

FINAL INVESTIGATION REPORT



ACCIDENT OF SUNWAY AIR CARRIER (GEORGIA)
IL-76TD AIRCRAFT REG # 4L-GNI AT KARACHI, PAKISTAN
ON 27th NOVEMBER, 2010

SCOPE

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Synopsis

The accident was reported to Safety Investigation Board (SIB), Pakistan through Incident Occurrence and Unserviceability (IOU) Report of CAA, Pakistan. The accident was notified by SIB, Pakistan in accordance with provisions of ICAO Annex-13. Accredited Representative (ACCREP) was appointed by Interstate Aviation Committee (IAC) along with technical advisors from Open Joint Stock Company Ilyushin Aviation Complex (further referred to as ILYUSHIN) (Aircraft designer) and from Joint Stock Company NPO Saturn (Engine Manufacturer).

The IAC provided extensive technical support by furnishing a report which included crew information, flight data analysis, metallurgical analysis, history of the aircraft / engines, aircraft performance simulation and necessary safety recommendations. Civil Aviation Authority (CAA), Pakistan issued Memorandum vide letter No. HQCAA/1901/339/SIB dated 29th November, 2010 and Corrigendum to memorandum dated 25th July, 2016, authorizing SIB, Pakistan to conduct the investigation of the accident as state of occurrence.

The flight was intended to carry humanitarian aid from Karachi (Pakistan), and was on its way to Khartoum (Sudan). After successfully getting airborne from Jinnah International Airport (JIAP), Karachi, the aircraft Engine # 4 and adjacent right wing area caught fire. The flight could not be sustained and it crashed about 2 NM from the JIAP Karachi, fatally injuring all souls on board. The cause of the accident was uncontained failure of 2nd stage disk of Engine # 4 Low Pressure(LP) compressor during climb after takeoff. The debris from engine failure damaged the right wing and flaps in the vicinity of Engine # 4. Consequent to the damage, the fuel in the right wing caught fire and resulted in loss of lateral control. The most probable cause of the engine failure was the fatigue fracture of LP compressor second stage disk. The fatigue cracks developed due to fretting in the hole, designed for holding the bushing for LP compressor blade pin as the mishap engine was being used beyond its manufacturer's assigned life at bearing of 070°.

1. FACTUAL INFORMATION

1.1. History of the Flight

1.1.1. On 27th November, 2010 the operating crew of mishap aircraft flew from Fujairah (UAE) to JIAP, Karachi (Pakistan) at 1000 UTC. The load onboard was weighing 9 tons (Packaged Boeing 747 engine).The aircraft had flown to Fujairah airport from Kandahar.

1.1.2. According to the provided information on the 27-11-2010 the crew comprising Aircraft Commander, Second Pilot, Navigator, Flight Engineer, Flight Radio Operator, and Flight Operator flew from Fujairah (UAE) to JIAP Karachi.

1.1.3. After landing the crew members were shifted to "Regent Plaza" hotel in Karachi. The stay of crew in the hotel was not less than 8 hours.

1.1.4. The aircraft was refuelled at JIAP, Karachi and total fuel onboard was 74 tons. A cargo load of 30.5 tons was also loaded after refuelling the aircraft. The aircraft mass was 197 tons with its CG at 30% Mean Aerodynamic Chord (MAC) before undertaking the mishap flight.

1.1.5. The aircraft was scheduled for departure from JIAP, Karachi at 2025 UTC 28th November, 2010) on route "Karachi – Khartoum – Douala, Cameroon to deliver humanitarian aid (tents).

1.1.6. The crew arrived at airport around 1900 UTC. The weather conditions were satisfactory. The weather details are mentioned in this report at Para 1.7.

1.1.7. After starting engines the crew taxied the plane to Runway 25L and reported to the air traffic controller that the plane would take off in 3 minutes and the aircraft took off at 2048 UTC.

1.1.8. According to the radar data the aircraft ascended to 600 ft, started descending and then disappeared from the radar screen. The air traffic controller did not receive any information from the crew members about emergency conditions onboard.

1.1.9. The aircraft crashed at about 2050 UTC on a bearing of 070 degree and approximately 02 NM from JIAP, Karachi at geographical location N24°53.651', E 067°06.406'.

1.2. **Injuries to Persons.** The data of injuries / fatalities is appended below:

Injuries	Crew	Passengers	Others	Nationality
Fatal	06	-	02 Engineering support service specialists (in aircraft) 03 Workers (on ground)	07 Ukrainian 01 Russian 03 Pakistani
Serious	-	-	-	-
Minor / None	-	-	-	-

1.3. **Damage to Aircraft.** The aircraft was destroyed in the accident.

1.4. **Other Damage.** As a result of ground impact, in a residential area, several under construction houses were severely damaged.

1.5. **Personnel Information.** The details of operating crew are given below:

Captain	
Aircraft Commander (Flight Instructor)	<ul style="list-style-type: none"> ▪ Male ▪ Born in 1953 ▪ Graduated from Balashov Aviation School in 1997 ▪ Trained to operate AN-12, IL-76T/TD/MD aircraft
Pilot's License	<ul style="list-style-type: none"> ▪ License of Transport Aviation Pilot # 000331, issued by the State Aviation Administration of Ukraine on 25-02-2005 ▪ The addendum to the license ЛС # 038207 was valid till 12-01-2011
Medical Certificate	<ul style="list-style-type: none"> ▪ MC # 01606 issued by the Medical Station of the Dnepropetrovsk Airport ▪ Valid till 01-12-2012
Weather Minima	<ul style="list-style-type: none"> ▪ CAT-1 ICAO, 60x800 (RVR 500m) +Take-off – 400 m (minima)

Total Flight Experience	<ul style="list-style-type: none"> ▪ As on 19-01-2010 – 7272:00 hours including 3202:00 hours at night
Flight Experience on this type of aircraft / including as aircraft commander	<ul style="list-style-type: none"> ▪ As on 19-01-2010 – 5502 / 5502 hours, including 3150 hours at night
Pilot Technique Test – IL-76TD	<ul style="list-style-type: none"> ▪ Certification test held on 12-04-2009 at “VOLARE” Aviation Complex (Ukraine). ▪ Secured standard “C” ▪ Last Simulator was held on 22-12-2009 by Ukrainian Defense Ministry. ▪ Secured standard “C” ▪ He was also issued Extension Courses certificate # 366 on 02-04-2010 by The Main Training & Certificate Center of Civil Aviation of Ukraine
Rest Before Flight	<ul style="list-style-type: none"> ▪ Provided
Access / Permissions to Flight	<ul style="list-style-type: none"> ▪ Access / permission granted to international flights and area navigation route flights ▪ The order # 23 issued on 22-04-1996 by “VOLARE” Aviation Complex, Ukraine
Access / Permission to conduct radio communication in English	<ul style="list-style-type: none"> ▪ Access / permission granted on 07-11-1995, level “3” of ICAO gradation ▪ Protocol # 212 of 15-12-2008, “VOLARE” Aviation Complex (Ukraine)
Pre training to conduct flight Al-Fujairah-Karachi-Khartoum-Duala	<ul style="list-style-type: none"> ▪ Information was not provided
Preflight Action	<ul style="list-style-type: none"> ▪ All required actions performed under aircraft commander’s control on the day of occurrence prior to the departure
First Officer (Co-pilot)	
Second Pilot	<ul style="list-style-type: none"> ▪ Male. ▪ Born in 1964 ▪ Graduated from Poltava Aviation School ▪ Access granted to operate IL-76 T/TD/MD aircraft
Pilot’s License	<ul style="list-style-type: none"> ▪ Certificate of a commercial pilot III-CA # 00562 issued on 16-04-2003 by the State Aviation Administration of Ukraine ▪ The addendum to the certificate of a commercial pilot ЛС # 038207 was valid till 17-08-2011
Medical Certificate	<ul style="list-style-type: none"> ▪ Certificate # 020501 was issued by the Medical Station of the Dnepropetrovsk Airport ▪ Valid till 17-08-2012
Total Flight Experience	<ul style="list-style-type: none"> ▪ Total flight experience 2220:00 hours including 924:00 hours at night ▪ IL-76 flight experience data was not provided
Access / Permission to conduct radio communication in English	<ul style="list-style-type: none"> ▪ Certificate # 50 was issued on 06-06-1995 level “3” of the ICAO gradation ▪ Protocol # 1P904 24-06-2010
Pilot Technique Test on IL-76TD	<ul style="list-style-type: none"> ▪ Conducted on 15-11-2009 by “VOLARE” Aviation Complex ▪ Secured standard “C” ▪ Last Simulator test on 10-08-2010 by

	Ukrainian Defense Ministry ▪ Secured standard "C"
Pre training to Conduct Flight AI-Fujairah-Karachi-Khartoum-Duala	▪ Information was not provided
Rest before the flight	▪ Provided

Navigator	
Navigator	<ul style="list-style-type: none"> ▪ Male ▪ Born in 1961 ▪ Graduated from Voroshilovgrad Aviation School ▪ Access / Permission granted to AN-12, IL-76 T/TD/MD flights
Navigator's License	<ul style="list-style-type: none"> ▪ 1-FN # 001164 issued by Ukrainian State Department of Air Transport ▪ Addendum to the Navigator's License ЛС # 038206 was valid till 12-01-2011
Medical Certificate	<ul style="list-style-type: none"> ▪ MC # 0116066 issued by the Medical Station of Dnepropetrovsk Airport ▪ Valid till 12-01-2012
Total Flight Experience including IL-76	<ul style="list-style-type: none"> ▪ Total 6350:00 hours as on 19-01-2010 including 2711:00 hours at night ▪ IL-76 flight experience 4800:00 hours
Aero-navigation / Aviation test	<ul style="list-style-type: none"> ▪ Conducted on 29.12.2009 at "VOLARE" Aviation Complex, Ukraine ▪ Secured standard "C" ▪ Last simulator test conducted on 22-12-2009 by Ukrainian Defense Ministry. ▪ Secured standard "C"
Access / Permission	<ul style="list-style-type: none"> ▪ Access / Permission were granted for international flights and area navigation route flights
Access / Permission to conduct radio communication in English	<ul style="list-style-type: none"> ▪ Certificate # 106 issued on 12-08-1995 with level "4" of the ICAO gradation ▪ Protocol # 280 dated 21-01-2009
Pre training to conduct flights AI-Fujairah-Karachi-Khartoum-Duala	<ul style="list-style-type: none"> ▪ Information is not provided
Rest Before Flight	<ul style="list-style-type: none"> ▪ Provided
Flight Engineer	
Flight Engineer	<ul style="list-style-type: none"> ▪ Male ▪ born in 1968 ▪ Graduated from Vasilkovskoe Transport Aviation School in 1988 ▪ Access / Permission was granted to IL-76 T/TD/MD flights
Flight Engineer's License	<ul style="list-style-type: none"> ▪ FE # 001163 issued by the State Department of Air Transport of Ukraine on 20-07-2004 ▪ Addendum to the flight engineer's license ЛС # 038238 valid till 20-01-2011

Medical Certificate	<ul style="list-style-type: none"> ▪ MC # 017673 was issued by the medical station of Dnepropetrovsk Airport on 20-01-2010 ▪ Valid till 18-01-2012
Total Flight Experience / including IL-76	<ul style="list-style-type: none"> ▪ Total 3391:00 hours on 21-01-2010 including 929:00 hours at night
Practical Air Work Test	<ul style="list-style-type: none"> ▪ Conducted on 26-11-2009 at "VOLARE" Aviation Complex ▪ Secured standard "C" ▪ Last simulator test conducted on 22-12-2009 by Ukrainian Defense Ministry. ▪ Secured standard "C"
Access / Permission	<ul style="list-style-type: none"> ▪ Access / Permission granted to international flights by "VOLARE" Aviation Complex (Ukraine) in 2009
Pre training to conduct flight Al-Fujairah-Karachi-Khartoum-Duala	<ul style="list-style-type: none"> ▪ Information was not provided
Preflight Action	<ul style="list-style-type: none"> ▪ Under aircraft commander control
Rest Before Flight	<ul style="list-style-type: none"> ▪ Provided
Flight Radio Operator	
Flight Radio Operator	<ul style="list-style-type: none"> ▪ Male ▪ Born in 1959 ▪ Graduated from Kannsky School of Flight Radio Operators in 1981 ▪ Access / Permission granted to flights on IL-76 T/TD/MD aircraft ▪ The Order # 68 of 26-01-1983 Military Unit # 22527 ▪ Extension courses certificate # 23/5 of 30-01-1997
Flight Radio Operator's License	<ul style="list-style-type: none"> ▪ II-RO # 000102 issued by the State Aviation Administration of Ukraine on 24-12-2004 ▪ Valid till 12-01-2011 ▪ Addendum to the Flight Radio Operator's License ЛС # 038208 ▪ Valid till 12-01-2011
Medical Certificate	<ul style="list-style-type: none"> ▪ MC # 016068 was issued by the Dnepropetrovsk Airport Medical Station ▪ Valid till 12-01-2012
Total Flight Experience, including IL-76	<ul style="list-style-type: none"> ▪ Total 3393:00 hours on 29-11-2010 including 1393:00 hours at night on IL-76 ▪ Flight experience on IL-76 3334:00 hours
Practical work air test	<ul style="list-style-type: none"> ▪ Qualification air test conducted on 29-12-2009 by "Eastern Express Airlines" Aviation Complex (Kazakhstan) ▪ Secured standard "C" ▪ Last simulator test conducted on 22-12-2009 by Defense Ministry of Ukraine ▪ Secured standard "C"
Access / Permission	<ul style="list-style-type: none"> ▪ Granted for International Flights on 16-10-1996 by the "VOLARE" Aviation Complex
Access / Permission to conduct radio communication in English	<ul style="list-style-type: none"> ▪ Level "3" of ICAO gradation was achieved ▪ Certificate # 101 / 2 issued on 29-05-1995 ▪ Protocol # 009 of 17-03-2008

Pre training to conduct flight Al-Fujairah-Karachi-Khartoum-Duala	▪ Information was not provided
Preflight Action	▪ Under aircraft commander control
Rest Before Flight	▪ Provided
Flight Operator	
Flight Operator	▪ Male
Flight Operator's License	▪ Second class, BO # 000613 ▪ Valid till 25-05-2011 ▪ The license was issued by "Domodedovo Airlines" Aviation Complex
Access / Permission	▪ Granted by "IL-avia" through the order # 39 of 26-05-1997
Medical Certificate	▪ MC # 016068 ▪ Valid till 25-05-2011 ▪ Issued by the Health Flights Expert Commission at "Domodedovo" Airport
Total IL-76 Flight Experience	▪ 4870:00 hours

1.5.1. According to the provided data the aircraft crew had enough flight experience to safely conduct this flight. Moreover, they had valid medical and related training certificates. The detail information related to the route briefing for Al-Fujairah-Karachi-Khartoum-Duala received by the crew was not provided to the investigation team.

1.5.2. The crew completed pre-flight preparation under the supervision of Pilot in Command (PIC).

1.6. Aircraft Information

1.6.1. The operator did not provide the complete log books of the aircraft, instead copies of some pages of the log books were provided to investigation team. The pertinent information extracted from the provided documents is summarized below:

Registration Marking	4L-GNI
Make and Model	IL-76TD
Manufacturer and date of Manufacture	Tashkent Aviation Production Association under V.P. Chkalov, 29 th May, 1984
Manufacture Serial No (MSN)	0043454546
Total Flight Hours / Cycles	8357 / 3373
Certificate of Airworthiness (C of A)	▪ C of A # 250 / 03 was issued by Georgian Regional Development & Infrastructure Ministry on 14 th May, 2010 ▪ C of A valid till 15 th May, 2011
Aircraft Registration	▪ Registered in Georgia ▪ Certificate of Registration No 250 / 03 dated 2 nd February, 2010
Operator	▪ Sunway Air Carrier Georgia ▪ Certificate of operator was valid till 3 rd February, 2011

1.6.2. The service life of aircraft before first overhaul was defined 20 years or 7000 / 3500 flying hours / cycles in accordance with ILYUSHIN (IL) Public Corporation decision # 76TD-022 / 3

dated 2nd June, 2003. According to the information provided, the aircraft flew 1357 hours before the first overhaul.

1.6.3. The assigned calendar based service life of the aircraft expired on 29th May, 2004.

1.6.4. The service life of aircraft according to Bulletin # 2080БЭ-Г was set at 13000 / 4500 hours / cycles or 20 years. It is pertinent to mention that the extension of service life after expiration of its assigned calendar based life was without the approval of the manufacturer.

1.6.5. The periodical ground technical service of the mishap aircraft and engines was conducted by the "Airline Transport Incorporation FZC" according to the Agreement No 11-10 dated 20th October, 2010 which is situated on Osh, Kyrgyziya and Sharjah, UAE airports.

1.6.6. The last periodic maintenance of the aircraft was conducted on 13th November, 2010 in the city of Osh, Kyrgyziya.

1.6.7. **Engine Life Extension Procedure.** The life extension of D-30KP engine can only be granted by the manufacturer (NPO Saturn) irrespective of the engine last overhaul facility. The procedure for obtaining life extension of type engine is defined by the manufacturer, NPO Saturn Bulletin # 1809БЭ-Г. The pertinent information from this bulletin is summarized below:

1.6.7.1. The operator is required to forward the request for calendar service life extension to NPO Saturn before the expiry of the assigned life.

1.6.7.2. NPO Saturn on receipt of such request will check the engine documents to ensure that no such parts for which life extension is prohibited are installed on the engine.

1.6.7.3. NPO Saturn after being satisfied that the extension can be granted defines the work package required to be performed prior to extension and permits the operator to perform the defined work package.

1.6.7.4. The operator is to get the defined work package performed and make a record in section 12.2 of the engine log book.

1.6.7.5. The operator is to issue a "Technical Condition Report" for the engine based on the results of the defined work package. The report is to be signed by the specialist who carried out the work package. The certificate number of the individual signing the report must be mentioned in the report.

1.6.7.6. The operator will forward the signed "Technical Condition Report" to NPO Saturn and the copy will also be forwarded to the organization which conducted the overhaul of the engine.

1.6.7.7. NPO Saturn after analyzing the report authorizes the life extension through a telegram to the operator.

1.6.7.8. After receipt of the authorization telegram, the operator submits the "Technical Condition Report" to Civil Aviation Administration.

1.6.7.9. The availability of the record with Civil Aviation Administration of its approval of the "Technical Condition Report" is the final permission for the operator for extension of calendar life.

1.6.7.10. The first signed copy of the "Technical Condition Report" along with "NPO Saturn" telegram is to be retained in engine log book, the counterpart is to be sent to "NPO Saturn" and a carbon copy is to be submitted to Federal State Unitary Enterprise "State Scientific-Research Institute of the Civil Aviation (in case the aircraft is registered in Russian Federation).

1.6.8. **Engines' Information.** The engine log books were not provided by the Operator and only copies of log book pages were made available. The pertinent information extracted from the provided aircraft and engine documents is summarized in table below:

	ENGINE # 1	ENGINE # 2	ENGINE # 3	ENGINE # 4
Engine Type	Д-30КП	Д-30КП	Д-30КП	Д-30КП
Manufacturer S No.	0304401801513	0304404112859	0304404112862	0304404011876
Date of Manufacturing	26-01-1978	25-12-1981	25-12-1981	30-12-1980
Number of Overhauls	4	4	5	3
Date & Place of the Last Overhaul	4/7/2002 PM	21-08-2001 123AP3	21-09-2000 123AP3	26-10-2000 BAP3-400
Initial Defined Life (hours/cycles)	9000 / 4620	9000 / 4620	9000 / 4620	6500 / 3375
Between Overhauls Life (hours/cycles)	3000 / 1540	2000 / 1025	2000 / 1025	1653 / 947
Used Life Since New (hours/cycles)	8577 / 3786	7669 / 2967	6734 / 2700	6055 / 2877
Used Life Since Last Overhaul (hours/cycles)	2674 / 1275	1184 / 467	1468 / 561	1209 / 451
Remaining Life from Initial Defined (hours/cycles)	435 / 838	1331 / 1653	2266 / 1920	445 / 498
Between Overhauls Remaining Life (hours/cycles)	326 / 269	816 / 558	532 / 464	444 / 496
Calendar Service Limit	4-7-2011	21-08-11	21-09-11	26-10-11

1.6.8.1. It is worth mentioning here that numbers found on Engine # 4 Inlet Guide Vane and the 1st Stage LP Compressor Disk, did not belong to Engine S. No. 0304404011876 (The engine installed at position No. 4 as per aircraft records). These parts belonged to Engine S No. 0304402801646 (date of manufacturing 27-12-1981) as per NPO Saturn database. Since, it was impossible to recognize the numbers of the mishap aircraft engines as they were damaged by high temperatures, therefore, the history of the Engine (S No. 0304402801646) will also be discussed in following paragraphs. The following paragraphs will present information obtained from NPO Saturn database and highlight the differences with the information obtained from operator documents.

1.6.9. Engine # 1 (S No. 0304401801513) History

1.6.9.1. The date of manufacture of the engine was 27th January, 1978.

1.6.9.2. The former owner of the engine was Avian-Invest and former operator was Volga-Dnepr.

1.6.9.3. The life between-overhaul was 2000 hours / 6 years. This life could further be prolonged up to 3000 hours after overhaul at 2000 hours, over interval of 333 hours (Bulletin # 670 БЭ-Г).

1.6.9.4. The engine had undergone 5 overhauls after completion of between-overhaul service life. The operator documents reflected that the engine had undergone 4 overhauls.

1.6.9.5. The last overhaul was performed by "NPO Saturn" on 31st May, 2002. The engine had completed 3563 / 5159 hours (since previous overhaul / since new) and 1014 / 2009 cycles before this overhaul.

1.6.9.6. After the above stated overhaul the guaranteed service life was set at 2000 hours / 6 years, service life on technical condition evaluation was set at 3000 hours and total service life since new was set at 9000 hours / 4620 cycles. NPO Saturn granted service life enhancement till 2333 hours and Calendar service life till 04th January, 2009 vide NPO Saturn telegram dated 17th June, 2008. Subsequently life was granted till 2666 hours, Calendar service life till 04th July, 2009 vide NPO Saturn telegram dated 26th December, 2008.

1.6.9.7. The engine was removed from aircraft # 76493 on 1st April, 2009 and was stored as reserve. The running time of the engine at removal was 2666 hours and 1282 cycles.

1.6.9.8. NPO Saturn did not have any information about operation, maintenance and prolongation of between-overhaul hours / cycles life or calendar service life after 1st April, 2009.

1.6.9.9. The section 6.2 of the engine log book (resource, service life) had entry of service life extended up to 4th July, 2009 by NPO Saturn on 26th December, 2008. However, it was not supported by "Technical Condition Report", NPO Saturn telegram and record of log book section 12.2.

1.6.9.10. According to the information provided by the operator as on 13th November, 2010 this engine had between-overhaul remaining life of 326 hours / 269 cycles and its calendar service life were expiring on 4th July, 2011. The operator, however, could not provide "Technical Condition Report", NPO Saturn telegrams and relevant log book records in support of service life extensions after 1st April, 2009.

1.6.9.11. Based on the available evidence it was established that at the time of the crash this engine (S No. 0304401801513) was being operated beyond the service life established by NPO Saturn.

1.6.9.12. The ground testing of the engine was performed on 13th November, 2010 in the city of Osh. The test document shows no deviation in performance of the engine. Oil analysis and parameters of inter shaft bearings were also normal.

1.6.10. Engine # 2 (S No. 0304404112859) History

1.6.10.1. The date of manufacture of the engine was 27th December, 1981 (same as in operator documents).

1.6.10.2. The former operator of the engine was Aeroflot, Sheremetyevo Airport.

1.6.10.3. The engine had undergone 4 overhauls after completion of between-overhaul service life.

1.6.10.4. The last overhaul was performed on 21st August, 2001 in Staraya, Russia. The engine had completed 2276 / 6485 hours and 614 / 2500 cycles before overhaul.

1.6.10.5. After the above stated overhaul the guaranteed service life was set at 2000 hours / 6 years, service life on technical condition evaluation was set at 2515 hours and total service life since new was set at 9000 hours / 4620 cycles.

1.6.10.6. The engine was removed from aircraft # 76785 on 31st January, 2009 and was stored as reserve. The running time of the engine at removal was 514 / 6999 hours and 104 / 2604 cycles.

1.6.10.7. NPO Saturn did not have any information about operation, maintenance and prolongation between-overhaul hours / cycle's life or calendar service life after 31st January, 2009.

1.6.10.8. The section 6.2 of the engine log book (resource, service life) had entry of between-overhaul life extended up to 21st August, 2001 referring "Technical Condition Report" dated 3rd August, 2010. However, "Technical Condition Report", NPO Saturn telegram and record of log book section 12.2 were not made available by the operator.

1.6.10.9. According to the information provided by the operator as on 13th November, 2010 this engine had between-overhaul remaining life of 816 hours / 558 cycles and its calendar service life were expiring on 21st August, 2011. The operator however, could not provide "Technical Condition Report", NPO Saturn telegrams and relevant log book records in support of service life extensions after 31st January, 2009.

1.6.10.10. Based on the available evidence it was established that at the time of the crash this engine (S No. 0304404112859) was being operated beyond the service life established by NPO Saturn.

1.6.10.11. The ground testing of the engine was performed on 13th November, 2010 in the city of Osh. The test document shows no deviation in performance of the engine. Oil analysis and parameters of inter shaft bearings were also normal.

1.6.11. Engine # 3 (S No. 0304404112862) History

1.6.11.1. The date of manufacture of the engine was 27th December, 1981.

1.6.11.2. The former owner of the engine was Avia-Invest, and the former operator was Volga-Dneper.

1.6.11.3. The engine had undergone 5 overhauls after completion of between-overhaul service life.

1.6.11.4. The last overhaul was performed on 20th January, 2001 in Staraya, Russia. The engine had completed 1509 / 5207 hours and 695 / 2139 cycles before overhaul.

1.6.11.5. After the above stated overhaul the guaranteed service life was set at 2000 hours / 6 years, service life on technical condition evaluation was set at 3000 hours and total service life since new was set at 9000 hours / 4620 cycles.

1.6.11.6. The between-overhaul life of the engine was not prolonged, however calendar service life was prolonged till 21st September, 2008 vide NPO Saturn telegram # 240 / 1946T dated 06th November, 2007.

1.6.11.7. The engine was removed from aircraft # 76493 on 10th August, 2008 and was stored as reserve. The running time of the engine as on 29th July, 2008 was 1218 / 6425 hours and 473 / 2612 cycles.

1.6.11.8. NPO Saturn did not have any information about operation, maintenance and prolongation between-overhaul hours / cycle's life or calendar service life after 10th August, 2008.

1.6.11.9. The section 6.2 of the engine log book (resource, service life) had entries of between-overhaul life extended up to 21st September 2007, 21st September 2008, 21st September 2010 and 21st September 2011 referring "Technical Condition Reports" dated 30th October 2006, 30th October 2007, 17th October 2008, 9th March 2010 and 11th September 2010 respectively. However, "Technical Condition Reports", NPO Saturn telegrams and records of log book section 12.2 were not made available by the operator.

1.6.11.10. Based on the available evidence it was established that at the time of the crash this engine (S No. 0304404112862) was being operated beyond the service life established by NPO Saturn.

1.6.11.11. The ground testing of the engine was performed on 13th November, 2010 in the city of Osh. The test document shows no deviation in performance of the engine. Oil analysis and parameters of inter shaft bearings were also normal.

1.6.12. Engine # 4 (S No. 0304404011876) History

1.6.12.1. The date of manufacture of the engine was 11th December, 1980.

1.6.12.2. The former operator of the engine was Aviation Complex Baikal-Aerogrooz.

1.6.12.3. The engine had undergone 3 overhauls after completion of between-overhaul service life.

1.6.12.4. The last overhaul was performed on 26th October, 2000.

1.6.12.5. After the above stated overhaul the guaranteed service life was set at 1653 hours / 6 years and total service life since new was set at 6500 hours / 3375 cycles.

1.6.12.6. The prolongation of between-overhaul life and calendar service life as set in above stated overhaul was not issued by NPO Saturn for this engine.

1.6.12.7. The engine was put out of service on 1st May, 2004 after completion of its assigned life. The engine had completed 1638 / 6485 hours 501 / 2929 cycles at the time it was put out of service.

1.6.12.8. NPO Saturn did not have any information about operation, maintenance and prolongation between-overhaul hours / cycle's life or calendar service life after 1st May, 2004.

1.6.12.9. The section 6.2 of the engine log book (resource, service life) had entries of between-overhaul life extended up to 26th October, 2010 and 26th October, 2011 referring "Technical Condition Reports" dated 20th May, 2010 and 19th July, 2010 respectively. However, "Technical Condition Reports", NPO Saturn telegrams and records of log book section 12.2 were not made available by the operator.

1.6.12.10. According to the information provided by the operator as on 13th November, 2010 this engine had between-overhaul remaining life of 444 hours / 496 cycles and its calendar service life were expiring on 20th October, 2011. The operator however, could not provide "Technical Condition Report" and NPO Saturn telegrams in support of service life extensions.

1.6.12.11. Based on the available evidence it was established that at the time of the crash this engine (S No. 0304404011876) was being operated beyond the service life established by NPO Saturn.

1.6.12.12. The ground testing of the engine was performed on 13th November, 2010 in the city of Osh. The test document shows no deviation in performance of the engine. Oil analysis and parameters of inter shaft bearings were also normal.

1.6.13. Engine (S No. 0304402801646) History

1.6.13.1. The date of manufacture of the engine was 29th May, 1978.

1.6.13.2. The former owner of the engine was Aviakon Tsitotrans.

1.6.13.3. The engine had undergone 4 overhauls after completion of between-overhaul service life.

1.6.13.4. The last overhaul was performed on 7th April, 2000 in Staraya, Russia. The engine had completed 2359 / 5080 hours and 655 / 1976 cycles before overhaul.

1.6.13.5. After the above stated overhaul the guaranteed service life was set at 2000 hours / 6 years, service life on technical condition evaluation was set at 3000 hours and total service life since new was set at 9000 hours / 4620 cycles.

1.6.13.6. The prolongation of between-overhaul life and calendar service life as set in above stated overhaul was not issued by NPO Saturn for this engine.

1.6.13.7. The engine was removed on 10th March, 2004 and was stored as reserve. The engine had completed 2759 / 7012 hours and 803 / 2779 cycles prior to removal.

1.6.13.8. NPO Saturn did not have any information about operation, maintenance and prolongation of between-overhaul hours / cycle's life or calendar service life after 10th March, 2004.

Take off Mass

1.6.14. At JIAP Karachi the aircraft was serviced with 24 tons of fuel by Shell and Chevron and therefore, had about 74 tons of fuel onboard before start up. After refuelling the aircraft was loaded with 30.5 tons of goods. The take-off mass was approximately 197 tons with CG at 30% Mean Aerodynamic Chord (MAC). This is an approximate calculation because exact data about the remaining fuel after landing at Karachi was not available. The mathematical modelling by IL specialists shows that FDR recorded data and modelling data correspond to take-off mass of 195 tons and CG at 30% MAC. The FCOM limits maximum taxing mass to 191 tons and take off mass to 190 tons which means that aircraft was above FCOM recommended taxi and takeoff mass.

1.6.15. **Type of Fuel Used.** The aircraft was refuelled with JET A-1 fuel. The Laboratory analysis of the fuel from supplier source was conducted; the fuel test laboratory report did not reveal any abnormality.

1.7. **Meteorological Information.** The detailed weather information at the time of accident is mentioned below :-

Time	Visibility	Wind	Outlook	Temperature	QNH
2030 UTC	6 Km	360 ⁰ 04 Kts	Partly Cloudy	14 ⁰	1013 hpa
2100 UTC	5 Km	010 ⁰ 04 Kts	Haze	13 ⁰	1014 hpa

1.8. **Aids to Navigation.** At the time of accident, the serviceability of navigational aids onboard the mishap aircraft could not be ascertained, however no problem was reported / documented by the flight crew at JIAP, Karachi.

1.9. **Communication.** While on ground and during take-off as well, the flight crew had radio contact with ATC which indicated that communication aids onboard were serviceable.

1.10. Aerodrome Information

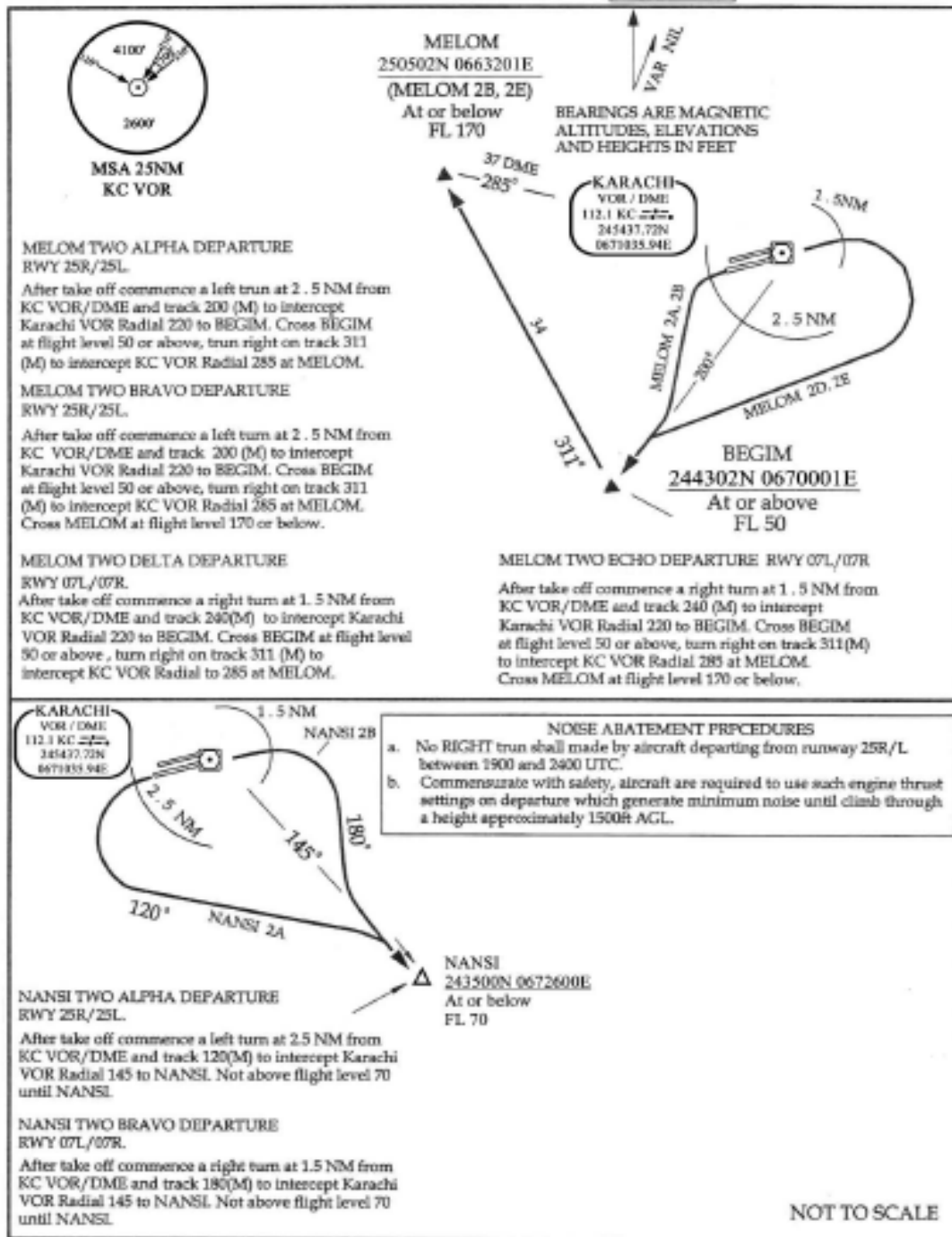
1.10.1. The JIAP Karachi Standard Departure Chart for "MELOM - 2A" is appended on following page (The mishap aircraft was cleared for "MELOM - 2A" departure):

STANDARD DEPARTURE CHART
INSTRUMENT (SID) - ICAO

TRANS LEVEL FL 50
TRANS ALT 3000'

TWR 118.3
121.8
APP 125.5
121.3
ATIS 126.7

KARACHI/Jinnah Int'l
MELOM 2A, 2B, 2D, 2E
NANSI 2A, 2B



1.10.2. The JIAP Karachi detailed aerodrome data is appended below:

OPKC AD 2.12 RUNWAY PHYSICAL CHARACTERISTICS

Designations RWY NR	True bearing	Dimensions of RWY (M)	Strength (PCN) and surface of RWY and SWY	THR coordinates	THR elevation and highest elevation of TDZ of precision APP RWY
1	2	3	4	5	6
07L	074.29	3200 x 46	54/R/C/X/U CONCRETE Able for ACFT having Max TKOF Weight Aprox 42000LBS (19TON)	245416.90N 0670851.02E	THR 23.50M / 77FT
25R	254.29			245444.69N 0671040.84E	THR 30.40M / 100FT
07R	074.29	3400 x 45	87/R/B/W/T CONCRETE SWY bitumen	245402.15N 0670833.56E	THR 21.62M / 71FT
25L	254.29			245431.79N 0671030.20E	THR 27.25M / 89FT

Designations RWY NR	Slope of RWY/SWY	SWY dimension (M)	CWY dimension (M)	Strip dimension (M)	Obstacle Free Zone
7	8	9	10	11	12
07L	0.2% UP	305 x 46	914	3931 x 305	-
25R		305 x 46	580		
07R	0.168% UP	305 x 45	870x150	4753 x 150	-
25L		301 x 45	483X150		

Remarks: RWY 07R RESA – 180M X 120M

OPKC AD 2.13 DECLARED DISTANCES (M)

Designations RWY NR	TORA	ASDA	TODA	LDA	Remarks
1	2	3	4	5	6
07L	3200	3500	4114	3200	-
25R	3200	3505	3780	3200	-
07R	3400	3705	4270	3400	-
25L	3400	3701	3883	3400	-

OPKC AD 2.14 APPROACH AND RUNWAY LIGHTS

Designations RWY NR	APCH LGT type LEN INTST	THR LGT colour WBAR	VASIS (MEH) PAPI	TDZM LGT LEN	RWY Centre line LGT Length, spacing, colour, INTST	RWY EDGE line LGT Length, spacing, colour, INTST	RWY End LGT spacing colour WBAR	SWY LGT LEN (M) colour	Remarks
1	2	3	4	5	6	7	8	9	10
07L	SALS LIH	GREEN	PAPI/ Left 3*	-	-	3200 M, 60 M,	RED	-	Strobe LGT
25R	PALS LIH	GREEN	PAPI/ Left 3*	-	-	WHITE LIH	RED	-	-
07R	SALS LIH 300 M	GREEN	PAPI/ Both sides 2.91*	-	3400M 30 M white LIH	3400 M, 60 M, white LIH	RED	-	-
25L	PALS LIH 900M	GREEN	PAPI/ Both sides 2.98*	900 M	Last 900 M alternate white/red	Last 600 M yellow	RED	-	Flashers

OPKC AD 2.18 ATIS COMMUNICATION FACILITIES

Service designation	Call sign	Frequency	Hours of operation	Remarks
TWR	KARACHI Tower	118.3 MHZ	H24	Primary
		118.8 MHZ	H24	Secondary
		121.5 MHZ	H24	Emergency
APRON	Karachi Ground	121.6 MHZ	H24	Primary
		118.4 MHZ	H24	Secondary
		121.8 MHZ	H24	Vehicle
		123.0 MHZ	H24	
ATIS	ATIS	126.7 MHZ	H24	
APP	Karachi APP	125.5 MHZ	H24	Primary
	Karachi APP	121.3 MHZ	H24	Secondary
	Karachi APP	121.5 MHZ	H24	Emergency
BS	Radio	830 KHZ	HX	0130-1900 HR
BS	Pakistan	1450 KHZ	HX	Variable SKED

OPKC AD 2.19 RADIO NAVIGATION AND LANDING AIDS

Type of aid. CAT of ILS (VAR VOR/ILS)	ID	Frequency	Hours of operation	Site of transmitting antenna coordinates	Elevation of DME transmitting antenna	Remarks
1	2	3	4	5	6	7
GP 25R	Dots/Dashes	334.4 MHZ	H24	245448.11N 0671029.32E	-	-
LLZ 25R	IKC	110.1MHZ	H24	245413.64N 0670837.68E	-	-
ILS CAT I (1°E/1995)					-	-
LOM	KO	235 KHZ	H24	245547.74N 0671449.89E	-	3.9 NM FM THR
MM		75 MHZ	H24	245453.00N 0671107.98E	-	0.57 NM FM THR
GP/DME 25L	Dots/Dashes	333.2 MHZ CH34X	H24	245432.35N 0671013.96E	-	2.98 ⁵ RDH 72 FT
LLZ25L ILS CAT I (1°E/1995)	IQA	109.7 MHZ	H24	245359.00N 0670820.94E	-	-
NDB	KC	271 KHZ	H24	245523.80N 0670936.28E		Coverage 500NM
VOR / DME	KC	112.1 MHZ CH 58X	H24	245437.72N 0671035.94E	37.83M	Coverage 200NM Radial 300 un-reliable

1.10.3. All facilities available at JIAP, Karachi at the time of accident were serviceable.

1.11. Flight Recorders.

1.11.1. **Flight Data Recorder (FDR).** The aircraft was equipped with FDR system MSRP-64 containing protected parameters information data storage “MLP-14-15”, placed in the fuselage tail section. The system is capable of recording flight parameters for the last 25 hours. The FDR was identified and recovered from the crash site. The recorder was taken to IAC laboratory in Moscow, Russia by the investigation team members. As per the IAC Report all the recorded data of FDR was successfully downloaded and recovered including the data of the mishap flight.

1.11.2. **Cockpit Voice Recorder (CVR).** There are two CVRs (MS 61B) installed on the aircraft IL-76 and are placed in the fuselage. One CVR is the main and the second serves as reserve. The reserve CVR turns “ON” only in case of ending or breaks in sound medium on the main CVR or in case of its failure. The voice data processing was conducted in the IAC laboratory using the

SAPPHIRE-MAK software. The analysis of recorded data from the first and the second CVR showed that the second CVR was the main. However, no voice data for the mishap flight could be retrieved from the medium of both the CVRs because of post accident damage.

1.11.3. The detailed FDR and CVR analysis report was provided by IAC.

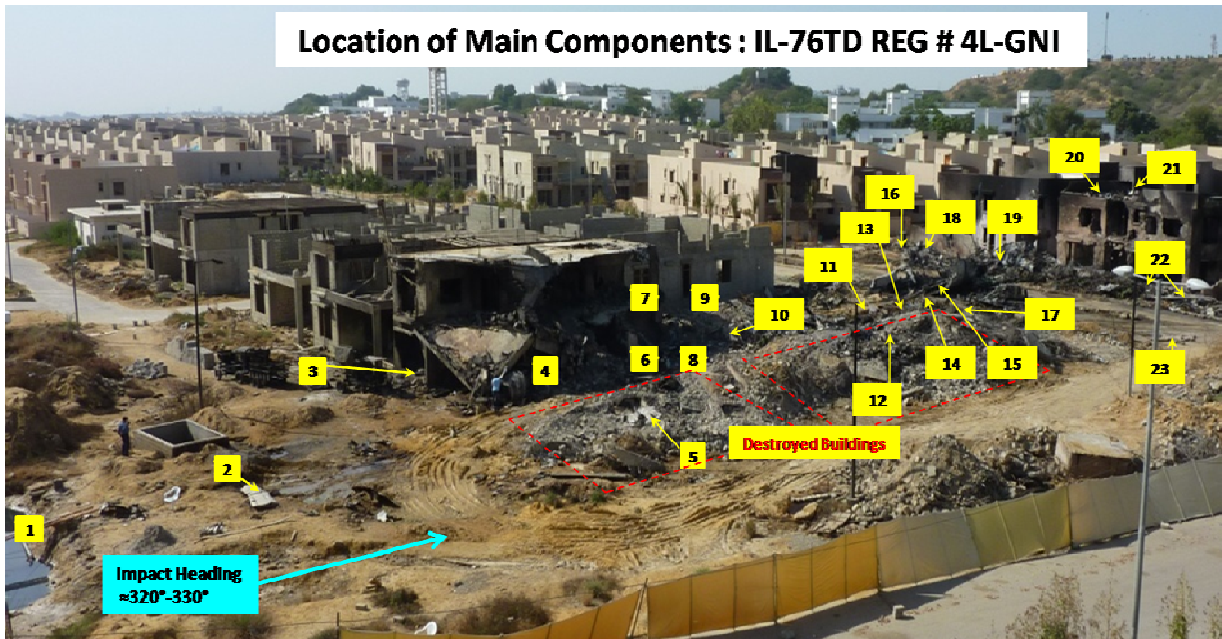
1.12. **Wreckage and Impact Information.** Most of the wreckage was located in an area approximately 150m (long) x 60m (wide). The aircraft crashed on under construction buildings and was in right bank before the impact. At the time of impact, aircraft heading was approximately 320-330 degrees. As a result of the aircraft's collision with the ground, under construction buildings and subsequent fire almost entire aircraft structure was destroyed. The following pictures explain location and condition of major parts as found after ground impact. The details are presented in the wreckage analysis report.



Aircraft crash site and wreckage

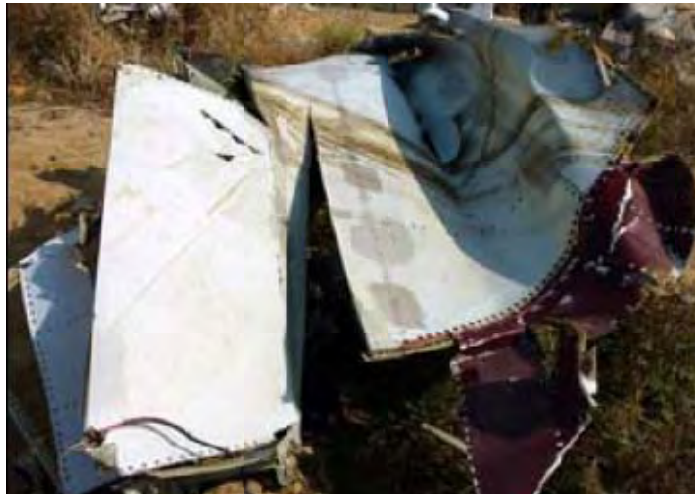


Location of engines



1.12.1. The close up photographs of major components as annotated in above picture (Location of Main Components : IL-76TD Reg # 4L-GNI) are as follows:

#1. Part of right outer wing



#2. Part of right aileron



#3. Right wing lower panel



#4. Engine # 4
&
Engine # 3



#5. Vertical
Stabilizer
panel



#6. Part of right
flap with its
track



#7. Right flap fragment



#8. Left side crew cabin transparency frame fragment



#9. Part of right middle wing with rear spar



#10. Right main landing gear



#11. Nose landing gear



#12. Wing centre section lower panel from middle to the front spar



#13. Cargo (tents)



#14. Rear centre part of the stabilizer





#15. Fuselage tail section with control rods



#16. Left main landing gear



#17. Flap Track



#18. APU



#19. Engine # 1 & 2



#20. Centre wing section
upper and lower
panels from the
middle to the rear
spar



#21. Flap track



#22. Left wing fragments



#22. Left wing fragments



#23. Upper panel fragments
of left outer wing



1.13. **Medical and Pathological Information.** The body parts / remains of operating crew were identified through DNA testing at Bio Medical and Genetic Institute KRL Hospital, Islamabad and handed over to Ukraine and Russia representatives at Islamabad, Pakistan for onward despatch to their respective country. As a result of biochemical studies of the remains of the crew, alcohol, drugs and psychotropic substances were not found. The accident is not associated with health conditions of the flight crew. The SIB report includes all necessary details.

1.14. **Fire**

1.14.1. The in-flight fire occurred after uncontained failure of Engine # 4 during climb. Most probably failed parts of the engine damaged the right wing and caused fuel ignition. It was impossible to evaluate the fire suppression measures undertaken by the crew using the FDR record. It is pertinent to mention that as per IL-76 system design, on initiation of Fire Alarm System warning the Main Fire Extinguishing system turns on automatically.

1.14.2. According to the FDR information a single “fire in the engine” event registration provided evidence of in-flight fire. The destruction of the aircraft after ground impact caused fuel outflow and fire on the ground which was suppressed by fire fighters teams.

1.14.3. An amateur video also provided evidence that fire occurred onboard during climb after takeoff and continued till its impact with ground.



The amateur video record of mishap aircraft in-flight fire

1.15. **Survival Aspects.** The aircraft impacted the ground (under construction residential complex of houses) at airspeed of about 300 kph and was exposed to extensive ground fire. Hence there was no chance of survival of persons onboard the aircraft.

1.16. **Tests and Research.** Flight data recorder was analysed and performance simulation of the aircraft was conducted. Material analysis of failed parts was also conducted.

1.17. **Organizational and Management Information.** The SUNWAY Company had the Operator Certificate (# 042) issued by the Ministry of Development of Infrastructure of Georgia along with the United Transport Administration on 3rd February, 2011. Organization and control of flights, aircraft maintenance and crew training were conducted by the Georgian Aviation Administration. The aircraft was used by the operating company in accordance with the lease contract between the plane owner and air carrier. Accordingly, the aircraft maintenance was the responsibility of SUNWAY.

1.18. **Additional Information.** Georgian Aviation Administration issued Airworthiness Certificate not being the designer of the aircraft, therefore, in accordance with Annexes 6 & 8 to the International Civil Aviation Convention:

1.18.1. Georgian Aviation Administration must abide by the designer requirements when putting the aircraft into the state register.

1.18.2. Notification on inclusion of the aircraft into the state register must be provided to the designer.

1.18.3. The status of continuing airworthiness of the aircraft and engines must be determined in accordance with the requirements set forth by the designer.

1.19. **Useful Investigation Techniques.** No unique (special) methods were used during the investigation. The investigation was conducted using standard procedures.

2. ANALYSIS

2.1. The crew arrived at the airport on 27-11-2010 at 1900 UTC. The weather conditions were within limits to undertake the flight. As per provided data the crew had enough flight experience to conduct the flight. All crew members had valid certificates. The flight crew was provided no less than 8 hours rest before flight. The information about crew members' pre-training for the route of the flight was not provided to IAC / SIB. In case of out of base operation, the aircraft commander was to ensure the pre-training of his crew.

2.2. After completion of necessary pre flight requisites by the flight crew, the cockpit crew contacted Karachi airport at 20:14:53 UTC and informed about their readiness to start for Khartoum and parked at stand No. 68. After receiving the permission from the air traffic controller, the crew started the engines. The ramp heading was about 039°.

2.3. Before starting the engines, the crew unlocked the handlebars, completed the check up of the steering system and put the stabilizer in position -5° (on pitching). The crew followed the FCOM for checking aircraft steering system before starting the engines.

2.4. The engines were started between 20:21:50 to 20:24:20 UTC (Engine # 1, # 2, # 3, # 4 respectively). The auxiliary power unit was used to start the engines and was switched off after starting Engine # 4. Engines starting order was made in accordance with FCOM.

2.5. At 20:24:20 UTC almost right after Engine # 4 was set at idle power, the crew extended the high-lift devices in take-off position. The flaps extension was 30°. The FDR MCPП-64 system does not register slats position. The FDR registered parameter "The slats extended", only confirms that the slats were in extended position. Most probably the slats extension was 14° because the high-lift devices position 14° / 30° is in accordance with FCOM recommendations to take-off from the concrete runway.

2.6. Before Engine # 4 start, the FDR registered parameter "Engine Anti Ice System ON". After engine # 4 was set idle power air bleeding for inlet guide vane heating was switched off. The temperature at JIAP, Karachi airport at the moment of starting the engines was about +14°C. While starting the other engines the crew did not turn on the inlet guide vane heating. The FCOM of "IL-76TD" aircraft requires that the inlet guide vane should be warmed up when temperature is below +10°C.

2.7. The FDR analysis of the engines starting procedure of previous flights was carried out. The analysis showed that the crew had some difficulties while starting Engine # 4 during previous flights. The FDR MCPП-64 system of the aircraft contained information about flights from 21-11-2010 to 28-11-2010. It was noted that on 22nd and 25th November, 2010 the Emergency Stop Valve was used to shut down Engine # 4 providing evidence that there was some problem with the engine during starting. After shut downs, the crew opened Air Bleeding for Inlet Guide Vane heating for restart of Engine # 4. In all cases the waiting time interval between re-start attempts was less than specified by the FCOM.

2.8. It was not possible to exactly determine the reason of abnormal starts of Engine # 4 based on the available information. However, the most probable reason for interrupting Engine # 4 starts was hung starts.

2.9. The most probable reason of abnormal starts of the Engine # 4 was reduction of compressor efficiency because of wear of blades. The service wear of blades increases axial and radial clearances and blade surface becomes rough, thus reducing the compressor efficiency. With the inlet guide vanes heating mode on the amount of air through the compressor's first stages increases thus improving the start reliability. This indirectly proves that Engine # 4 had considerable wear of compressor blades.

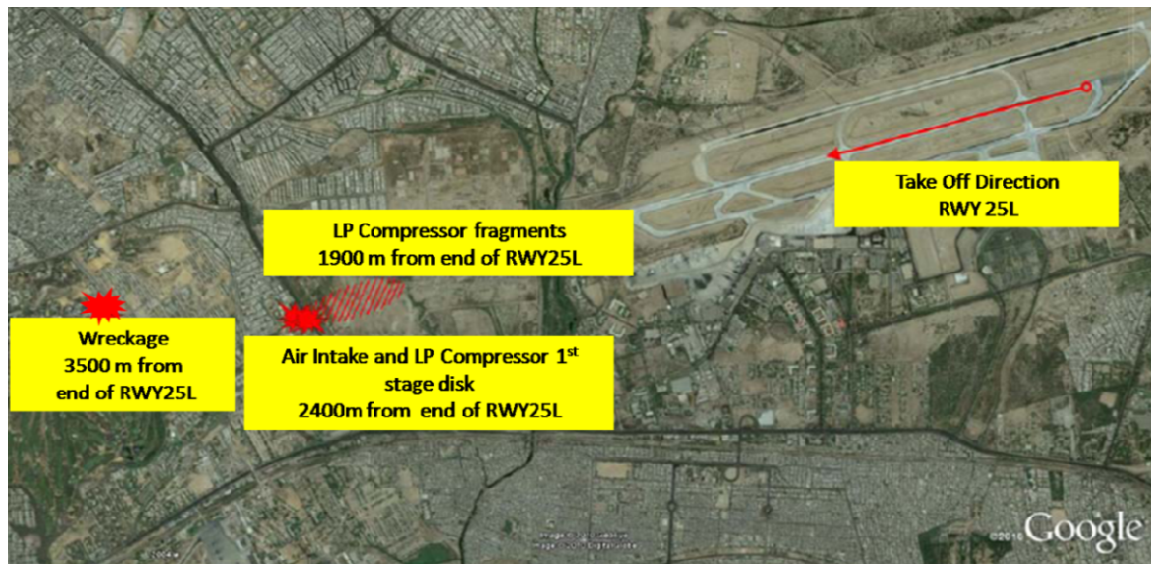
2.10. The take-off run began at 20:43:05 UTC and at 20:43:53 UTC at a speed 274 km/h the elevator deflection for pitching was registered. Within 3 seconds the elevator was deflected in -3° position (for pitching). The pitch angle at that time corresponds to nose gear lift off. The aircraft

speed was significantly higher (36 km/h) than the rotation speed (VR) recommended by FCOM. It is possible that speed was increased by pilots to match the overweight condition.

2.11. The FDR did not have provision for recording the undercarriage position. However, wreckage analysis proved that the landing gears were in retracted position at the time of impact.

2.12. At 20:44:27 UTC the aircraft was making left bank with the angle -8° , the altitude had increased to 90m, the speed was 320 km/h. At that moment the crew reported to the flight controller: "1255, Good-day MGC 22..." The phrase had not been completed and the radio contact was broken. Incorrect information about the flight number (real number was 4412) and radio contact interruption might have been caused by the appearance of the critical situation onboard.

2.13. At 20:44:30.5 UTC the rotational speed of high-pressure compressor's rotor of Engine # 4 spontaneously went down along with the alarm "Fire of the engine nacelle" and "Fire onboard". At the moment of the Engine # 4 failure the aircraft was making a left turn with -12° bank, altitude was about 100m, speed was 325 km/h, flaps were extended at 30° , slats were extended and undercarriage was retracted. Other three engines were working at take-off power. The aircraft at that moment was 2 km away from the runway 25L end. It may be noted that fragments of Engine # 4 were located at a distance of 1900-2400m from runway 25L end. All these fragments had only mechanical damages and no signs of fire. This information proves that Engine # 4 disintegration occurred during climb after take-off.



Engine # 4 fragments between the end of Runway 25L and crash site

2.14. Approximately one to 2 seconds after Engine # 4 failure rapidly increasing right bank ($8-9^\circ$ /second) was recorded, that consequently caused the right turn of the aircraft.

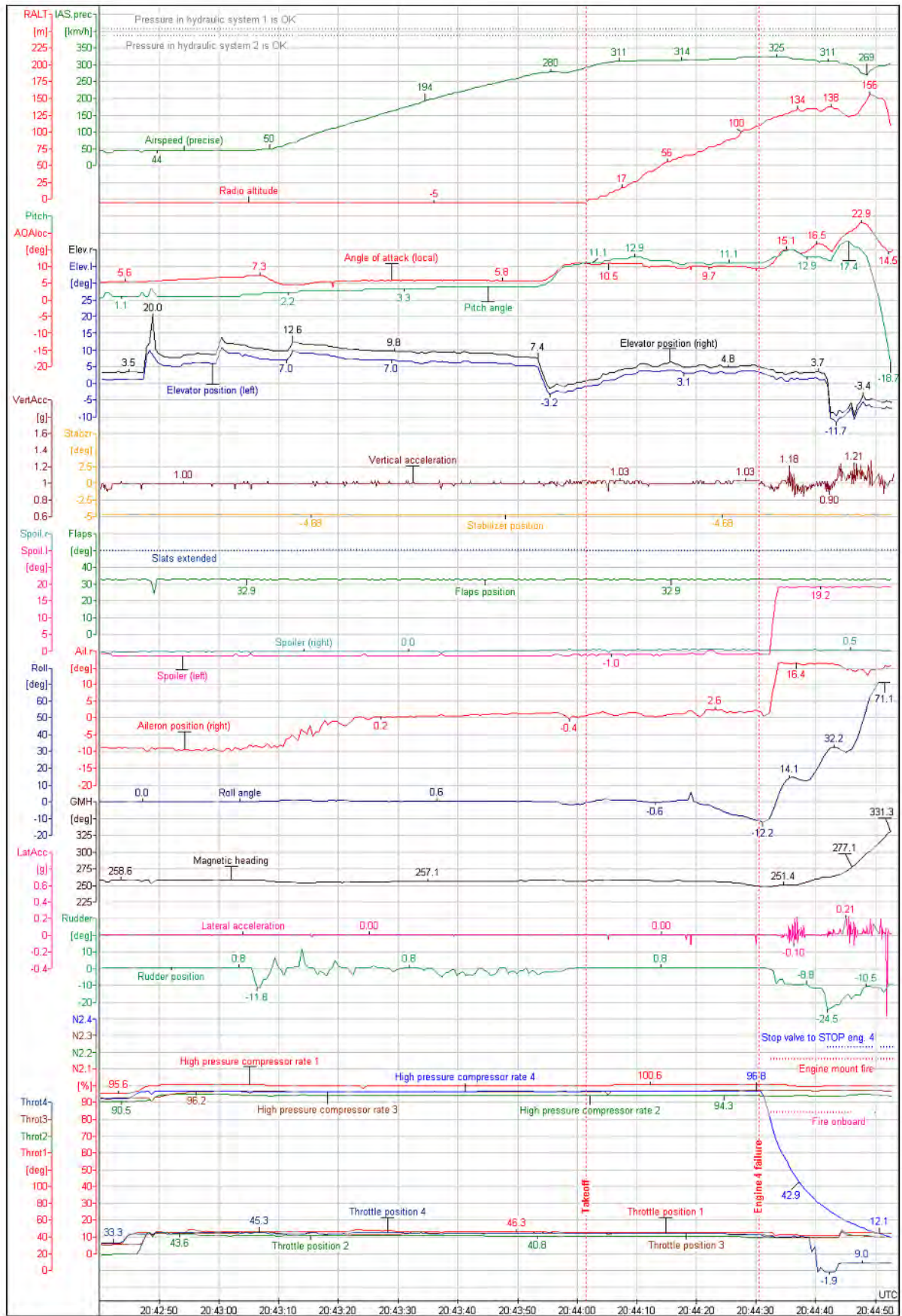
2.15. Approximately 1.5 seconds after Engine # 4 disintegration FDR record indicated that the ailerons and spoilers had been deflected on maximum angle to compensate the right bank. At the same time with ailerons deflection the pilot deflected the rudder to -9° (to the left). By 20:44:36 the right bank reached 14.7° and the increase stopped for a short while. In 2 seconds the angle of the bank decreased to 12.4° .

2.16. The Engine # 4 throttle was put to "idle power" 8 seconds after engine RPM drop and was switched off using emergency stop valve 3 seconds after putting to idle.

2.17. All inputs of the flight controls were to compensate the right bank of the plane.

2.18. Most probably because of rapid development of the critical safety situation, the crew did not report the fire onboard to ATC. It may be noted that main fire extinguishing system onboard IL-76TD aircraft starts automatically after fire alarm.

- 2.19. After 20:44:39 UTC onwards despite fully deflected ailerons and spoilers to create left bank, the aircraft continued in right bank. In next 4 seconds right bank had increased to 32° while the recorded deflection of the rudder was -24° (to the left) and elevator to -10° for pitch up.
- 2.20. The recorded data also shows that after attaining 140m altitude the aircraft altitude started decreasing. The recorded increase in radio altitude during the last phase flight was a result of incorrect measurement of this parameter when the aircraft was in a bank above 30°.
- 2.21. By 20:44:51 UTC the bank angle became 71° to the right. The aircraft continued moving to right from the runway line and hit the ground and under construction buildings at 20:44:53 UTC.
- 2.22. **Flight & Wreckage Analysis.** The wreckage analysis report is summarized in following paragraphs:
- 2.22.1. At the time of impact aircraft heading was approximately 320-330°. The wreckage was located in approximately 150m (long) x 60m (wide) area. Most of the mishap aircraft structure was extensively damaged due to impact loads and fire.
- 2.22.2. The right wing fragments of the mishap aircraft were found in the beginning of the aircraft wreckage, indicating that right wing impacted the ground first. The damage pattern on the root of vertical tail and horizontal stabilizer also indicated impact loads from right side thus confirming that aircraft was in right hand bank before its impact with the ground. The FDR data analysis also confirmed that the aircraft was in a right hand bank of about 70° just before the impact with ground and obstacles.
- 2.22.3. The preserved flight control components and linkages were found to be installed correctly and secured properly.
- 2.22.4. The examination of damaged flap screw mechanism indicated that aircraft impacted the ground with its flaps extended to 30° position (take-off selection).
- 2.22.5. One of the preserved main landing gear actuating cylinder shaft and nose landing gear up lock mechanism indicated that at the time of impact landing gears were in the retracted position.
- 2.22.6. All four engines were found in the main wreckage of the crashed aircraft. However, some parts of Engine # 4 were found on the flight path of the aircraft after takeoff. The engine parts found before the main aircraft wreckage included, fragments of engine front cowl, fragments of inlet guided vanes, fragments of LP compressor 1st, 2nd and 3rd stage casing, LP compressor 2nd and 3rd stage blades, LP compressor 1st stage disk with broken shaft and LP compressor 2nd and 3rd stage disks. These parts were located at a distance of approximately 1900-2400 meters from the runway end and about 1200-1400 meters before the main aircraft wreckage. These fragments had signs of mechanical damage only, and no signs of thermal / fire damage. This indicates that some part out of these experienced uncontained failure and caused extensive damage to Engine # 4.
- 2.22.7. Since the fragments of LP compressor 2nd stage disk were found approximately 1200-1400 meters before the main wreckage of the rest of the aircraft it was assumed that most probably it was the first component to fail. Most likely after failure of the LP compressor the LP turbine over speeded and its 6th stage disk disintegrated.
- 2.22.8. After the disintegration of Engine # 4 LP turbine disk, its debris caused damage to aircraft right half of the wing, fuel system and flaps. Damage to wing area containing fuel by the debris resulting into fuel ignition was the cause of in-flight fire. The LP compressor 2nd stage disk was lost during the investigation and only its pictures were available, therefore, material and fractographic analysis was not possible to ascertain the exact cause of disintegration.
- 2.22.9. There was no evidence of bird strike, sabotage activity or flight controls failure of the aircraft.
- 2.23. The plot of pertinent FDR parameters is provided on following page:



Pic 2.3 The FDR MSRP-64M of the aircraft IL-76TD 4L-GNI flight information. Takeoff in airport Karachi on 28.11.2010.

2.24. Failure Analysis of Engine # 4

2.24.1. To find out the engine's fracture mode NPO Saturn conducted failure analysis on the following parts of the Engine # 4 (S No. 0304404011876) of the mishap aircraft:

2.24.2. Four blades of 1st stage guide vanes (1 intact blade and 3 damaged blade pins in the ring).

2.24.3. Blade of 2nd stage guide vanes.

2.24.4. A torn off 2nd stage blade.

2.24.5. A part of the inner ring of the guide vanes 1st stage along with a part of a labyrinth packing ring of the guide vanes 1st stage.

2.24.6. A fragment of the 2nd stage disk of the LP compressor rotor (without marking).

2.24.7. A blade of the LP compressor 1st stage (with "646" marking).

2.24.8. A blade of LP compressor guide vane (without marking).

2.24.9. A fragment of the connecting bolt (without marking).

2.24.10. The analysis of above listed parts concluded that all materials which were used in parts production met the manufacturer's requirements. The fracture surfaces analysis of above listed parts concluded that all damages were of static character and were caused by non-calculated loads. No signs of fatigue were found in the above stated parts.

2.24.11. Since the fragments of LP compressor 2nd stage disk were found approximately 1200-1400 meters before the main wreckage of the rest of the aircraft it was assumed that most probably it was the first component to fail which subsequently caused damage to downstream engine components.

2.24.12. The fragment of the 2nd stage disk of the LP compressor was lost during the investigation. The fracture mode analysis was therefore, performed based on photographs of the damaged part.



The fragment of LP Compressor
2nd stage disk



Fracture surface of LP Compressor
2nd stage disk.

2.24.13. The close examination of photographs revealed following features:

2.24.14. No signs of plastic deformation of the cross-section at and around fracture surface.

2.24.15. No angularity caused by plastic deformation in the initial fracture zone.

2.24.16. Smooth surface region in the fracture initiation zone.

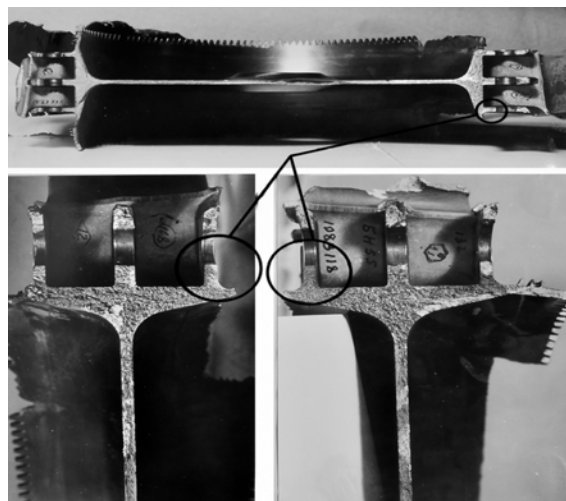
2.24.17. The macro lines indicating stops of crack front.

2.24.18. The fatigue crack in the disk of LP compressor 2nd stage started from the extreme edges of the hole of the disk. The hole is meant for installing the bushing for pin of compressor blades (picture below).



The arrow shows the place of a fatigue crack initiation on LP compressor 2nd stage disk

2.24.19. According to the data of the “State Centre for Flight Safety of Air Transport” of Russia, there had been cases of D-30 (Д-30) engine failures caused by fatigue fractures of the LP compressor 2nd stage disk. Fatigue cracks appeared because of fretting corrosion in the holes designed to install the bushings for pin of the compressor blades. Comparative analysis of disks fractures in previous cases and on the mishap aircraft Engine # 4 showed that they were of similar character. The picture below shows such fracture of an accident which occurred on 30th October, 1989.



LP Compressor 2nd Stage Disk Fracture : Accident on 30th October, 1989

2.24.20. This type of failure was discovered in 1992 and subsequently remedial measures were instituted vide bulletins # 252-БП-Г, # 287-БП-Г, # 300-БП-Г and # 281-БП-Г. All engine installed to IL-76 aircraft operating in the Russian Federation were modified to remove the defect in the time period between years 2000 to 2002.

2.24.21. Since the log book of the engine was not provided by the operator, therefore institution of the remedial measures vide above referred bulletins could not be established. According to the

information of manufacturer of the engines this issue is checked every time during life prolongation procedure.

2.24.22. Since some fragments of LP compressor 2nd stage were not available, therefore, fatigue fracture could not be confirmed and was concluded as the most probable cause based on the available photographic evidence.

2.25. Take-off Analysis by Mathematical Modelling

2.25.1. The take-off mathematical modelling was conducted by ILYUSHIN to verify correspondence of FDR data with action of control devices and engines' thrust. The mathematical modelling was performed using the conditions prevalent at the time of accident. The significant findings of the modelling are presented in following paragraphs.

2.25.2. The best correspondence of the calculated and recorded data was reached with the 195 tons aircraft weight and CG at 30%.

2.25.3. The IL-76 aircraft was designed with ability to sustain failure of one engine. In order to attain wings level with failed Engine # 4, it was necessary to apply right aileron at 2.4° and rudder at 16°. In case of an engine failure the Operation Manual recommends that the aircraft should be balanced with a bank of 2° to 3°. To do the same it's necessary to apply the right aileron at 5.7° and the rudder at 4.5°.

2.25.4. The recorded flight control application was not only enough for countering the Engine # 4 failure but also was sufficient for executing a left bank with a rather high angular velocity. The only single engine failure on the mishap aircraft could not lead to situation that was impossible to counter using ailerons and interceptors.

2.25.5. In the particular situation of mishap aircraft, the extra banking effect might have appeared because of damage to the flaps located right above and behind the Engine # 4. This caused loss of lift on the right half wing.

2.25.6. The computation showed that to get the Lift force (ΔY) and rolling moment (ΔMX) equal to FDR recorded values it was enough to eliminate 20% of the flaps on one wing. This assumption is supported by the fact that the flaps are located right behind the Engine # 4 and most likely to be damaged in case of uncontained engine failure and fire. Most probably the rolling moment kept increasing because the flaps' damage continued due to in-flight fire.

2.25.7. The mathematical modelling concluded that the mishap aircraft movement during takeoff at Karachi Airport till the moment of Engine # 4 failure was corresponding to the stick force. However, after the Engine # 4 failure it was not corresponding with the stick force.

2.25.8. The deflections of lateral and rudder controls registered by the FDR were enough to counteract the tendency of roll and to continue the takeoff with one failed engine. However, in reality Engine # 4 failure was followed by damage to right half of the wing (most probably the flaps). This damage caused the loss of lift on the right wing and undesired rolling moment. Taking into consideration low altitude and speed it was almost impossible to counter this situation by input of the flight controls.

3. CONCLUSION

3.1. Findings

3.1.1. The operating crews had valid licenses and were authorized to undertake the flight.

3.1.2. All the members of flight crew had valid medical fitness and sufficient rest was provided to them before undertaking the flight.

3.1.3. The cockpit crew was adequately trained on IL-76 aircraft and operationally fit to fly the aircraft on mishap day.

- 3.1.4. At the time of accident, the prevailing weather at JIAP, Karachi and its surroundings was well above the minima's required to undertake mishap flight.
- 3.1.5. The CVR of mishap flight did not reveal any usable information for this investigation.
- 3.1.6. The aircraft and engine complete log books were not made available by the operator, instead copies of few pages of log books were made available.
- 3.1.7. The mishap aircraft's designer (ILYUSHIN) assigned calendar based service life expired on 29th May, 2004. The aircraft was operated beyond its assigned life without approval of the designer.
- 3.1.8. All four engine of the mishap aircraft were operated beyond the service life established by the manufacturer (NPO Saturn).
- 3.1.9. The life extension of the engines was not approved by NPO Saturn.
- 3.1.10. Serial Numbers found on inlet guide vane, LP compressor 1st stage disk, Guides Apparatus 1st stage blades were not the same as they should have been according to the information available in the engine documents.
- 3.1.11. According to information provided by NPO Saturn some parts of Engine # 4 (inlet guide vane, LP compressor 1st stage disk, Guides Apparatus 1st stage blades) of Engine # 4 (S No. 0304404011876) recovered from the wreckage belonged to Engine S No. 0304402801646.
- 3.1.12. NPO Saturn did not have any information about operation, maintenance and prolongation between-overhaul hours / cycle's life or calendar service life of Engine S No. 0304402801646 after 10th March, 2004.
- 3.1.13. The wreckage analysis indicated that right wing impacted the ground first. The FDR data analysis also confirmed that the aircraft was in a right hand roll of about 70° just before the impact with ground and obstacles.
- 3.1.14. The wreckage indicated that the aircraft impacted the ground with its flaps extended at 30° (also confirmed from FDR data analysis).
- 3.1.15. The damage of preserved parts of landing gears indicated that the gears in retracted position at the time of impact.
- 3.1.16. All four engines were found in the main wreckage of the crashed aircraft. However, some parts of Engine # 4 were found on the flight path of the aircraft after takeoff.
- 3.1.17. The engine parts found before the main aircraft wreckage included, fragments of engine front cowl, fragments of inlet guided vanes, fragments of LP compressor 1st, 2nd and 3rd stage casing, LP compressor 2nd and 3rd stages' blades, LP compressor 1st stage disk with broken shaft and LP compressor 2nd and 3rd stage disks. These parts were located at a distance of approximately 1900-2400 meters from the runway end and about 1200-1400 meters before the main aircraft wreckage. These fragments had signs of mechanical damage only, and no signs of thermal / fire damage. This indicates that some part out of these experienced uncontained failure and caused extensive damage to Engine # 4.
- 3.1.18. There was no evidence of bird strike, sabotage activity or in flight controls failure of the aircraft. Most probably the damage caused by Engine # 4 uncontained failures to aircraft right wing and flaps caused in-flight fire due to presence of fuel in the vicinity.
- 3.1.19. Analysis of fracture surfaces of Engine # 4 indicated signs of fatigue failure of LP compressor 2nd stage disk.

- 3.1.20. The fragment of the 2nd stage disk of the LP compressor was lost during the investigation. The disk fracture mode analysis was therefore, performed based on photographs of the damaged part.
- 3.1.21. Comparative analysis of disks fractures in previous cases and on the mishap aircraft Engine # 4 showed that they were of similar character i.e. because of fatigue cracks due fretting corrosion in the holes designed to install the bushings for pin of the compressor blades.
- 3.1.22. Since the log book of the Engines # 4 was not available, it was not established whether bulletins for remedial measures to address fatigue cracks due to fretting corrosion was instituted or not.
- 3.1.23. According to the data of the “State Centre for Flight Safety of Air Transport” of Russia, there had been cases of D-30 (Д-30) engine failures caused by fatigue fractures of the LP compressor 2nd stage disk. Fatigue cracks appeared because of fretting corrosion in the holes designed to install the bushings for pin of the compressor blades.
- 3.1.24. Since some fragments of LP compressor 2nd stage were not available, therefore, fatigue fracture could not be confirmed and was concluded as the most probable cause based on the available evidence.
- 3.1.25. The FDR data analysis showed that Engine # 4 experienced starting problem on at least two occasions prior to mishap flight. The restart attempt was made after putting on “air bleed for inlet guide vanes heating”. In absence of log book the most probable reason for this type of defect is reduction in compressor efficiency due to increased clearance because of wear of blades and increase of their surface roughness.
- 3.1.26. FDR recorded an alarm due to “Fire of the engine nacelle” and “Fire onboard” accompanied with Engine # 4 HP rotor RPM drop. In-flight fire was also recorded by an amateur video of the mishap flight.
- 3.1.27. The aircraft took off with 195 tons mass against the FCOM specified limits of maximum taxing mass of 191 tons and maximum takeoff mass of 190 tons.
- 3.1.28. The mathematical modelling confirmed the fact that with Engine # 4 failed and about 20% damage to flaps of right wing the aircraft was unable to sustain flight as flight control inputs were not capable of countering the rolling to right.
- 3.2. **The Sequence of Events.** Based on the wreckage analysis, detailed inspection of Engine # 4, FDR data analysis and failure mode analysis the most probable sequence of events was as follows:
- 3.2.1. The 2nd stage disk of LP compressor was the first component to fail because of fatigue fracture due to fretting corrosion in the holes designed to install the bushings for pin of the compressor blades.
- 3.2.2. Uncontained failure of LP compressor damaged surrounding engine parts.
- 3.2.3. Most likely, after failure of the LP compressor the LP turbine over sped and its 6th stage disk disintegrated.
- 3.2.4. After the disintegration of LP turbine disk its debris caused damage to right wing, fuel system and flaps.
- 3.2.5. Damage to wing area containing fuel by the debris ignited the fuel in the wing tanks.
- 3.2.6. In-flight fire damaged right wing flaps which are located just behind the Engine # 4.

- 3.2.7. Damage to right wing and flaps reduced lift on right wing and aircraft started rolling to right.
- 3.2.8. Even full application of corrective flight controls was not sufficient to control the right rolling moment.
- 3.2.9. The flaps damage progressively increased due to in-flight fire and aircraft continued to lose height and increase right roll till it impacted the under construction buildings and ground.

3.3. Cause of Occurrence

- 3.3.1. The cause of the occurrence was uncontained failure of the 2nd stage disk of LP compressor of Engine # 4 due to fatigue fracture which resulted in in-flight fire and damage to adjacent areas of right wing / flaps to an extent that flight could not be sustained.
- 3.3.2. The use of mishap engine beyond its manufacturer's assigned life without assessment and life enhancement by the manufacturer was the cause of its uncontained fatigue failure.

4. SAFETY RECOMMENDATIONS

- 4.1. All operators and ground handlers are to ensure preparation of proper load / trim sheet while keeping maximum authorized allowable takeoff mass of aircraft / cargo loads for the specific type of aircraft.
- 4.2. Georgian Aviation Administration to cooperate with the state of the designer when putting the aircraft into the state register as being the state issuing the Airworthiness Certificate. Notification on including the aircraft into the state register must be provided, the condition of continuing airworthiness of the aircraft and engines must be determined in accordance with the requirements applicable to the type of the aircraft.
- 4.3. Aviation regulatory authority of the states which have the IL-76TD aircraft in the public register or under lease in the state airlines to organize the check of the log books of the D-30KP engines. Such checks to ensure that life limits, records and documentation are in conformance with Bulletin No 670-БЭ-Г dated 8th February, 2002. The results of the checks to be coordinated with the NPO Saturn, the manufacturer of the Д-30КП engines.
- 4.4. The Civil Aviation Regulatory Authority of the states which have the IL-76TD aircraft in the public register or under lease in the state airlines to organize the check of the IL-76TD aircraft log books for following:
- 4.4.1. Assigned life limit observance till the first overhaul.
- 4.4.2. The presence of the life limit prolongation Permits (Conclusions) issued by the IL, JSC (manufacturer) till the first overhaul in accordance with the applicable bulletins on the subject.
- 4.4.3. The conformity of the issued (available) airworthiness certificates data to the assigned life limits till the first overhaul.
- 4.4.4. The results of the checks to be coordinated with the IL, JSC (Aircraft manufacturer) and NPO Saturn, the manufacturer of Д-30КП engines.
- 4.5. The airline management to ensure thorough check of aircraft and technical log books for correctness of records and trustworthiness of the life limits data while following the procedure of the aircraft inclusion in the Air Operator's Certificate. Moreover, required data as desired by investigation agencies should be provided.
- 4.6. The airline management to ensure that at the time of delivery of the aircraft from the owner to the airline under lease arrangements the complete aircraft and technical documentation must be delivered to the operator. The management of Independent Certified Maintenance

Organizations to ensure the availability of all applicable technical documentation, correctness of records and trustworthiness of the life limits data of the aircraft maintained by the organization.

4.7. The Civil Aviation Regulatory Authority of the state to ensure that at the time of inclusion of the IL-76TD aircraft in the public register the thorough check of the aircraft and engine log books contents and the life limits data shall be organized. The final decision of the inclusion in the public register shall be taken only after the coordination with the aircraft and engine manufacturer (IL, JSC and NPO Saturn).

4.8. The Civil Aviation Regulatory Authority of the state to ensure that the continuing airworthiness aspects of the aircraft included in the public register, are in accordance with the Annex 6, 8 to the Convention on International Civil Aviation. Special attention to be paid to the airworthiness status of the aircraft included in the public register but operated outside the state of registry.

4.9. The Civil Aviation Regulatory Authority of the state to ensure that in case of disclosure of the non-conformity or the violation of aircraft / engine life limits or TBO prolongation procedure the operation must be stopped immediately.

4.10. CAA, Pakistan should ensure proper preservation of all available evidences collected during the process of investigation till finalization of investigation.

4.11. The Civil Aviation Regulatory Authority of the state to ensure institution and compliance of air crew training on the emergency procedures, related to the engine failure during takeoff.

4.12. The Д-30КП designer and manufacturer to conduct one-time inspection of the LP compressor 2nd and 3rd stage aft and fore ledges by the vortex-current method under the procedure prescribed by the Bulletin No 578БД-Г.

4.13. To the Aviation Administration of the Kirghiz Republic to perform the check of the conformity of the maintenance company function – the Airline Transport Incorporation FZC Osh branch – to the Certificate Regulations.

4.14. With a view to identify the engine after the air accident the designer and manufacturer of the Д-30КП-1-2 shall introduce the engine marking that allows determination of its number in air accidents in particular and at the time of purchase for further operation.