INVESTIGATION REPORT
INTO THE CRASH OF F-27 FOKKER FRIENDSHIP-200 REG NO. AP-BAL AT MULTAN ON 10 JULY 2006

Authority: Government of Pakistan, Ministry of Defence, (Defence Division) letter No. AT-8(4)/06 dated 19th July 2006.

Synopsis

On 10 July 2006, F-27 Fokker registration No AP-BAL, belonging to Pakistan International Airline was scheduled to fly from Multan to Lahore.

The aircraft had 45 souls on board including four crew members. The Captain of the aircraft was Captain Hamid Qureshi. The aircraft took off for Lahore at 1205 hours Pakistan Standard Time (PST) from Multan Runway 36. Soon after takeoff, the aircraft was observed by the ATC and other eye witnesses to be maintaining very low altitude and drifting right in a bank. ATC Control tower tried to establish contact with aircraft, but no contact was established. Subsequently a call from the local resident was received stating that an aircraft had crashed at about 2 km, NE of the Runway. All souls on board the aircraft sustained fatal injuries and the aircraft was completely burned.

1 Factual Information

1.1 Aircraft Information

1.1.1	Registration Marking	:	AP-BAL
1.1.2	Aircraft Inducted in PIA	:	24-01-1979.
1.1.3	Aircraft Make and Model	:	Fokker F-27-250.
1.1.4	Manufacture Serial No.	:	10243
1.1.5	Engine Make and Model RR Dart	:	532-7
1.1.6	Engine Serial No.	:	No. 1 Engine 13009
		:	No. 2 Engine 8273
1.1.7	Time & Cycle since new	:	No. 1 53,866
		:	No. 2 56,717
1.1.8	Time since OH	:	No. 1 Engine 1,369 hrs
		:	No. 2 engine 3,635 hrs
1.1.9	Certificate of Airworthiness and validity:	:	Issued in March 2006

1.1.9.1	Date of Issue	:	14-03-2006
1.1.9.2	Date of Expiry	:	13-03-2007
1.1.9.3	Year of Manufacture	:	Feb 1964
1.1.9.4	Name and Addresses	:	PIA Head Office, Karachi
1.1.9.5	Total Hours	:	73,591:46 as on 10.07.06
1.1.9.6	Total Landings	:	83,485

1.1.9.7 **Record of Last Inspections**:

Check 'A'	:	On 21-06-06 at 73,488 hours
Check 'B'	:	On 25.04.06 at 73,190 hours
Check 'C'	:	On 25.04.06 at 73,190 hours
Check 'D'	:	On 10.01.05 at 71,230 hours

1.2 **Propeller Data**

1.2.1	Make & Model Dowty Rotal	:	1561959
1.2.2	Serial No.	:	Prop1 248/66 Prop 2 193/59/95
1.2.3	Time since New	:	Prop 1 23072 Prop 2 23668
1.2.4	Time since OH	:	Prop 1 2361 Prop 2 2304

1.3 **Aircraft Wreckage:**

1.4 **Engine History**

1.4.1 **Last Three Months Significant Defects**

1.4.1.1 L H (13009) : Propeller Renewal and Installed for Hub Switch. Inspection DT 13/2/6. Ground Run up c/o when Replacing R/H Engine.

1.4.1.2 R/H Engine R/H (8273) : Propeller Renewed and Installed for Hub Switch. Inspection dated 13/6/6. Ground Run up c/o at Installation.

1.4.2 **Shop Visit Record**

1.4.2.1 4H (13009): Engine schedule Renewed for O/H at 52497 TSN Not on any defect. No shop visit after Last O/H.

1.4.2.2 R/H (8273): Engine Schedule Renewed for Mid O/H at 55041 TSN. Not on any defect. No Schedule/unscheduled shop visit after last Mid O/H.

1.5 **Certificates of Airworthiness (C of A):** The inquiry committee considered the preconceived public opinion regarding the ill effects of age of Fokker

Fleet. Hence C of A renewal for last ten years was scrutinized. C of A for the year 2006-2007 was issued vide letter No. CAW/4787/3/AP-BAL/182 dated 9th March 2006. It was observed that the certificate is issued on the basis of an application by operator for renewal in which the operator declares that the a/c is maintained in accordance with airworthiness requirements of CAA PAK. The operator also declares that aircraft has been maintained in accordance with maintenance schedule approved by airworthiness. It further states that no Airworthiness Directives or Service Bulletin are out standing. On the basis of this comprehensive declaration by operator, the airworthiness inspector inspects the aircraft as per their check list and the C of A is issued. The operator also submits a list of major inspection and modification carried out during last year.

1.6 **History Engine S. No. 8273**

1.6.1 Date of Manufacture October 1958

1.6.2 Last Mid O/H carried out 26-12-2005
TSO 3629 Hrs. TSN 56711 Hrs

1.6.3 Time since Mid O/H = 876

1.6.4 Cycle since Mid O/H = 94

1.6.5 Period since Mid O/H = 07 Months

1.6.6 Due for Overhaul at 5000 Hrs

1.6.7 The Inspection Form from Engine Log Book containing all relevant run-up data was despatched to Rolls Royce, Germany. It was determined that all the parameters were in required range

1.7 **History Engine S. No. 13009**

1.7.1 Date of Manufacture May 1959

1.7.2 Last Overhaul 01-09-05 00:00 at Hrs TSN 52497

1.7.3 Time since last O/H = 1369 Hrs.

1.7.4 Cycle since last O/H = 1494 Cyc.

1.7.5 Period since last O/H = 11 Months.

1.7.6 Due for Mid O/H at 2600 +200 Hrs

1.7.7 The Inspection Form from Engine Log Book containing all relevant run-up data was despatched to Rolls Royce, Germany. It was determined that all the parameters were in required range.

1.8 **Records of Transit and Check I & II:** The aircraft records for transit Checks and Check I & II were examined for any omissions or shortcomings.

1.9 **Component Which has Bearing to the Engine Failure**

1.10 The turbine bearing assembly which will be subject of discussion is assembled as per Rolls Royce Dart Engine procedure. The manufacturer's procedures are translated by the operator for the purpose of recording all maintenance actions.

Max Approved Life 16000 hrs.

1.10.1 Ball bearing S. No. 107V was installed at 1166 Hrs.

1.10.2 Complete Turbine Assembly module was installed from engine S. NO. 14202 with bearing. The same bearing was new when used on # 14202 dated 24/03/04 after full inspection.

1.10.3 The original turbine ball bearing S. No. 314E with 8233 TSN was installed on Engine S/No. 7378 which is under overhaul process in these days and the bearing is available in shop.

1.11 **Bearing Inspection**

1.11.1 Ref. standard practice Manual Dart OHM. Chap. 89-10 volume 6.

1.12 **Crew Information**

1.12.1 **Pilot In-Command**

1.12.1.1 Name :Captain Hamid Qureshi

1.12.1.2 Position in the Cockpit : Left Side

1.12.1.3 Date of Birth : 06.01.1953

1.12.1.4 Type of Licence held and No.: ATPL No. 1010-A

1.12.1.5 Medical date with status: Class 1 Medical valid until February 2007.

1.12.2 **Rating**

1.12.2.1 B-747, A-300, B-737 + F-27

1.12.2.2 Type Current : F-27

1.12.2.3 Flight Instructor Rating: Nil

1.12.3 **Flying Experience**

1.12.3.1 Grand Total : 9320:19

1.12.3.2 Total in Command : 1286 hrs

1.12.3.3 Total in Command on F-27: 138:20 hrs

1.12.3.4 Where Trained: PAF Academy, Risalpur

1.12.3.5 Date of Joining the Organization: Dec, 1989

1.12.4 **Co-Pilot**

1.12.4.1 Name: Captain Abrar Chughtai

1.12.4.2 Position in the Cockpit: Right Side

1.12.4.3 Date of Birth: 07.09.1978

1.12.4.4 Type of Licence held and No. CPL No. 2354-A Class 1 Medical valid upto Nov 2006.

1.12.5 **Rating**

1.12.5.1 Type(s) held: F-27, Cessna

1.12.5.2 Type Current: F-27

1.12.5.3 Flight Instructor Rating: Nil

1.12.6 **Flying Experience**

1.12.6.1 Grand Total : 520 : 00

1.12.6.2 Total on F-27: 303:00

1.13 **History of Flight :** The Aircraft was to fly from Multan to Lahore

1.14 **Injury to Persons:** Fatal injuries to all 41 passengers and 04 crew members.

1.15 **Damage to Aircraft:** Destroyed completely.

1.16 **Other Damages:** No co-lateral damage. Aircraft burnt completely.

1.17 **Metrological Condition:** Fair weather.

1.18 **Aid to Navigation:** A serviceable transponder was on board.

1.19 **Communication:** Serviceable VHF Radio

1.20 **Aerodrome and Ground Facilities:** Communication facilities were serviceable and available.

1.21 **Flight Recorders:** Installed and recovered.

1.22 **Wreckage & Impact Information:** The aircraft crashed about 2.0 KM NE of Multan Runway.

1.23 **Fire:** Aircraft was burnt completely.

1.24 **Test and Research:** Engine and aircraft parts were sent to various laboratories for tests and analysis.

2. Technical Investigations

2.1 Introduction

2.1.1 The technical investigations have availed the services of Accident Investigation Branch (AAIB) of UK, BAE of France, DSB of Netherlands, FAA of USA and FBA of Germany. It ensured that down loading of CVR, and DFDR,; investigations into Rolls Royce Engines, Dowty Propellers and Goodrich Control Units were done in accordance with ICAO standards. The interests of Pakistan as state of registry and occurrence are guarded when parts are sent to states of manufacture and design.

Objectives

2.1.2 The technical investigation was focused to answer the following three primary questions:-

(a) Were the engines capable of producing required power and producing it at the time of impact or crash?

(b) Was aircraft intact and its control surfaces operable without any difficulty till it departed from its intended flight path?

(c) Was there any other cause of accident such as sabotage, fire, bird hit or a system failure?

2.2 Analysis of wreckage for following probable causes.

3.2.1 In-flight Structural or Engine Fire.

3.2.2 Mechanical Failure of Flight Controls resulting into lack of flight control by pilot.

3.2.3 A Propeller pitch and/or engine control malfunction leading power problem resulting in state where flight could not be sustained.

3.2.4 In-flight Structural Failure due to pilot overload i.e. excessive dive, pitch or turn by pilot causing loads exceeding aircraft limit loads.

3.2.5 Engine failure including compressor failure, turbine failure, disc rupture, or a blade failure due to fatigue.

3.2.6 Internal/External Sabotage or fuel explosion.

3.2.7 Failure due to metal Fatigue.

3.2.8 Evidence from position of control levers and jacks.

3.3 The Story of the Crash from the Wreckage

3.3.1 Let us summarize the evidences concluded from the wreckage. A detailed analysis reveals that

(a) The aircraft was in one piece, it was complete with all major minor parts with the exception of few metallic debris which fell on right side of the runway.
(b) The flaps were found in zero position.
(c) The nose and main landing gears were found extended.
(d) The oxygen and fire bottles were discharged due to ground fire.
(e) There was no apparent evidence for any internal or external sabotage.
(f) There is no evidence of any in flight fire.
(g) There was no in flight structural failure of any primary or secondary surface.
(h) The right engine appears to be in low RPM i.e. was not producing power. Its two propeller blades were in feathered position.
(i) The left engine was rotating at high speed.
(j) The left propeller's blades have over turned due to internal breakages.
(k) There is no evidence of any bird hit causing injuries to aircrew.
(l) There was extensive ground fire due to fuel.
(m) The aircraft was still on fire when various agencies reached the scene for rescue.

3.4 Conclusion of Engine Tear Down Inspection

3.4.1 The impressions drawn at the wreckage site were further strengthened i.e. the left engine was producing significant power at the time of impact and right engine was dead. However the damage to left engine turbine and main bearing was quiet different than expected only due to rotational damage at impact

3.5 Conclusion by Dowty Propellers

3.5.1 Prior to the event, the propeller equipment was operating normally. At the point of impact, the left hand propeller equipment was operating at take-off power as designed and the right hand propeller had feathered as intended in the event of low torque pressure. There were no untoward features found in the propeller equipment, which would have contributed to the accident.

3.6 DFDR and CVR analysis for engine and Propeller evidence

3.6.1 The salient conclusions regarding the performance of engines in the report are that:

(a) After 29 min 16 sec of recording, an engine spool down i.e. winding of revolutions can be heard.

(b) A spectrum analysis shows changes in the frequencies produced by the engine or its propeller.

(c) About 1 second after the beginning of the engine spool down, an electric interference was recorded on channel 3 of the CVR (dedicated to VHF communications and flight crew headsets) It is visible on the following spectrum analysis. This electrical interference is visible for about 12.7 seconds and its maximum frequency is around 945 Hz.

(d) After 29 min 18.8 sec of recording, i.e. about 2.8 seconds after the engine spool down, an alarm similar to the Fire Alarm is recorded on the CAM channel. It is visible on the spectrum analysis, and its fundamental frequency appears to be approximately 1500 Hz.

3.7 Conclusions from CVR Analysis

(a) Engine speed characteristics during throttle increase are as expected

(b) Small decay in Engine 2 RPM just after max RPM achieved.

(c) Engine failure occurs 54s after increase in RPM, at around point of altitude increase

(d) Engine 1 RPM remains relatively constant until end of recording

(e) Feathering pump + fire bell operates coincidently with decay of engine 2 RPM

3.8 CONCLUSIONS

(a) **No. 1 engine S/N 13009** was confirmed to be operating at the required take-off power until the point of impact. The evidence is a combination of Spectral analysis of the CVR data, confirming that the engine speed was operating at the necessary 15,000 rpm throughout the flight sequence, and Physical examination of the propeller control linkage by the manufacturer, confirming that the blade angle was 28 degrees at the point of impact, which is the correct setting for take-off power. Additionally, the controls units were investigated and no problems were found that would affect operation of the engine.

(b) **No. 2 engine S/N 8273** was confirmed by CVR analysis to have run down, approximately, at the time of rotation of the aircraft. There was no evidence to suggest that an uncontained release of high-energy engine debris had occurred. There was also no evidence to suggest that a thermal break out had occurred. The engine was confirmed not to be rotating at the point of impact the evidence for this is:

(i) Lack of ingestion of debris into the compressor

(ii) Physical examination of the propeller control linkage by the manufacturer, confirming the blades to be in the feathered position as expected following an engine run-down

(iii) Distressed condition of the turbine, a sequence of events leading up to the final run-down had originated in the area of the rear turbine location bearing.

(iv) Laboratory examination revealed that two of the bolts retaining the rear turbine location bearing had fractured as a result of reverse bending fatigue development.

(v) A third bolt had cracked also as a result of the same mechanism. It is considered that distress to the inner track of the location bearing

resulted in a cyclic load acting on the bearing outer track retaining assembly, resulting in the cyclic loading and fatigue fracture of these bolts.

(vi) Examination of the rear location bearing revealed that it had sustained inner track distress and the clamping load on the bearing assembly had been lost. Due to the extensive damage to the inner track, it was not possible to conclusively identify the primary cause of the bearing distress, however it had initiated some time before the subject flight.

(vii) Loss of clamping load and subsequent axial displacement of the bearing assembly led to axial movement of the turbine rotor assembly. This axial displacement resulted in rubbing contact between the rear of the HPT blade / disc roots with the front inner platforms of the IPT NGV's leading to localised overheating of the blade root neck sections, the loss of mechanical properties and the subsequent blade release. A similar rub occurred between the IPT rotor and the LPT NGV's with one IPT blade fracturing in fatigue as a result of excitation due to the axial rub.

(viii) The reason for the final run down of the engine is considered to be the result of the release of the HPT and IPT rotor blades, leading to a significant loss of engine performance, combined with loss of axial and radial location of the rotor causing considerable mechanical distress and resistance to rotation.

3.9 Discussion and Analysis

Analysis and investigations into the technical causes through appraisal at scene of accident at Multan, final flight path from take- off roll to impact point, aircraft and engines maintenance history, strip examination at Dart Engine shop PIAC Karachi, CVR and DFDR analysis in Paris, Netherlands and UK, Engine and Propeller Control units analysis at Goodrich, Glasgow; Propeller's investigations at Dowty, Gloucester, thermal and metallurgical analysis of damages to turbine rotor assemblies at the Rolls Royce, Bristol and final analysis of entire evidence by the board of inquiry has revealed that:

(a) Occurrence or failure of right hand engine initiated much earlier than the eventful flight on 10th July.

(b) The thrust bearing of right hand engine was improperly assembled during last overhaul at DART Engine Shop PIAC in September 2005.

(c) The thrust bearing assembly had some eccentricity while assembled and hence it was orbiting during normal operations instead of ideal rotation.

(d) The effects of imbalance at thrust bearing, through the motion in orbits caused reverse bending loads on the bold heads of bearing assembly.

(e) Failure of one bolt head provided impetus to undefined stresses and caused bearing housing to open through successive failures of next 5 bolts.

(f) The rotor assembly of turbine increased its radii of orbit and caused turbine rotor to get free and move forward.

(g) The turbines discs experienced heavy rub during the eventful flight during take off roll.

(h) The high pressure turbine blades failed due to heavy rub and resulting thermal stresses during latter part of take off roll of eventful flight.

(i) Initially the right engine's propeller went to feathered position automatically and latter it was feathered by aircrew.

(j) The left engine and propeller were producing required rotation and thrust respectively during final flight path till impact.

(k) There was no evidence of either in flight fire, sabotage or bird hit.

(l) There was no fatigue evidence to point out any chances of failure of any flight control surface or structural joint, thereby negating any apprehension of structural failure due to old age of the aircraft.

(m) The ground fire was caused by the fuel which came in contact with the hot parts of the engine during disintegrating sequence after initial impact with ground.

(n) There was no electrical fire in the aircraft prior to impact or any electric current to the aircraft structure due its entanglement with high tension electrical wires.

(o) PIAC Engineering Quality Control failed to detect improper assembly of thrust bearing during last overhaul and its effects during operations during next months.

(p) The last inspection for renewal of certificate of airworthiness was carried out by only one airworthiness surveyor.

(q) The issue of Certificate of airworthiness of F-27 aircraft was left to junior field officers and the check list and procedures for issue of C of A are not adequate to detect weaknesses.

(r) The right engine feathering motor was found in a poor condition of maintenance i.e. worn armature and wrongly fitted bearing.

(s) PIA engineering did not have the diagrams of CVR and DFDR for maintenance.

(t) The bearing of right hand feathering motor was fitted by penning, a maintenance malpractice.

(u) The health of the oil was not monitored by any Spectrometric Oil Analysis Program.

4. Ops Investigation

4.1 It was conclusively established in the technical investigation that F-27 air craft Reg. No. AP-BAL had the right engine failure during take-off. The pilot continued with the take-off and climbed through segment 1. The eye witnesses' statements and the FDR report confirmed that the aircraft, after segment I, was observed to be turning to the right, while flying at a very low altitude and ultimately stalled after about 45 seconds of flight and crashed in a mango garden 1-2 NM at 042° from the take-off point.

4.2 Manufacturer of F-27 air craft claims that the aircraft is designed to perform single engine take-off, climb, cruise and is very much capable of executing a safe single engine landing from any phase of flight. But it did not happen in the case of mishap aircraft (MA) i.e., Flight PK-688.

4.3 Therefore, a dichotomy existed between the expected performance of the aircraft and the sequence of events which followed in the accident under discussion, necessitating a very thorough ops investigation, in order to analyse all operational / environmental factors, which could have played a pivotal role in the causation of the accident.

4.4 The following domains were critically analysed.

(a) Aircrew History and Background
(b) Aircrew Rest Periods / Aircrew Duty Timings
(c) Weight and balance / overloading
(d) Aerodrome weather
(e) Onset of emergency and CVR/FDR Analysis
(f) Extract from the Eye Witnesses Statements
(g) Emergency Handling by Aircrew
(h) Final Flight Path
(i) Sabotage
(j) Bird Strike
(k) Causes of Fatalities
(l) Role of Crash and Rescue Crew
(m) Air Crew Training

(n) Scheduling
(o) Human Factor
(p) CRM

4.5 Aircrew History and Background

4.5.1 **The Captain:** Capt Hamid Qureshi, P-48983 was 53 years old and had joined PIA on 17 December, 1989, as a Cadet Pilot. To date, he had a grand total of 9320 Hrs on various types of aircraft with 138 Hrs as Capt and 577 Hrs as co-pilot on F-27 a/c. His date of 1st Flight as captain on Fokker a/c was 28th May, 2006. (42 days before the accident) He belonged to Lahore and therefore was based at Lahore. His parents lived at Lahore. Capt Hamid lived independently with his family. He was married. The scrutiny of his professional record showed that he possessed a valid ATPL issued on 8th Jan, 1990 and had class I valid medical category and was fully fit to undertake this flight.

4.5.2 **The Co-Pilot:** First Officer Abrar Azhar Chughtai, P-60722 was 28 years old and had joined PIA on 15th December, 2006 and to date had accumulated 303 Hrs on F-27 air craft. He belonged to Islamabad and was based at Islamabad. His father is working / residing in Saudi Arabia. First Officer Abrar was unmarried and lived independently in a rented house at Scheme III, Chacklala, Rawalpindi. He had a valid CPL issued to him in Sept, 1997 and he was medically fit to undertake this flight.

4.5.3 **Rest Period**

Rest planned	=	13:10
Total duty carried out	=	06:20
Rest required	=	12:40

4.6 However, due Wx diversion on 9th July, the min rest availed by aircrew at Lahore was 10:05 which is as per ANO 91.0012 issue IIIA dated 25 May 2006. As per the ANO 91.0012, Para 1.1 note, states:

> "To avoid inconvenience of pax on subsequent flight minimum rest period may be reduced to 12 Hrs on int'l sectors and 10 Hrs

on domestic sectors, with the consent of each crew member, provided that the crew member does not feel fatigued and feels in good physical/mental condition to operate a flight.

4.7 From the analysis of the evidence available, the Board considers that the rest period /duty timings were not the factor in this accident.

4.8 Weight & Balance/Overloading

4.8.1 Therefore, while a possibility does exist that the aircraft weighed more than its limitations, and the load sheet did not show it, yet it could not be conclusively established, through the evidence on record that the aircraft was overweight.

4.9 Airfield and En-route Weather

4.9.1 In order to obviate any possibility of the weather being a factor in this accident, the Board carried out an in depth study of the aerodrome weather on the mishap day. The following was revealed through the evidence.

(a)	Visibility	=	1.2 Kms
(b)	Wind	=	130^0/5-8 Kts
(c)	Clouds	=	Scattered 4000’ Broken 10,000’
(d)	Present Wx	=	Dust n Suspension / cloudy
(e)	Temperature	=	35^0 C
(f)	Trend for next 2 Hrs	=	No significant trend

4.9.2 The last weather picture and me tar showed that weather was fit for undertaking this flight and no significant weather existed, which could be termed as a factor in the causation of this accident.

4.10 **The Evidence Found from the Runway:** The pieces of the broken blades of the right engine turbine were found on the runway edges, indicating that some abnormality with the right engine and breakage of turbine blades had taken place The location on the final flight path of the pieces (fire spots) was plotted on the runway sketch and their analyses showed the following evidence.

(i) When these hot turbine pieces fell on the edges of the runway, the dry grass on the edges caught fire.

(ii) Abeam 4000' Distance Marker Board (DMB), the a/c started veering to the right side and by about 6000' DMB, paralleled the runway in the right half.

(iii) The right engine kept spitting the red hot pieces of the turbine, in intervals and these pieces fell at 30' from the right edge of the runway, on fair weather strip till about 6800' distance .

(iv) After 6800' of runway, the distance of the pieces from the right edge of runway was seen to be increasing suddenly to 140' away from the runway, indicating possibly that the a/c had started to drift to the right due to some abnormality or started gaining altitude or both.

4.11 The above evidence clearly indicated that some abnormality had occurred abeam 4000' DMB, which caused directional control problems and the aircraft veered to the right half of the runway. The abnormality could either be attributed to the engine asymmetric power or a cross wind or pilots inability to control the direction. Since there was no cross wind, so the more possible reason in this case was the engine asymmetric power, because of right engine turbine blades breakage thus deteriorating the right engine performance. The reduction of right engine torque (ref FDR report) along with pilot's inability to counter the yaw caused veering of aircraft to the right side. The evidence on the runway also showed that the aircraft took off in much longer than the prescribed take off distance, in those ambient conditions. The increased take off distance could also be attributed to the asymmetric power and overall reduced available power for takeoff or higher take off speeds.

4.12 Summary

4.12.1 Right engine partial power loss, due turbine blades breakage, had initiated after about 4000' of take-off roll.

4.12.2 The increased take off distance was attributed to an overall reduction in total take off power available or higher take off speeds.

4.12.3 The asymmetric power caused the veering of aircraft into the right half of the runway. However, aircrew were able to keep it straight, close to the right edge of the runway.

4.13 The CVR and FDR Tape

4.13.1 The Cockpit Voice Recorder (CVR) was decoded by BEA (Bureau d" Enquetes et d" Analysis) of France in the presence of members of the Board. The FDR was decoded by Honeywell of USA and final report issued by Fokker Services. The salient features of the CVR / FDR gave certain clues which are discussed below: -

4.14 CVR Analysis

4.14.1 Spectrum analysis of the CVR was carried out in France in the presence of board members. It was done in order to retrieve some additional information related to engine /aircraft. Beside transcript following were noted:

4.14.1.1 Engine spool down can be heard very clearly. Spectrum analysis also shows changes in the frequencies reduced by the engine or its propeller.

4.14.1.2 After about 2.8 sec of the engine spool down, a bell is recorded on the channel which is visible in the spectrum.

4.15 CVR And FDR

4.15.1 Fokker services analysed the FDR and CVR information.

4.15.2 It was difficult to correlate the CVR data with the FDR information due to lack of an event that is clearly recognizable on both recorders that could be used for synchronization. Because of this, sound of impact on CVR was aligned with large fluctuation in the vertical acceleration in the FDR.

4.15.3 FDR and CVR data on a common time based. The salient outcome are reproduced below:

a. It is clear from the CVR that the crew noticed a deviation from the required torque pressure of the RH engine while the aircraft was still on ground and the airspeed was below V_1.

b. About 5-6 sec after the noted deviation in torque pressure CVR recorded V_1 crossed.

c. Just after rotation the auto feathering circuit activated and can be identified on the CV R. Activation of auto feathering circuit occur when the engine torque drops below a certain pressure.

d. The speed at rotation was 120 Kts which is well above the VR (109 Kts).

e. After approximately 11 sec after the engine failure the crew started to feather the RH propeller manually.

f. The MA should reach screen height (35 feet) in approx 38 seconds when appropriate take off speed are maintained. The take off roll until screen height is reached took 45 seconds in this case.

g. After lift off the crew did not correct the heading and roll deviation.

4.21. Final Flight Path

4.21.1 The sequence of events from line up to culmination of the short duration flight has been depicted (Pictorial) in the final flight path. The depiction is the portrayed of the data retrieved from the CVR and DFDR. The salient features of the final flight path are as follows:

(a) The initial rate of climb, just after takeoff was at a gradient higher than the required with single engine.

(b) The max altitude attained by the MA was 160'.

(c) The max speed attained in the complete duration was 120 Kts, which thereafter kept depleting till the aircraft stalled.

(d) The ten seconds interval, sequential data shows that after reaching top of climb (160' AGL), reduction in speed and height is discernable, indicating non sustenance of flight with the available power and aircraft configuration.

(e) The last speed noted on FDR was 85 Kts at which the aircraft stalled and crashed in a mango garden, at a radial of 042^{o} and 1.2 NM from the break ground point.

(f) The aircraft continued to turn right with varying bank (Max 30^{o}) and the last heading of aircraft just before stall was 115^{o} close to village Suraj Miani.

4.22 Sabotage

4.22.1 In the wake of prevalent security situation in the country, it was considered appropriate to rule out all possibilities, more specifically the sabotage. Following three main areas were analyzed in this domain:

(a) An external sabotage, i.e. firing of some external device from the ground.

(b) An internal sabotage by exploding device inside the aircraft.

(c) An internal sabotage by in capacitating some of the aircraft engine systems/crew.

4.23 External / Internal explosive device

4.23.1 This sabotage was ruled out on the basis of the following:

(a) The aircraft did not disintegrate or explode in the air, and no part of the aircraft structure was found from outside the general wreckage area or from the final flight path, or from the route. And the complete inventory of the aircraft structure was available from within the wreckage.

(b) The cockpit voice recorder (CVR) portrayed complete conversation between the pilots and even the sound of the engines and feathering pump when it auto feathered. The CVR also neither showed any abnormal sound of explosive or aircraft disintegration, nor did the pilots show any concern about any detonation or explosion.

(c) The complete wreckage analysis also did not reveal any chemical explosive deposits on any of the aircraft components or the engine parts.

(d) No one stated that he saw the aircraft being hit from outside.

4.24 In Capacitating of an Aircraft System

4.24.1 This possibility was studied in detail the following came to light:

(a) All systems other than the right engine were functioning normal, till the aircraft stalled.

(b) The aircrew did not announce any such emergency or a snag in any of the aircraft systems.

(c) The technical malfunction (turbine blades failure) in the right engine was found to be the cause of right engine failure. The blades failure was analyzed by Dowty Propellers, and it did not show an intentional disruption / damage to the blades by some one. The sequence of events and the initiation of emergency, followed by the pilot's improper emergency handling, bears testimony to the absence of a sabotage caused accident.

4.25 Bird Strike

4.25.1 The possibility of a bird strike to the aircraft or to the engine, causing damaged to the engine, was also studied in detail and ruled out on the following grounds:

(a) The pilots or the ATCOs did not announce the presence of the birds on the runway or the adjoining areas.

(b) The bird remains were not found on any of the aircraft body parts or in the engine area.

(c) The bird shooters and witnesses neither saw any bird activity at the airfield nor did they observe an actual bird strike to the aircraft.

4.25.2 On the basis of above evidence, the possibility of a bird strike to the aircraft or bird ingestion into the engine was ruled out.

4.26 Cause of Fatalities

4.26.1 Despite a very prompt fire fighting and rescue operation, all 45 souls on board sustained fatal injuries. The board deliberated at length, upon this aspect and came up with the following reasons:-

(a) The aircraft took off with required fuel from Multan and after short while crashed at 3 KM NE of the runway. Therefore, at the time of crash, it had almost total fuel available, which still to be consumed.

(b) Before impacting the ground, the aircraft stalled and was hammered on to the ground. During the process of falling, it hit some stems and branches of the trees and encountered sudden deceleration. Soon after impacting the ground it hit a mud wall and its nose stuck in a ditch and it did a front roll and turned turtle. During the front roll, its tail while crossing over, hit the thick electric wire, broke the wire and hit the ground very hard in the inverted fashion. During all these movements and throwing around all passengers and crew sustained serious/fatal injuries, and the aircraft broke into pieces and the wreckage caught fire due to presence of colossal amount of fuel in the aircraft

(c) The pattern in which the aircraft crashed, broke into pieces and came to a sudden stop, it is expected that many passengers and crew must have sustained concussions and bony injuries and must have died immediately.

(d) It is also known that ground fires of jet fuel, produce up to 1600^0 F of temperatures, when burnt in the aircraft wreckage.

(e) A human exposure to such high temperatures can cause death in seconds, not to talk of ten minutes of burning. Therefore, as per the doctor's report on causes of death of the passengers, the cause of fatalities was attributed to high degree of burns.

(f) The local residents who had gathered around the wreckage within few moments described the fire and heat to be so intense that no body could go close to the burning wreckage, until the fire fighting crew reached the site after ten minutes of burning.

CONCLUSION

Accidents and losses are part of aviation business, but avoidable accidents hurt us the most. PIA or any other company can ill afford such losses. In this accident, while the aircraft had developed a problem in its right engine turbine, resulting in the engine failure, yet a professional handling by the aircrew could have saved 45 precious lives and a valuable aircraft.

It is also felt that this accident may not be viewed as an isolated case of a pilot's failure to handle the emergency. The problems were observed to be complex and deep routed and reflect towards the organization and her culture. The occurrence (right engine failure) took place due to improper assembly during over haul. Quality Control system of PIA Engineering appears to be in affective in detecting the weaknesses. The accident took place due to improper handling of the emergency by the air crew which reflected towards in adequacies of PIA Training/Assessment and Scheduling System. The CAA Airworthiness, too, can not be absolved of their responsibilities of regulating and monitoring the quality control system at PIAC Engineering.

5 Observations

5.1 Certificate of Airworthiness Procedure:

5.1.1 The procedure for issue of certificate of airworthiness is inadequate and weak to ensure that aircraft is maintained in accordance with Technical Literature.

5.1.2 The last inspection for renewal of certificate of airworthiness was carried out by only one airworthiness surveyor with avionics back ground only.

5.1.3 The issue of Certificate of airworthiness to F27 aircraft is left to field officers and the check list and procedures for issue of C of A are not adequate to detect weaknesses.

5.1.4 It is the opinion of the inquiry committee that present procedure of C of A cannot ensure that aircraft is maintained in accordance with Technical Literature and there is no Service Bulletin or Mandatory Airworthiness Directive (AD) outstanding. The inspection by Airworthiness for renewal of C of A is also a weak area.

5.1.5 The analysis of last 05 years of renewal processes of C of A for AP-BAL, show that no significant defects were detected despite it being a 30 years old aircraft. Similarly, there were only three modifications during the same period. The Board, after scrutiny of C of A records, is of the opinion that Airworthiness Directorate needs to improve the check list for C of A. However, their weaknesses have no bearing on the accident.

5.2 Maintenance Procedures

5.2.1 The right engine feathering motor was found in a poor condition of maintenance i.e. worn out armature and wrongly fitted bearing.

5.2.2 PIA Engineering did not have the diagrams of CVR and DFDR for maintenance.

5.2.3 The bearing of right hand feathering motor was fitted by penning, a maintenance malpractice.

5.2.4 The health of the oil was not monitored by any Spectrometric Oil Analysis Program. The oil recovered from right engine was extremely

dirty. The ultrasonic cleaning and captured debris showed deposits of aluminium, bronze – copper alloy including lead (bearing cage and plain bearing material).

5.2.5 Oil transfer tube and main bearing housing had deposits of silicon sealant.

5.2.6 The investigations by Dowty Propellers, Good rich Control units, Rolls Royce and Fokker services have pointed out a number of maintenance errors such as use of Silicon based sealant in oil feed tube, incorrect installation of tab washers, use of non standard part numbers, penning while fitting a bearing and poor condition of feathering pump motors. Though these observations cannot be related to the cause of occurrence but these indicate weaknesses of maintenance and failure of quality control.

5.2.7 The health of oil or its quality was also not monitored through any locally introduced procedure. The SOAP could have been used. The inquiry could not establish exact period or the time since the bearing area was undergoing wear and tear due to stresses; however the detection of presence of different materials in the engine oil through an inspection of oil quality might have been an indication that there was a problem in bearing area.

6 FINDINGS

6.1 Technical

6.1.1 **Aircraft History:** The Fokker 27 which crashed on 10 July 2006 near Multan, registration Number AP-BAL, Serial Number 10243 was manufactured in 1964 and inducted in PIA on 24th January 1979. It has completed 73, 591 hours of airframe before crash. The last certificate of airworthiness was issued at Islamabad on 14th, March, 2006 for one year. It was complied with all mandatory Airworthiness Directives and Service Bulletins. The last A, B, C and D checks were performed in year 2006.

6.1.2 **Engine History:** The engine serial number 13009 was installed on left position and engine serial number 8273 on right position. The left engine was last overhauled in September 2005 with 1369 hours and 1494 cycles since last overhaul. The right engine visited shop for mid overhaul in December, 2006. It had accumulated 876 hours and 947 cycles since last mid overhaul inspection.

6.1.3 **Defect History:** The last three months analysis of defects reported by air and ground crew did not show any defect which can be related to the accident.

6.2 Wreckage Evidence

6.2.1 There was no evidence of either in flight fire, sabotage or bird hit.

6.2.2 There was no fatigue evidence to point out any chances of failure of any flight control surface or structural joint, thereby negating any apprehension of structural failure due to old age of the aircraft.

6.2.3 The ground fire was caused by the fuel on board the aircraft.

6.2.4 There was no electrical fire in the aircraft prior to impact.

6.2.5 There was no short circuiting due to its post impact entanglement with high tension electrical wires.

6.3 Engines Failure/Performance

6.3.1 The **No. 1 engine S/N 13009** was operating at the required take-off power until the point of impact. It is based on:-

(a) Spectral analysis of the CVR data which confirmed the engine operating speed at 15,000 rpm throughout the flight sequence.

(b) Physical examination of the propeller control linkage by the manufacturer, confirming that the blade angle was 28 degrees at the point of impact, which is the correct setting for take-off power.

(c) Additionally, the controls units were found serviceable.

6.3.2 **The No. 2 engine S/N 8273 failed during takeoff roll. It is based on:-**

(a) Recovery of engine blades debris from Multan runway.

(b) Evidence from wreckage and strip examination

(c) Confirmation by CVR analysis.

(d) The engine was not rotating at the point of impact as there was lack of ingestion and confirmation of the same by manufacturer.

6.4 Main Turbine Bearing

6.4.1 The thrust bearing of right engine was improperly assembled during last overhaul at DART Engine Shop PIAC in September 2005.

6.4.2 The thrust bearing assembly had some eccentricity while assembled and hence it was orbiting during normal operations instead of ideal rotation.

6.4.3 The effects of imbalance or misalignment at thrust bearing, through the motion in orbits caused reverse bending loads on the bold heads of bearing assembly.

6.4.4 The failure of one bolt head provided impetus to undefined stresses and caused bearing housing to open through successive failures of next 5 bolts.

6.4.5 The rotor assembly of turbine increased its radii of orbit and caused turbine rotor to get free and move forward.

6.4.6 The turbines discs experienced heavy rub during the eventful flight during takeoff roll.

6.4.7 The high pressure turbine blades failed due to heavy rub and resulting in thermal stresses which caused the blades of HPT break away during latter part of take off roll of eventful flight.

6.4.8 Due to the extent of damage, the primary cause of distress to the inner tracks of the bearing could not be conclusively established.

6.4.9 The oil scavenge and pressure filters were found with deposits of aluminium (bearing housing), bronze – copper alloy including lead (bearing cage and plain bearing material), silver and cadmium (bolt plating material), soft black elastic organic particles containing some magnesium (the same composition as 'O' ring seals – most likely from the ball bearing housing 'O' seal) and soft plastic particles rich in silicon similar to the red sealant found on the oil transfer tube.

6.5 Quality Control Failure

6.5.1 PIAC Engineering, Quality Control, failed to detect improper assembly of thrust bearing during last overhaul.

6.6 Operations Analysis

6.6.1 **Authorizations**

6.6.1.1 PIA Flight PK-688 was scheduled to operate from Multan to Lahore / Islamabad, with departure time of 1200 hrs from Multan on 10th July 2006, with 45 souls (41 passengers and 4 crew members) on board.

6.6.1.2 Capt. Hamid Qureshi and 1st Officer Abrar Azhar Chughtai were detailed as the Captain and the Co-pilot of the aircraft respectively. Miss Tabana Jamil and Miss Amerah Sikander Azeem were detailed as the cabin crew.

6.6.1.3 All the aircrew and cabin crew possessed the requisite clearances and qualifications to operate the flight, however, cockpit crew were low experienced on F-27 aircraft.

6.6.1.4 Weather was fit to undertake this flight.

6.6.1.5 The aircrew and cabin crew were medically fit and had rested as per ANO 91.0012 dated 25.05.2006.

6.6.1.6 Aircraft weighed within the prescribe weight limitations.

6.6.2 **Sequence till onset of emergency**

6.6.2.1 The startup, taxi, line up and run-up checks, all remained uneventful.

6.6.2.2 During the roll for take off at about 60-70 Kts of speed, an unidentified pump was observed to be malfunctioning about which the aircrew showed their concern and the word pump was recorded in the CVR.

6.6.2.3 Subsequently the aircraft started to veer to the right side but the captain was able to straighten it to the runway direction in the right half of the runway.

6.6.2.4 At about 90 Kts of speed, the captain asked his co-pilot, if the right engine torque was less, to which he replied in affirmative.

6.6.2.5 After another 5 seconds, the co-pilot announced, "V_1 crossed. The speed at this point was calculated to be around 108-110 Kts.

6.6.2.6 The aircraft lifted off at 120 Kts of speed, which was above the scheduled Vr.

6.6.2.7 After about 44 seconds of the take off roll, the right engine flamed out (spooled down) and auto feathered.

6.6.2.8 Pieces of right engine turbine blades were found from 4000 feet to 6800 feet of runway.

6.6.3 **Aircrew actions to handle the emergency**

6.6.3.1 The sequence of events from Paras above, showed that the emergency had initiated when the aircraft was still rolling on the runway for takeoff and was at a speed much lower than V_1 (a speed below which the take off is to be abandoned for any abnormality with the engine or aircraft) and the aircrew had very clear indications of the abnormal engine behavior during the takeoff role.

6.6.3.2 The aircrew decided to continue the take off contrary to the procedures.

6.6.3.3 Soon after the right engine failure the aircrew indulged in manual feathering and securing the right engine, which is forbidden unless a height of 400 feet AGL has been attained.

6.6.3.4 After take off the aircrew did not raise the gears contrary to the procedures.

6.6.3.5 Because the gears were not raised and the aircraft was not wings level rather was in a varying bank, the speed started to deplete.

6.6.3.6 Consequently the aircraft stopped climbing and attained maximum of 150-160 feet AGL height.

6.6.3.7 After 40 seconds from the take off, the speed reduced to a value at which the aircraft stalled.

6.6.4 **Aircrew omissions**

6.6.4.1 Right from the onset of emergency, all the way to the stalling of aircraft, the aircrew took the following actions contrary to the SOPs:-

- 6.4.4.1.1 Did not abort on the runway despite having very clear indications for an engine/aircraft abnormality.
- 6.4.4.1.2 Did not announce the emergency throughout.
- 6.4.4.1.3 Did not raise the gears.
- 6.4.4.1.4 Started the engine feathering drill before 400 feet AGL, instead of taking positive control of the aircraft.
- 6.4.4.1.5 Did not maintain runway direction. The constant turn consequently accentuated the speed reduction phenomenon.
- 6.4.4.1.6 The actions of aircrew lacked professionalism, a poor display of airmanship and an extremely poor emergency handling.

6.6.5 **Miscellaneous**

6.6.5.1 The aircraft stalled / crashed at 1.2 nautical miles North East of the break ground point.

6.6.5.2 All 45 souls on board sustained fatal injuries due to concussions and extensive burns.

6.6.5.3 MA was completely destroyed.

6.6.5.4 The response of the crash and rescue teams was prompt and within the minimum possible time.

6.6.5.5 The valuables/ belongings of the passengers recovered from the debris were handed over to the successors by the Multan Airport Management.

6.6.5.6 The members from the AAIB (UK) France, Germany, USA, and Holland contributed immensely towards unfolding all events.

6.6.5.7 The poor emergency handling by the aircrew showed inadequacies in training/assessment system.

6.6.5.8 Scheduling of both low experienced pilots (Capt and Co-pilot) for the flight, contributed to the improper emergency handling, resulting in the loss of precious lives and an aircraft.

7. Finalization

7.1 Human Factor – Air Crew – Poor Emergency Handling
Avoidable

7.2 Human Factor – Maintenance Crew – Poor Maintenance Improper Assembly of Right Engine Main Bearing
Avoidable

8. Recommendations

8.1 The working efficiency of quality control at PIAC Maintenance and Engineering be improved to minimize poor maintenance and maintenance malpractices.

8.2 The airworthiness directorate at CAA should enhance surveillance of Engine Overhaul Shop at PIAC Engineering.

8.3 The Spectrometric Oil Analysis Programme (SOAP) be utilized for all engines.

8.4 A study be carried out with a view to determine the inadequacies in flying training/assessment system.

8.5 CRM training be made meaningful with participation from cockpit crew and qualified facilitators be deployed.

8.6 While scheduling, the pairing be done in a manner that at least one of the two aircrew should posses substantial experience on the type in their capacity as Captain or Co-Pilot.

8.7 PIA should institutionalize their system to study the human behaviour of aircrew with a view to pre-empt their behaviour under emergencies.

8.8 Figure of 72 Kgs of weight per person used for the calculation of all up weight in the Trim sheet be reviewed.

8.9 SIB be tasked to carry out a study to remove the inadequacies in the issuance and renewal of Certificate of Airworthiness.

8.10 Safety Division of PIAC be made more potent and effective by appointing Flight Specialists with substantial experience in Safety Program Management.

8.11 Those who failed to perform during overhaul of the engine and carrying out quality inspection and issued Certificate of Airworthiness, should be proceeded against under the existing Rules.