

FINAL INVESTIGATION REPORT



SERIOUS INCIDENT OF M/S PIAC FLIGHT NO. PK451
(SECTOR ISB – SKD) A-320 AIRCRAFT REG NO. AP-BLA
AT BBIAP, ISLAMABAD ON 08TH AUGUST, 2016

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Synopsis

The serious incident was reported to Safety Investigation Board (SIB), Pakistan by the operator through Mandatory Occurrence Report (**Appendix 'A'**). The incident was notified in accordance with ICAO Annex-13 (**Appendix 'B'**). Aviation Division, Government of Pakistan issued Memorandum vide letter No. HQCAA/1901/384/SIB/440 dated 10th August, 2016 (**Appendix 'C'**) and investigation was conducted by SIB, Pakistan.

M/s Pakistan International Airlines A320-200, while performing flight PK451 from Islamabad to Skardu (Pakistan). The flight experienced green hydraulic pressure / quantity drop while climbing through 5000 feet. The cockpit crew stopped climb at FL150 and reported hydraulic failure while deciding return to Islamabad. After reaching overhead Islamabad, the flight entered a hold while the crew completed requisite actions besides burning off extra fuel; the aircraft landed at runway 30, touched down safely but veered right, went off the runway. There were no injuries. No.2 engine however, ingested one of the PAPI lights when the aircraft departed the runway.

1. FACTUAL INFORMATION

- 1.1 **History of the Flight.** On 08th August, 2016, M/s PIAC Flight PK451 of (Airbus 320 Reg. No. AP-BLA) was a scheduled passenger flight from Islamabad to Skardu. After taxi out, the aircraft returned to ramp due to green hydraulic and brakes problem. The necessary rectification was done and the aircraft was declared serviceable for flight. The subsequent start up and taxi out remained uneventful, however, after takeoff, when the aircraft was climbing, the green hydraulic system fault appeared again. The aircrew decided to proceed back to Islamabad. After landing, the aircraft departed the runway after travelling approximately 8500 feet from beginning of runway 30 towards right side at 50 kts ingesting one of the PAPI lights by No. 2 engine.



- 1.2 **Injuries to Persons.** There were no injuries to any person during the incident.
- 1.3 **Damage to Aircraft.** No. 2 engine received substantial damage due to hitting / ingestion of PAPI light. There was no other damage to the aircraft.



- 1.4 **Other Damages.** None.
- 1.5 **Personnel Information.** A total of 167 souls were onboard including 160 passengers and 07 crew members. The cockpit crew included one Captain and one First Officer (FO). Their details are mentioned below:

Captain

• Date of Birth	:	1 st November, 1964
• ATPL No.	:	ATPL 1514 (A)
• Medical Validity Date	:	31 st January, 2017
• Total Flying Experience	:	8700 Hrs
• Total In command on type Hrs	:	1000 Hrs
• Total in command	:	2000 Hrs

First Officer

• Date of Birth	:	2 nd May, 1974
• CPL No.	:	CPL 2284 (A)
• Medical Validity Date	:	1 st February, 2017
• Total Flying Experience	:	2200 Hrs
• Total On Type Hrs	:	1500 Hrs (P-2)

- 1.6 **Aircraft information.** The mishap aircraft was maintained by the operator in accordance with the regulations of Pakistan Civil Aviation Authority. Pertinent aircraft and major parts maintenance and life information is as follows:

1.6.1 Aircraft

Aircraft Make & Model	A320-214
Registration Marking	AP-BLA
Manufacturer Serial No.	3031
Year of Manufacture	2007
C of A (S No. expiry date)	26 th May, 2017
Daily inspection prior to 08 th August, 2016 occurrence (date, location)	07 th August, 2016 at Islamabad
Transit check prior to occurrence (date, location)	08 th August, 2016 at Islamabad
Total Aircraft Hours as on 08 th August, 2016 (prior to occurrence)	29659
Total aircraft cycles as on 08 th August, 2016 (prior to occurrence)	14209
Total Landings as on 08 th August, 2016 (prior to occurrence)	14208
Last Check-C (type, date, hrs, cycles, agency performed & location) prior to occurrence	18 th May, 2015 25659 hours / 12252 landings. Carried out in Czech Republic.
Last Check-A (type, date, hrs, cycles, agency performed & location) prior to Occurrence	25 th June, 2016 29235 hours / 13891 landings / PIA

1.6.2 The information of hose which was removed prior to occurrence, due leakage:

Part No.	AE2463921G0097
S No. / Identification	Consumable item. No serial number.
Time Since New (TSN)	Not available
Time Since Installed	Not available
Remaining life at time of removal	Not available

1.6.3 The information of hose which was installed for leak repair :

Part No.	AE2463921G0097
S No. / Identification	Consumable item. No serial number.
Time Since New (TSN)	Not available
Remaining life at time of installation	Not available

1.6.4 **Left Engine**

Type	CFM56-5B4/P
Manufacturer S No.	697-119
Time Since New (TSN)	29659
Time Since Overhaul (TSO)	29659
Next overhaul due hrs/cycles	5861 cycles remaining

1.6.5 **Right Engine**

Type	CFM56-5B4/P
Manufacturer S No.	697-120
Time Since New (TSN)	29659
Time Since Overhaul (TSO)	29569
Next overhaul due hrs/cycles	5861 cycles remaining

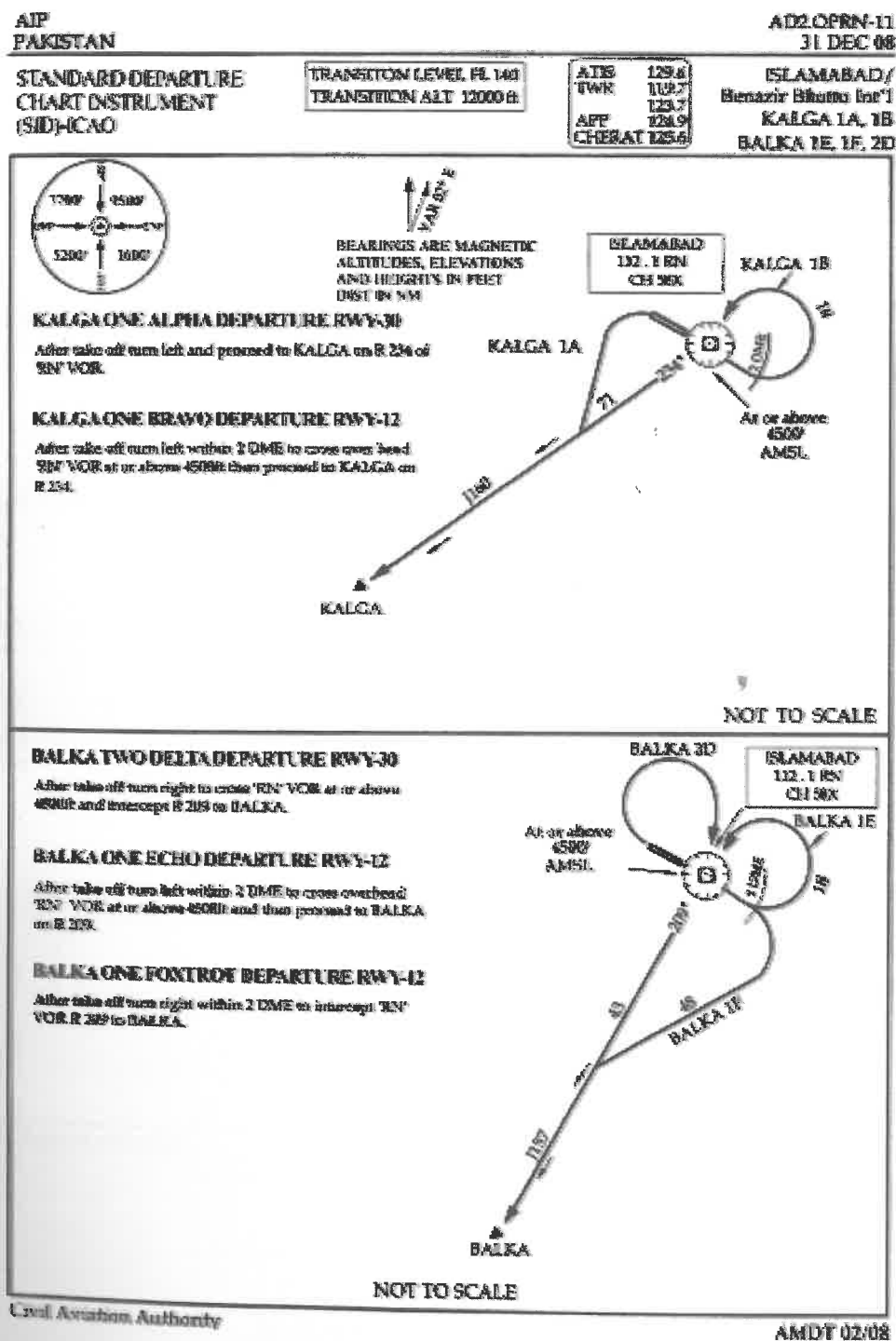
1.6.6 The records of life limited parts of RMLG (**Appendix 'D'**) were reviewed. All life limited parts had sufficient remaining life.

1.6.7 The aircraft used Jet-A1 fuel.

1.7 **Meteorological Information.** On 8th August, 2016, at the time of occurrence the weather prevailing at Benazir Bhutto International Airport (BBIAP), Islamabad is appended below:

Outlook	Visibility	Clouds	Wind	Temp	QNH
Hazy	4 Km	SCT 040	130 ⁰ 06 Kts	33 ⁰ C	1005

- 1.8 **Aids to Navigation.** Airbus 320 AP-BLA aircraft was equipped with serviceable ADF, VOR / DME, ILS and GPS equipment for the conduct of flight operations. All the ground equipment installed at BBIAP related to ADF, VOR / DME and ILS was found serviceable at the time of occurrence.
- 1.9 **Communications.** Airbus 320 AP-BLA aircraft was equipped with UHF and VHF sets for radio contact with all concerned / relevant agencies during the conduct of flight.
- 1.10 **Aerodrome Information.** The BBIAP Islamabad detailed aerodrome data is appended below:



1.10.1 The BBIAP, Islamabad detailed aerodrome data is appended below:

AIP
PAKISTAN

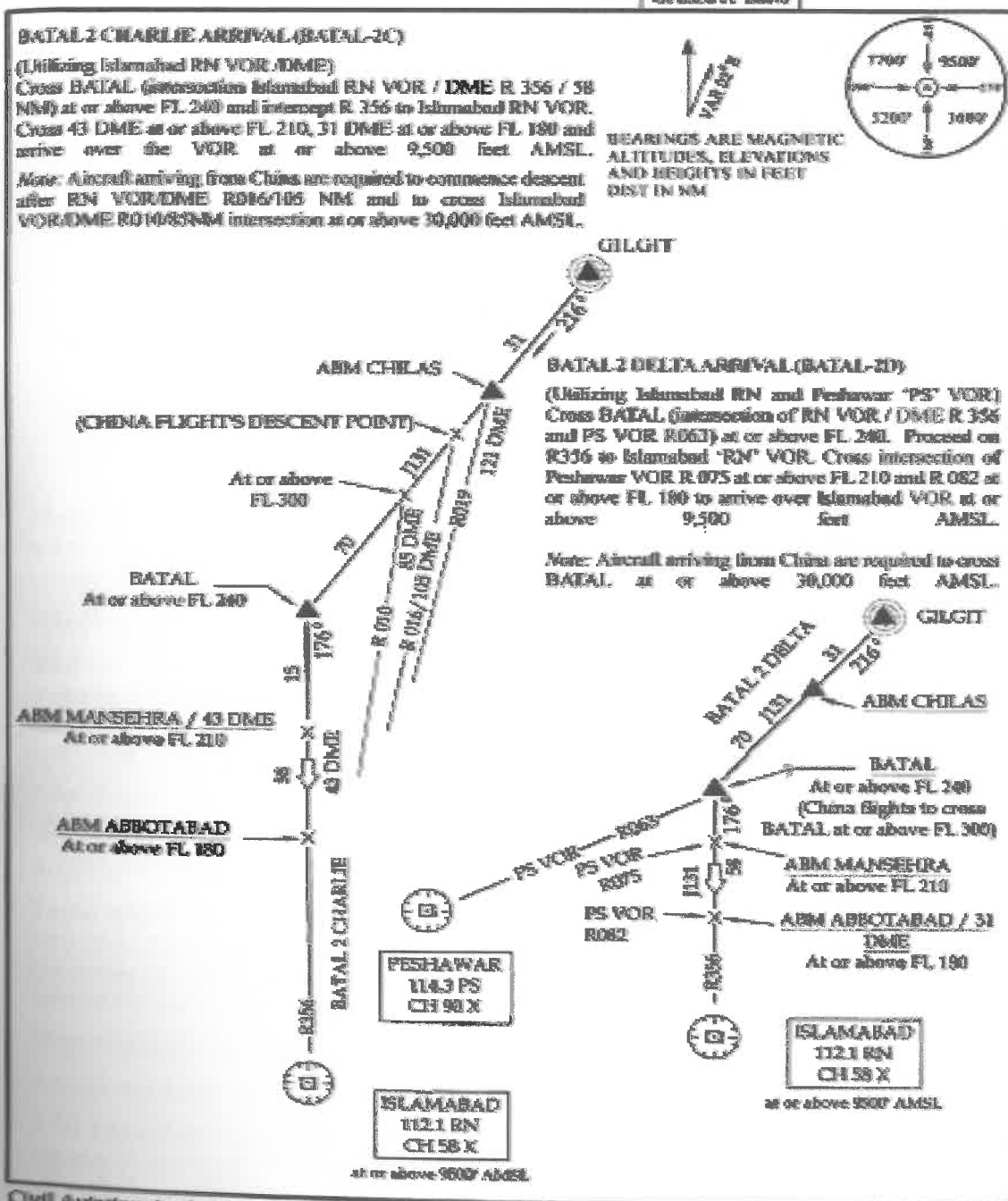
AD2.0PRN-17
31 DEC 88

STANDARD ARRIVAL
CHART INSTRUMENT
(STAR) - ICAO

TRANSITION LEVEL FL 140
TRANSITION ALT 12000'

ATIS 129.6
TWR 119.7
123.7
APP 124.9
CHERAT 125.6

ISLAMABAD/
Benazir Bhutto Int'l
BATAL 2C, 2D



Civil Aviation Authority

AMDT 02/08

OPRN 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
12	118°	3292 x 46	111/F/C/W/T Bitumen	333721.41N 0736508.40E 333639.32N 0736642.32E	THR 506M / 1660 FT THR 505 M / 1657 FT

Designations RWY NR	Slope of RWY/SWY	SWY dimension (M)	CLWY dimension (M)	Strip dimension (M)	Obstacle Free Zone
7	8	9	10	11	12
12	0.15% up to 1951 M from displaced THR 0.5% up to 762 M from displaced THR then .15%	229	-	-	-
30	-	213	-	-	-

Remarks: THR RWY 12 displaced 274 m. THR RWY 30 displaced 274 m. LCN 08 for 274 m (900') in the portion of runway before displaced THR RWY 12. Fair weather strip on both sides of RWY 12/30 not available due uneven level.

OPRN AD 2.13 DECLARED DISTANCES (M)

Designations RWY NR	TORA	ASDA	TODA	LDA	Remarks
1	2	3	4	5	6
12	3017	3246	3246	3017	-
30	3292	3505	3505	2743	-

OPRN AD 2.14 APPROACH AND RUNWAY LIGHTS

Designations RWY NR	APCH LGT type LEM INTST	THR LGT colour WBAR	VASIS (MEH) PAPI	TDZM LGT LEM	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
12	SALS 518 M LH	GREEN	PAPI Le83°	-	2743 M 30 M WHITE LIL	2743 M 60 M WHITE LIL Last 600 M yellow	RED	Additional Strobe by RWY edge lights. Sequenced flasher	PAPI Max range 3 NM. Strobe LGT
30	PALS 200 M LH	GREEN	PAPI Le83°	-	-	-	RED	-	-

Strobe lights will be available when RWY 12 is in use or 2nd VIX or on request.

- 1.11 **Flight Recorders.** The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were recovered from the aircraft. Data from both recorders was successfully retrieved and used during investigation process.
- 1.12 **Wreckage and Runway Marks Information.** Not Applicable.
- 1.13 **Medical and Pathological Information.** There was no injury to any passenger or crew member. The Captain and First Officer, however, were taken to hospital and necessary medical evaluations were conducted. There were no signs of any abnormality in blood and urine samples of both. All medical evaluation results were within normal limit.
- 1.14 **Fire.** There was no fire reported by the crew members or observed by the investigation team members at the site.
- 1.15 **Survival Aspects.** Not applicable.
- 1.16 **Tests and Research.** All available information pertaining Brake System Components and past documented maintenance history of the aircraft was shared with Airbus. As an outcome, a detailed report (**Appendix 'E'**) was rendered by Airbus which shall be referred to as Airbus report.
- 1.17 **Organizational and Management Information.** Not applicable.
- 1.18 **Additional Information.**
 - 1.18.1 **ATC Tape Extracts.** ATC Tower Tape Extracts were retrieved and utilized during the course of investigation for detailed analysis.
 - 1.18.2 **Crew Resource Management (CRM).** At the time of occurrence, the First Officer was the Pilot Flying (PF) whereas the Captain was Pilot Monitoring (PM) and both the cockpit crew had valid CRM certification.
 - 1.18.3 **Use of Effective Investigation Techniques.** Besides employing various investigation techniques and procedures, data extracted from CVR and FDR was extensively utilized for development of flight profile and events leading to the accident and their analyses. The pertinent CVR transcription is attached as **Appendix 'F'**.

2. ANALYSIS

2.1 Operational Analysis

- 2.1.1 The mishap flight was a scheduled passenger flight from Islamabad to Skardu.
- 2.1.2 The cockpit crew was qualified and medically fit to undertake the mishap flight. They had valid ATP / CP licenses and medical fitness certificates. They also had sufficient rest as per FDTL requirement.
- 2.1.3 The aircraft had returned to ramp after taxi out in previous flight due to green hydraulic / brakes problem, however for this flight the start up and taxi was uneventful. The details of reasons of ramp return along with rectification performed are discussed in technical analysis.
- 2.1.4 At 0748:00 UTC the aircraft took off with a gross weight of 64.7 Tons which was within maximum permissible limit of 73.5 Tons.
- 2.1.5 Take off remained uneventful and landing gears / flaps were raised normal. When landing gears were up-locked at 0749:51 UTC, while climbing through 5000 ft, the first ECAM message "HYD G ENG 1 PUMP LO PR" appeared. The green hydraulic pressure dropped from 3008 PSI to 1728 PSI. This alert triggers when hydraulic pressure drops below 1750 PSI.
- 2.1.6 The cockpit crew took actions as per ECAM message by putting green Engine Driven Pump (EDP) and Power Transfer Unit (PTU) off and continued to climb to FL 150 as per radar clearance. As the aircraft was climbing through FL 100 and 15 NM from BBIAP, the Green "HYD G RSVR LO LVL" warning also appeared on ECAM. The green hydraulic reservoir low level warning is associated with hydraulic fluid quantity drop below 3.5 litres. The appearance of brake faults and Green "HYD G RSVR LO LVL" warning were result of putting EDP and PTU off. Additional ECAM procedures were triggered: BRAKES NORM+ALTN FAULT, BRAKES SYS 1 FAULT and BRAKES A/SKID FAULT.
- 2.1.7 The failures on the alternate brake system were already present on the aircraft in many flights prior to the occurrence, also at this stage the cockpit crew focussed on ECAM procedures but could not acknowledge the Alternate Brake Fault. The alternate brake system failure is categorized as class 1 failure which is a NO GO item (refer to technical investigation for details).
- 2.1.8 While analysing the sequence of events during the non normal situation, the fact was established that when green hydraulic pressure was dropped and cockpit crew put off the green hydraulic pump following the ECAM procedure, the normal braking was lost. Therefore the braking system was auto reconfigured on the alternate system (which was already unserviceable). Later, when the green hydraulic system was put ON by the cockpit crew, the normal braking could not come online because BSCU 1 & 2 had declared themselves faulty (details mentioned in technical investigation).
- 2.1.9 Resultantly, the normal and alternate braking systems were not available but the Parking Brake was available (without anti-skid and nose-wheel steering) as per system design, which should have been utilized to slow down the aircraft after landing.
- 2.1.10 Consequent to green hydraulic system malfunction the cockpit crew mutually decided to turn back and land at BBIAP, Islamabad considering that the aircraft may not be rectifiable at Skardu. A request to turn back was made to radar which was approved.
- 2.1.11 The aircraft turned back towards Islamabad and stayed in hold maintaining FL150 for approximately 30 minutes. While holding overhead Islamabad the cockpit crew discussed / completed ECAM actions (refer **Appendix 'F'**). They also mentioned services available / lost during their discussion. It is important to mention here that they were planning for landing considering that normal brakes, anti skid and nose wheel steering was not

available, however they never acknowledged ECAM message indicating Alternate Brake Inoperative and therefore did not apply the relevant landing distance computation from the QRH "In Flight Performance" (Brake System) PER-32 1/4.

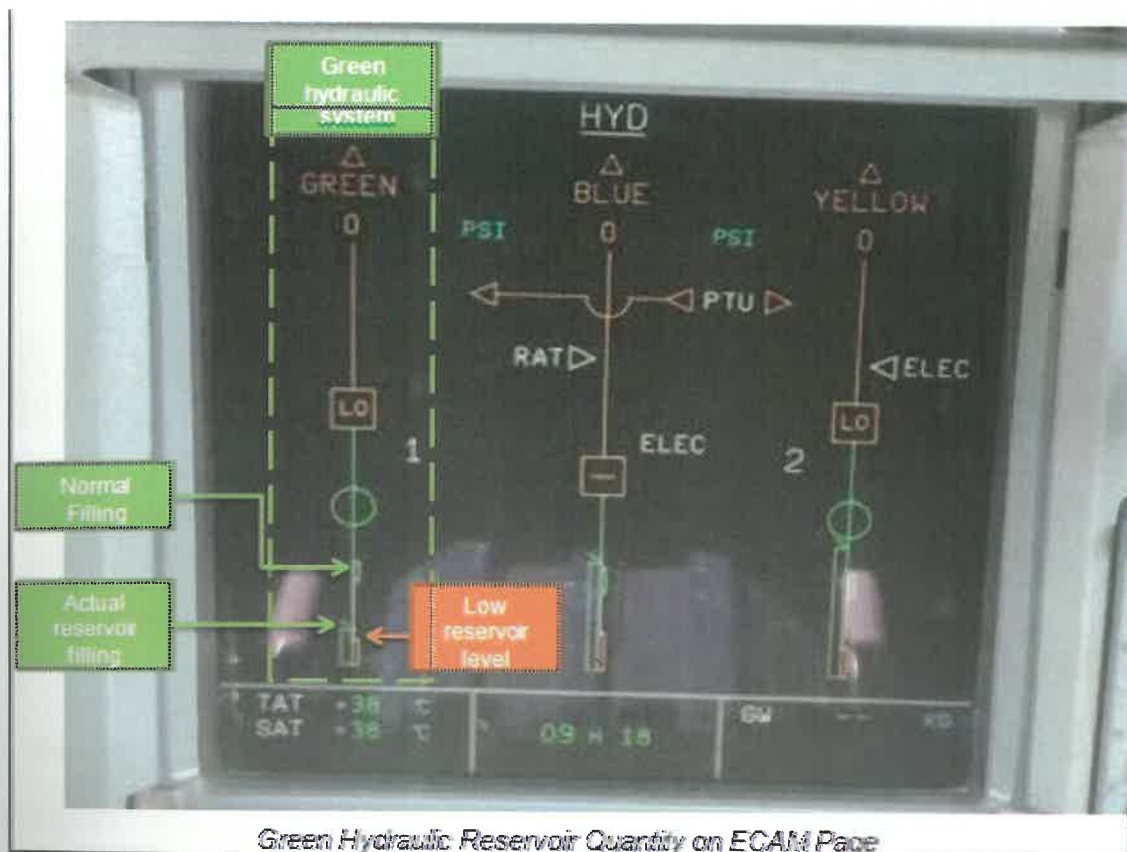
BRAKES NORM + ALTN FAULT (Cont'd)	
Ident.: PRO-ABN-32-Q-00011325.000100N / 11 MAY 12	
STATUS	
PARK BRK ONLY	INOP SYS
LDG DIST PROC	CAT 3
APPLY	ANTI SKID
CAT 2 ONLY	N/W STRG
	NORM BRK
	AUTO BRK
	ALTN BRK

- 2.1.12 The cockpit crew planned and executed an ILS approach on runway 30. During final approach before lowering landing gears, green hydraulic EDP was switched on and observing hydraulic pressure built up, the landing gears were lowered by normal method.
- 2.1.13 While ascertaining the lost / available services due to green hydraulic loss, the cockpit crew misjudged that "they had Alternate Brakes" while it was clearly mentioned in ECAM message in inoperative systems (INOP SYS).
- 2.1.14 While landing on runway 30 at BBIAP, the touchdown was made at 146 kts Ground Speed (GS). After touchdown, and down to 93 kts GS, maximum thrust reversers were used without pedal braking. When the aircraft had slowed down below 93 kts and in the latter half of landing roll, pedal braking was done three times. Although both pedals were pressed simultaneously and equally but significant differential pressure got transmitted to wheels resulting in asymmetrical braking (refer technical investigation for details). This asymmetrical braking resulted in aircraft drifting towards right side, ultimately departing the runway at approximately 50 kts of ground speed, 8500 ft down the runway and hitting No. 2 engine with one of the PAPI lights. The pictorial view of entire landing roll and blow up of braking portion is appended below:

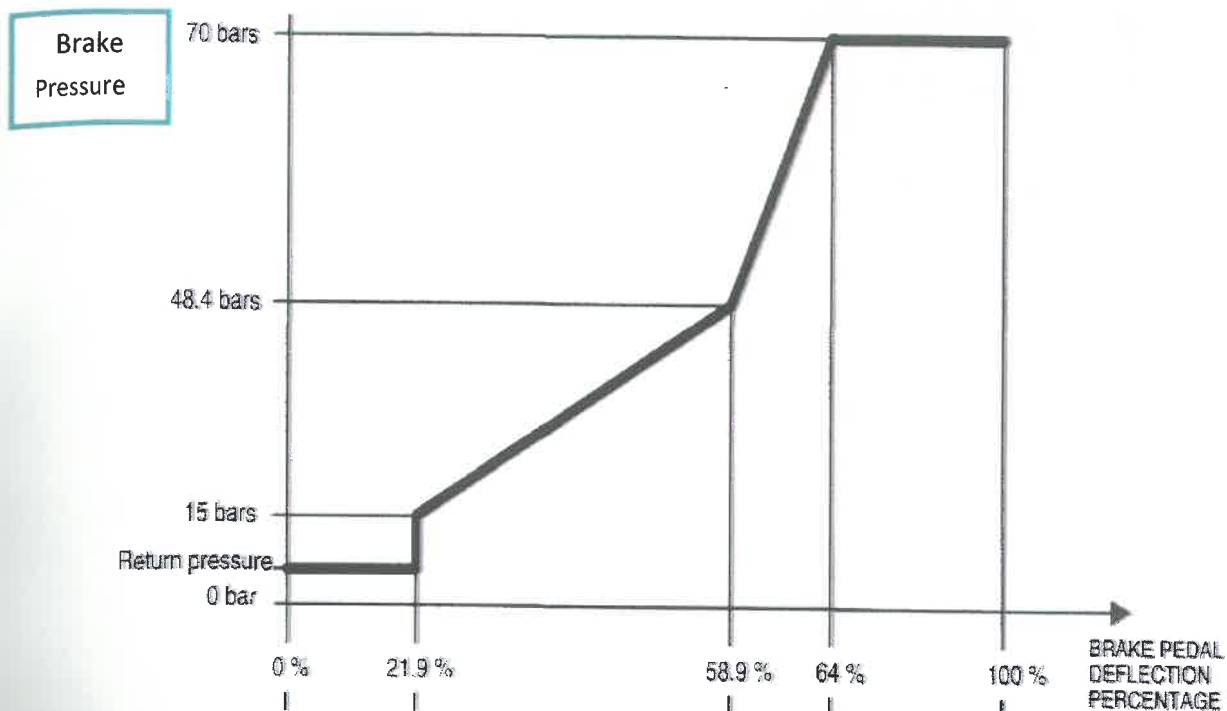


Pictorial view of landing roll

- 2.2.2 After the in-flight event, photo of the ECAM Hydraulic SD page also shows that the green reservoir quantity is green, therefore above the low level warning level (otherwise the indication would have been amber). However, there was clearly a low green hydraulic reservoir quantity, just above the warning level, as illustrated on the picture below:



- 2.3 **Green Hydraulic System.** During taxi, lift-off and initial climb in the misshaped flight, the three hydraulic systems pressurized the aircraft systems. On[®] the DFDR recordings, pressure fluctuations due to consumer loads (first landing gear retraction, followed by slats and flaps retraction) can be seen. However, the transient pressure drops on the green hydraulic system was observed. As mentioned in previous paragraphs, the maintenance bleeding procedure was not followed during 1st ramp return / hydraulic pipe replacement. Consequently :
- 2.3.1 The aircraft departed with a low hydraulic fluid quantity in the green hydraulic reservoir, just above the low level warning threshold (and therefore could not be detected on ground).
- 2.3.2 Due to the lack of bleeding, there was air in the green hydraulic system (present in the landing gear and door system) which was pushed back slowly into the green hydraulic system. During the landing gear retraction and doors closure sequence, the air finally entered into the reservoir, which lowered the reservoir level and resulted in the green reservoir low level during flight.
- 2.3.3 It is worth mentioning here that presence of air in the landing gear and door system may not be detected on ground when bleeding is not correctly performed after the maintenance. For the landing gear and door system, air bleeding means an opening / closing cycle that will push any air towards the hydraulic reservoir. This allows identifying a reduced reservoir fluid level and the consequent need for a reservoir filling.



Brake Pedal Law in Alternate Brake without Anti Skid

- 2.11 **Braking system history on event aircraft.** The first defects entries start on the 13th May 2016. The details of previous 08 entries prior to the incident are as mentioned below:

Date	Item	Defect
28 th July, 2016	40	WITH LDGGEAREXTENSIONFOLLOWINGMSG ONECAMBRAKESALTNBKFAULT
28 th July, 2016	71	WITH LDGGEAREXTENSIONFOLLOWINGMSG ONECAMBRAKESN/WSMINORFAULT.
28 th July, 2016	74	REFITEM70 ONEXTENDSINGL/GMESSAGE"BRAKESALTNBRAKEFAULT" APPEARS.
28 th July, 2016	75	REF ITEM 71BRAKESN/W/S MINORFAULT.
29 th July, 2016	95	BRAKESALTN BRKFAULT SYS-1FAULT COMEON DURINGCRUISE.
29 th July, 2016	96	BRAKESN/WSMINORFAULT CAMEON AFTER PARKINGBRAKEON.
3 rd August, 2016	43	BRAKESN/WSMINORFAULT.
4 th August, 2016	51	BRAKES-N/WSMINOR FAULT.

- 2.12 The DFDR analysis of the 8 previous flights confirms that the failures on both the LH and the RH sides of the alternate braking system were present on the aircraft prior to the event. However, the BSCU was being reset in flight during the previous legs, which is not authorized by the QRH Computer Reset Table.

Flight	Date	From	To	UTC Engine START	UTC Engine STOP
EVENT	08/08/2016	OPRN	OPRN	07:37:41	08:35:57
TAXI	08/08/2016	OPRN	OPRN	04:12:13	04:41:27
EVENT-1	07/08/2016	OMAA	OPRN	21:28:13	00:30:06
EVENT-2	07/08/2016	OPRN	OMAA	17:04:15	20:09:55
EVENT-3	07/08/2016	OMDB	OPRN	12:30:09	15:31:54
EVENT-4	07/08/2016	OPRN	OMDB	08:04:52	11:11:22
EVENT-5	07/08/2016	OPSD	OPRN	05:14:16	06:13:25
EVENT-6	07/08/2016	OPRN	OPSD	03:19:43	04:14:36
EVENT-7	06/08/2016	OOMS	OPRN	09:42:54	12:31:43
EVENT-8	06/08/2016	OPRN	OOMS	06:12:49	08:53:12

2.13 **Analysis of the Post Flight Reports (PFRs).** Previous Legs data from the PFR (refer **Appendix 'G'**) was analyzed. It was learnt that 03 braking failure messages were present in all these previous legs. These 09 legs correspond to the time period between 5th and 7th of August, 2016. These 03 failure messages are also present in the PFR of the event flight. The messages are as mentioned below :

2.13.1 ABCU (95GG)/BRK ALTN SERVOVALVE(97GG).

2.13.2 ABCU (95GG).

2.13.3 BRK ALTN SERVVLV(98GG)/ABCU(95GG).

2.14 **Analysis of the BSCU BITE.** The BSCU supplier (Safran Landing System) did an extraction of the BSCU BITE using an acceptance test bench (ATEC) in Massy (France) (refer **Appendix 'H'**). The BSCU BITE was analyzed by Safran and the conclusions are as follows :

2.14.1 Each system of the BSCU recorded fault codes related to ABCU at almost each flight of the last **50 consecutive flights** during pre-land functional tests. The details are as mentioned below :

S No.	Fault Code	System	Remarks
1	Fault code 1533	BRK ALTN SERVVLV (98GG) / ABCU (95GG)	
2	Fault code 1530	ABCU (95GG) / BRK ALTN SERVOVALVE (97GG)	Except during previous flight No. 29 th
3	Fault code 1550	ABCU (95GG)	
4	Fault code 1570	ABCU (95GG)	Except during previous flight Nos. 16 th , 40 th , 45 th & 48 th

2.14.2 According to the TSM (refer to section 9.1), these fault messages are of class-I. The oldest faults recorded in this BITE extract are dated from the 20th July, 2016 on the system 1 and 19th July, 2016 at for the system 2. Moreover, Safran has also recovered

more fault history from the BSCU using their avionics development bench in Velizy (France). This is documented in the Safran report (**Appendix 'H'**).

2.15 **DDV and ABCU Investigation at SLS.** Other braking system equipment have been investigated by Safran : Alternate Servo-Valve / Direct Drive Valves (Molsheim, France) and ABCU (Angoulême, France) The associated findings have been documented by Safran in their investigation report (**Appendix 'H'**), which covers all braking system equipment (BSCU, ABCU and ASV/DDV).

2.16 Braking System Behavior During the Event Flight

2.16.1 **Normal braking.** The normal braking was lost due to the loss of the green hydraulic system, which was shut down by the crew during the event, as requested by the ECAM procedure. However, when the green hydraulic system was restored by the flight crew, the normal braking could not be recovered because BSCU 1 & 2 had already declared themselves faulty.

2.16.2 **Alternate braking – in-Flight Tests.** Following the loss of the normal braking system during the flight, the BSCU launched the Alternate braking Pre-Land Tests. During these tests, a braking pressure of 101 Bars is commanded. In the DFDR recording of the event flight it was observed that on LH side, the alternate braking pressure was limited to only ~76 Bars, which indicate a negative drift of the ASV. On the RH side, the alternate braking pressure reached the full pressure of ~206 Bars. Therefore, both the BSCU system 1 and system 2 detected the alternate braking system as faulty, and declared themselves as faulty. The ABCU took over the control of the braking system, which therefore reverted to the alternate mode, without anti-skid. Due to the loss of the anti-skid, the commanded braking pressure was limited to 70 Bars (1000 PSI), to prevent wheel locking. The Nose-wheel steering was lost due to the BSCU fault. The ECAM alerts of **BRAKES NORM+ALTN FAULT** and **BRAKES A/SKID NWS FAULT** on the braking system were displayed to the crew (Level 2 failures, associated with a Master Caution).

2.16.3 **Alternate braking – during roll-out.** Based on the DFDR recording while analyzing the alternate braking behavior during the aircraft roll-out, it was observed that on the LH side, the ASV drift was confirmed during the different LH pedal braking applications. As the commanded pressure in alternate braking without anti-skid is basically limited to 70 Bars (1000 PSI) to avoid wheel locking, this failure resulted in the actual braking pressure limited to a maximum of ~50 Bars on the LH side. On the RH side, the failure resulted in the full pressure of ~206 Bars being immediately applied on the RH side (even for very low brake pedal orders), irrespective of the 70 Bars (1000 PSI) limitation, therefore resulting in RH wheels (3 & 4) locking as soon as RH brake pedals were being pressed. The wheel locking was confirmed with the tyre marks present on the runway.

2.16.4 **Parking brake.** In case both the normal and the alternate braking systems are lost, the ECAM procedure associated with the **BRAKES NORM + ALTN FAULT** is as follows:

BRAKES NORM + ALTN FAULT (Cont'd)	
Ident: PRO-ABN-32-Q-00011325.0001001 / 11 MAY 12	
STATUS	
PARK BRK ONLY LDG DIST PROC. APPLY CAT 2 ONLY	<u>INOP SYS</u> CAT 3 ANTI SKID N/W STRG NORM BRK AUTO BRK ALTN BRK

- 2.16.5 This procedure indicate that both the normal (NORM BRK) and the alternate (ALTN BRK) braking systems are lost (as shown in INOP SYS column), and that the Park brake is available. Had the park brake been used during the event, the braking would have been symmetrical, as the brake pressure would have been applied downstream of the Alternate Servo Valves / Direct Drive Valves (DDV), at the level of the shuttle valve (refer to the braking architecture schematics provided in §2.4). The park brake pressure is 145 Bars (~2100 PSI).
- 2.17 **Technical Audit of Operating and Maintenance Procedures at M/s PIAC.** Consequent to the anomalies observed during abovementioned course of investigation, an audit of the procedures & working practices at M/s PIAC was carried out which surfaced few aspects which lead to this serious incident.
- 2.17.1 As it was learnt from the downloaded data of BSCU that Alternate Brake System was faulty for the last at least 50 flight legs operated by AP-BLA, therefore, data of all pilots and engineers was acquired from PIAC (refer **Appendix 'J'**). The data reveals that in 47 legs the report ECAM warning message was reset by the Aircrew during flight which was not allowed. For the remaining 03 legs (at different time intervals), the problem was reported to the Engineering, however, the engineering staff as well resorted to reset the system without carrying out adequate investigation. This clearly indicates an un-healthy working culture at M/s PIAC of living even with the problems and operating the aircraft with a NO GO status.
- 2.17.2 In PIAC, as per existing procedures, the Post Flight Reports (PFRs) are retrieved and checked on arrival by the concerned engineers. During visit of PIAC, it was noted that although PFRs of aircraft having some repeated defects are being emailed to production, yet there exists no central system where PFRs are recorded and monitored.
- 2.17.3 In PIAC, as per the centralized policy (refer **Appendix 'K'**), the reported defects are being logged in Aircraft Technical Log book. The computerized record is then required to be archived in PIA Aircraft Maintenance Management Information System (PAMMIS) for utilization by various sections including PIA Airworthiness division for monitoring of repeated defect (refer **Appendix 'L'**). However, it has been observed that there exist noticeable lags in the updating of observed and Pilot Reported Defects (PIREPs) in the PAMMIS system. Consequent to such poor and delayed updating of the PAMMIS, the entire system of monitoring of defects becomes futile. In particular to this incident, the data of the reported defect Vs when it was fed in PAMMIS reveals major lags (refer **Appendix 'M'**).

3. CONCLUSIONS

3.1 Operational Findings

- 3.1.1 The mishap flight was a scheduled passenger flight from Islamabad to Skardu.
- 3.1.2 The cockpit crew was qualified and medically fit to undertake the mishap flight. They had valid ATP/CP licenses and medical fitness certificates. There was no Flight Duty Time Limit (FDTL) violation observed.
- 3.1.3 The aircraft had green hydraulic / brakes problem in previous flight and had returned to ramp after taxi out.
- 3.1.4 During mishap flight the start up and taxi was uneventful.
- 3.1.5 At 0748:00 UTC the aircraft took off with a gross weight of 64.7 Tons which was within maximum permissible limit of 73.5 Tons.
- 3.1.6 Take off remained uneventful and landing gears / flaps were raised normal. When landing gears were up-locked at 0749:51 UTC, while climbing through 5000 ft, the first ECAM message "HYD G ENG 1 PUMP LO PR" appeared. The green hydraulic pressure

dropped from 3008 PSI to 1728 PSI. This alert triggers when hydraulic pressure drops below 1750 psi. The cockpit crew took actions as per ECAM message by putting green Engine Driven Pump (EDP) and Power Transfer Unit (PTU) off and continued to climb to FL 150 as per radar clearance. Additional ECAM procedures were triggered: BRAKES NORM+ALTN FAULT, BRAKES SYS 1 FAULT and BRAKES A/SKID FAULT.

- 3.1.7 As the aircraft was climbing through FL 100 and 15 NM from BBIAP, the Green "HYD G RSVR LO LVL" warning also appeared on ECAM. The green hydraulic reservoir low level warning is associated with hydraulic fluid quantity drop below 3.5 litres. The appearance of brake faults and Green "HYD G RSVR LO LVL" warning were result of putting EDP and PTU off.
- 3.1.8 The failures on the alternate brake system were already present on the aircraft in many flights prior to the occurrence, also at this stage the cockpit crew focussed on ECAM procedures but could not acknowledge the Alternate Brake Fault. The alternate brake system failure is categorized as class 1 failure which is a NO GO item meaning that the aircraft is not airworthy.
- 3.1.9 During initial climb after takeoff, when green hydraulic pressure was dropped and cockpit crew put off the green hydraulic pump and the Power Transfer Unit (PTU) following the ECAM procedure, the normal braking was lost. Therefore the braking system was auto reconfigured on the alternate system (which was already unserviceable).
- 3.1.10 Later, when the green hydraulic system was put ON by the flight crew, the normal braking could not be recovered because BSCU 1&2 had declared themselves faulty.
- 3.1.11 Resultantly, the normal and alternate braking systems were not available but the Parking Brake was available (without anti-skid and nose-wheel steering) as per system design, which should have been utilized to slow down the aircraft after landing.
- 3.1.12 Consequent to green hydraulic system malfunction the cockpit crew mutually decided to turn back and land at BBIAP, Islamabad considering that the aircraft may not be rectifiable at Skardu. A request to turn back was made to radar which was approved.
- 3.1.13 The aircraft turned back towards Islamabad and stayed in hold maintaining FL150 for approximately 30 minutes.
- 3.1.14 While holding overhead Islamabad the cockpit crew discussed / completed ECAM actions. They also mentioned services available / lost during their discussion.
- 3.1.15 The aircrew planned for landing considering that normal brakes, anti skid and nose wheel steering was not available, however they never acknowledged ECAM message indicating Alternate Brake Inoperative and therefore did not apply the relevant landing distance computation from the QRH "In Flight Performance (Brake System) PER-32 1/4.
- 3.1.16 The cockpit crew executed an ILS approach on runway 30. During final approach before lowering landing gears, green hydraulic EDP was switched on and observing hydraulic pressure built up, the landing gears were lowered by normal method.
- 3.1.17 While ascertaining the lost / available services due to green hydraulic loss, the cockpit crew misjudged that "they had Alternate Brakes" while it was clearly mentioned in ECAM message in inoperative systems (INOP SYS).
- 3.1.18 While landing on runway 30 at BBIAP, the touchdown was made at 146 kts. After touchdown, maximum thrust reversers were used till 93 kts. When the aircraft had slowed down below 93 kts and in the latter half of landing roll pedal braking was done three times. Although both pedals were pressed simultaneously and equally but significant differential pressure got transmitted to wheels resulting in asymmetrical braking (refer technical investigation for details). This asymmetrical braking resulted in aircraft drifting towards right side, ultimately departing the runway at approximately 50 kts of

ground speed, 8500 ft down the runway and hitting No. 2 engine with one of the PAPI lights.

- 3.1.19 Analysing the entire sequence of events mentioned above, the only option left was to use parking brake which would have been symmetrical, as mentioned in the ECAM caution BRAKES NORM+ALTN FAULT ("PARK BRK ONLY"). This procedure was not applied.
- 3.1.20 The aircraft came to final stop approximately 475 feet short of end of runway 30 and 123 feet towards right (north) from the edge of runway. The aircrew carried out engine shut down checklist and passengers were disembarked normally through stairs.

3.2 Technical Findings

- 3.2.1 On 8th August, 2016 during 1st launch, after starting No. 1 engine and before taxi out, ECAM appeared for Green Hyd Low level followed by low pressure which lead to the 1st ramp return.
- 3.2.2 While returning to ramp, brakes were catchy and aircraft was pulling towards right on application of brakes besides hydraulic leakage from left main landing gear door area.
- 3.2.3 After ramp return, maintenance crew found one metal braided hose of left hand main landing gear door actuator ruptured. Temporary repair was made by installing an alternate hose.
- 3.2.4 After this temporary repair, aircraft Green Hydraulic reservoir was replenished. However, the engineer did not follow the procedure of bleeding the system after charging hydraulic fluid. Consequently, air remained trapped inside the Green Hydraulic System.
- 3.2.5 The aircraft took off normal for Skardu, however, after the landing gear retraction, this air was pushed back slowly into the reservoir leading to a reduced reservoir level of the Green Hydraulic System.
- 3.2.6 After the event of the green hydraulic system loss, the normal braking was lost and was no more available for the landing.
- 3.2.7 Consequently, the braking system reconfigured on the alternate braking system, however, the internal tests of the alternate system indicated failures on both LH & RH ASV (Alternate Servo Valve).
- 3.2.8 Now, both normal and alternate braking systems were declared lost on the ECAM. Accordingly, the Parking Brake remained available without anti-skid and nose-wheel steering as per Brake System Architecture.
- 3.2.9 Analysis of the available aircraft maintenance records (defects history, PFR last legs reports, and BSCU BITE) confirmed that the failures on the alternate brake system were already present on the aircraft prior to the event at least since 19th July, 2016 (50 flights).
- 3.2.10 These were class 1 failure messages and the associated ECAM alert (BRAKES ALTN BRAKES FAULT) was a NOGO item. However, the ECAM alert / reported defect was being addressed by resetting the system by Pilots & Engineering Staff of PIAC without carrying out any investigation behind this repeated / frequently reported defect.
- 3.2.11 Post-event investigation of both the ASVs by the OEM (M/s Safran Landing Gear Systems) confirmed presence of hardware failures on both ASVs due to unserviceable pressure transducers.
- 3.2.12 During the landing roll-out, pedal braking was used instead of Parking Brake.
- 3.2.13 Due to the failures present on the Alternate Braking System, full braking pressure (206 Bars) got applied on the RH side and limited 50 Bars on the LH side during application of the brakes after landing.
- 3.2.14 The resulting significant asymmetrical braking, combined with the loss of NWS (Nose Wheel Steering), led to a lateral (right) runway excursion.

- 3.2.15 The aircraft suffered damage to the RH engine (FOD ingestion) during the runway excursion.
- 3.2.16 In case, the parking brake was used as per procedure during landing, the braking would have been symmetrical, as the brake pressure would have been applied symmetrically on both sides.
- 3.2.17 The data of previous 50 legs flown on this aircraft revealed that the ECAM warning about failure of Alternate Brake System was reset for 47 times by the pilots (mostly repeated). For the remaining three times, the Pilots reported this problem; however, the engineering also applied the same solution of resetting the system without carrying out proper investigation.
- 3.2.18 This indicated that there exists a culture of operating aircraft having defects of NO GO status while compromising on the safety of aircraft and souls aboard.
- 3.2.19 There exists no central system where PFRs are recorded and monitored in M/s PIAC.
- 3.2.20 A noticeable lag has been observed in the updating of reported defects / PIREPs in the PAMMIS system in M/s PIAC.

4. OBSERVATIONS

- 4.1 In-flight BSCU was reset by the aircrew for approximately 50 flights prior to this flight; however it was not done in the event flight.
- 4.2 As per BSCU reset policy, the in-flight BSCU reset is only authorized in case 'BRAKES SYS 1 (2) FAULT' and 'BRAKES BSCU CH 1 (2) FAULT' ECAM alert(s) are triggered, and the landing gears are up. Also, any BSCU reset is to be recorded in the logbook.
- 4.3 The specific QRH procedure in section 80.18H is appended below:


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 QUICK REFERENCE HANDBOOK

**ABNORMAL AND
EMERGENCY PROCEDURES**

80.18H

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Continued from the previous page

ATA	System malfunction or ECAM Warning/Caution	Affected System	Reset
	BRAKES SYS 1(2) FAULT or BRAKES BSCU CH 1(2) FAULT	BSCU	<u>On ground:</u> - STOP aircraft. - Set PARK BRK handle to ON. - Confirm that towing bar is disconnected. - Set A/SKID & N/W STRG sw to OFF. - Set A/SKID & N/W STRG sw to ON. - If unsuccessful: - Pull C/Bs M33 and M34 on 121VU for BSCU channel 1. - Pull C/Bs M36 and M35 on 121VU for BSCU channel 2. - Push C/Bs. After a successful reset, resume to normal operation. <u>Note:</u> After any BSCU reset: 1. Check brake efficiency. 2. Record BSCU reset in the logbook. <u>In Flight:</u> When landing gear is up only: - Set A/SKID & N/W STRG sw to OFF. - Set A/SKID & N/W STRG sw to ON. - If required, rearm the autobrake. When landing gear is down: reset not authorized. <u>Note:</u> After any BSCU reset: - Record BSCU reset in the logbook.

- 4.4 Therefore the BSCU reset in-flight following either the BRAKES NWS MINOR FAULT or the BRAKES ALTN FAULT ECAM alerts is not authorized.
- 4.5 **Cause of Occurrence.**
- 4.5.1 Using pedal braking instead of parking brakes by cockpit crew when both normal & alternate brakes were inoperative.
- 4.5.2 Non application of OEM recommended landing distance calculation procedure by the cockpit crew prior to landing.
- 4.5.3 Not carrying out Hydraulic System purging after replacement of flexible hose of LH main landing gear door actuator contrary to the laid down OEM's procedure was the cause of returning back during flight.
- 4.5.4 Improper defect rectifications, poor defect monitoring due lag in defect record updating in system & absence of centralized system for monitoring of PFRs are causes due to which the NOGO defect of alternate braking continued to persist and was never adequately rectified. Consequentially, once normal braking system was lost due green hydraulic system failure, the alternate braking did not take over due to already persisting failures of both ASVs (Alternate servo valves) which lead to an asymmetric braking after landing.
- 4.5.5 The culture of **not documenting** even the observed serious problems by pilots and engineering staff lead to operating the aircraft with a NO GO status.
- 4.5.6 The culture of **improper defect rectification** by the engineering staff leads to non-availability of the Alternate Braking System when it was desperately required after the failure of Green Hydraulic System.

5. SAFETY RECOMMENDATIONS

- 5.1 All operators to advise their aircrew to follow the OEM recommended procedures for handling non normal situations and follow QRH procedures, wherever required.
- 5.2 The involved Captain and First Officer are to undergo ground schooling of one day with special emphasis on hydraulic systems.
- 5.3 The involved Captain and First Officer are to undergo CRM refresher training.
- 5.4 The involved Captain and First Officer (as a pair) are to undergo route check by operators' DCP "A", monitored by PCAA Flight Inspector (Pilot).
- 5.5 PIAC Engineering is required to ensure that :-
- 5.5.1 The OEM's recommended procedures for hydraulic charging / bleeding are followed in true & spirit. Recurrent training / Refreshers on regular basis to be arranged for an improved maintenance culture.
- 5.5.2 The defect rectifications against a reported defect must be as per OEM's recommended troubleshooting manual, especially considering a NO GO defect.
- 5.5.3 The lag in defects record updating must be reduced to minimum in line with defined policy to rule out any deficiency on part of the defect monitoring system. The Technical Publication & Record system of PIAC Engineering must implement improved strategies for on time updating of defects of A320 fleet in their PAMMIS system.
- 5.5.4 A centralized policy for recording & monitoring of PFRs (Post Flight Reports) of A320 fleet of PIAC must be designed and implemented by Quality Assurance division in coordination with Airworthiness Management division to avoid such events.

- 5.6 The culture of not documenting the defects amongst pilots and taking short cuts amongst engineers at M/s PIAC for defect rectifications must be discouraged through improved working ethics and regular indoctrination.