there was a right bank introduced. Left rudder was applied during time frames 323 and 324 and again between 326 and 327 possibly to lift the wing. During this bank the right hand side roll spoilers have also been activated. The bank, roll spoiler activation and rudder application under the critical stage of the flight with high angles of attack would have caused certain loss in lift.

DFDR has also shown an increase in CAS from 106.5 kts at 323 to 113 kts at 329. The aircraft was not permitted to hold the speed of 106.5 kts by the elevator computers even though the side stick was held fully back.

The court desired to analyse the performance on an A 320 simulator when the bank angle and the rudder application was removed, commencement of engine acceleration 1 second and 2 seconds earlier compared to VT-EPN actual, permitting the aircraft to go up to a maximum angle of attack of 17° and 18° angle of attack etc when compared to a reference data programmed as close to VT-EPN as possible.

CAE Electronics of Canada have built a Phase III quality simulator for Indian Airlines using aircraft data and parts supplied by Aerospatiale of France who is a partner of Airbus Industrie. Indian Airlines had specified that the data supplied should be based on the performance of the Indian Airlines aircraft with tail No.045. That aircraft is now flying with Indian Airlines. The data and aircraft parts supplied by Aerospatiale is expected to correspond to the performance of the Indian Airlines aircraft with V 2500 engines derived from the performance of aircraft with tail No.045.

The Court commissioned CAE Electonics to programme certain data into the simulator. The results of the various tests in the form of plots of simulator response were to be taken and submitted to the court.

The following tests were performed:

TEST No.1 : The first test attempts to match the flight data as close as possible. This is accomplished by allowing certain control surfaces to diverge in order to maintain specific outputs. This is necessary in order to limit error accumulation due to factors mentioned above.

TEST No.2 : This test is identical to test No.1 except that all roll and yaw movements have been removed. Aileron, spoilers and rudder inputs are zero for this test.

TEST No.3 : These tests are the same as test No.1 except that the final thrust initiation is:

a) 1 second earlier

b) 2 seconds earlier

TEST No.4 : These tests are the same as tests 3a) and 3b) except that all roll and yaw movements have been removed.

TEST No.5 : Omitted.

TEST No.6 : These tests were done in direct law by pulling the CB's of the two radio altimeters. This allows the simulator to go beyond the angle of attack protection.

TEST No.6a : Same as test No.1 except that the simulator was allowed to attain an angle of attack of 18 degrees in the final portion of the approach.

TEST No.6b : Same as6a)except that thrust initiation is 1 second earlier.

TEST No.6c : Same as 6a) except that thrust initiation is 2 seconds earlier.

TEST No.7 : These tests are the same as 6 except that a maximum angle of attack of 17 degrees was allowed.

The following parameters are displayed in the various pages as below and can be compared with the crash flight data where available. Test No.1 has been simulated in the following manner:

PAGE No.1 : Calibrated airspeed is an output that was matched with the crash flight data except for the effect of wind gusts.

PAGE No.2 : Magnetic heading is an output that was initialized at the start of the test.

PAGE No.3 & 4 : EPR of engines 1 and 2 are displayed with an inherent time lag due to the simulator system. Therefore, they do not represent the true state of the engines at any one time. However, net thrust developed which is correct is, displayed on page 15.

PAGE No.5 : Roll angle is an output that is matched with the crash flight data by introducing necessary deviations in the aileron inputs.

PAGE No.6 : Pitch angle is an output that is matched with crash flight data by introducing necessary deviations in the elevator inputs.

PAGE No.7 : Radio altitude is an output that was initialized at the start of the test from the point of ground contact.

PAGE No.8 : Elevator position is an input (see note for page 6).

PAGE No.9 TOP: Stabilizer position is an exact input.

PAGE No.9 BOTTOM: Aileron position is an input (see note for page 5).

PAGE No.10 : Rudder angle is an exact input.

PAGE No.11 : Average left and right spoilers are exact inputs. Slight deviations from the crash flight data are due to averaging of spoiler surfaces.

PAGE No.12 : Aerodynamic angle of attach is an output.

PAGE No.13 : Pressure altitude is an output.

PAGE No.14 : Longitudinal and normal accelerations are outputs.

PAGE No.15 : Net thrust is displayed in order to reflect the true state of the engine.

PAGE No.16 : Altitude rate is an output.

Test Numbers 2 to 7 are results of certain modifcations intruduced to test No.1 Specific variations of the inputs with respect to test No.1 are explained against each test.

The data that was obtained have shown certain trends.

The court was aware that exact simulation was not possible due to non availability of complete environmental data and also due to slight difference in the simulator data and the actual VT-EPN performance. However certain vital parameters were closely matched to the best possible extent in test No.1 to form a base for comparison purpose keeping in view some of the design characteristics as given in FCOM. Radio altitude and pressure altitude were matched at ground level to obtain a reference of the first touch down at about 329.8 seconds. The time base has been from DFDR times 295 to 331.5 seconds, as the DFDR had stopped recording at approximately 331.4 seconds. A generic visual data base was used with R/W direction as 09.

The details of inputs and outputs for test No.1 have been explained earlier. Certain modifications to the test No.1 were introduced in the subsequent tests for evaluating the reactions of the simulator.

The results of these tests are limited by the accuracy of the various system models and the sample rate of the input data (most flight data has a sample rate of once per second). One copy of the plots obtained during these tests was submitted to the court by CAE Electronics Limited which was marked as Exhibit 118. On the plots the dotted lines are DFDR data and full lines are simulator plots. Weight of aircraft, centre of gravity (CG)TAT (Total Air Temperature)were closely matched.

Altitude of the first touch down was considered as the reference altitude and for survival of the aircraft it was assumed that the aircraft should be at least 30 ft. above this reference altitude at time 331.4 seconds to clear the embankment and the small trees on top of the embankment. The following were observed during the play back of the profiles and the generated plots:

Test 1 : Aircraft crashed short of R/W. Maximum angle of attack reached is approximately a little over 13°.

Test 2 : Aircraft crashed a little beyond the reference point of test No.1 as it could not clear the embankment.

Test 3(a): Aircraft crashed shortly after time 330 though net thrust reached approximately 56000 Newtons at 331.4 seconds.

Test 3(b): Aircraft crashed into embankment through net thrust reached a little over 80000 Newtons at 331.4 seconds. CAS showed improvement just before 331.4 seconds or assumed embankment position.

Test 4(a): Not being able to clear the embankment, the aircraft crashed.

Test 4(b): Again not being able to clear the embankment the aircraft crashed. CAS showed improvement just before embankment.

Test 5 : Omitted.

Test 6(a), 6(b) and 6(c) are under direct law permitting the aircraft to go upto 18° angle of attack. Tests 7(a), 7(b) and 7(c) are under direct low permitting the aircraft to go up to 17° angle of attack.

Test 6(a): CAS went below base line of 105 knots but aircraft did not stall and crash. Maximum pitch angle reached was ∠ 17.5° Minimum radio altitude reached was approximately 40 feet at 329 seconds (above reference touchdown point of Test 1). Aircraft survived clearing embankment.

Test 6(b): CAS went below 105 knots but aircraft did not stall. Minimum radio altitude reached was 65 ft. at 328 seconds (above reference touch down point of Test 1). Pressure altitude also reflects in similar fashion.

Altitude rate became positive from 328.4 seconds.

Test 6(c): CAS went below 105 knots but aircraft did not stall. Lowest radio altidue was again 65 ft. at 328 seconds (above reference touch down point of Test 1). Pressure altitude also reflects in similar fashion. Altitude rate become positive from 328 seconds.

Test 7(a): CAS went below 105 knots but aircraft did not stall and crash.

Maximum pitch angle reached 16°.

Lowest radio altitude was 35 ft. at 329.5 seconds.

Aircraft survived clearing embankment.

Test 7(b): CAS went below 105 knots but aircraft did not stall.

Lowest radio altitude was 55 ft. at 328.7 seconds. Pressure altitude is also reflected in a similar manner. Rate of climb became positive at 329 seconds and was approximately 450 ft. per minute at 331 seconds.

Test 7(c): Minimum CAS reached is 105.75 knots at 330.2 seconds. Aircraft did not stall and crash. Lowest radio altitude recorded is 60 ft. at 328 seconds.

Pressure altitude is also reflected in a in a similar manner.

Rate of climb became positive at 328.4 seoonds and exceeded 500 ft. per minute at 329.8 seconds.

The results indicate:-

At 58 tonnes Vs 1g was 104 knots as confirmed by A.I. Based on CAA requirements Vs minimum would work out to 98 knots (0.94 Vs1g) and a as per FAA regulations it would workout to 95 knots (0.91 Vs1g) if this was a conventional aircraft. Airbus Industrie have manufactured other aircraft such as A 300, A 310, A300-600, which have conventional primary flight controls and are presently operating all over the world using Vs minimum and other speeds computed with respect to Vs minimum. Vs 1g is a new terminology which has come recently, and merely changing the terminology would not alter the characteristics of the plane.

Compared to Test 1 which was under pitch normal law, when direct law was used for Tests 6a, 6b and 6 c with maximum angle of attack up to 18° and Tests 7a, 7b and 7c with maximum angle of attack up to 17° the altitude of the aircraft from the simulator plots was above 30 ft. at time frame 331.4 seconds.

From comparision of radio altitude plots of Tests 1 & 2, it is observed that the simulator was at approximately 15 ft. above reference altitude at 329.8 seconds. This test No.2 was identical to Test No.1 except for the removal of all roll and yaw movements. The plane was assumed to have flown with wings level.

Airbus Industrie has indicated in its letter AI/E FS 420.0145/90, dated 26.6.1990 that the total loss of altitude due to the roll and yaw inputs of VT-EPN from time 308 to the time of impact was 7 ft. This figure from A.I was based on some simulations it had carried out. Though the court had requested Airbus Industrie to get another opinion from the wing manufacturers of the A 320, court has not received any such information.

Test 6a was the same as Test No.1 but the simulator was permitted to go to 18^{o} in the final portion of the approach under direct law. The maximum pitch angle reached was 17.5^{o}. The minimum radio altitude reached was 40 ft. at 329 seconds and the aircraft was 50 ft above reference altitude at 331 seconds showing a climb gradient. The speed did go below the base line of 105 knots which had been selected for the plot but the the simulator did not stall. Aircraft survived clearing embankment. Test 7a was similar to Test 6a but the aircraft waspermitted to go to 17^{o} angle of attack under pitch direct law. Themaximum pitch angle reached was 16^{o}, lowest altitude was 35 ft. above reference altitude at 329.5 seconds. Aircraft was showing a climb at 331 seconds and was at 40 ft. above reference altitude. The aircraft did not stall and survived clearing the embankment. The CAS went below the base line of 105 knots.

The performance of the aircraft under direct law with commencement of engine acceleration 1 second and 2 seconds earlier for conditions of Tests 6a and 7a showed marked improvement. At 331 seconds the heights above reference datum were higher and in Test 7c the minimum CAS also remained above 105 knots.

In the present VT-EPN accident the aircraft dropped the right wing when CM1 pulled the side stick fully back. The court wanted to check about this coincidental occurance during the test flight planned with Indian Airlines aircraft at 3000 ft. pressure altitude over the sea to simulate approach of VT-EPN at Bangalore with line pilot volunteers operating controls under the supervision of an examiner.

Unfortunately ICPA declined to give volunteer pilots. Even a flight with examiners only, was not agreed to by the DGCA to carry out the profiles at 3000 ft. pressure altitude over the sea, though two of the examiners namely Capt.S.T.Deo, Director of

Training and Capt.V.P.Thergaonkar, Operations Manager, Training of Indian Airlines who met the assessors on their arrival at Hyderabad on 17.7.1990 were inclined to carry out the profiles as line pilots were not going to be on board.

It would be a useful exercise for A.I as the manufacturer to carry out further research using ordinary line pilots to see if a CM1 pulling the side stick fully back whilst looking outside would generate a roll to the right. There is a possibility of the CM2 generating a roll to the left.

Though the aircraft has been certified by various authorities, again it would advantageous for the certifying authorities including the DGCA, India, Airbus Industrie as the manufacturers and Indian Airlines asbig operator of aircrafts, to carry out further research regarding the possibility of increasing alpha max under pitch normal law which may possibly improve the performance, should a situation similar to that of VT-EPN should ever occur again, even if it was due to severe wind shear close to the ground.

Both I.A and IAE, the engine manufacturers have already started the process towards increasing the approach idle RPM by 2.5%. This would definitely improve the engine acceleration time. Tests 6b and 6c, 7b and 7c when compared to 6a and 7a have shown that an earlier acceleration by 1 second and 2 seconds considerably improves the performance. Similarly test 3a and 3b compared to Test 1 showed an improvement; certainly this is an improvement towards flight safety.

FLIGHT TEST BY AIR BUS INDUSTRIE:

It was felt that there was a possibility of a slight delay in acceleration of the engines at high angles of attack due to the change in the air flow pattern into the engines. Another possibility was uneven acceleration of the two engines because of an abrupt rudder input in the last few seconds which could cause change of air flow into the engines.

The acceleration data in respect of the V 2500 engines provided to the court indicated the acceleration characteristics at a pressure altitude of 5000 ft. an under ISA conditions, the acceleration commencing at 0.25 Mach from approach idle to take off thrust.

The FAA requirements specify that the engines should accelerate from approach idle to a thrust level required by the aircraft to achieve a climb gradient of 3.2% in landing configuration with both engines operating within a period of 8 seconds.

Though alpha max by design was 15^{0}, on VT-EPN, we had observed an angle of attack reaching the value of 16.759 at DFDR time frame 328.641 seconds. The court desired that a flight test be made to see if such angles of attack was achieved by other aircraft and also to establish if this high angle of attack experienced by VT-EPN was due to any other reason. The court had desired to carry out this manoeuvre simulating Bangalore conditions at a pressure altitude of 3000 ft. over the sea under pitch normal law with an Indian Airlines aircraft also with Indian Airlines both with examiners operating the controls and with line pilots operating the controls under supervision of examiners to establish in addition to the above, the altitude loss during during such manoeuvres for comparing such loss with the VT-EPN altitude loss. Unfortunately, as explained earlier, the flight test was not permitted by the DGCA, India. The flight test would have given valuable information to the court.

AIRBUS Industrie promptly carried out the tests desired by the court both under pitch normal law and pitch direct law. Capt. G.Corps was in command with Mr.Guyot as first officer. One of the Assessors, Capt.C.R.S.Rao was on board as an observer. Total flight time was 0145 hrs. Weight at take off was 59 tonnes, with centre of gravity at 28%. The aircraft registration was FWWAI and it was fitted with V 2500 engines similar to that of Indian Airlines. All relevant computers were at the standard of the Indian Airlines aircraft. Date of the flight was 20.6.1990. The meteorological conditions were clear and calm with QNH of 1017 HP which was the same as at Bangalore at the time of the crash of VT-EPN. Airbus Industrie made an attempt to be as close as possible to the Bangalore VT-EPN profile.

The profiles carried out were:

1. A repeat of the Bangalore accident scenario.
2. A recovery in direct law at stall warning.
3. A recovery at stall speed plus 12 kts.
4. A demonstration of engine acceleration at maximum angle of attack.

From the detailed DFDR data made available to the court the following were evident:

1) A repeat of the Bangalore accident scenario:

The DFDR data from 15.8.00 UTC to 15.11.59 UTC has been provided to cover this profile. In these four minutes recording, the complete DFDR data from 15.10.36 to 15.10.43 could not be retrieved for reasons which have not been explained by Airbus Industrie.

Prior to the alpha floor activation the approach idle of engine No.1 was 65.25% N2 and of engine No.2 was 65.50% N2. Activation of alpha floor was at 15.10 14.5 UTC based on EPR command assuming version 1 (as Airbus Industrie have not indicated the version). EPR command engine 1 would be in word 34. Though EPR command initially was 1.422 on both engines it reduced to 1.418 a few seconds later for reasons unknown and came back to 1.422 and later to 1.430. EPR command on both engines remained at 1.418 against time 15.10.24 but EPR actual engine 1 at the same time was 1.425 and for engine 2 was 1.420. This was the maximum power reached during acceleration. However after another 20 seconds EPR went up to 1.432 because of the increased EPR command. From the point of view of engine acceleration if we consider that the 1.425 EPR of engine 1 and 1.420 EPR of engine 2 as the equivalent of TOGA during this engine acceleration, it was achieved against time frame 15.10.24. There was a slight difference in the EPR's of the two engines at every stage of the acceler tion with engine 1 EPR leading the engine 2 EPR. Both engines acclerated from approach idle to TOGA in almost the same time (ie) in 9.5 seconds.

SSPPC was -13.27 at 15.10.12.5 secs and -14.94 at 15 10 13.5. Interpolating, SSPPC would have gone through 14^{o} at 15 10 12.9 secs, which would be the time alpha floor was triggered. From the above it can be seen that the time lapse between alpha floor triggering and alpha floor activation is 1.6 secs. If it is considered that alpha floor activation has occured fractionally before 15 10 14.5 secs, then the acceleration time would increase beyond 9.5 secs by that fraction. But, for comparison purposes with further tests, the EPR command has been taken as alpha floor activation.

During this profile the pressure altitude loss was 124 ft. (2827-2703), minimum speed reached was 110.25 at time 15.10.17. The maximum angle of attack prior to commencement of acceleration was 13.53^{o} actual against time 15.10.13 which increased to 14.94^{o} during engine acceleration when EPR had reached approximately 1.12 (slightly higher EPR than VT-EPN at the time of touch-down). The angle of attack recorded a maximum of 16.16^{o} at 15.10.24 when both engines were at take off thrust.

Alpha prot of 12^{o} was passed at 15.10.08. The stabilizer position recorded at that time was -6.32. Though the stabilizer position recorded was after the angle of attack recording of 12^{o} actual angle of attack, the stabilizer position continued to increase to -6.58 at 15.10.10. SSPPC was held fully back and the stabilizer position changed to -6.50 at 15 10 22 and -6.23 at 15 10 23 and continued to change further to -5.18 at 15 10 26. The SSPPC has been moved forward between the times 15 10 26 and 15 10 27. The actual angle of attack based on the formula given to the court by Airbus Industrie remained above 12^{0} throughout this period. The initial change of stabilizer position towards further nose up trim in alpha protection zone cannot be explained as it is contrary to what is described in the FCOM.

The pitch angle which was 8.44^{0} at 15 10 10 went on reducing to the lowest figure of 7.56^{0} at times 15 10 16, 15 10 17 and 15 10 18 before it started increasing and the engine power built up. During this period the sidestick was pulled back and held fully back.

Within a short period after the court's requirement of the Bangalore scenario was completed and the aircraft continued to climb away, it was noticed that a large number of errors occured in the DFDR data recordings. Of particular interest would be 12 incorrect readings of normal acceleration, 6 of lateral acceleration and 9 of longitudinal acceleration. Within a time period of 4 minutes there were 82 incorrect recordings plus complete 8 seconds DFDR data was missing.

There are some very significant differences seen in the performance of this aircraft when compared to the performance of VT-EPN which would be discussed later after observations regarding all profiles are completed.

2) Recovery in direct law at stall warning:

The assessors had requested for a profile under direct law to be flown at a speed when stall warning occurs and maintain such speed to get intermittent stall warning and the thrust levers were to be moved from idle to TOGA at the first stall warning. Again aircraft would be in landing configuration. The stall warning occurred at 120 knots and TOGA command was given at 15.16.46. Approach idle on both engines was 65.25% N2. The initial EPR command was 1.422 which again reduced to 1.418 during engine acceleration. The left engine reached 1.419 EPR at 15.16.55. The right engine reached 1.421 EPR at 15.16.54. Both engines reached 1.422 EPR at 15.16.56, which was the maximum. During this engine acceleration the right engine EPR was leading the left engine EPR which was opposite to the previous profile. Secondly the time taken to reach the maximum thrust was 10 seconds which was again more than the previous case. The angles of attack (actual) during this profile were 15.05° at 15.16.46, 14.84° at 15.16.48, 15.85° at 15.16.51 and 16.86° at 15.16.52 which came down to 14.34° at 15.16.54. During this maneouver the pressure altitude loss was only 55 ft. (2966-2911). As per Airbus Industrie report, stall warning occurred at 120 knots. TOGA was applied at 119 knots and minimum speed during manoeuver was 116 knots at 15.16.50. The duration of the DFDR recording supplied to the court was for 2 minutes from 15.16.00 to 15.17.59 to cover this profile. There were three erroneous recordings in the data in this 2 minutes period of which 2 were longitudinal acceleration parameters.

3) Recovery at stall speed plus 12 knots:

The assessors had requested for this profile to be carried out at 12 knots above the actual aerodynamic stall speed of the aircraft under direct law to simulate a performance of an aircraft with conventional controls close to stall warning. We had anticipated that at 58 tonnes the aerodynamic stall would be close to 98 knots (Vmin as per CAA regulations). However it does appear that Airbus Industrie had misunderstood our request. The assessors had not indicated any specific speed because of not being able to know the weight of the aircraft when this profile was performed. The excercise was carried out maintaining a higher speed. Still, this profile also gives a good amount of information for analysis.

The TOGA command through thrust levers was given at 15.23.34 UTC. Approach idle of both engines prior to acceleration was 65.25% N2. The EPR command was 1.422 which again later reduced to 1.418. However during acceleration maximum EPR actual reached by engine no.1 was 1.421 at 15.23.45. Similarly EPR actual of engine 2 reached the maximum of 1.421 at 15.23.46. During this acceleration the No.2 engine was leading the No.1 engine till 15.23.44 but lagged behind in the last two seconds to reach 1.421.

The pressure altitude loss from TOGA command to recovery was 121 ft. (2965-2944). CAS maintained was from 119 to 121 knots. Maximum actual angle-of attack reached prior to TOGA command was 9.69° at 15.23.32.

It increased to 11.51^{0} at 15.23.36. After a slight reduction during the next few seconds, it increased to 14.84^{0} at 15.23.42 and 16.05^{0} at 15.23.43.

The DFDR data covering the profile was for a period of 4 minutes from 15.22.00 UTC to 15.25.59 UTC. The period covered the fourth profile of engine acceleration at high angles of attack also. There were many incorrect recordings on the DFDR, and this would be discussed after profile 4.

4) Demonstration of engine acceleration at maximum angle of attack:

During this exercise, stabilized approach idle was 65.25% on both engines. TOGA command by thrust levers was at 15.24.42. Pressure altitude loss was 56 ft. (2875-2819). The CAS during altitude loss was 118 and 117 knots. During acceleration the EPR command was 1.418. However a maximum EPR of 1.428 was reached by engine 1 at 15.24.52. An EPR of 1.423 was reached by engine 2 at 15.24.52. Both engines during this profile accelerated to maximum thrust in 10 seconds. During the acceleration the left engine started leading the right engine after the lapse of 6 seconds. The angle of attack at TOGA initiation was 10.90^{0} at 15.24.42. Earlier it was slightly less. The angle of attack started increasing from 15.24.45 to a value of 17.78^{0} at 15.24.49. The angle of attack started decreasing from then on.

In the 4 minutes of the DFDR data which covered profiles no.3 and 4, there were a total of 66 erroneous recordings. Of these 14 were normal acceleration values, 6 were longitudinal acceleration values and 5 were lateral acceleration values.

Though the flight was for a total duration of 0145 hours, we have considered only 10 minutes data of which 8 secondswere missing. In this data we have observed 151 erroneous recordings, themaximum number being a total of 26 in the normal acceleration parameter followed by 17 in the longitudinal acceleration parameter, 12 in the pressure altitude parameter and 11 in the lateral acceleration parameter.

Surprisingly, majority of such erroneous recordings occurred within a short period after a flight at high angle of attack is carried out. The acceleration parameters themselves accounted for 54 of these erroneous recordings which is 36% of the total number. The incorrect acceleration recordings ranged from -7.37488 to +5.89178. The aircraft was in flight and there was no way that these values could be achieved either by design or by severe violent manual handling. Some of the recordings were isolated and some were grouped in 2,3,4 and even 5 consecutive recordings. At some places, in consecutive recordings, the incorrect figures were close to each other while in other places the figures were very much different.

Airbus Industrie had furnished certain limited parameter data to check on increase in N2 rpm on slat extension. This data was from 14.45.00 to 14.48.59 It was observed that N2 rpm of engine 1 increased from 64.75% to 69.25%, an increase of 4.5%. The N2 rpm of engine 2 increased from 65.25% to 69.50% which was an increase of 4.25%. The pressure altitude during this test was approximately 9000 ft. Airbus Industrie have tried to be close to the speed of VT-EPN. There were no erroneous recordings in this limited part of the DFDR data. On VT-EPN the increase recorded was less than these figures. The no.1 increased by 2.75% from 66 to 68.75. No.2 increased by 3% from 65.75 to 68.75. Exhibits 102 and 103 which were taken on other aircraft has shown increases from 6% to 8%. For some reason, VT-EPN showed a lower increase.

Significant comments about erroneous recordings would be:

a) There was not a single erroneous recording from 15.08.00 to 15.10.14 at which time the first profile recovery commenced. Theinitial erroneous recordings were in the acceleration parameters from 15.10.21 which was followed later by other parameters. There were no erroneous recordings from 15.11.20 till 15.11.59. The aircraft was again at low angles of attack during this period.

b) Similarly there were no errors recorded from 15.22.00 till 15.23.34 while carrying out profiles 3 and 4. The recovery had been commenced at 15.23.34.

c) In data of profile 2 there were no errors from 15.16.00 to 15.16.46 when recovery was commenced.

d) There is a definite possibility that accelerometers are prone towards erroneous values after a flight at high angles of attack. Airbus Industrie should carefully investigate the quality of the accelerometers fitted on the A 320 which feeds the data to the DFDR for acceleration recordings for their behaviour during and shortly after recovery from a flight at high angles of attack. As many other parameters have also been recorded erroneously. Airbus Industrie may have to investigate the DFDR as well as the intervening computers which collect the date, for their performance, after a flight at high angles of attack.

VT-EPN had gone through a phase of a flight at high angles of attack prior to the high normal acceleration recordings against time frames 329 and 330. Therefore a doubt may arise about the correctness of the DFDR recordings under such circumstances, in the light of the physical evidence and survivor statement.

The above 4 profiles have also indicated that the same two engines, when different profiles were carried out, did not accelerate at the same time from approach idle to TOGA (maximum go around thrust reached during accleration). Even the same characteristics of acceleration were not maintained. More data could have been spplied if a flight as planned with another aircraft belonging to Indian Airlines, had been carried out.

During June 1990, the assessors had visited the Engine Manufacturers Establishment at Hartford in USA. The International Aero Engines use a private 'Andrew Willgoose facility' for testing their engines at high altitude, bird ingestion tests, etc. They also use the Pratt and Whitney facility nearby for assembly of the engines and final.

delivery tests prior to shipping the engines to the aircraft manufacturers or the customers.

They had no facility to carry out acceleration tests at different angles of attack let alone at high angles of attack. The only way these characteristics could be established was by carrying out actual flight tests and that is the reason why the court had requested Airbus Industrie and Indian Airlines to carry out certain profiles.

The present certification requirements as per FAA as described under 33.73 power or thrust response, is the requirement for acceleration demonstration by the engine manufacturers, and under 25.119 landing climb: all engines operating is for demonstration in flight by the aircraft manufacturer. The salient features of these are:

a) Engine should accelerate from the fixed minimum flight idle power lever position when provided, or if not provided, from not more than 15% of rated take off power to 95% of rated take off power in not more than 5 seconds. The thrust lever should be moved from minimum to maximum position in less than 1 sec. Only bleed air and accessories loads necessary to run the engines should be used. This is to be demonstrated by the engine manufacturer.

b) During flight in the landing configuration the steady gradient of climb may not be less than 3.2% with:

i) the engines at the power or thrust that is available 8 secs after initiation of movement of the power or thrust controls from the minimum flight idle to the take off position; and

ii) a climb speed of not more than 1.3 Vs.

In respect of A 320 instead of 1.3 Vs it would be 1.23 Vslg.

This acceleration ispredicated on a speed of Vref being maintained at the time of commencement of acceleration. Normally the aircraft, would be at low angles of attack during approach when Vref is maintained. There are no requirements for demonstration of acceleration at high angles of attack.

A representative of Indernational Aero Engines, Mr.Craig R.Bolt, during his cross examination, stated that the current requirements under FAA regulations have been in force since the late 1960's but he was unable to confirm the exact date on which these regulations came into being.

Possibly these regulations were first brought in at the time ot the first jet transport aircraft. During the 1960's the early turbo fan engines had a fairly low by pass ratio. The by pass ratio of the V 2500 engine is approximately 5.42 according to V 2500/A 320 operations review of IAE(Exhibit 44).

Mr. Craig R.Bolt stated that there are other engine models that have by pass ratios slightly over 6.

Engine design and performance have made tremendous progress during the last 30 years. The acceleration characteristics of the earlier engines are different from those of the present day engines. For example in the V 2500 there is hardly any net thrust increase during the first 5 to 6 secs. In the last two secs. the thrust increase is very rapid

The only acceleration data recorded during flight made available to the court was at 5000 ft. in level flight with acceleration commencing from approach idle to TOGA at a speed of 0.25 Mach and ISA. No acceleration data recorded under different conditions were made available by Airbus Industrie until these profiles were carried out.

The certification authorities may carefully evaluate if the regulations which are in existence for the last 30 years or more should be reviewed for change if necessary to cater to the modern high by pass ratio engine like the V 2500. It is also necessary for the air crew to be advised that engine acceleration may not be achieved within 8 secs. under high angle of attack conditions. DGCA, India may also consider whether it is necessary to advise Indian air crew who operate such engines on this aspect.

Another significant observation is the pressure altitude loss during the 4 profiles. Repeat of Bangalore scenario showed an altitude loss of 124 ft. The recovery at stall speed plus 12 kts which was carried out at CAS of 119 kts to 121 kts during altitude loss showed a pressure altitude reduction of 121 ft. Flight under direct law at intermittent stall warning, wherein speed was 119 to 116 kts, the altitude loss was only 55 ft. Similarly, during engine acceleration at high angles of attack the altitude loss was 56 ft. The actual angles of attack, as computed by the Airbus Industrie formula sent to the court, have been indicated earlier. In the direct law exercises with minimum loss of altitude the angle of attack had reached nearly 13° in one case and nearly 17° in the other and the aircraft did not stall. It is very important to note that the stall warning had occurred at 120 kts and not at 105 or 106 kts. This stall warning speed had been discussed extensively during the deposition of the Airbus Industrie representative. There were confusing statements by them and later it was confirmed by letter No.AI/E FS 420.0163/90 of 20.7.1990, that in the condition of Bangalore accident it would have been activated at 110 kts. As the warning had come at 120 kts during this flight test, it does indicate a certain lack of knowledge about the onset of stall warning in the plane among the Airbus Industrie representatives assisting this investigation.

If stall warning was available on VT-EPN under pitch normal law and it had come at a speed of 120 k CAS, it would have come between time frames 312 and 313. Any pilot would push the thrust levers to TOG immediately on stall warning. There is absolutely no doubt that VT-EPN would have survived if audio stall warning had come at 120 kts.

When alpha floor was activated, pressure altitude of VT-EPN was approximately 2960 ft. When the aircraft was on ground at the time of first touch down, the pressure altitude indication of 2773 has been recorded. Elevation of the threshold of R/W 09 is 2872 ft.

Definately the point of first touchdown was not 100 ft. below the threshold of R/W 09. The altitude of that area should be approximately 2820 to 2822 ft. This would mean an altitude loss of 138 to 140 ft. in pressure altitude in a period of 6.7 secs. This altitude loss was more than any of the four profiles carried out during the flight tests. The extra altitude loss may have been due to the bank that might arise when the side stick is pulled fully back and also due to the possibility of rough air when VT-EPN passed over uneven ground and trees during the last few seconds. in mid afternoon with a certain amount of wind existing. The maximum angle of attack reached by VT-EPN was 16.8° while, during the flight test repeat of the Bangalore scenario, it was 16.16°.

In VT-EPN the speed was 106.5 kts. at 323 which increased to 113 kts at 329. Under pitch normal law, the computers did not permit the aircraft to convert this kinetic energy to reduce the height loss. The tailwind which was existing had shown a decrease during the last few seconds of VT-EPN. As per the photograph when the aircraft was burning published by some magazines, there was a head wind component as shown by the way the smoke was drifting. A tail wind to head wind change improves the performance of the aircraft. Possibly, this is the reason why the CAS increased and the aircraft touched down lightly during the first touchdown. But still, the height loss of VT-EPN was more than the height loss during the simulation of the Bangalore scenario in the flight test. Most probably, this is due to the possibility of rough air.

However, two of the profiles of the flight tests have established that under direct law, going to slightly higher angles of attack, height loss is reduced. It would be for the certification authorities, Airbus Industrie, DGCA India and Indian Airlines (as a major operator who has lost an aircraft) to examine the matter very carefully and to see if V alpha max could be increased slightly to improve performance and thereby future flight safety.

Stall warning may be introduced under pitch normal law at a weight/speed correlation similar to that which occurred on the Airbus Industrie aircraft during the flight test.

			Revised by CASB.	Revised by Two Assessors.
294	CM 1	O.K.,700 ft.rate of descent.	293.9	292 to 293.3
	CM 2	Missed approach is ... (Airfield information)		294.9 to 295.3
		Southerly wind,variable 5 Knots, temperatures 28, 1017.		
301		RA Call out"Four Hundred"	300.5	298.6
305	CM 2	You are descending on idle open descend all this time.	304.9	304.8 to 306.06
		RA call out "Three Hundred".	305.3	303.7 to 304.8
308	CM 2	You want the FD's off now.	308.9	308.7
309	CM 1	Ya	309.9	310.0
	CM 1	OK, I already put it off	310.6	311.7
312	CM 2	But you did not put off mine.	312.9	313.5
315		RA call out "Two Hundred".	316.0	316.6
319	CM 2	You are on the Auto Pilot still?	319.8	320.7
321	CM 1	No	321.4	
	CM 2	It's off.	322.1	323.0
322	CM 1	Hey, we are going down.	323.0	324.05 to 324.80
323	CM 2	O Shit	324.2	
		RA Call out "One Hundred" and "Sink Rate"	324.3	325.4
	CM 1	Captain		

			Revised by CASB.	Revised by Two Assessors.
324	CM 1	Captain still going.		
325		"Sink Rate"	326.2	327.5
326		"Chime"	326.5	327.8
327		"Sink Rate" & RA Call out 50 or 30.	327.7	329
328		"Sink Rate" RA Call out "10"	329.0	330.8
329		Crash sounds.	329.8	331.4

JEPPESEN 25 AUG 89 (13-2)

BANGALORE, INDIA
BANGALORE
VOR DME Rwy 09
VOR Rwy 09

VOR 115.5 BBG

Apt. Elev 2914'

VIII/DI

BANGALORE Approach (R) 122.7

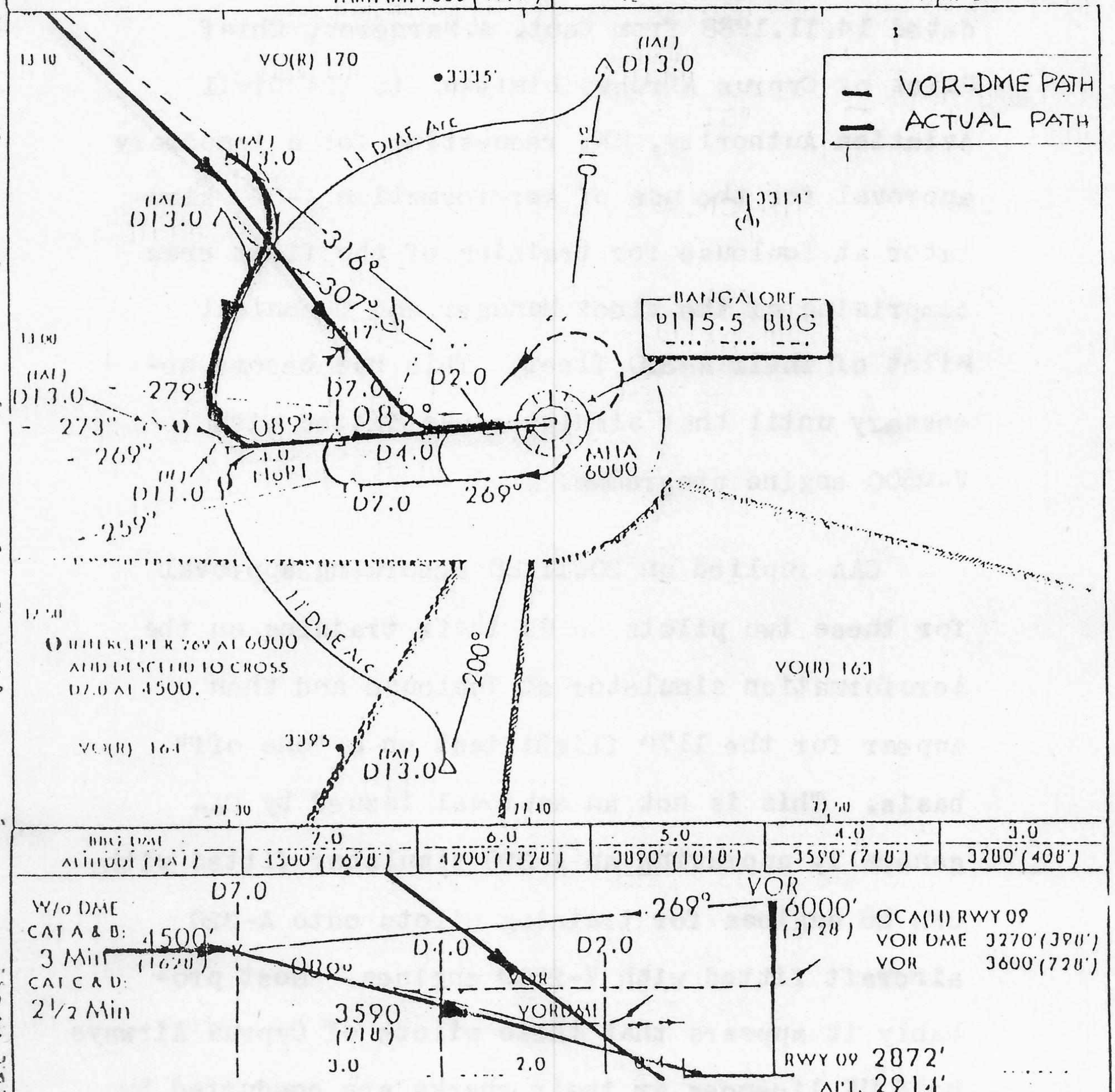
BANGALORE Tower 123.5

Alt Set: hPa

Trans level: By ATC

Trans alt: 7000' (4128')

MSA BBG VOR: 6000' (090°–270°), 5100'



OCA(H) RWY 09

VOR DME	3270' (390')
VOR	3600' (720')

MISSED APPROACH: VOR DME: Climb STRAIGHT AHEAD to VOR, then turn LEFT to join the holding at 6000' (3128'). VOR: Over VOR turn LEFT to join the holding at 6000' (3128').

	STRAIGHT-IN LANDING RWY 09 VOR DME MDA(H) 3270' (390')	VOR MDA(H) 3600' (720')
A	1600m	1600m
B	1600m	1600m
C	2000m	3200m
D	2000m	3600m

CIRCLE-TO-LAND

Max Kt	MDA(H)	
100	3600' (686')	1600m
135	3600' (686')	1600m
180	3920' (1006')	4800m
205	3920' (1006')	4800m

Gnd speed-Kts	70	90	100	120	140	160
Descent Gradient 4.9%	348	447	497	596	695	794

VOR DME MAP at D2.0

VOR: MAP at VOR

CHANGES: Arrival route. Thresh elev.

APPENDIX VI

On 26th October 1990 the court received certain documentation. In that we find a letter dated 14.11.1988 from Capt. A.Marneros, Chief Pilot of Cyprus Airways Limited to the Civil Aviation Authority, UK, requesting for a temporary approval for the use of Aeroformation A-320 simulator at Toulouse for training of the first crew comprising of the Fleet Manager and Technical Pilot of their A-320 fleet. This had become necessary until that simulator was fitted with V-2500 engine programme.

CAA replied on 30.11.88 according approval for these two pilots to do their training on the Aeroformation simulator at Toulouse and then appear for the 1179 flight test on a "one off" basis. This is not an approval issued by CAA generally approving an A-320 simulator fitted with CFM 56 engines for training pilots onto A-320 aircraft fitted with V-2500 engines. Most probably it appears that these pilots of Cyprus Airways hold UK licences or their checks are conducted by UK, CAA and hence specific request for an exemption for two pilots was made, which normally any authority may grant with or without stipulations, evaluating the specific existing conditions.

In the same documentation we find an English translation of a letter from Yugoslav FAA. It is a general approval of the Aeroformation transition training programme for A-320 flight crews. This approval was granted on 16.2.1989. This approval does not specify anything about an A-320 simulator fitted with CFM 56 engines having been approved for training flight crews for A-320 aircraft with V 2500 engines.

The documentation also contains a report of Recurrent Inspection of Flight Simulators by the DGAC, France which was dated 24.11.1989. On 22.11.1989 Airbus A-320 simulator registered S 5 of Aeroformation, was inspected. Simulator was approved for initial training, recurrent training, precision approaches (CAT III), LOFT. The simulated aircraft series was A-320 111 and A-320 211 with engines CFM 56 5. Cockpit layout simulated was Standard Air Inter (without HUD).

This approval does not indicate that this simulator could be used for training A-320 231 flight crews which are the aircraft operated by Indian Airlines.

Canadian Aviation Safety Board | Bureau canadien de la sécurité aérienne

APPENDIX VII

Engineering Branch
PO Box 9120
Alta Vista Terminal
Ottawa, Ontario
K1G 3T8

Your file Votre référence

Our file Notre référence

February 23, 1990

CONFIDENTIAL

Mr. H.S. Khola
Director General of Civil Aviation
Civil Aviation Department
New Dehli, India

Re: Indian Airlines Flight 605
Airbus A-320, VT-EPN, Accident
February 14, 1990

Dear Mr. Khola,

The following is a factual documentation of the work provided by CASB to date.

1.0 Introduction

1.1 An Airbus A-320, Indian Airlines flight 605, registration VT-EPN, crashed during a non precision approach to Bangalore airport.

1.2 The aircraft's digital Flight Data Recorder (DFDR) was hand carried to the Engineering Branch of the Canadian Aviation Safety Board (CASB) by a team of three officials of the Government of India after a request for playback was made by the Indian Government through the Indian High Commission in Ottawa, Canada. After initial discussions between CASB and the Indian team on Monday February 19, 1990, the work of playing back the recorder began on Tuesday, February 20, 1990.

1.3 The DFDR was a Fairchild model 17M-800-251 digital recorder (serial number 3768). The DFDR recorded 216 parameters within the 64 fifteen bit word per second structure.

1.5 A flight recorder specialist from the National Transportation Safety Board (United States) and the National Research Council of Canada participated in the playback as advisors to the CASB in order to ensure the accuracy of the data.

Canada

2.0 DFDR Playback

4.1 The magnetic tape medium was removed from the DFDR for playback. The tape was cut just before the record heads such that the physical end of the tape represented the end of continuous data. After removal of the tape, the DFDR was powered up to determine the last recorded track. Track #4 (of the six track tape) was determined to be the last recorded track.

4.2 At approximately five and a half minutes back into the last flight, an arbitrary reference time was set to zero which is referred to as 'Reference Time' on all of the data plots.

4.4 The data were converted to engineering units using the standard conversion equations for this particular aircraft. Data from the maiden flight of VT-EPN was recovered from another tape made available to the CASB by Airbus Industrie to confirm the conversions. The data of the maiden flight played back through CASB's system provided the same numerical results and sign conventions as the Airbus Industrie printout of the maiden flight, thus confirming the conversions were the same.

4.5 The DFDR records the data in 15 bit words which require mapping into 12 bit words prior to conversion to engineering units. For the last five minutes, all of the subframes of data contained the proper number of bits (64 15 bit words or 960 bits) except for the subframe corresponding to reference time 329. This subframe was short six bits (954). The NRZ signal was analyzed and it was evident that the signal had experienced expansion and compression distortion after approximately three quarters of the way through the subframe. This distortion was considered to be as a result of vibrations induced by the aircraft's impact with terrain. The data from this subframe can probably be recovered through analysis of the NRZ waveform. Additionally, a portion of a second after reference time 330 can probably be recovered. The recorder stopped somewhere between reference time 330 and 331.

4.6 During the process of mapping the 15 bit data into 12 bit data for the last five and one half minutes, 19 mappings (19 seconds) did not conform to the allowable mapping patterns for this type of code. Such data losses are not uncommon and most of these data losses can be recovered with CASB's systems, given time.

4.7 The CASB has provided data plots and printouts of the last five and one half minutes of flight, excepting the above mentioned data losses, which show up as blank data in the printout.

5.0 Additional Work to Complete if Required

5.1 The bad mapped data areas and the area where the signal has been distorted due to severe vibration can be studied in an attempt to gain 100% data recovery of the last five and a half minutes of flight. The partial second after the last valid synchronization code may also be recovered.

5.2 A three dimensional real time flight reconstruction could be made to facilitate detailed analysis of the sequence of events during the approach. The CVR would be advantageous in for integrating with the flight reconstruction.

5.3 A final report detailing the entire DFDR work done by CASB including the additional work suggested above could be prepared.

Sincerely,

Michael R. Poole, P.Eng.
Flight Recorders Group Chairman
Canadian Aviation Safety Board

cc: D. Langdon, CASB
R. Hayman, CASB

Canadian Aviation Safety Board
Bureau canadien de la sécurité aérienne

gineering Branch
PO Box 9120
Alta Vista Terminal
Ottawa, Ontario
K1G 3T8

Your file Votre référence

March 15, 1990

Our file Notre référence
142-1

Mr. H.S. Khola
Director General of Civil Aviation
Civil Aviation Department
Ramkrishna Puram
New Dehli, 110066, India

Re: Indian Airlines Flight 605 - Airbus A-320, VT-EPN

Dear Mr. Khola,

Enclosed please find two copies of the accident flight data as plotted and printed. All of the data for the accident flight has been recovered including the partial second at the end of the recording. Also included is a printout, for the whole accident flight of the parameters that you requested. This data should replace the preliminary copies of data that you already have as we have found a few small errors in the first set of data that you brought back. Specifically, Figure #4 had the wrong label (aileron position should be elevator position) and some of the printouts (such as fuel flow) were not in the proper time sequence. Please ensure that any parties that received the first set of data are given this replacement set.

The latitude and longitude for the fourth flight back did not seem to match the Bangalore airport. The sixth flight back was an approach to Bangalore and a set of print outs and plots for this flight are also included.

Since we have not received the CVR or any other information, we assume that you no longer require our services. We are therefore in the process of preparing our final report detailing our involvement and assessment of the DFDR investigation. Our final report will include a three-dimensional flight animation of the accident approach.

Regards,

Michael R. Poole, P.Eng.
Flight Recorders Group Chairman
Canadian Aviation Safety Board

cc: D. Langdon, Chief, Systems Engineering - CASB
R. Hayman, Director of Engineering - CASB
R. Johnson - External Affairs, Canada

Canadä

1.0 INTRODUCTION

1.1 On February 14, 1990, an Airbus A-320, Indian Airlines flight 605, registration VT-EPN, crashed during a non-precision approach to Bangalore airport.

1.2 The aircraft's Digital Flight Data Recorder (DFDR) was hand carried to the Engineering Branch of the Canadian Transportation Accident Investigation and Safety Board (CTAISB) by a team of three officials of the Government of India after a request for playback was made by the Indian Government through the Indian High Commission in Ottawa, Canada. After initial discussions between CTAISB and the Indian team on Monday February 19, 1990, the work of playing back the recorder began on Tuesday, February 20, 1990.

1.3 The DFDR was a Fairchild model 17M-800-251 digital recorder (serial number 3768). The DFDR recorded 216 parameters in a standard 64 words per second format.

1.5 Flight Recorder Specialists from the National Transportation Safety Board (United States) and from the National Research Council of Canada participated in the playback as advisors to the CTAISB.

1.6 At the request of the India Government, this report contains no analysis of the flight in terms of aircraft operation or performance.

2.0 DFDR PLAYBACK

2.1 The magnetic tape medium was removed from the DFDR for playback. The tape was cut just before the record heads such that the physical end of the tape represented the end of continuous data. After removal of the tape, the DFDR was powered up to determine the last recorded track. Track #4 (of the six track tape) was determined to be the last recorded track.

2.2 At approximately five and a half minutes back into the last flight, an arbitrary reference time was set to zero which is referred to as 'Reference Time' on all of the data plots.

2.4 The data were converted to engineering units using the standard conversion equations for this particular aircraft. Data from the maiden flight of VT-EPN was recovered from another tape made available to the CTAISB by Airbus Industrie to confirm the conversions. The data of the maiden flight played back through CTAISB's system provided the same numerical results and sign conventions as the Airbus Industrie printout of the maiden flight, thus confirming the conversions were the same.

2.5 This particular DFDR records the data in 15 bit words which require mapping into 12 bit words prior to conversion to engineering units. For the last five minutes, all of the subframes (one subframe is one second) of data contained the proper number of bits (64 fifteen bit words or 960 bits) except for the subframe corresponding to reference time 329. This subframe was short six bits. The DFDR signal was analyzed and it was evident that the signal had experienced expansion and compression distortion after approximately three quarters of the way through the subframe. This distortion was considered to be as a result of vibrations induced by the aircraft's impact with terrain. The data from this subframe was subsequently recovered through analysis of the DFDR waveform. Additionally, a portion of a second after reference time 331 was also recovered. The recorder was determined to have stopped at 331 25/64. 25 words were recorded in the 64 word format prior to the end of recording.

2.6 During the process of mapping the 15 bit data into 12 bit data for the last five and one half minutes, 19 mappings (19 seconds) did not conform to the allowable mapping patterns for this type of code. A subsequent run of the tape, after fine tuning of our playback system for this specific recording, resulted in no bad mappings during the last five and one half minutes.

2.7 The data plots and printouts of the last five and one half minutes of flight are attached as Appendix 'A' of this report.

2.8 On March 6, 1990, the Indian Government requested additional data from a previous landing at Bangalore. A review of past flights on the 25 hour DFDR revealed that the sixth flight back was also an approach to Bangalore. Data were therefore plotted and printed for the sixth flight back and forwarded to India. These printouts and plots are contained in Appendix 'B' of this report.

3.0 FLIGHT RECONSTRUCTION AND FLIGHT PATH ANALYSIS

3.1 A three-dimensional flight reconstruction was made for the final approach to Bangalore. The flight path was determined by integrating the recorded ground speed in the direction of recorded magnetic heading. Appendix 'C' contains examples of figures taken from the flight reconstruction. A VHS (PAL or NTSC) video tape is available depicting various views of the flight in real time with the cockpit voice recording (CVR) synchronized to it.

3.2 (The CVR tape provided by the Indian Government on Tuesday, April 17, 1990 was played back at the CTAISB laboratory at its standard speed and it was determined that the 400 hertz aircraft power was displaying as 384 hertz. The CVR was therefore played back 4% faster and a copy tape was made while a simultaneous real time code was written to the copy tape. The time code, correlated to DFDR reference time, is shown on the partial CVR transcript provided in Appendix 'D'.) The transcript for the CVR was obtained from the Indian Government and was therefore not necessarily the CTAISB's interpretation of the CVR's contents.

3.3 (The DFDR and the CVR were aligned such that the crash sound on the CVR occurred at reference time 329.8, the time at which an impact occurred on the DFDR as evidenced by the normal acceleration and the distortion of the DFDR waveform signal. This time matched well with the VHF keying and the radio altitude calls by the aircraft.)

3.4 The altitude for the flight reconstruction was determined by plotting the radio altitude and the pressure altitude on the same scales and attempting to correlate the two (Figures 2a and 2b of Appendix 'A'). The pressure altitude was matched to the radio altitude of 12 feet at time 328 (subtracting 2830 feet). The values of pressure altitude at 329 and 330 were set to the corresponding radio altitude values as the pressure altitude values were obviously in error, probably due to ground effect and impact. The aircraft was 'flown' for the purposes of flight reconstruction, with the pressure altitude, matched to the radio altitude and corrected for the last two pressure altitude values which were determined to be invalid.

3.5 The reported description of the crash site suggested that there were two distinct impacts, the first being a 'light' touchdown of the main gear on relatively flat terrain and the second being a harder hit, just prior to a small hill which the aircraft contacted. Analysis of the DFDR data, (pressure altitude, radio altitude, normal acceleration, and landing gear squat switches) the distorted waveform signal in subframe 329 and the single crash sound on the CVR, indicated that only the first impact was recorded and not the second. The recording continued for about one and one half seconds and then ended, on both recorders, without recording a second impact.

3.6 The normal acceleration data after subframe 329 suggested that the aircraft was in a bounce, after the first impact, when the recording stopped. The first impact was therefore considered sufficient to have caused internal damage to the aircraft, which affected the operation of both recorders. After subframe 329, the side stick pitch controllers for both crew went to exactly the same number (-9.51 degrees). It would be highly coincidental that both side sticks were moved to the same value. It is considered more likely that the aircraft was 'broken' in some manner which caused the system to malfunction. Additionally, the engine values which reflect a spooling up of the engines, deviate from a spool up after subframe 329. The engine values, side stick controller pitch data, lack of a second impact recorded in normal acceleration, single crash sound on the CVR, and lack of a squat switch signal prior to subframe 329, all indicate the the first impact with the ground occurred in subframe 329 and no second impact was recorded. The data could not be fit to a scenario in which subframe 329 was the second impact, just prior to the hill.

3.7 For the purposes of the flight reconstruction the following parameters were displayed as they were perceived to be significantly related to the accident: time; computed airspeed; radio altitude; pitch attitude; both side stick controllers; auto-pilot 1; altitude capture 1; auto throttle speed mode; ground proximity warning system; left and right elevator position; left and right exhaust gas temperature; left and right N2; left and right throttle lever angle; left and right engine pressure ratio command; left and right actual engine pressure; magnetic heading compass; pitch and roll gyro; altimeter and airspeed indicator.

4.0 ADDITIONAL DFDR ASSISTANCE

4.1 On Tuesday, April 17, 1990, two representatives from the Indian Government arrived with a second DFDR tape from another A320, VT-EPO. This aircraft was involved in a go-around on February 27, 1990 (flight time 6:10 to 7:55). Within the flight, there were two touch and goes and one go-around. The engine parameters for all three of these cases of engine power application are included in Appendix 'E' of this report.

5.0 CONCLUSIONS

5.1 The data were recovered from two DFDR's (VT-EPN and subsequently VT-EPO) as requested by the Indian Government.

5.2 The data quality for both recordings was considered excellent.

5.3 All of the data were provided in numerical print out format as well as graphical plots. A three-dimensional flight reconstruction was also made of the accident sequence.

5.4 The DFDR only recorded one impact which was determined to be the first impact with the ground.

PROTECTED

Indian Airlines A320 VT-EPN
CVR Transcript derived from Indian Govt. Transcript

Revised: April 18 1990

<u>Legend:</u>

P1	---	Left Seat
P2	---	Right Seat
RDO	---	Radio Transmission By Crew
ATC	---	Flight Service Station
OTHER	---	Other Radio Transmission
[ ]	---	Sounds Heard In Cockpit
( )	---	Questionable Text
{ }	---	Comments
#	---	Expletive Deleted
*	---	Unintelligible word or words
OB Comp	---	On Board Computer Warnings

IRIG TIME	DFDR Time	IDENT	CONTENTS
29:00.1	123.7	P2	4600, 605.
29:24.3	147.9	P1	Flaps 2.
29:27.0	150.6	P2	2 Gear down.
29:27.9	151.5	P1	Gear down.
29:30.1	153.7		[Sound of Gear Lowering]
29:49.0	172.6	P2	Runway in sight.
29:56.4	180.0	P2	123.5, Thank-you, good day.
30:14.3	197.9	P2	Bangalore tower India 605 go morning.
30:19.7	203.2	P2	Roger.
30:42.9	226.5	P2	Speed - alt star.
30:47.0	230.6	P2	Speed - alt star.
30:59.1	242.7	P2	Or do you want vertical spe
31:01.7	245.3	P1	Vertical speed.
31:02.7	246.3	P2	How much?
31:03.4	247.0	P1	Thousand.
31:04.9	248.5	P2	Thousand
31:15.4	259.0	P2	Tower, 605, confirm cleared
		P1	Go around - 6000.
31:19.5	263.1	ATC	605, report short finals.
31:22.1	265.7	P2	We are short finals.
31:24.4	268.0	ATC	Roger, cleared to land 1205
31:27.7	271.3	P2	120-05, cleared to land, 60
31:28.9	272.5	P1	Ok, landing checks.
31:30.8	274.4	P2	OK Landing gear is down, 3 g release signs are ON, spoil armed, flaps are full, landi

Canadian Transportation Accident Investigation and Safety Board
Bureau canadien d'enquête sur les accidents de transport et de la sécurité des transports

ngineering Branch
PO Box 9120
Alta Vista Terminal
Ottawa, Ontario
K1G 3T8

Your file Votre référence

Oct. 2, 1990

Our file Notre référence
142-1

Mr. K. Prabhakar Rao
Secretary, Court of Inquiry
Accident to Indian Airlines
Airbus A320 at Bangalore
High Court Buildings
Vidhana Veedhi
Bangalore-560 001
India

Dear Mr. K. Prabhakar Rao,

Concerning the queries you raised in your letter dated September 15, 1990 concerning data quality after subframe 329, it was noted that the non-return-to-zero waveform of the DFDR, which represents 'ones' and 'zeros' was distorted during subframe 329. The distortion was considered to be due to severe vibration (due to aircraft impact with the ground) which caused the signal to expand and contract in the time domain (x-axis). The signal was analyzed and corrected until the proper number of bits (960) was reached, without regard for what the parameter values should be. Subframe 330 had a valid synchronization word at the beginning of the subframe and the next one in sequence at the beginning of subframe 331. The recording ended part way through subframe 331, during the 26'th word where the signal was again distorted and it was determined that old data from 25 hours earlier began.

The data which follows trends shoul? ?enerally be considered valid, right through to the end o? ?ecording. Most of the data does, in fact, appear to follow trends (it is not way off). While the data may be considered valid, it is important to realize that, after the impact during subframe 329, the source (signal from the transducer or electronic busses) of the data may no longer be representing reality, even though the DFDR appears to record a valid word. As this is likely impossible to determine absolutely, one can only judge the data by the trends it is following and try to assess it as it relates to the accident.

As for vertical acceleration which was specifically queried, it appears to follow a believable trend and I think that it is therefore most probably valid, including the value of 6.125 g during the end of subframe 329. The vertical acceleration is recorded eight times a second and it can be a very dynamic parameter by nature. It is possible that the

Canada

impact at 329 was greater than 6.125 g but was not recorded due to the sampling rate of eight times per second.

I hope that this additional clarification assists you in your investigation. I also hope you can appreciate that it is difficult for us to assess or validate the data any further, unless we have the benefit of participating in a thorough analysis of the data as it relates to the accident sequence. At the beginning of this investigation, it was strongly indicated by your government representatives that you did not require nor wish us to participate in an analysis of the data. While our report (EP36/90) did contain some analysis of the data, it was the minimum amount of analysis we considered acceptable to accompany the data under the circumstances.

Sincerely,

Michael R. Poole, P.Eng.
Flight Recorders Group Chairman

APPENDIX - VIII (a)

INJURY PATTERN

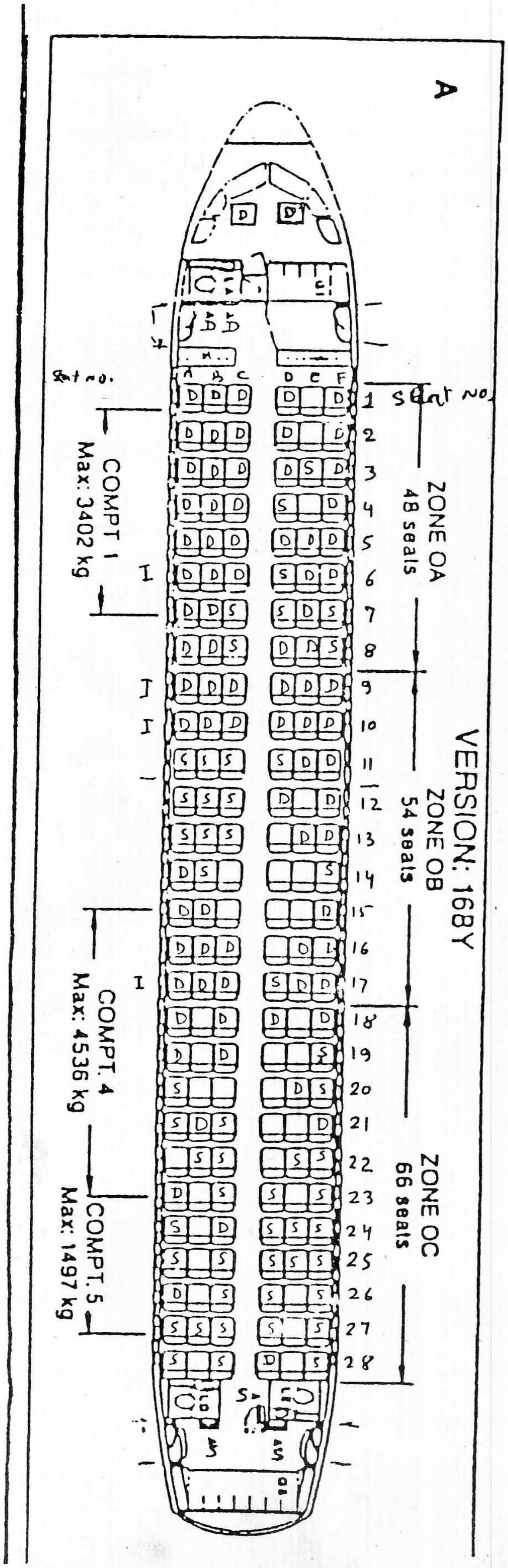
No.	Injury		Total No. of cases
1.	Injury to leg/ankle	1,2,5,6,7,8,9,11,13,18,21,31,39,49,54, 65, 69,70,73,75,85,88,89,90	24
2.	Injury to knee/thigh	7,8,9,13,20,40,41,62,63,67,70,76,90	13
3.	Pelvic injury	40,41	2
4.	Injury to hard/fore-arm	3,5,6,8,9,11,20,31,39,67,70,81,86,88,89	15
5.	Injury shoulder/arm/elbow	6,22,23,25,28,35,39,40,63,69,71,76,88,89	14
6.	Head injury	4,16,22,23,25,29,31,34,35,40,41,57,62,63, 66,70,71,76,88,89	20
7.	Injury thorax	23,24,33,35,40,41, 88	7
8.	Abdominal injury	22,35	2

APPENDIX - VIII (b) SEAT ALLOCATION OF ALL PASSENGER

~~APPENDIX XC~~

I Dead Infant

S Survivor



APPENDIX- VIII (c)

IDENTIFIED PASSENGER SEAT ALLOCATION

ANNEXURE - 18

B 50 | 56 B

B 6 1,4 | B 45 1

	A	B	C	D	E	F
1	B 70 (1,2,4,6)	B 57	B 55	B 10		
2	B 80	B 75 (1)	B 69			55 (5,6,7,8)
3	90 B (1,2)	B 9 (1,2,4)		B 2		B 51 (4)
4	~~x~~	~~x~~	~~x~~			B 43
5	62 (2,6)	89 (1,4,5)	22 (5,6,8)	B 14	B 1 (1)	B 78
6	4+23	71 (5,6)			59 B	B 47
7	B 27	B 19			B 28 (5)	
8	B 25 (5,6)	B 29 (6)			B 26	
9		63+64	B 20 (2,4)	B 24 (7)		
10	84+31				B 54 (1)	B 57 (6)
11						
12						B 9 (8,4)
13						
14	B 72					
15	B 66 (5)	B 76				B 48
16				B 61		
17	83 B	B 45	74			B 82
18	B 12		B 56	B 44		21 (1)
19	B 60		B 77			
20	B 33				B 69 (1,4,5)	
21						B 32
22						
23						
24						
25						
26	15 B					
27						
28				B 8		

INDEX

(No)	Sl. no. of body
B	Burns
1	Injury leg / ankle
2	Injury thigh / knee
3	Injury Pelvis
4	Injury forearm / hand
5	Shoulder / arm / elbow
6	Injury Head
7	Injury thorax
8	Injury Abdomen

6A (4) B, 6.
(23) 5, 6, 7

9B (63) B, 2, 5, 6
(64) B

10A (84) B
(31) B, 1, 4, 6

Body (89) stated to be in 6 E is more likely to have been seated in 6 C due to injuries 1,4,5,6,7

IN THE COURT OF INQUIRY AT BANGALORE

INQUIRY CASE No. 1/90

LIST OF WITNESSES EXAMINED IN THE INQUIRY.

Witness No.	Name of the Witness	Date of Examination
1	2	3
	Sriyuth's/Smts:	
	H.A.L.	
1.	A.K. Sharma	7-5-90
2.	Joseph George Malaikal	7-5-90
3.	Wg. Cdr. P.M. Rao	7-5-90 & 8-5-90
	INDIAN AIRLINES	
4.	Sadhana Pawar	9-5-90
5.	Neela Sawant	9-5-90
	COURT WITNESSES (PASSENGERS).	
6.	J. Hemchand Jaichand	11-5-90
7.	E. S. Sreedhar	11-5-90
	INDIAN AIRLINES	
8.	Capt. V.P. Thergaonkar.	14-5-90 & 15-5-90

1	2	3
9.	Charles Joseph D'Souza	15-5-90
10.	M. Satapathy	15-5-90
11.	Rajendra Sahai	15-5-90
	AIRBUS INDUSTRIE	
12.	Christopher Alan Protheroe	17-5-90
	INDIAN AIRLINES	
13.	Capt. Vijay S. Sathaye	21-5-90
14.	K. Narayanan	21-5-90
15.	G. Venkateshwara Rao	21-5-90
16.	K. Manjunatha Ural	21-5-90
	COURT WITNESS (PASSENGER)	
17.	Kumar Nadig	22-5-90
	COURT WITNESS (EYE WITNESS)	
18.	Mohammed Ayub	22-5-90
	AIRBUS INDUSTRIE	
19.	Capt. Richard Steele	23-5-90 & 9-7-90

1	2	3
	COURT WITNESSES (DOCTORS)	
20.	Dr. S. B. Patil	2-7-90
21.	Dr. S. C. Shankaralingaiah	2-7-90
	EYE WITNESS	
22.	M. Lakshmaiah Reddy	2-7-90
	COURT WITNESS.	
23.	Satendra Singh	3-7-90, 5-7-90 & 6-7-90
	INDIAN AIRLINES	
24.	Capt. P. A. Bhujwala	9-7-90
25.	Capt. K. Shrestha	9-7-90
	D. G. C. A.	
26.	O. P. Ahuja	9-7-90 & 10-7-90
	INDIAN AIRLINES	
27.	Ramachandran Ragunath	11-7-90
	I. C. P. A.	
28.	Capt. P. K. Gupta	11-7-90, 12-7-90 & 13-7-90

1	2	3
	I.A.E.	
29.	Ronald W. Weaver	13-7-90
	AIRBUS INDUSTRIE	
30.	Gerard Guyot	13-7-90, 16-7-90, 23-7-90, 24-7-90, 25-7-90, 26-7-90, & 27-7-90.
	D.G.C.A.	
31.	N. Ramesh	27-7-90
	AIRBUS INDUSTRIE	
32.	Capt. Gordon Corps	30-7-90, 31-7-90, 1-8-90, 6-8-90 & 7-8-90.
	C.A.G.	
33.	Subhashchandra Satish-chandra Gopujkar.	31-7-90
	I.A.E.	
34.	Craig R. Bolt.	7-8-90, 8-8-90 & 9-8-90
35.	Sundar Venkat	9-8-90

1	2	3	4
10.	Copy of Report on training conference for A-320 Aircraft held from 17-11-87 to 20-11-87 Annexure 1 to the affidavit of Capt. Thergaonkar.	14-5-90	8
11	Copy of Minutes of training conference held on 17-11-87 and finalised in July 1988 - Annexure II to the affidavit of Capt. Thergaonkar.	"	"
12.	Copy of Evaluation of Pilots conversation course on A-320 at Toulouse Annexure III to the affidavit of Capt. Thergaonkar.	"	"
13	Copy of Telex Message - Annexure IV to the affidavit of Capt. Thergaonkar.		"
14	Copy of letter dated 24-4-89 addressed to the D.G.C.A. - Annexure 5 to the affidavit of Capt. Thergaonkar.		"
15	Copy of another letter dated 23-4-89 - Annexure 6 to the affidavit of Capt. Thergaonkar.	"	"
16	Copy of letter dated 8-5-89 with the lest of 70 Pilots - Annexure 7 to the affidavit of Capt. Thergaonkar.	"	"
17	Copy of Order dated 3-7-89 - Annexure 8 to the affidavit of Capt. Thergaonkar.	"	"
18	Copy of Type rating certificate Exhibit A to the affidavit of Capt. Thergaonkar.	"	"

1	2	3	4
19	Copy of certificate of course completion - Exhibit B to the affidavit of Capt. Thergaonkar.	14-5-90	8
20	Copy of certificate of course completion CAI Training - Exhibit C to the affidavit of Capt. Thergaonkar.	"	"
21	Copy of Certificate of Course completion - Exhibit D to the affidavit of Capt. Thergaonkar.	"	"
22	Copy of Certificate of course completion - CAI II Training - Exhibit E to the affidavit of Capt. Thergaonkar.	"	"
23	Copy of Circular No. DT/A-320/19 dated 07-12-89.	"	"
24	Copy of NOTAM 7/1985 dated 21-1-85 - Annexure A to the affidavit of Capt. Rajnarain Tandon.	15-5-90	9
25.	Airbus A-320 Flight Plan - Annexure B to the affidavit of Capt. Rajnarain Tandon.	"	"
26	Copy of Pre-flight Medical Examination for Alcohol pertaining to Capt. S. S. Gopujkar - Annexure C to the affidavit of Capt. Rajnarain Tandon.	"	"
27	Copy of Pre-flight Medical Examination for Alcohol pertaining to Capt. Fernandez - Annexure D to the affidavit of Capt. Rajnarain Tandon.	"	"

1	2	3	4
28	Copy of Certificate of Registration - Annexure A to the affidavit of Mr. Satpathy.	15-5-90	10
29	Copy of Certificate of Air worthiness - Annexure B to the affidavit of Mr. Satapathy.	"	"
30	Copy of Certificate - DC Navigabilite pour exportation Ex. C1, C2 to the affidavit of Mr. Satapathy.	"	"
31	Copy of Wireless Telegraphy licence - Annexure D to the affidavit of Mr. Satapathy.	"	"
32	Copy of Flight Release Certificate dated 11-3-90 - Annexure E to the affidavit of Mr. Satapathy.	"	"
33	Copy of Aircraft weight schedule Annexure F to the affidavit of Mr. Satapathy.	"	"
34	Copy of Certificate DC Confirmite Certificate of Compliance - Annexure G to the affidavit of Mr. Satapathy	"	"
35	Aircraft Tech. log Record - Annexure H to the affidavit of Mr. Satapathy.	"	"
36	Pre-flight check - Annexure I to the affidavit of Mr. Satapathy.	"	"
37	Copy of Snag Sheet.	"	"

1	2	3	4
38	Copy of Weight and Balance Manual.	15-5-90	11
39	Copy of letter dated 1-1-83	"	"
40	Copy of Load Trim Sheet	"	"
41	Copy of Cargo Invoice	"	"
42	Copy of Inland Air Mail delivery bill.	"	"
43	Copy of Passenger Manifest (Ex.38 to 43 are enclosures to the affidavit of Mr.Rajendra Sahai)	"	"
44	V-2500/A-320 Operations Review Flight Operations Support March 1989.	17-5-90	12
45	Altitude Acquire Transfer Logic	"	"
46(1)	to 46(99) Photos	21-5-90	14
47	Copy of rough sketch prepared by Witness No.14 - Annexure A to the affidavit of Sri K. Narayanan.	"	"
48	Copy of preliminary report - Annexure B to the affidavit of Witness No.14 - Sri K. Narayanan.	"	"
49	Copy of letter dated 10-5-90 with an Annexure, addressed by the Aeroformation to I.A.L.	23-5-90	19
50	Copy of letter dated 21-2-90 with an Annexure from Capt.E. Jaranowski to Capt.R.L.Kapur.	"	"

1	2	3	4
51	Copy of post-mortem report pertaining to Capt. Fernandez	2-7-90	20
52	Copy of post-mortem report pertaining to unknown male person.	"	"
53	Copy of post-mortem report pertaining to Capt. S. S. Gopujkar	"	21
54	Letter (Report) for Dr. S. C. Shankaralingaiah (Witness No. 21) to the I.A.M.	"	"
55.	Letter dated 22-3-90 from Airbus Industrie to Mr. H. S. Khola.	3-7-90	23
56	Copy of letter dated 10-12-86 from Sri T. R. Chandramouli to Sri R. Balasubramanian.	5-7-90	"
57 58 & 59	Copies of Inspection Reports reg. HAL Aerodrome for the years 1982, 1983 and 1984.	"	"
60.	Copies of Telex Message (7 in numbers).	"	"
61	Article in International Magazine.	"	"
62	Copy of Circular No. 2/19/90 April (-) dated - April 1990.	"	"
63	Copy of OEB Bulletin No. 51/1 dated April 1989 issued by the Airbus Industrie.	"	"
64	Copy of FCOM Bulletin No. 1/89 dated February 1989 issued by the Airbus Industrie.	"	"
65	Copy of letter dated 2-4-90 from Engineering Manager to the Director of Safety.	"	"

1	2	3	4
66	Paper presented by Capt.Heino Caesar, General Manager, Flight Operations Inspection and Safety	6-7-90	23
67	Copy of Revised FCOM Bulletin dated 1-4-90	"	"
68.	Article on the control of the crew caused accident (publication from the Airlines)	"	"
69.	Copies of training records pertaining to Capt.P. Bhujwala	9-7-90	24
70.	Copies of training records pertaining to Capt.K.Shrestha	"	25
71	Copies of letters of correspondence pertaining to the seeking of exemption from the required flying and route checks.	10-7-90	26
72(1) to 72(3)	Three files pertaining to the grant of exemption to the pilots from the requirements on Airbus A-320	"	"
73	Copy of exemption order dated 18-4-86	"	"
74	Copy of letter dated 10-4-86 with the list of pilots from the Director of Training and licensing.	11-7-90	"
75	Copy of letter dated 10/12-1-90 from the Indian Airlines to the DGCA.	"	"
76	PDR (marked from the file of pre-flight check).	"	27
77	Copy of Aircraft Flight Manual (only three sheets)	"	28
78	Copy of FCM for landing.	"	"
79	Copy of letter dated 8-10-88 from ICPA to the IAL - Annexure A to the affidavit of Capt. P.K.Gupta.	12-7-90	"

1	2	3	4
80	Copy of note prepared on 31-10-88 by the Director of Operations of Training.	12-7-90	28
81	Copy of letter dated 26-10-88 by the Director (Project)	"	"
82	Copy of Memorandum of understanding between the Management of IAL and the Representatives of ICPA re-career pattern.	"	"
83	Copy of letter dated 8-6-89 from ICPA to the IAL - Annexure C to the affidavit of Capt.P.K.Gupta.	"	"
84	Copy of Airbus A-320 operations Circular No.DT/A-320/18 dated 7-12-89.	"	"
85	Suggestions made to the Airbus Industrie.	"	"
86	Copy of supplemental report of findings.	13-7-90	29
87	Photos along with index (60 in number)	"	"
88	Copy of Report relating to post accident (Boroscope) investigation.	"	"
89	Copy of report on Dis-Assembly of V-2500 Engines installed on crashed Airbus A-320	"	"
90	Photos (114 in number)	"	"
91	Enlarged photos with index (16 in numbers)	"	"

1	2	3	4
91(1) to 91(3)	Enlarged photos out of photos marked as Ex.91.	13.7.90	29
92	Copy of most probable Scenario as established by the Airbus Industrie.	"	30
92(a) to 92(d)	Copies of Graphs - Annexure to Exhibit 92.	"	"
93	Copy of Reply dated 10.4.90 to the Telex ro floor certification on the Airbus A-320.	16.7.90	"
94	Copy of records of soft landing (one page).	"	"
95	Copy of calculation of vertical speed of A-320 at first touch down.	"	"
96	Copy of communication (reply) dated 4.5.90 from the Airbus Industrie to the Deputy Director of Air Safety.	"	"
97	Copy of Report (filed by the IAL) in respect of Bird Strike incident at Delhi on 10.8.89.	"	"
98	Copy of Technical note dated 19.7.90 issued by the Airbus Industrie.	23.7.90	"
99	Copy of Master Minimum Equipment list in respect of Airbus A-320.	"	"
100	Copy of four sheets of time frame-328 to 331.	"	"
101	Copy of technical note dated 5/6.90.	"	"
102	Copy of A-320 BMU MENU PRINT OUT pertaining to VT-EPN, dated 1.6.90.	"	"

1	2	3	4
103	Copy of another Menu-print dated 11.6.90 re-aircraft EPM.	23.7.90	30
104	Copy of N2 values as carried on A-320 Simulator at CTE, Hyderabad.	"	"
105	Engine acceleration curve (copy of sketch) issued by the Airbus Industrie.	"	"
106	Copy of Examinations dated 15.6.90 in respect of A-320/V-2500-A/Engine idle Examination during A/C VT-EPN, Bangalore Approach.	24.7.90	"
107	Copy of Telex dated 20.7.89 from DGAC, France to Airbus Industrie re-practice of issuing blank pre-signed certificate.	"	"
107(a)	Copy of letter dated 31.7.89 which is the French version.	27.7.90	"
107(b)	Copy of letter dated 24.7.90 together with enclosures from Airbus Industrie to Witness 30.	"	"
108	Copy of FCOM (flight crew operating manual) (one sheet).	24.7.90	"
109	Copy of complaint dated 2.5.90 by the Indian Airlines to the Airbus Industrie.	25.7.90	"
110	Copies of correspondence letters between DGCA & Air Bus Industrie	25.7.90	"

1	2	3	4
111	Original affidavit of Mr.Gordon Corps dated 21.7.90 filed on 23.7.90.	25.7.90	30
112	Copy of letter dated 3.5.90 from the Airbus Industrie to Capt.Gopal.	27.7.90	"
113	Copy of Flight Crew Operating Manual - page 35.	"	"
113(a)	Copy of Flight Crew Operating Manual - page 36.	"	"
114	Photographs (25 in number).	30.7.90	32
115	Copy of letter dated 23.2.90 addressed to Sri H.S.Khola, DGCA by the Flight Recorders Group Chairman, Canadian Aviation Safety Board.	"	"
116	Copy of Report of Air France submitted to the DGAC., France (produced by the ICPA)	"	"
117	Copy of letter dated 4.5.90 from Mr.Benoist Director Flight Safety, Airbus Industrie to Mr.Gohain.	31.7.90	"
118	Indian Airlines A-320 Crash Simulator Test (marked by consent).	"	"
119	Copy of list of minor and major A-320 incidents.	"	"
120	Copy of Bulletin No.06/2 dated May 1988.	"	"
121	Copy of Bulletin No.33/1 dated August 1988.	"	"

1	2	3	4
122(a) to (c)	The training manuals pertaining to Capt. Satish Gopujkar.	31.7.90	38
123	Copy of OEB Bulletin No.04/7 issued in April 1989.	1.8.90	38
124	Copy of another OEB No.04/8 issued in December 1989 by the Airbus Industrie.	"	"
125(a) to (e)	Copies of Bulletin No.50/1 dated April 1989 No.54/1 dated May 1989 No.50/2 dated Nov.1989 No.54/2 dated Nov.1989 No.50/3 dated Dec.1989	 " " " " "	 " " " " "
126	Copy of OEB Bulletin No.66/1 dated Aug.1989	"	"
127	Copy of OEB Bulletin No.50/1 dated Nov.1989.	"	"
128	Copy of OEB Bulletin No.34/1 dated Sept.1989.	"	"
129	Copy of OEB Bulletin No.60/1 dated June 1989	"	"
130	Copy of OEB Bulletin No.60/2 dated Aug.1989.	"	"
131	Copy of OEB Bulletin No.62/1 dated July 1989	"	"
132	Copy of OEB Bulletin No.64/1 dated Aug.1989.	"	"
133	Copy of OEB Bulletin No.55/1 dated May 1989.	"	"
134	Copy of OEB Bulletin No.37/3 dated April 1989	"	"
135	Copy of A-320 operations Circular dated 29.6.90 which is in the nature of informatory.	"	"

1	2	3	4
136	Copy of Airbus A-320 operations Circular No.DT/A-320/33 dated 23.3.90 which is in the nature of informatory.	1.8.90	32
137	Copy of Airbus A-320 operations Circular dated 5.7.90 which is in the nature of informatory.	"	"
138	Copy of A 1B Bulletin No.62 dated August 1989 issued by the Airbus Industrie.	"	"
139	Copy of Airbus A-320 operations Circular No.DT/320/26 dated 26.2.90 which is in the nature of mandatory.	"	"
140	Copy of on site Inspection Report on MSN 079 wreckage at Bangalore.	"	"
141	Copy of final report of the Investigation Commission in respect of the accident dated 26.6.88 at Mulhouse.	"	"
142	Copy of A-300 FCOM (one sheet).	"	"
143	Copy of Specialists of actual report of Investigation Spectrum analysis in respect of Accident at Philadelphia International Airport on 5.4.85.	6.8.90	"
144	Copy of IFALPA Accident analysis committee meeting, London, 17th-18th October 1989.	"	"
145	A-320 Flight Crew Training Documentation.	"	"

1	2	3	4
146	An experimental study on instrument scaning in A Glass cockpit by Capt.Yashonoda.	7.8.90	32
147	Copy of Transcript - Fly-by-Wire channel-4 Television Equinox.	"	"
148	Copy of Article on merging trends in present and future aircraft cockpit designs challenges in analysis - Design and Evaluation.	"	"
149	Copy of NASA	"	"
150	Copy of NASA Re-mode error.	"	"
151	Copy of letter dated 19.2.90 issued by the operations Manager to all Pilots, IAL, Western Region, Bombay.	"	"
152	Copy of view graph of the presentation to the A-320 Operations.	"	"
153	Copy of Standard Callouts re-final approach of landing.	"	"
154	Copy of CRV Transcript with a covering letter sent by NAL.	"	"
155	Copy of Engine Acceleration Graph.	"	"
156	Copy of OEB No,19/2 dated August 1988 (Not in existence).	"	"
157	Copy of 29 pages document describing the general function basic rules and other aspects of A-320 Autothrust, issued in March 1990.	"	"

1	2	3	4
158	Copy of handwritten 15 pages document issued by the Airbus Industrie on the subject digital computer.	7.8.90	32
159	Copy of handwritten document on sidestick priority.	"	"
160	Copy of handwritten document of 21 pages giving general information at V-2500 engine.	"	"
161	Copy of Article written by Russel Kane.	"	"
162	Copy of 11 pages hand written document on the subject of Flight Director particulars etc.	"	"
163	Copy of type certificate of Engine dated 24.6.88 (enclosure to the affidavit of Witness-34).	"	34
164	Copy of export certificate of Airworthiness Dated 31.1.89.	"	"
165	Copy of another export certificate of Airworthiness dated 27.2.89.	"	"
166	Copy of production certificate dated 9.11.88.	"	"
167	Copy of production limitation record dated 9.11.88.	"	"
168	Copy of study (graph).	"	"
169(a) & (b)	Copies of Service Bulletin issued on 4.12.1989.	8.8.90	"
170	Copy of Service Bulletin dated 1.6.90.	"	"

1	2	3	4
171	Copy of Service Bu-lletin dated 23.3.90 re-removal of seal rings.	8.8.90	34
172	Copy of N2 readings.	"	"
173	Copy of letter dated 8.3.90 from Airbus Industrie to Mr.Kbola, Dy. D.G.C.A.	"	"

IN THE COURT OF INQUIRY AT BANGALORE

INQUIRY CASE No. 1/90

MATERIAL OBJECTS MARKED IN THE INQUIRY

Sl. No.	Nature of M.O.	Date of Marking
M.O.1	A Casette	21-5-1990

/ ACKNOWLEDGMENTS /

When I agreed on 15th February 1990 to be the Court of Inquiry, with the then Acting Chief Justice Sri Rama Jois, I had no idea of the intricate questions that may come up before me during the investigation. As a sitting Judge of the High Court, I agreed to share the responsibility of the High Court in this regard.

2. The Court of Inquiry is grateful to the Scientists at NAL, Bangalore, and in parti-cular to Prof. Narasimha, Dr. Nagabhushan, Dr. Adiga, Mr. Muralidhar and Mr. Viswanathan. At NAL theCVR was replayed on several occasions with several channels. The Scientists worked even beyond office hours, including on a few holidays. The UV recordings and cepstrum analysis of the sound was an onerous experiment. It has shown that even the sound emanating from a particular object or of a person's voice can be identified scientifically.

3. The Indian Airforce Headquarters and the Officers of the Institute of Aerospace Medicine at Bangalore rendered valuable assistance in many relevant areas.

4. At the outset I acknowledge the industry and

and punctualities shown throughout by the staff attached to the Court of Inquiry. Sri A. Vijayamurthy, Asst.Registrar of the High Court organised the entire set up, supervised the working and has been very helpful to me throughout. He has once again reinforced his reputation for sincerity, integrity and industry.

6. Sri Muthaiah, the Court Officer did a commendable job throughout.

7. The two Stenographers, who recorded the depositions in the Court, with accuracy and speed are M/s. Raghavendra Upadya and Gowrishankar. In the work of finalising the Report, they were supplemented by Ms. A. Alice Mary.

8. My Personal Secretary Sri S. Karunakaran Nair, as usual worked with zeal and promptitude.

9. I cannot omit mentioning of Sri Chikkarangaiah, my personal attendant.

10. Hon'ble Chief Justice Sri Mohan and earlier, the Acting Chief Justice Sri Rama Jois saw to it that the Court of Inquiry functioned comfortably and smoothly; they, even allowed the user of the First Court Hall (one of our finest Court Halls and mainly used by the Hon'ble Chief Justice), by the Court of Inquiry for several weeks.

11. The Assessors were amiable and worked very hard, throughout. I appreciated their initial difficulty to adjust themselves to the concept of an

'Open Court Inquiry' and the formalities of Court procedure, but all of them were able to adjust themselves very early.

12. Sri K.P. Rao has been the Secretary to the Court of Inquiry; in February 1990 he was the Controller of Airworthiness at Bangalore. During these months, he was promoted as the Director of Airworthiness (Hyderabad). He had to sacrifice his time as the Director, to discharge his functions as the Court's Secretary. He has been throughout very attentive to the Court, bearing silently the inconveniences and irksome errands he had to carry out. His knowledge in Aeronautical Engineering and experience has helped me to enlighten many of my doubts. The office staff of Controller of Airworthiness, Bangalore, also worked without demur, enthusiastically, even beyond office hours and during holidays to supplement the staff provided by the High Court.

13. The proceedings in the Court attracted wide publicity; the Press was present throughout to remind the Court, of the magnitude of the problem and enormous public interest involved.

14. I had to visit the Central Training Establishment of the Indian Airlines at Hyderabad, on several occasions to acquaint myself with some aspects of flying. The Director and others were very courteous and helpful, throughout. At no time any one of them touched the basic question before the Court of Inquiry; they always guarded themselves against

embarrassing the Court. The High Court of Andhra Pradesh and the State Government of Andhra Pradesh looked after my comforts as their favoured guest during my stay at Hyderabad.

15. The Assessors have been throughout available and devoted their entire energy to aid the investigation.

Capt. C. R. S. Rao is a retired Director of Training, Flight Operations and Flight Safety, Air India; he was also an ace pilot with a blemishless career.

Sri S. G. Goswami, retired as a Director of Airworthiness with vast experience in engineering aspects of aircrafts.

Capt. B. S. Gopal, the youngest among the Assessors, is presently, Director of Air Safety, Air India. He became a Graduate of Institution of Engineers and later an Associate Member and Member of the Institute; a qualification equated to B. E. degree; his subjects of study included Aeronautics Theory & Design of Structures and Thermo Dynamics and Heat Engines; his training and working experiences are manifold. He has been a pilot in B-707, B-747, A-300 and A-310 as PIC; he had, also, flown aircrafts of the Indian Air Force as a Volunteer when there was shortage of pilots in the Air Force. His industry, devotion to work and curiosity to know cannot be easily matched.

16. Sri V. S. Arunachalam, Scientific Advisor to the Ministry of Defence and Commodore Ray of A. D. E. Bangalore, Air Commodore Surjith Singh, A.O.C. I.A.M. Bangalore and his Officers were very helpful to the Assessors.

17. The finding as to the probable cause and circumstances of the crash is not to blame anyone; purpose is to take remedial measures to prevent recurrence of such accidents; the basic cause of the crash can be conveyed in the words of an author:

> "The moments we forego,
> Eternity itself cannot retrieve".