FINAL INVESTIGATION REPORT

INVESTIGATION INTO SERIOUS INCIDENT OF M/S SHAHEEN AIR INTERNATIONAL FLIGHT # NL-148, (SECTOR KHI–LHE) B-737-400 AIRCRAFT, REG # AP-BJN (BIRD HIT AT SHORT FINALS AND RUNWAY EXCURSION AFTER LANDING AT LAHORE ON 30TH DECEMBER 2014

FINAL REPORT

SERIOUS INCIDENT OF M/S SHAHEEN AIR INT'L (SAI) FLIGHT NL-148 (SECTOR KHI-LHE), B737-400 AIRCRAFT, REG # AP-BJN AT AIIAP, LAHORE ON 30TH DECEMBER, 2014

Synopsis

The serious incident was reported to Safety Investigation Board (SIB) of Pakistan, through Mandatory Occurrence Report (MOR) by the operator (Appendix "A") and was duly notified (Appendix "B") by SIB in accordance with provisions of ICAO Annex-13. Accredited Representative (ACCREP) was appointed by the state of Manufacture and Design, the United States of America (USA).

The aircraft experienced bird hit before landing at about 100 ft AGL. The nose wheel steering cable fractured due to bird hit. After landing aircraft drifted towards right side and went off the runway. The left main landing gear collapsed after aircraft covered some distance off the runway. All personnel onboard the aircraft remained safe.

Authority

Director General Civil Aviation Authority (CAA) Pakistan issued Memorandum vide letter No. HQCAA/1901/366/SIB/787 dated 31st December, 2014 and corrigendum to memorandum vide letter No. HQCAA/1901/366/SIB/186 dated 16th March, 2016, authorizing SIB of Pakistan to investigate the incident (Appendix "C").

1. FACTUAL INFORMATION

1.1. **History of Flight**. M/s Shaheen Air International (SAI) Flight NL-148, B737-400 aircraft, Reg # AP-BJN was operating a routine revenue flight from Karachi to Lahore on 30th December, 2014. The flight remained uneventful, however, before landing at Lahore at about 100 ft AGL the cockpit crew experienced a bird strike in the nose wheel well area. After landing on Runway 36R, the aircraft drifted towards right side. It could not be controlled by inputs of cockpit crew and thus departed the runway. The left main landing gear collapsed shortly after the aircraft departed the runway.

1.2. **Injuries to Persons**. No injuries to the personnel onboard were reported.

1.3. **Damage to Aircraft**. The aircraft left wing sustained substantial damage around landing gear attachment points due to landing gear collapse. After left gear collapse, the left engine came in contact with ground and engine cowling was also damaged. Post occurrence inspection revealed blood stains marks and bird feathers in the nose wheel well area. The nose wheel steering system cable was also found broken as a result of the bird impact.

1.4. **Other Damages**. There was no other damage reported as a result of this incident.

1.5. **Personnel Information.** The flight carried 172 souls onboard which included 06 crew members and 166 passengers. The details of cockpit crew are as under:

(a) Captain

- Date of Birth : 26th June, 1957
- ATPL No. : 1394 (A)
- Medical Status : Class ONE till 31st March, 2015
- Type Rating (current) : B-737/300-800
- Experience (PIC) on the type : 1344:35
- Total Flying Experience : 6688:10 hrs

(b) First Officer

- Date of Birth : 14th June, 1958
- ATPL No : 1476 (A)
- Medical Status : Class ONE till 30th June, 2015
- Type Rating (current) : B-737/300-800
- Experience (P-2) on the type : 1454:00
- Total Flying Experience : 5439:00 hrs

The cockpit crew was fit to undertake the flight and they had valid licenses and medical fitness certificates. CAA Pakistan approved rules and regulations in respect of flight duty time limitation (FDTL) were adhered to. Therefore, the cockpit crew of mishap aircraft (MA) was not observed to be exposed to any undesired stress / fatigue prior to flight as a result of FDTL violation.

1.6. **Aircraft Information.**

1.6.1. The mishap aircraft was maintained by the operator in accordance with the regulations of Pakistan Civil Aviation Authority. The Certificate of the Airworthiness No. 760 of the aircraft was valid till 16 May, 2015. Transit Check of the aircraft was carried out at Karachi on 30 December, 2014. There was no carried forward item on Minimum Equipment List (MEL) related to the nose wheel steering system or wheel brakes. The mass and center of gravity of the aircraft were within prescribed limits.

1.6.2. Nose Landing Gear Assembly SNo T5173P2462 was released after overhaul on 16 Feb, 2007 at 31683 hrs time since new (TSN) and 31828 cycles since new (CSN) by Messier Services Asia Pte Ltd. The nose wheel steering cable is a non life item and aircraft documents did not have any record of its replacement in the past. Pertinent aircraft maintenance and life information is as follows:

- Aircraft Make & Model : Boeing 737-400
- Serial No. : 26460
- Year of Manufacture : September, 1993
- Registration Number : AP-BJN
- Total Aircraft Hours / Cycles : 45061/ 42180
- Total Landings : 42180

- Last C Check : 42848 Hrs / 41117 Cyc
- Last A Check : 44992 Hrs / 42142 Cyc

1.7. **Metrological Information**. On 30th December, 2014 the weather report of AIIAP, Lahore at the time of incident is as follows:

Time UTC	Weather Report					
	Vis	Outlook	Wind	Clouds	Temp	QNH
1000 Hrs	1000 M	Mist	Calm	Nil	11/08°C	1017

1.8. **Aids to Navigation**. Aircraft was equipped with serviceable VOR / DME and ILS equipment. Following navigation aids were available and serviceable at AIIAP, Lahore prior to the incident of AP-BJN.

OPLA AD 2.19 RADIO NAVIGATION AND LANDING AIDS

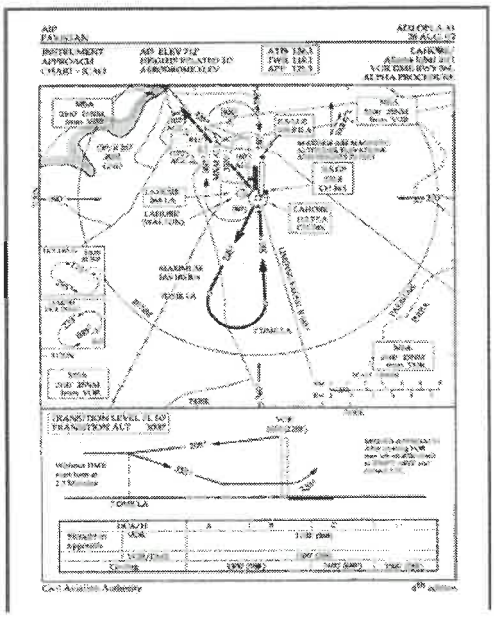
Type of aid. CAT of ILS (VAR VOR/ILS)	*ID*	*Frequency*	*Hours of operation*	*Site of transmitting antenna coordinates*	*Elevation of DME transmitting antenna*	*Remarks*
1	2	3	4	5	6	7
GP/TDME 36R	Dots / Dashes	333.8 MHz CH36X	H24	313032.40N 0742419.84E	230.61M	Coverage 7-10 NM
LLZ 36R ILS CAT II (1°E/1995)	ILA	109.9 MHz	H24	313223.46N 0742417.64E	-	Coverage 20 NM
MM 36R	Dashes	75 MHz	H24	-	-	-
L	LO	338 KHz	H24	-	-	-
OM 36R	Dashes	75 MHz	H24		-	-
NDB	LA	268 KHz	H24	*3130.4N 07423.0E		
DVOR/DME (1°E/1995)	LA	112.7 MHz CH74X	H24	312959.00N 0742400.07E	222.70M	Coverage 200 NM

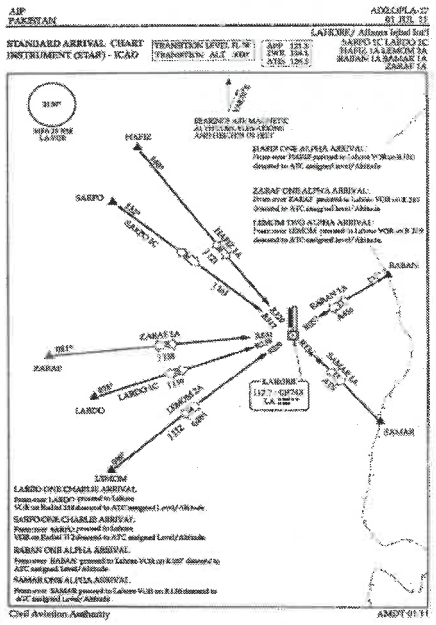
1.9. **Communications**. Following communication aids were available and found serviceable **at** AIIAP, Lahore at the time of incident of AP-BJO.

OPLA AD 2.18 ATS COMMUNICATION FACILITIES

Service designation	*Call sign*	*Frequency*	*Hours of operation*	*Remarks*
1	2	3	4	5
TWR	Lahore Tower	118.1 MHz	H24	Primary
TWR	Lahore Tower	118.875 MHz	H24	Secondary
Apron	Lahore Ground	118.4 MHz	H24	Primary
Apron	Lahore Ground	121.8 MHz	H24	Secondary
ATIS	ATIS	126.3 MHz	H24	
APP	Lahore APP	121.3 MHz	H24	Primary
	Lahore APP	125.3 MHz	H24	Secondary
	Lahore APP	121.5 MHz	H24	Emergency
BS	Radio	630 KHz	HX	0130-1900 HR
BS	Pakistan	1090 KHz	HX	Variable SKED

1.10. **Aerodrome Information**. The AIIAP, Lahore standard departure and pertinent arrival charts for runway 36L are appended below:





1.10.1. The AIIAP, Lahore detailed aerodrome data is appended below:

OPLA 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
18L	180°	3360 x 46	PCN 85/R/B/X/U (concrete)	313211.94N 0742417.44E	THR 216.9M / 712 FT
36R	360°			313023.30N 0742415.49E	THR 215.1M / 706 FT
18R	180°	2743 x 46	PCN 55/F/C/X/T	313202.14N 0742410.18E	THR 216.5M / 710 FT
36L	360°			313033.13N 0742408.60E	THR 214.8M / 705 FT

OPLA 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
18L	SALS 420 M LIL	GREEN	PAPI Both side 3°	-	3360, 30m. White/ Red	3360, 60m, White	RED	-	-
36R	PALS CAT II 900M LIH	GREEN	PAPI Both side 3°	900 m.	3360, 30m. White/ Red	3360, 60m, White	RED	-	-
18R	SALS 420 M LIL	GREEN	PAPI 3°	-	-	2743, 60m, White LIL	RED	-	-
36L	SALS 420 M LIL	GREEN	PAPI 3°	-	-	-	RED	-	Strobe lights

OPLA 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
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1.11. **Flight Recorders**. Flight Data Recorder (FDR) Part Number 980-4700-001 SNo. 01717 and Cockpit Voice Recorder (CVR) Part Number 980-6020-001 SNo. 0707 were intact. The data of both recorders was successfully downloaded and extensively

utilized during investigation process. CVR transcript and FDR data is attached as Appendix "D" and "F" respectively.

1.12. **Wreckage and Impact Information**. The aircraft remained intact after departing the runway. Left Main Landing Gear (LMLG) tires ploughed into the soft ground for about three meters and then the landing gear collapsed. The left engine touched the ground after the landing gear collapse and dragged for about two meters till aircraft came to a final stop. Fresh blood stains and bird feathers were present in the nose wheel well area, and nose wheel steering cable was found broken.

Bird hit area, blood stains and feathers on the broken cable

The lower end of broken steering cable on steering collar

1.13. **Fire**. There was no evidence of before, during and post incident fire.

1.14. **Survival Aspects**. The incident did not require emergency evacuation, hence door slides were not deployed and passengers were disembarked using steps. No injuries to any passenger or crew member occurred.

1.15. **Tests and Research.** The visual examination of all fractured parts, Fractography of the broken nose wheel steering cable and bird impact force calculations were performed.

1.16. **DESCRIPTION OF NOSE WHEEL STEERING SYSTEM**

1.17. The description and operation of the nose wheel steering system of B737-400 is explained in detail in the aircraft maintenance manual. The relevant pages are placed as Appendix "E". The salient features of the system are summarized in following paragraphs:

1.18. The cam mechanism in the nose landing gear oleo ensures that that nose wheel is centered when it is off the ground.

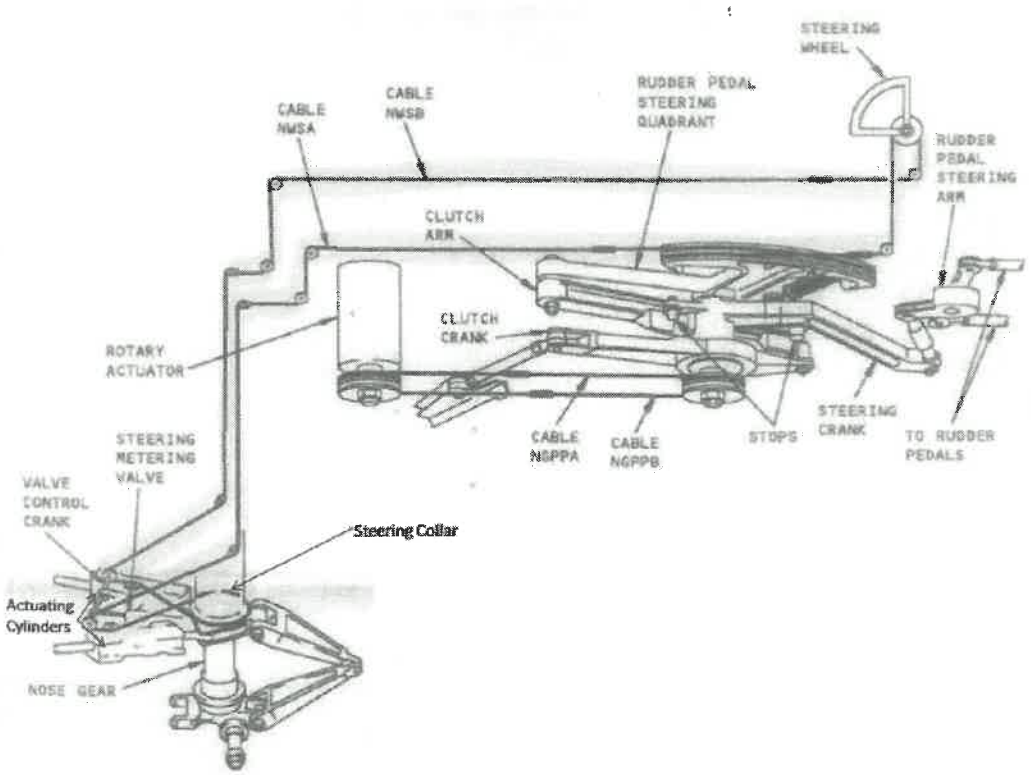
1.19. Positioning of the landing gear lever to "Down" makes hydraulic pressure available for the nose wheel steering system. The normal steering is accomplished by the use of "Steering Wheel" on the captain's side wall. Movement of the steering wheel is transmitted via cable mechanism to steering control metering valve which directs hydraulic pressure to the steering actuators. Steering wheel enables 78 degrees of nose wheel turning.

1.20. The steering of nose wheel up to 7 degrees is also available with rudder pedals while the aircraft is on ground during takeoff, landing and taxiing. A squat switch senses the aircraft weight on nose wheel and gives signal to a "Rotary Actuator" which actuates

a clutch mechanism. The clutch mechanism when engaged transmits the rudder pedal movement to nose wheel steering cable system. When weight is off the nose wheel the clutch mechanism disengages, and movement of rudder pedals is not transmitted to the nose wheel steering cable system.

1.21. The steering system cables NWSA and NWSB are finally connected at the steering collar on the NLG. Movement of the steering wheel or rudder pedal (with clutch mechanism engaged) puts one of cable under tension. The under tension cable through a "Valve Control Crank" moves the control piston in the steering metering valve. Steering metering valve directs hydraulic fluid to the actuating cylinder. The actuating cylinder is further connected to the steering collar which swivels the nose wheel. As the desired amount of turn is reached the movement of steering collar releases the cable tension and swiveled position of the nose wheel is thus maintained. When steering wheel is released, it returns to its neutral position, and the mechanism works again in similar manner to bring the nose wheel to neutral position.

1.22. Maintenance manual also states that nose gear must be compressed more than two inches before steering is attempted so as to avoid damage to the centering cam mechanism. This caution implies that with landing gears down and weight off the nose leg, the actuation of nose wheel steering system cables (NWSA or NWSB) will direct the hydraulic to the actuating cylinder. However, turning of the nose wheel will be resisted by the centering cam mechanism.



Nose wheel steering system, schematic diagram

2. ANALYSIS

2.1. Operational Analysis

2.1.1. The mishap flight was a scheduled passenger flight from Karachi to Lahore. The departure time from Karachi was 0830 UTC and it arrived at Lahore at 1020 UTC. The cockpit crew had received Flight Plan, latest weather information and NOTAMS prior to departure. The reported visibility at destination was poor besides advisory for exercising caution due heavy bird activity around airport. The flight remained uneventful from departure till final approach for landing at AIIAP, Lahore.

2.1.2. During the sector Karachi – Lahore, First Officer was the pilot flying (PF) and the Captain was pilot monitoring (PM). The cockpit crew had completed their landing checklist and got established on final approach through ILS on runway 36R.

2.1.3. Since the slant visibility at lower altitude was poor, hence PF was busy in flying the aircraft / maintaining desired flying parameters of final approach before landing. Whereas, the captain was keeping a good lookout for spotting the runway. The Captain of MA had picked visual with runway at distance 1.14 NM and height of 403 Ft AGL.

2.1.4. The First Officer of the mishap flight noticed a flock of birds at approximately 250 Ft AGL on final approach and immediately announced it to the captain, who advised him to "take care of birds". In the meantime, they heard a thud. The First Officer announced the bird strike to Captain. The mishap aircraft, by this time, was descending through 100 Ft AGL. The approach was getting shallow and Captain advised First Officer to hold height which he acknowledged.

2.1.5. The touchdown on the runway was smooth and at correct speed. Both thrust reversers were deployed after touchdown. When the nose wheel was lowered, the aircraft started to drift towards right side. The Captain advised First Officer to control the direction and keep the aircraft towards left. First Officer applied full left rudder but the direction could not be controlled and the aircraft continued forward in right half of the runway.

2.1.6. In order to bring the aircraft back towards centerline, the Captain took over the controls and applied full left rudder along with left brake. This input turned the aircraft towards left but as the speed decreased the aircraft again started to turn right sharply and departed the runway on heading 060^0 at approximately 40 Kts, 6000 Ft from thresholds Runway 36R.

2.1.7. The left wheel of MA plunged into soft ground, travelled 27 feet and broke left main landing gear. The left wing of MA rested on left engine which dragged on soft ground by another 07 feet before final stop.

2.1.8. The right main landing gear remained intact after runway excursion, and traveled 74 feet on fair weather strip before coming to a stop.

2.1.9. The nose wheel also did not receive any damage as a result of runway excursion and remained intact.

2.1.10. The cockpit crew switched off the engines and carried out engine shut down checklist. They also informed ATC about encountering a bird hit while they were on short finals and later on departing the runway after landing.

2.1.11. ATC dispatched all emergency vehicles to the MA. The emergency services arrived in time but they were not utilized as onsite situation did not demand so.

2.1.12. The Captain apprised all onboard personnel through announcement about the bird strike and subsequent events. He advised them to remain calm and wait for disembarkation.

2.1.13. The Fire personnel and ground engineers gave clearance to Captain and all the passengers were disembarked through ladder.

2.1.14. During post occurrence inspection bird remains and blood stains were observed in the nose wheel well area, on the nose wheel steering cable and its surroundings.

2.1.15. The nose wheel steering cable of mishap aircraft was found broken / fractured.

2.1.16. The runway surface was inspected and no evidence of other mechanical failures, tire deflation or brake binding was observed.

2.1.17. The aircraft technical log was scrutinized, there was no carried forward snag related to brakes and nose wheel steering system. Additionally, there was no documented previous snag related to these systems.

2.1.18. The corrective inputs by the crew on rudder pedal and nose wheel steering tiller were not being transmitted to the nose wheel steering system of the aircraft because of the failure of the nose wheel steering cable.

2.2. Technical Analysis

2.2.1. The detailed examination of the collapsed left main landing gear and ground marks indicated that LMLG collapsed when its tires ploughed through the soft ground off the runway, while the aircraft was moving forward.

2.2.2. The fractured surfaces of failed parts of the LMLG were closely examined, overload fracture was indicated by failure surfaces and associated deformation pattern.

The unspecified loads while tires of LMLG ploughed through the soft ground caused failure of attachment points and thus resulted in collapse of the landing gear.

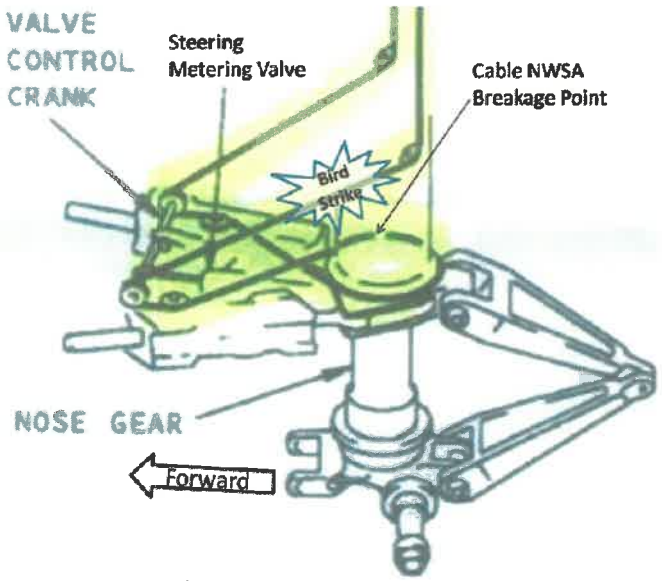
2.2.3. The aircraft brake assemblies were examined for any evidence of brake binding and no such abnormality was found, thus ruling out runway excursion due to brake malfunction.

2.2.4. The nose landing gear had evidence of bird hit in the form of fresh blood stains. Few bird feathers were also found in the hardware around the bird strike area.

2.2.5. The bird feathers recovered from the wheel well area were similar in appearance to feathers of kite generally found in the local area.

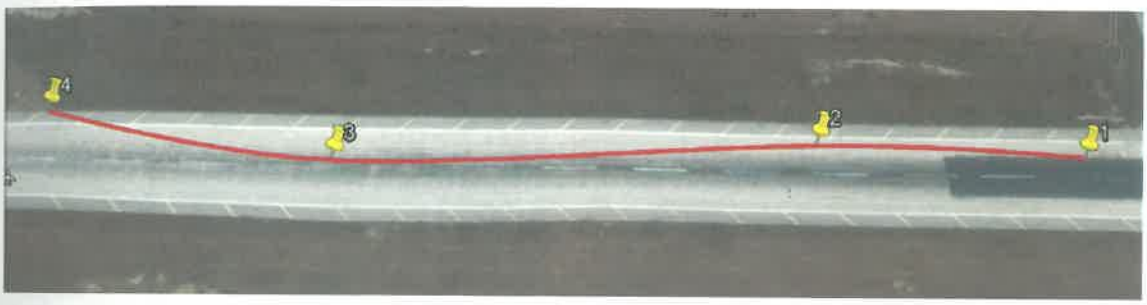
Bird feather recovered from nose wheel area

2.2.6. The bird strike took place on left side of the nose leg top fork. The left side nose wheel system steering cable (NWSA) was found fractured approximately at a point where it starts its routing on the steering collar. A portion of the cable was found pulled out from the lower side pulleys mechanism (closer to steering metering valve). The upper side of the cable was dislodged from the pulley groove and was found stuck between the pulley guard and the pulley. The position of the cable indicated that the bird most probably struck directly on the cable.



2.2.7. **Aircraft Track on Runway and Tire Marks**. The runway was critically examined to identify the tire marks of the mishap aircraft after landing. The aircraft track of the on the runway is depicted and described in following pictures and paragraphs:

Approximate track of the aircraft after landing based on tire marks



Enlarged view of the approximate track of the aircraft after landing

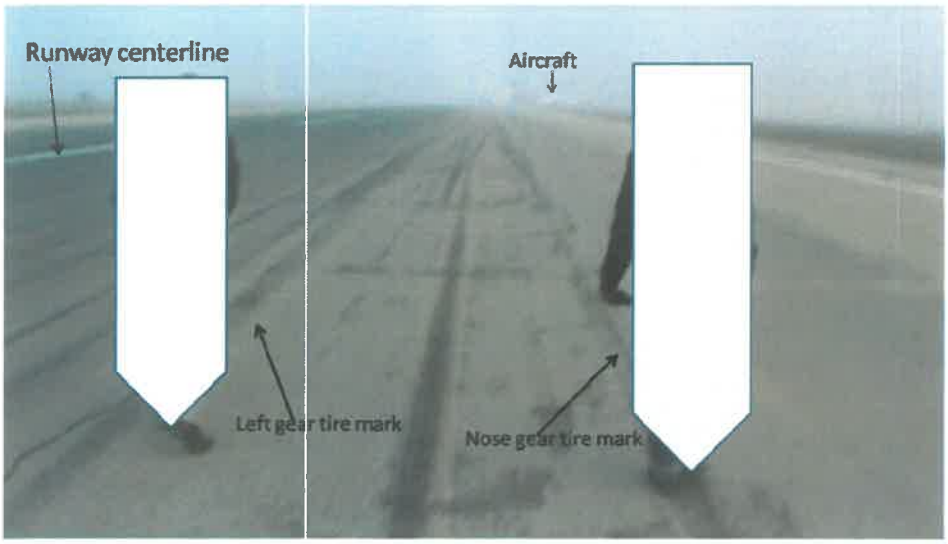
2.2.8. The measured distance from the runway threshold to the first identifiable mark of nose wheel on the surface of the runway (Point# 1) was 1049 m from runway threshold and 11.3m to right of runway centerline (CL).

2.2.9. The tire mark from Point# 1 to Point# 2 indicated that the aircraft was drifting towards right. Point # 2 depicted on the track is 151 m from Point # 1 and 17.5 m right of CL.

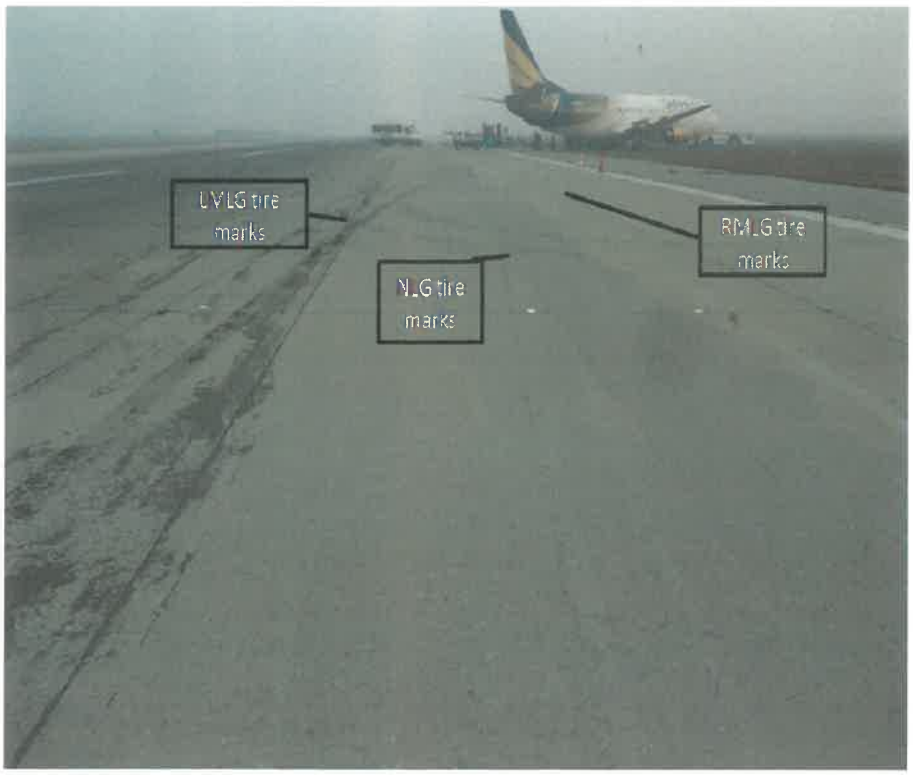
2.2.10. After Point # 2 the aircraft started moving towards left side, however, nose tire mark still remained on right of centerline. Point# 3 is 273 m from Point# 2 m and 7.5 m to right of CL. Between Point# 2 to Point# 3, most probably is the time when rudder correction was applied and aircraft had sufficient speed for rudder control to be effective and thus right side deviation was corrected to some extent. FDR time 10:20:32 approximately corresponds to Point#3 (based on FDR recorded 1463 m distance from threshold). The aircraft speed at that time was approximately 81 Kts.

2.2.11. Aircraft went off the runway at Point# 4 which is 170m from point# 3. The aircraft left the runway after about 600 m from Point# 1. It covered about 35 m off the right side of the runway and then stopped after collapse of the LMLG.

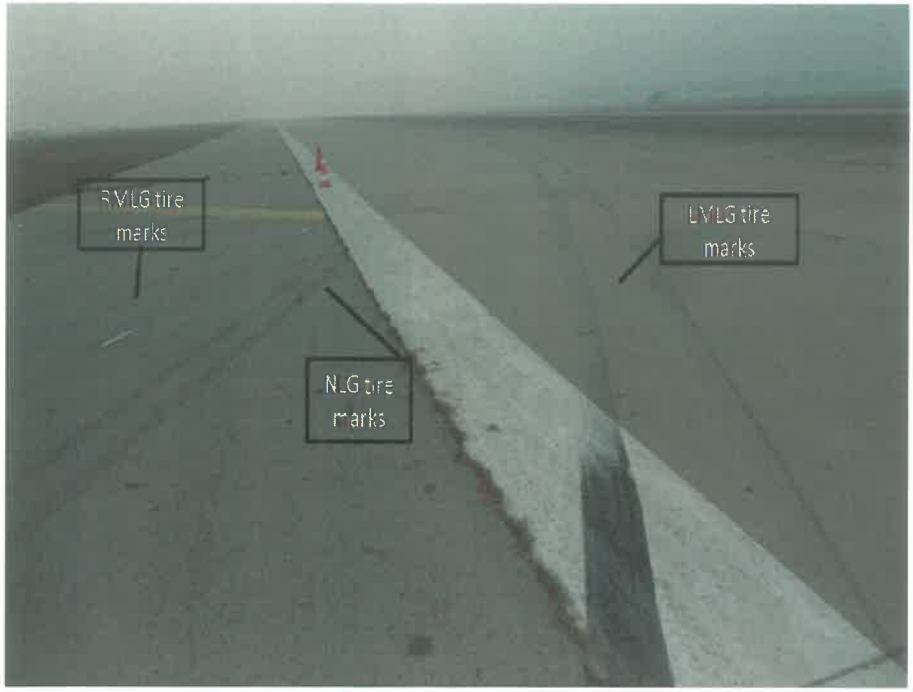
2.2.12. Tire marks indicated that significant left wheel brake pressure was applied in an attempt to turn the aircraft to left before it finally went off the runway on right side.



First identifiable tire marks on the runway



Tire marks before leaving the runway



Tire marks before leaving the runway (viewing backward)

2.2.13. The dragging marks on the circumference of both nose tires had a consistent pattern as shown in the picture below. This pattern supports the finding that nose tire turned towards right while aircraft was forced to move towards left by application of rudder at high ground speed and probably some wheel braking at lower speeds. With the nose tire turned towards right the application of corrective controls dragged it left along with forward motion of the aircraft.

Nose wheel sideways dragging marks

2.3. **FDR and CVR Analysis**. The FDR and CVR data was retrieved and analyzed. The salient aspects are presented in following paragraphs:

2.3.1. The aircraft contact with runway was indicated by a spike in vertical acceleration to 1.49 Gs and downward slope of longitudinal acceleration between time interval 10:20:15 to 10:20:16. FDR recorded distance from runway threshold corresponding to these times was 426m and 500m respectively. The aircraft speed was approximately 148 knots at the time of touchdown.

2.3.2. The maximum roll angle during this time interval was 0.7 degree to right side, and pitch attitude was 4 to 2.8 degrees nose up. These parameters indicate that aircraft made first contact with the runway was on both main landing gears with almost level wings.

2.3.3. Main landing gear squat switches recorded "GROUND" position at 10:20:16. The main landing gears squat switch is installed in RMLG and the LMLG takes its signal from the same switch. The RMLG squat is recorded twice a second and Nose Landing Gear (NLG) squat is recorded once per second.

2.3.4. The NLG indicated "GROUND" position at 10:20:18. FDR recorded distance from runway threshold corresponding to this time was 648 m.

2.3.5. The landing gear squat switches recorded position also corroborate with the information provided by vertical / horizontal acceleration and pitch roll angle.

2.3.6. The CVR time was matched with the FDR with the help of system generated altitude announcement just before landing in the CVR record. The FDR time at the moment of this announcement was set as the reference for subsequent estimation of time for CVR recorded information. The matched time of significant FDR parameters, CVR information and correspondence with measured distances is presented below.

FDR Time	FDR Parameters	CVR Information
10:20:06	Radio altitude 99 ft	System generated altitude announcement "One Hundred"
10:20:18	NLG squat switch senses "GROUND"	Captain directs FO to control direction
10:20:24	Distance from threshold 1037m, Corresponds to Point# 1	-
10:20:27	Distance from threshold 1222m, Corresponds to Point# 2	-
10:20:32	Distance from threshold 1463m, Corresponds to Point# 3	-
10:20:37	Distance from threshold 1630m, Corresponds to Point# 4	-
10:20:40 10:20:41	Roll angle is negative (0.4 degrees)	Breakage noise (most probably from LMLG parts)
10:20:43	Roll angle changes from -0.7 degrees to -4.6 in one second	A louder breakage noise (most probably LMLG collapse)

2.3.7. The FDR data showed left wheel brake pressure at its maximum throughout the flight. The right brake pressure was less than 500 psi after 10:20:16 and after 10:20:40 there were few spikes. The physical condition of the left wheel brakes and tires did not indicate any abnormality or binding. Additionally if left brake was binding aircraft should have drifted towards left side of the runway and LMLG tire marks should have been evident on the runway just after the touchdown. Based on the physical evidence it was concluded that FDR recorded brake pressure and position parameters were indicative of malfunction in recording or sensor corresponding to this parameter and therefore, not reliable. Tire marks indicated that significant left wheel brake pressure was applied in an attempt to turn the aircraft to left before it finally went off the runway on right side.

2.4. **Experimental Research of Similar Past Incident Investigation**. A similar case of bird hit on nose wheel steering system cable took place on 28 November, 2004 on KLM B737 aircraft Registration No. PH-BTC and was investigated by Civil Aviation Accident and Incident Investigation Commission of Spain. During this incident the right side cable (NWSB) got fractured and aircraft drifted off the runway on left side. The investigation report stated that KLM conducted tests by actually cutting the nose wheel steering cable while the system was operating. The research concluded that when left side cable (NWSA) was cut a steering input of 12 Degrees to right was generated and when right cable (NWSB) was cut a steering input of 20 Degrees to the left was generated.

2.5. **Explanation of Nose Wheel Steering System Response after one of the Cable Failure**. The construction and operation of the B737-400 systems was analyzed and it was concluded that when either of cable is cut, most probably the tension on the other moves the control piston of the metering valve and generates the resulting steering input. When nose gear is not compressed, the centering mechanism will try to oppose the movement being generated by the hydraulic pressure directed by the action of metering valve. As soon as the gear gets compressed the opposition of centering cam is removed and nose wheel readily takes the position according to steering input by the control cable.

2.6. **Failure Mode and Fractographic Analysis**. The failure mode fractographic analysis of nose wheel steering system cable (NWSA) was performed by Failure Analysis Center (FAC), Institute of Space Technology (IST), and Pakistan. The significant findings of the FAC failure analysis report (Appendix "G") are summarized below:

2.6.1. The failed steering control cable is a corrosion resistant steel of 3/32 diameter and 7x7 construction as per MIL-W-83420, type-1B with no finish.

2.6.2. The surfaces of the strands of broken steering cable were examined under stereomicroscope. Minor surface cracks were observed closer to the failed end of the cable, however away from the failed end no such observations could be recorded. It was not possible to ascertain whether these cracks were pre-existent or they emanated as a result of the forces involved during the incident.

2.6.3. The observation of fracture surfaces under Field Emission Scanning Electron Microscope (FE-SEM) showed typical indicators of the cable failing under ductile overload. No traces of fatigue in the crack initiation area were observed.

2.6.4. The tests were conducted on the samples of the failed cable to determine its breaking load and average value found was 360.49 kg. The test value was marginally lower than the documented value of 417.3 kg for the cable of this specification.

2.6.5. The Bird Impact Force was estimated by using bird weight of 1.75 kg, length of 60 cm, wing span of 150 cm and taking the aircraft speed at impact as 150 knots. The bird-strike impact-force equation (Reference: 'Sharing the Skies' 2nd Ed. Bruce Mackinnon 2004. Ottawa, Canada) was used for calculation. The calculated impact force was 1009.24 kg which is almost three times compared to the tested breaking strength of the cable. The calculation by the referred equation showed that at aircraft speed of 150 knots, a bird mass of 630g was enough to break the cable.

2.7. **Damage to Aircraft**.

2.7.1. The area of the left wing of the aircraft was substantially damaged around left main landing gear attachment points.

2.7.2. The aircraft structure which came in contact with collapsed landing gear was also damaged.

2.7.3. Left engine cowling was damaged due to its contact with ground and dragging for some distance.

3. OBSERVATIONS

3.1. The occurrence took place at 1020 hrs on 30th December, 2014. The process of removal of the disabled aircraft was under taken by the operator with the assistance of M/s PIAC equipment and technical team. The pneumatic lifting bags, associated equipment and relevant technical crew had to be moved from Karachi. The actual recover process started around 1300 hrs on 31st December, 2014. The availability of basic recovery equipment and trained technical crew at Lahore could have saved time.

3.2. The recovery team initially tried to move the aircraft by supporting wings on wooden beams over a low bed tractor towed trolley. The technique was too risky as the support was very unstable and thus had to be abandoned.

3.3. After repeated adjustments of the initial movable support the left wing was supported over tug master. Few wooden beams and old tires were placed on tug masters to adjust support height. This technique was comparatively more stable and aircraft was moved to designated place with few stops for adjusting the supports. Suitable capacity fork lifters, heavy duty trailers and pre planning could have made the task much easier.

Stable movable wing support arrangement

Initial movable wing support arrangement (unstable)

3.4. Because of non availability of adequate equipment and hit and trial method to provide required movable support with sufficient stability, the recovery team was finally able to clear the runway after continuous work of about 21 hours.

3.5. A similar occurrence took place on 31st August, 2012 where M/s PIAC ATR42-500 aircraft Reg # AP-BHJ skidded off Lahore airport runway and sustained substantial damaged. After this incident the aircraft was removed from the site of incident after about 36 hours. The SIB released final investigation report of this incident on 4th February, 2013 with several recommendation including **provisioning /**

availability of appropriate recovery equipment at BBIAP, Islamabad or AIIAP, Lahore for reducing unnecessary and unwanted delay in making the runway available for routine flight operations.

3.6. Keeping in view the rising trend of bird hit cases, especially at Lahore and Karachi Airports, the existing Bird Hazard Control activities / campaign were observed to be insufficient to address the issue.

4. FINDINGS

4.1. Operational

4.1.1. The occurrence took place while M/s Shaheen Air International Flight NL-148 was landing at AIIAP, Lahore on 30th December, 2014.

4.1.2. At the time of landing, the First Officer was the pilot flying (PF) and the Captain was pilot monitoring (PM).

4.1.3. The cockpit crew of the mishap flight saw a flock of birds at 250 ft AGL on final approach before landing and immediately experienced the bird hit.

4.1.4. After landing thrust reversers were deployed, and as the nose wheel was lowered, the aircraft started to drift towards right side which could not be controlled through remedial actions by PF.

4.1.5. The Captain took over the controls and applied left rudder and brake to control the direction. The MA turned left but as the speed dropped, it sharply turned right and departed runway on heading 060° at 40Kts of speed.

4.1.6. The aircraft went off the runway towards right side approximately 6000 ft from thresholds runway 36R.

4.1.7. As the aircraft went off the runway, the left main landing gear collapsed after travelling 34 ft on fair weather strip.

4.1.8. After collapse of the left main landing gear, the left engine cowling touched the ground and aircraft came to stop.

4.1.9. The cockpit crew switched off both engines and passengers were disembarked using steps.

4.1.10. During post occurrence inspection bird remains and blood stains were observed in the nose wheel well area, on the nose wheel steering cable and its surroundings.

4.1.11. The nose wheel steering cable of mishap aircraft was found broken / fractured.

4.1.12. The runway surface was inspected and no evidence of other mechanical failures, tyre deflation or brake binding was observed.

4.1.13. The aircraft technical log was scrutinized, there was no carried forward snag related to brakes and nose wheel steering system. Additionally, there was no documented previous snag related to these systems.

4.1.14. The failure of the nose wheel steering cable resulted into pilot inputs on rudder pedal and nose wheel steering tiller not being transmitted to the nose wheel steering system of the aircraft.

4.1.15. An almost similar occurrence took place to M/s KLM Boeing B-737, registration PH-BTC at Barcelona Airport (Spain), on 28 November 2004. A thorough investigation was conducted into the occurrence including running of simulations in flight simulator. The simulations included breakage of nose wheel steering cable in air after a bird strike and nose wheel deflection to either side before landing. The test results were concurred by the manufacturer. In their Final Report No. A-070/2004 (Appendix "H") the investigators concluded :-

"The fracture (for any cause) of a NWS cable will result in a nose wheel deflection of up to 12° to the right and up to 20° to the left when the cable breaks. **A landing with a broken NWS cable will almost certainly result in a runway excursion regardless of the actions performed by the crew**, although the exact speed at the moment of departure will depend on several factors."

4.1.16. Keeping in view the efforts made by the cockpit crew to maintain direction in order to keep the aircraft on the runway and the test results of above mentioned incident of M/s KLM, **the runway excursion is considered unavoidable with the breakage of nose wheel steering cable.**

4.2. **Technical**

4.2.1. There was no evidence of malfunction of the wheel brakes which could result into runway excursion.

4.2.2. There were no evident pre-existing cracks in the wires of the steering control cable (NWSA) which could contribute towards its failure.

4.2.3. There was no evidence of signs of Fatigue or Stress Corrosion Cracking (SCC) on the wires of failed cable (NWSA).

4.2.4. The fracture surfaces of the failed cable (NWSA) revealed the failure mode as plain ductile overload.

4.2.5. The calculated bird impact force was sufficient to fracture the cable.

4.2.6. Subsequent to the fracture of nose wheel steering cable (NWSA), the nose wheel turned towards right side after the NLG touched the ground and its oleo got compressed under normal aircraft load.

4.2.7. The direction dictated by right turned nose wheel could not be fully countered by rudder input and aircraft wheel brakes application.

4.2.8. The LMLG experienced overload after the aircraft went off the runway, LMLG tires ploughed through the soft ground and collapsed after failure of its attachment fittings.

5. SEQUENCE OF EVENTS

5.1 The nose wheel steering cable (NWSA) fractured due to bird impact.

5.2 After failure of the cable (NWSA), the tension in the NWSB actuated the steering metering valve and directed the hydraulic pressure to actuating cylinder for turning the nose wheel to right side.

5.3 After lowering the nose wheel when weight of the aircraft compressed the NLG oleo, the centering cam resistance was no more available and the nose wheel turned towards right in accordance with the position dictated by tension of cable (NWSB) and thus aircraft started drifting right.

5.4 The rudder input by the cockpit crew was effective to some extent as long as the aircraft speed was sufficient for aerodynamic rudder effectiveness. As the rudder effectiveness was lost due to reduction in speed, aircraft started to go right. The differential braking was also applied but the aircraft could not be controlled.

5.5 The rudder pedal input to steer the nose wheel to left was not communicated to metering control valve because of fractured cable (NWSA). Finally the aircraft followed the track dictated by the right turned nose wheel and departed the runway.

5.6 The LMLG tires ploughed into the soft ground for about four meters and finally the aircraft stopped after collapse of the LMLG.

6. CAUSE OF OCCURRENCE

6.1. Factors leading to the Occurrence

6.1.1. The available evidence suggests that nose wheel steering cable broke after experiencing the bird impact in nose landing gear area.

6.1.2. The failure of the nose wheel steering cable resulted into pilot inputs not being transmitted to the nose wheel steering system. The right side drift of aircraft after landing could not thus be controlled and aircraft departed the runway.

6.1.3. The occurrence took place due to failure of nose wheel steering cable (NWSA) because of bird impact.

7. SAFETY RECOMMENDATIONS

7.1. CAA Pakistan is to ensure the availability of suitable wreckage recovery equipment with the operators for speedy removal of the disabled aircraft from operating surfaces.

7.2. The manufacturer ~~(M/s Boeing) to~~ may issue necessary amendment in fight manual to caution the crew about possibility of failure of nose wheel steering cable due to direct bird impact and consequent limitation on directional control and recommended corrective actions (if any).

7.3. In order to arrest the rising trend of bird hit cases, CAA Pakistan to study and adopt latest scientific means encompassing bird eradication and scaring measures from takeoff and landing paths at all airports in Pakistan.

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