PAKISTAN CIVIL AVIATION AUTHORITY

(SAFETY INVESTIGATION BOARD)

FINAL REPORT

SERIOUS INCIDENT OF M/S SAI FLIGHT NL-122 BOEING 737-400 AIRCRAFT, REG # AP-BJN ON 22ND APRIL, 2012 AT JIAP, KARACHI

FINAL REPORT

INVESTIGATION INTO SERIOUS INCIDENT OF M/S SHAHEEN AIR INTERNATIONAL FLIGHT NL – 122, BOEING 737-400 AIRCRAFT, REG # AP–BJN, (SECTOR ISB – KHI) AT JIAP, KARACHI ON 22ND APRIL, 2012

Synopsis

On 22nd April 2012, M/s Shaheen Air International (SAI), Boeing 737-400 aircraft, Reg # AP-BJN, Flight NL-122 (sector Islamabad – Karachi) was a scheduled passenger flight. After landing at 0716UTC on JIAP Karachi runway 25L, ATC Tower Controller observed slight smoke from the left wheel area of the aircraft. The cockpit crew considered it to be a tyre failure. The aircraft was stopped and kept on the main runway surface by the cockpit crew. The fire vehicles were promptly positioned by ATC Tower Controller to avert any untoward situation. The onboard passengers were disembarked normally through the steps. Subsequently, the left main landing gear was observed collapsed towards upward and inward side. The No 1 (left) engine of the mishap aircraft was observed resting on ground with dragging marks on the runway surface. The upper surface of left wing was also observed ruptured with fuel dripping from the left wing area.

Investigation Authority

DG CAA issued notification vide Letter No HQCAA/1901/351/SIB dated 26th April, 2012 & 16th October, 2012 (attached as Appendix "A") authorizing Safety Investigation Board (SIB), CAA Pakistan to investigate the serious incident. In accordance with ICAO Annex 13, as the state of aircraft manufacture, the National Transportation Safety Board (NTSB) appointed a US accredited representative.

1. FACTUAL INFORMATION

1.1 **History of the Flight.** The aircraft was declared serviceable before the scheduled flight on the day of occurrence by the M/s SAI engineering staff at BBIAP, Islamabad. The aircraft took off from Islamabad and proceeded as per plan on Islamabad – Karachi sector without encountering any operational or maintenance abnormality en-route till touchdown at JIAP, Karachi.

1.2 **Injuries to Persons.** No one onboard the mishap aircraft received any minor / major injury as a result of this occurrence.

1.3 **Damage to Aircraft.** As a result of the said occurrence, M/s SAI B737-400 aircraft (Reg # AP-BJN) suffered severe structural damage to Left Hand Side (LHS) Wing, No 1 Engine and LHS Main Landing Gear and its components. The onsite photographs of the mishap aircraft are appended below:

Collapsed LHS Main Landing and Engine No 1 resting on runway surface

1.4 **Other Damages.** No other apparent damage was observed to the runway surface / services except dragging marks on the operating surface.

1.5 **Cockpit Crew Information.** There was a set of two cockpit crew onboard the aircraft including Captain and First Officer. The cockpit crew detailed data is attached as Appendix "B", however brief details are as under:

(a) Captain AbdulBasit Saggu

- Date of Birth : 06th November, 1961
- Date of Last Medical : 24th March, 2012
- ATPL No : 1273
- Date of last Simulator Check : November, 2011
- Flying experience total : 8231:00 Hrs
- Total Command Experience : 5580 Hrs
- On type Command Experience : 55:00 Hrs

(b) First Officer (Captain) Muhammad Aslam

- Date of Birth : 17th March, 1967
- Date of Last Medical : 08th March, 2012
- ATPL No : 1201
- Date of last Simulator Check : 02nd April, 2012
- Total Flying experience : 7400:00 Hrs
- Total Command Experience : 4800 Hrs
- On type Command Experience : 25:00 Hrs

1.6 **Aircraft Information.** The Boeing 737-400 (Reg # AP-BJN) aircraft was inducted by M/s SAI and taken on Pakistan Civil Register on 09th February, 2012. The detailed aircraft and engine related data is appended below:

1.6.1 **Aircraft**

- Aircraft Make and Model : Boeing 737-400
- Serial No : 26460
- Manufacturing Date : 28th October, 1993
- Aircraft Registration : AP-BJN
- Aircraft Hours : 43299
- Aircraft Cycles : 41362

1.6.2 **Engine No 1**

- Type/Model : CFM-56-3C-1
- Engine S No : 857992
- Engine Hours since New : 38698
- Engine Cycles since New : 35755

1.6.3 **Engine No 2**

- Type/Model : CFM-56-3C-1
- Engine S No : 725551
- Engine Hours Since New : 41926
- Engine Cycles Since New : 40732

1.6.4 **Scheduled Inspections Accomplished**

INSPECTION TYPE	INSPECTION FREQUENCY	ACCOMPLISHED AT	
		FLIGHT HOURS	DATE
Check '2A'	500 FH	43278 FH	18th Apr, 2012
Check '1A'	250 FH	43056 FH	20th Mar, 2012
Check 'D'	24,000 FH	42827 FH	10th Jan, 2012

1.6.5 The daily inspection / servicing of mishap aircraft was carried out on 22nd April, 2012 prior to the departure of Flight NL-122 and no defect was recorded. No anomaly in any of the aircraft system performance was observed by cockpit crew before and during the flight till mishap aircraft touchdown at runway 25L at JIAP, Karachi.

1.7 **Meteorological information.** On 22nd April, 2012 the weather reported by meteorological department JIAP, Karachi at 0700UTC was 270°/18 kts, visibility 7 km, scattered at 2000 ft 32° / 17° QNH 1009 mb and RH 40% with no significant weather (Refer Appendix "C").

1.8 **Navigation Aids.** Boeing 737-400 aircraft was equipped with serviceable ADF, VOR / DME and ILS equipment for the conduct of flying operations. All the ground equipment related to ADF, VOR / DME and ILS was found serviceable at the time of occurrence.

1.9 **Communication Aids.** Boeing 737-400 aircraft was equipped with serviceable two VHF and one HF radio set for its two way radio contact with all concerned / relevant agencies during the conduct of flight.

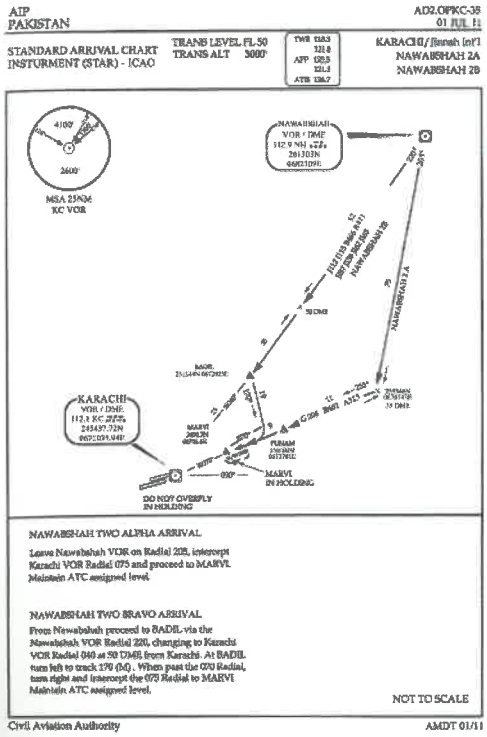
1.10 **Impact Information.** The aircraft landed within the authorized landing parameters as per the DFDR data. However, immediately after landing the aircraft started to behave in a manner which indicated some abnormality toward the LHS Main Landing Gear (MLG). The cockpit crew initially considered it to be a tyre failure. Subsequently, Engine No 1 also started dragging on the runway surface indicating LHS MLG collapse. After stopping on the runway, it was observed that LHS MLG had collapsed, one outboard tyre had flattened and the Engine No 1 was resting on the runway surface.

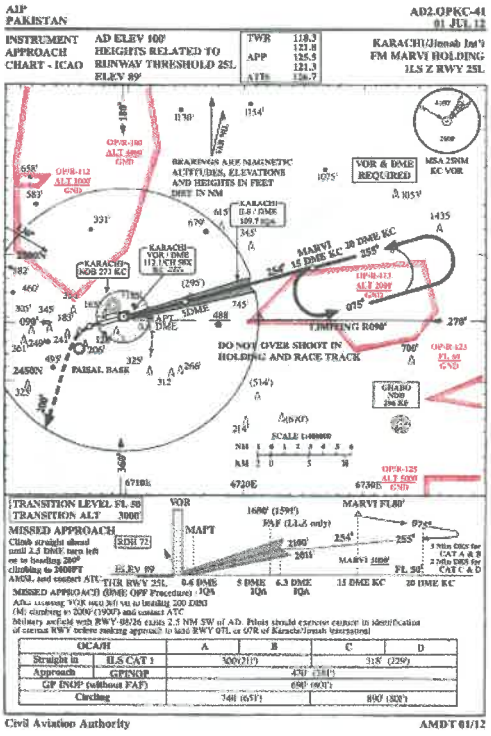
1.11 **Aids to Navigation Availability.** All the navigation aids were available and found serviceable at JIAP Karachi at the time of occurrence.

1.12 **Aids to Communications Availability.** All the communication facilities were available and found serviceable at JIAP Karachi at the time of occurrence.

1.13 Aerodrome information

1.13.1 The JIAP Karachi standard arrival chart along with ILS approach runway 25L are appended below:





1.13.2 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 45	SAR/RCXX/L CONCRETE Avble for ACFT having Max TKOF Weight Aorta 420001LBS (197TON)	245416.90N 0670851.02E	THR 23.50M / 77FT
25R	254.29			245444.59N 0671040.84E	THR 30.48M / 100FT
07R	074.29	3400 x 45	57/R/B/W/T CONCRETE SWY bitumen	245402.15N 0670833.56E	THR 21.62M / 71FT
25L	254.29			245431.75N 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	0.25% UP	305 x 45	914	3931 x 305	-
25R		305 x 45	560		
07R	0.168% UP	305 x 45	573x150	4753 x 150	-
25L		305 x 45	463x150		

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	3505	4114	3200	-
25R	3200	3505	3780	3203	-
07R	3400	3705	4270	3402	-
25L	3400	3701	3883	3405	

OPKC AD 2.14 APPROACH AND RUNWAY LIGHTS

Designations RWY NR	APCH LGT type LEN INTST	THR LGT colour WBAR	VASIS (MEHI) 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 305 M	GREEN	PAPI Both sides 2.91°	-	3403M 30 M white LIH	3403 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 ATS 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
		121.6 MHZ	H24	Vehicle
		133.0 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
SS	Radio	930 KHZ	HX	0130-1900 HR
SS	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 0670837.69E	-	-
ILS CAT I (1°E1995)						
LOM	KC	235 KHZ	H24	245547.74N 0671449.05E	-	3.9 NM FM THR
MM		75 MHZ	H24	245653.00N 0671107.99E	-	0.57 NM FM THR
GP/DME 25L	Dots/Dashes	333.2 MHZ CH340	H24	245432.35N 0671013.99E	-	2.98° RDH 72 FT
LLZ25L ILS CAT I (1°E1995)	IQA	109.7 MHZ	H24	245359.00N 0670929.94E	-	-
NDB	KC	271 KHZ	H24	245523.80N 0670936.28E		Coverage 500NM
VOR / DME	KC	112.1 MHZ CH 59X	H24	245437.72N 0671035.94E	37.83M	Coverage 200NM Radial 300 un-reliable

1.14 **Medical and Pathological Information.** Following the incident on 22nd April, 2012 at JIAP, Karachi Blood and Urine samples of Captain and

First Officer were collected which did not reveal any abnormality (Refer Appendix "D").

1.15 **Fire.** Pre / post occurrence air / ground fire indications were neither observed by the Captain and First Officer of the aircraft nor were any such evidences observed by the investigation team members.

1.16 **ATC Tape Extract.** ATC Tape Extracts (Refer Appendix "E") were retrieved for detailed analysis.

1.17 **Cockpit Voice Recorder (CVR) / Digital Flight Data Recorder (DFDR).** CVR and DFDR were retrieved for analyses by investigation team. The CVR and DFDR data was made available by using PIA facilities and detailed discussions on available data were conducted during analysis phase.

1.18 **Crew Resource Management (CRM).** At the time of occurrence, Captain of aircraft was the Pilot Flying (PF) whereas FO was Pilot Not Flying (PNF). Both the cockpit crew had valid CRM certification at the time of said occurrence.

2 Analyses

2.1 Operational Analysis

2.1.1 The mishap Flight NL-122 took off from BBIAP, Islamabad as per schedule.

2.1.2 The flight remained uneventful till touchdown during landing at JIAP, Karachi.

2.1.3 The aircraft landed through normal ILS approach at 0716UTC on 25L JIAP Karachi well within the permissible limits of Boeing 737-400 aircraft landing parameters.

2.1.4 The touchdown was normal and observed within the touchdown zone.

2.1.5 The DFDR and CVR data was downloaded at M/s PIAC facility at JIAP, Karachi.

2.1.6 The aircraft touched down at a crab angle of 3.69° along with left bank of 0.7° as per the recorded parameters of DFDR which are well within the authorized limits of the Boeing 737-400 aircraft (Refer NTSB USA DFDR Data Analysis Appendix "F").

2.1.7 After landing white smoke was reported by ATC Tower Controller from landing gear area and vibrations were experienced by cockpit crew from LHS MLG area which increased in intensity with the reduction in aircraft speed.

2.1.8 The cockpit crew applied the remedial corrective actions to keep the aircraft under control and on the runway surface.

2.1.9 The aircraft was switched off on the runway and passengers were disembarked normally using steps.

2.1.10 All the emergency services responded very promptly and reached the aircraft.

2.1.11 The remedial corrective actions as per the QRH and FCOM by the cockpit crew were correct and prompt, to keep the aircraft under control and on prepared runway surface after encountering the LHS MLG anomaly.

2.1.12 While leaving the mishap aircraft, cockpit Crew took all the available documents with them.

2.1.13 The mishap flight utilized the Load / Trim sheet of "Jordan Aviation" (Refer Appendix "G") and it did not carry the name or logo of "Shaheen Air International". The units of weight "kg or lbs" were not mentioned on the Load / Trim sheet. Additionally, the capacity of passenger seats on mishap aircraft were depicted / documented on flight NL – 121 (sector KHI – ISB) and flight NL – 122 (sector ISB – KHI) as 170Y and 164Y respectively.

2.1.14 The Dry Operating Weight (DOW) and Adjusted Dry Operating Weight of mishap flight was observed the same on Load / Trim sheet (Refer Appendix "G").

2.1.15 The takeoff data card used by the mishap flight crew was of B737-200 aircraft instead of B737-400 aircraft (Refer Appendix "H").

2.1.16 In the Computerized Flight Plan (CFP) of mishap flight, the actual data regarding time, fuel, wind, OAT etc at various check points en-route to destination was not documented by the cockpit crew (Refer Appendix "J" and "K").

2.2 Technical Analysis

2.2.1 History of Aircraft.

2.2.1.1 The aircraft Check D was accomplished at AAR Aircraft Services at Indianapolis USA from October, 2011 to January, 2012. Refer Appendix "L". Following non routine maintenance had been carried out on LHS MLG during the said Check D.

2.2.1.1.1 **Discrepancy**: LHS MLG Rust is emanating from under the head of the T bolt assembly.

Rectification: LHS MLG T bolt assembly replaced as per AMM 32-11-42 dated 22-10-2011

2.2.1.1.2 **Discrepancy:** LHS MLG aft trunion bearing is worn, MLG strut is making contact with the trunion bearing.

Rectification: Wear found to be protective coating, no material loss noted IAW AMM 32-11-11 dated 22-10-2011

2.2.1.1.3 **Discrepancy:** LHS MLG strut is damaged from making contact with the trunion bearing.

Rectification: Damaged area to LHS MLG upper aft trunion bearing repaired IAW AMM 32-11-11 and SOPM 20-42-10.

2.2.1.1.4 **Discrepancy:** LHS MLG conduit has deteriorated protective Teflon sleeve aft of damper.

Rectification: Replaced Teflon tape on conduit aft of the damper on LHS MLG IAW SWPM 20-10-91 pg 2.

2.2.1.1.5 **Discrepancy:** Rust accumulation observed on LHS MLG out board brake assembly hardware.

2.2.1.1.6 **Rectification:** Removed LHS MLG outboard brake assembly hardware rust accumulation IAW SRM 51-10-02 step 14, removed light corrosion. No measurable material loss noted.

2.2.1.2 The aircraft was registered by Civil Aviation Authority Pakistan on 9th February, 2012. Check 2A (A1+A2) was carried out on 19th February, 2012 during which all three landing gears hydraulic components were checked for leakage and no leakages were observed. All three landing wheel well areas and components including cables, wiring, sensing elements and tubes were visually inspected as per task cards and no anomaly was observed with any of the systems / sub-systems components and parts.

2.2.1.3 Daily check of aircraft was carried out on 22nd April, 2012 prior to departure of the Flight NL-122 during which also no anomaly was observed.

2.2.2 **Wreckage Information**

2.2.3 Immediately after the occurrence, the runway was inspected. It was observed that touchdown occurred approximately at 2000'. After 150' from touchdown, marks of tyre and Engine No 1 dragging on the runway surface were found in ZIGZAG pattern. At approximately 8000', green colour marks on the runway were also observed which indicated the touching of Engine No 1 on runway. When green colour marks vanished, visible white colour marks of the engine were observed till the final full stop point of the aircraft. Few aircraft parts and tyre remains were also found on the runway which were collected and preserved for further examination & analysis.

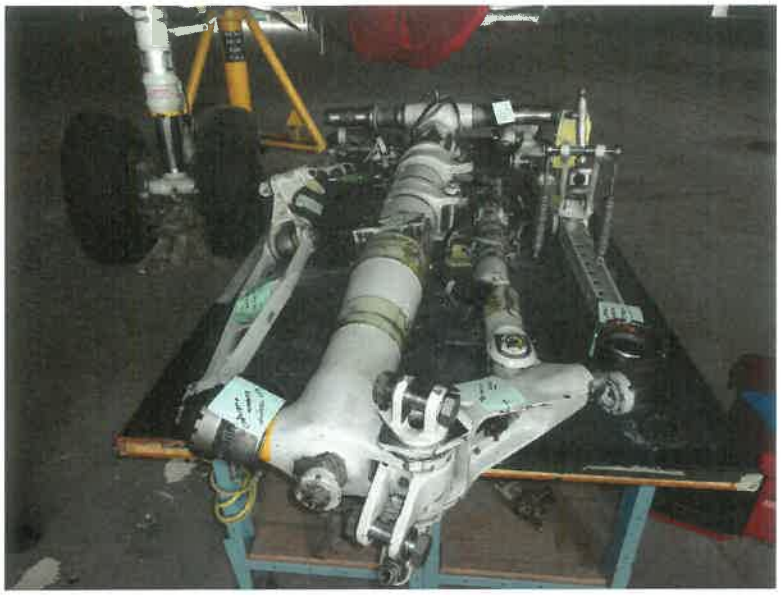
2.2.4 The onsite inspection of aircraft revealed that the LHS MLG had collapsed damaging severely the MLG sub parts and wing structure resulting into heavy fuel leakage from the damaged wing structure. However, no visible signs of any FOD or animal strike were observed. After collection and preservation of all the available evidences, the aircraft was moved to Shaheen Air Maintenance Hangar.

2.2.5 Subsequent inspection revealed that T-Bolt Part No 65-46140-9 Serial No 58060-0015 was broken into two pieces and the broken top end of the bolt had been still hanging with the T-Bolt. The broken parts of T-Bolt were preserved for failure mode analysis.

Broken T-Bolt

Nut with Top side of Broken T-bolt still inside

2.2.6 Most of the other damaged parts were found deformed and only a few had fractured apparently due to overload conditions consequent to LHS MLG collapse. The photographs of damaged parts after cleaning and examination are appended below:



2.2.7 The detailed damage assessment was carried out by a team of Boeing engineers which is listed below:

2.2.7.1 **Landing Gears**

2.2.7.1.1 LHS MLG upper wing triangular panel found badly damaged/broken.

2.2.7.1.2 LHS MLG mid-door found damaged/broken.

2.2.7.1.3 LHS Wing found deeply dented/damaged/punctured at wing station 167 (2 feet forward of aft spar) due to hitting of upper end of lower drag brace.

2.2.7.1.4 LHS Wing lower skin extension found damaged b/w wing station 155 to 169.

2.2.7.1.5 Small triangular panel found damaged near LHS wing root fillet area, aft of wing rear spar.

2.2.7.1.6 T-Bolt found broken and threads of nut found sheared-off.

2.2.7.1.7 LHS upper drag brace crushed into two pieces b/w shock strut and wing rear spar.

2.2.7.1.8 LHS up-lock assembly, attaching point with upper retraction link found bent and its bearing pulled out from its housing.

2.2.7.1.9 Trunion link fwd bearing pulled out from its housing.

2.2.7.1.10 Shock strut aft trunion bearing pulled out from its housing.

2.2.7.1.11 No.1 tyre found busted and sidewalls of tyre found rubbed-off.

2.2.7.1.12 Outboard door operating link fitting found broken.

2.2.7.1.13 NLG remains towards left approx 60 degree due to heavy taxi load.

2.2.7.1.14 Brake hydraulic tubes found broken.

2.2.7.1.15 Swivel coupling found damaged.

2.2.7.2 **Engine**

2.2.7.2.1 No.1 Engine faced severe dragging loads.

2.2.7.2.2 Both LHS Thrust Reverser cowling found badly rubbed-off / damaged from lower side and fasteners found pulled out from inside.

2.2.7.2.3 Both fan cowls found rubbed/damaged from lower side.

2.2.7.3 **Wings.** Heavy fuel leakage was observed under the left wing after the occurrence. Fuel was observed dripping from lower skin hole which was

damaged by the collapsed LHS MLG. The fuel was also observed leaking from forward trunion housing damaged by pulling out of the gear.

2.2.8 **Test and Research**

2.2.8.1 One part each of both the fractured parts of T-Bolt were subjected to detailed failure mode analysis at Failure Analysis Centre (FAC), Institute of Space Technology (IST) Islamabad and at National Transportation Safety Board (NTSB) USA. Failure analysis reports from both the facilities are attached as Appendices "M" and "N" respectively. The salient points of those reports are appended in the proceeding paragraphs.

2.2.8.1.1 ***Conclusions of FAC, IST***. *Based upon the available background information of the failed T-bolt and analysis of the test results, following conclusions were drawn:*

2.2.8.1.1.1 *The T-bolt failed due to inter-granular facture initiating from surface at thread root, which later propagated across the bolt diameter under high load.*

2.2.8.1.1.2 *Fatigue failure of the bolt, due to crack propagation under cyclic load, was ruled out mainly due to absence of fatigue signs on fracture surface at macro and micro levels.*

2.2.8.1.1.3 *Inter-granular fracture in the crack initiation zone could have resulted either from Stress Corrosion Cracking or Hydrogen Embrittlement. However, the available evidences were more supportive to 'Hydrogen Embrittlement' due to Cadmium plating.*

2.2.8.1.1.4 *Weakening of the grain boundaries at periphery of the failed T-bolt could have resulted from hydrogen, which could have been trapped during manufacturing process or during rework at the time of scheduled maintenance.*

2.2.8.1.1.5 *The overall failure mechanism of the bolt was ductile fast fracture due to overload in bending / shears.*

2.2.8.1.2 ***Recommendations of FAC, IST***

2.2.8.1.2.1 *Manufacturer of the T-bolt may be approached to review the manufacturing process and ascertain the cause of hydrogen embrittlement. The process of Cadmium plating a known source of HE, may be critically examined for possible errors.*

2.2.8.1.2.2 *History of the failed T-bolt may be explored to determine if processes like Cadmium plating were carried out during rework at any stage.*

2.2.8.1.2.3 *Data of the whole fleet may be collected to study the requirement of in-service NDI of subject T-bolt at appropriate intervals.*

2.2.8.1.3 ***Conclusions of NTSB***

2.2.8.1.3.1 *The T-Bolt remnant that fractured in the MLG failed from inter-granular cracking due to weakened grain boundaries.*

2.2.8.1.3.2 *Once the crack traversed to a certain depth, the remaining cross-section of the bolt succumbed to overstress.*

2.2.8.1.3.3 *No indications of fatigue or mechanical surface damage were found.*

2.2.8.1.3.4 *The material was found to be consistent with AISI 4340 with a hardness of 55 HRC. The part had been electroplated with cadmium.*

2.2.8.1.3.5 *While a variety of mechanisms can produce inter-granular fracture, the most probable cause in this situation is hydrogen embrittlement.*

2.2.8.1.3.6 *Boeing has allowed the local maintenance facilities to rework the bolts, and the fractured T-Bolt has recorded flight cycles time since overhaul. The reworking facility may have neglected proper and timely post-bake of the T-Bolt leaving it susceptible to hydrogen embrittlement.*

2.2.8.1.3.7 *The other discrepancies observed included use of a cotter pin with a self-locking non-castellated nut and paint and primer found on the washer flat face. Washers are generally not primed or painted since these processes can increase susceptibility to fatigue.*

2.2.8.1.4 ***Suggestions of NTSB***

2.2.8.1.4.1 *The fractured T-Bolt be tracked to determine how the part had been reworked, specifically plating and relief baking.*

2.2.8.1.4.2 *All bolts in this lot should be inspected by a non-destructive method, such as magnetic particle inspection, to determine if there are any existing cracks and indications.*

2.2.8.1.4.3 *All bolts with positive indications should be removed from service.*

2.2.8.1.4.4 *If the other bolts have not been reworked, then all bolts in this lot should be tracked and inspected, removing all bolts with cracks.*

2.2.8.1.4.5 *All other bolts should be relief baked at an appropriate temperature for a significant time (greater than 24 hours), or scrapped altogether.*

2.2.8.1.4.6 *Boeing should ensure proper process control of bolt surface treatments to prevent hydrogen charging by potential sources.*

2.2.8.1.5 ***Review of Original Failure Analysis Report by FAC, Islamabad in light of NTSB AccRep Comments on Draft Final Report***

2.2.8.1.5.1 *FAC, IST was approached to review its original report in light of the NTSB comments, (Appendix "M") forwarded as Acc Rep after review of the draft investigation report. It was opined by NTSB that the failure*

mode was attributable to Stress Corrosion Cracking (SCC) contrary to its earlier finding (Appendix "N") which attributed the T-bolt failure to inter granular crack initiation due to Hydrogen Embrittlement (HE).

2.2.8.1.5.2 *After review and some additional examination and analyses, it was concluded by FAC, IST that no change was required in its original report and no evidence could be found suggesting SCC as the cause of T-bolt failure. Instead it was observed that specific signatures of SCC were non-existent on the failed T-bolt part. The reviewed FAC, IST report is attached as Appendix "M". Hence, HE and not SCC was the cause of T-bolt failure. NTSB was intimated accordingly by Safety Investigation Board CAA Pakistan (Refer e-mail attached as Appendix "N").*

2.2.8.2 **Landing Gears System**

2.2.8.2.1 **Description and Operation**. The landing gears system consists of two main gears and one nose gear (Refer Appendix "O"). Each main gear is located aft of the rear wing spar inboard of the engine nacelles. The nose gear is located below the aft bulkhead of the control cabin.

2.2.8.2.2 The main and nose gear use air-oil type shock struts to absorb impact on landing and vibrations and shock from movement of the airplane on the ground. Each nose and main gear is equipped with two tyres and wheels assemblies. Each main gear wheel is fitted with disc-type hydraulic brakes modulated by an antiskid system.

2.2.8.2.3 The main gear is hydraulically actuated to retract inboard into the fuselage. Each main gear is locked in the down position by a folding lock strut and in the up position by an uplock hook. Shock strut doors close the opening in the wing for the main gear shock strut and drag strut. A wheel well seal closes against the main gear tyre circumference when the airplane is in flight with gear retracted.

2.2.8.2.4 The nose gear is hydraulically actuated to retract forward into the fuselage. A lock strut assembly locks the nose gear in the up and down positions. Clamshell-type nose gear doors close to fair with the fuselage contour when the nose gear is retracted and remain open when the nose gear is extended.

2.2.8.2.5 The main and nose gears' manual extension systems are cable operated to release each gear from the up and locked position and allow the gear to free fall to the down and locked position.

2.2.8.2.6 Nose wheel steering is provided for aircraft directional control during ground manoeuvres. Normal steering is accomplished by using a steering wheel located at the captain's position. A reduced range of steering by rudder pedal is available.

2.2.8.2.7 **Landing Gears Extension & Retraction**. Extension and retraction of the main and nose gear is by hydraulic power with a manual extension system for lowering the gear when hydraulic power is not available.

The landing gear is controlled by a single control lever mounted on the pilots' center panel. Cables from a drum actuated by the control lever transfer motion to a selector valve that directs hydraulic pressure for gear actuation. A safety lock prevents the control lever from entering the UP position when conditions are not right for gear retraction.

2.2.8.2.8 **Landing Gear Position Indicating & Warning System**. For the cockpit crew, a warning horn, indicator and warning lights provide indication for landing gears down and locked, landing gears not locked, and landing gears position not in accordance with the control lever position.

2.2.8.3 **Landing Gear System Analysis.** The operation of landing gears in the previous flights and in the mishap flight remained satisfactory throughout until the LHS MLG collapse event.

3 Findings

3.1 Operational

3.1.1 The mishap Flight NL-122 took off on 22nd April, 2012 from BBIAP, Islamabad as per plan for JIAP, Karachi.

3.1.2 All the aircraft systems' performance remained normal throughout the flight.

3.1.3 The flight remained uneventful till touchdown at JIAP, Karachi.

3.1.4 The detailed analyses of the DFDR data revealed that the aircraft touched down at a crab angle of 3.69° along with left bank of 0.7° which are well within the authorized limits of B737-400 aircraft.

3.1.5 After landing white smoke was reported by ATC Tower Controller from landing gear area and vibrations were experienced by the cockpit crew from LHS Main Landing Gear area which increased in intensity with the reduction in aircraft speed.

3.1.6 The cockpit crew applied the remedial actions to keep the aircraft under control and on the runway surface.

3.1.7 The remedial actions as per the QRH and FCOM by the cockpit crew were correct and prompt, to keep the aircraft under control and on prepared runway surface after encountering the left main landing gear anomaly.

3.1.8 The aircraft was switched off on the runway and passengers were disembarked normally.

3.1.9 All the emergency services responded very promptly and reached the aircraft.

3.1.10 The cockpit crew of mishap flight did not complete the required documentation of flight parameters in the Computerized Flight Plan (CFP) en-route to destination.

3.1.11 The cockpit crew of mishap flight did not carry the takeoff data card for the specific type of aircraft.

3.1.12 The Load / Trim sheet of mishap flight NL-122 belonged to Jordan Aviation.

3.1.13 The Load / Trim sheet of mishap aircraft on flight NL-121 and NL-122 on 22nd April, 2012 indicated seating capacity as 170Y and 164Y respectively.

3.1.14 While leaving the mishap aircraft on runway, the cockpit crew took available mishap aircraft documents with them.

3.2 **Technical**

3.2.1 The mishap aircraft was serviceable and had no outstanding snag before departure from BBIAP, Islamabad.

3.2.2 The daily inspection of the aircraft was carried out as per the approved Aircraft Maintenance Program (AMP) which did not indicate any anomaly with any of the landing gears' system / sub-systems components and parts.

3.2.3 The aircraft was properly serviced with Jet A-1 fuel before the mishap flight.

3.2.4 The aircraft start up, taxi and take off were all normal. No abnormality with any of the landing gears' system / sub-systems was observed throughout the flight.

3.2.5 As per the DFDR analysis, touchdown and landing parameters were normal.

3.2.6 Immediately after landing, the LHS MLG collapsed resulting into damage to MLG accessories, wing structure and the Engine No 1.

3.2.7 The LHS MLG collapsed due to fracture of T-Bolt Part No 65-46140-9 Serial No 58060-0015 due to inter-granular cracking as a result of weakened grain boundaries.

3.2.8 Once the crack traversed to a certain depth, the remaining cross-section of the bolt suffered instantaneous fracture due to overload.

3.2.9 The most probable cause of T-Bolt failure is hydrogen embrittlement due to inadequate heat treatment of the T-Bolt at manufacturing or reworking stage.

3.2.10 The manufacturing or the last reworking facility may have neglected proper and timely post-bake of the T-Bolt leaving it susceptible to hydrogen embrittlement.

3.2.11 The T-Bolt was replaced at AAR Aircraft Services Indianapolis USA during Check D that was carried out on the aircraft from October, 2011 to January, 2012.

3.2.12 The fractured T-Bolt had not been removed / installed during any scheduled or unscheduled inspection / repair at M/s Shaheen Engineering and Aircraft Maintenance Services (SEAMS), Pakistan since the aircraft induction in M/s SAI fleet in February, 2012.

3.2.13 The other discrepancies observed in the fractured T-Bolt attributable to the last reworking facility included paint and primer used on the washers of T-Bolt assembly. The washers are generally not primed or painted since these processes can increase susceptibility to fatigue.

4 Conclusion

4.1.1 The aircraft landed at JIAP Karachi well within the permissible limits of crosswind conditions at Boeing recommended speed. As per the investigation and detailed laboratory analyses, it is concluded that the LHS MLG collapsed due to failure of T-Bolt Part No 65-46140-9, Serial No 58060-0015. The T-Bolt fractured due to inter-granular cracking as a result of weakened grain boundaries. Once the crack traversed to a certain depth, the remaining cross-section of the bolt suffered instantaneous fracture due to overload.

4.1.2 The most probable cause of T-Bolt failure is hydrogen embrittlement due to inadequate heat treatment of the T-Bolt during manufacturing or at last reworking stage.

5 Finalization

5.1 The Left Hand Side Main Landing Gear of M/s Shaheen Air International Boeing 737-400 aircraft, Registration # AP-BJN collapsed after touchdown at JIAP, Karachi due to failure of its T-Bolt Part No 65-46140-9 Serial No 58060-0015 as a result of inadequate heat treatment during manufacturing or at last reworking stage.

6 Safety Recommendations

6.1 M/s Shaheen Air International is to develop her own Load / Trim sheet for specific type of aircraft with all the required contents / details.

6.2 M/s Shaheen Air International is to ensure that Load / Trim sheet is being filled correctly for all passenger flights.

6.3 M/s Shaheen Air International is to develop and use takeoff data card for the specific type of aircraft.

6.4 All operators in Pakistan are to brief their flight crew for not taking any aircraft document with them after experiencing or handling any incident / serious incident / accident.

6.5 All operators in Pakistan are to brief their flight crew for timely and correct flight documentation.

6.6 All operators in Pakistan are to brief their flight crew for correct documentation of required flight parameters in the Computerized Flight Plan (CFP) en-route to destination.

6.7 All operators in Pakistan operating Boeing 737 series aircraft are to carry out one time inspection of T-Bolts of all aircraft through appropriate NDT (Non Destructive Testing) for crack detection. The bolts with positive indications of crack(s) are to be removed from service.

6.8 All operators in Pakistan operating Boeing 737 series aircraft are to carry out one time inspection of washers Part No 69-41619-1 and AN960-1416 used with the T-Bolt and ensure those are not painted or greased to avoid fatigue in T-Bolt area.

6.9 CAA Pakistan is to ensure the implementation of all relevant safety recommendations at operators' level.

6.10 Boeing is to verify from AAR Aircraft Services where last Check 'D' was carried out for tracking the fractured T-Bolt Part No 65-46140-9, Serial No 58060-0015 and undertaking the following corrective and preventive measures :

6.10.1 Determine what all rework processes were conducted on that T- Bolt and how good quality of reworking processes was achieved and ensured.

6.10.2 Determine whether there was some lapse during rework processes with special focus on plating and relief baking.

6.10.3 All bolts in this lot should be inspected by a non-destructive method for crack detection. The bolts with positive indications of crack(s) are to be removed from service.

6.10.4 If the other bolts have not been reworked, then all bolts in this lot should be tracked, inspected and relief baked at an appropriate temperature for a significant time (greater than 24 hours), or scrapped altogether.

6.11 Boeing is to ensure proper process control at all maintenance facilities authorized to rework the T-Bolt for required heat treatment to prevent hydrogen charging by potential sources.

6.12 Boeing is to study the prospects of issuing a service bulletin to all operators of Boeing 737 series aircraft for carrying out one time inspection of T-Bolts of all aircraft other than the suspected lot as well.

6.13 NTSB, USA may like to advise Boeing for strict conformance of above referred safety recommendations.