FINAL REPORT

AIRCRAFT ACCIDENT INVESTIGATION INTO M/s BHOJA AIR FLIGHT BHO-213, BOEING 737-236A, REG # AP-BKC CRASHED ON 20th APRIL, 2012 NEAR BBIAP, ISLAMABAD

Synopsis

On 20th April, 2012, M/s Bhoja Air Boeing 737-236A Reg # AP-BKC was scheduled to fly domestic Flight BHO-213 from Jinnah International Airport (JIAP) Karachi to Benazir Bhutto International Airport (BBIAP) Islamabad. The aircraft had 127 souls onboard including 06 flight crew members. The Mishap Aircraft (MA) took off for Islamabad at 1705 hrs Pakistan Standard Time (PST) from Karachi. The reported weather at Islamabad was thunderstorm with gusty winds. During approach for landing at BBIAP, Islamabad (OPRN), Flight BHO-213 was cleared by Islamabad Approach Radar for an Instrument Landing System (ILS) approach for Runway 30. The MA, while established on ILS (aligned with Runway 30 at prescribed altitude), at 6 miles to touchdown was asked by the Approach Radar to change over to Air Traffic Control (ATC) Tower frequency for final landing clearance. The cockpit crew came on ATC Tower frequency and flight was cleared to land at BBIAP, Islamabad, but the cockpit crew did not respond to the landing clearance call. The ATC Tower repeated the clearance but there was no response. After a few minutes, a call from a local resident was received in ATC Tower, stating that an aircraft had crashed close to Hussain Abad (A population around 4 nm short of runway 30 BBIAP, Islamabad). It was later confirmed that Flight BHO-213 had crashed and all 127 souls onboard (121 passengers + 6 flight crew) had sustained fatal injuries along with complete destruction of aircraft.

Investigation Authority

Ministry of Defence issued notification vide Letter No AT-2(20)/93 (Accident) dated 22nd April, 2012 authorising to investigate the accident. In accordance with ICAO Annex 13, as the state of manufacture of the aircraft and engines, the National Transportation Safety Board (NTSB) appointed a US accredited representative. The US accredited representative was assisted by technical advisors from Boeing, the Federal Aviation Administration and Pratt & Whitney.

1. FACTUAL INFORMATION

1.1 **History of the Flight.** The aircraft was serviceable and earlier on that day had flown two flights BHO-211 & 212 on Karachi – Islamabad – Karachi sectors with no reported defect. The aircraft was serviced at Karachi by Pakistan Aviation Engineering Services' (PAES) maintenance staff and cleared for Flight BHO-213 (sector Karachi – Islamabad). The aircraft took off from Karachi at 1705 hrs and proceeded to the destination (BBIAP, Islamabad) without encountering any operational or maintenance abnormality en-route till intercepting final approach.

1.2 **Injuries to Persons.** All 127 souls (121 passengers and 06 flight crew) onboard the ill-fated Flight BHO-213 got fatally injured as a result of aircraft ground impact.

1.3 **Damage to Aircraft.** M/s Bhoja Air B737-236A (Reg # AP-BKC) aircraft was completely destroyed as a result of ground impact.

1.4 **Other Damages.** There were minor damages to the houses and wheat crop in the fields due to ground impact and subsequent disintegration of aircraft. All the damages were compensated by M/s Bhoja Air either in the form of cash payment or re-construction of their damaged parts of houses.

1.5 **Cockpit Crew Information.** There was a set of two pilots onboard the aircraft including one Captain and one First Officer. The details are as under:

(a) Captain

- Date of Birth : 15 February, 1954
- ATPL No : 948 (A)
- Medical Validity Date : 30 September, 2012
- Total Flying Experience : 10158:20 hrs
- Flying Hrs on B737-200 : 2027:00 hrs
- Flying Hrs on B737-236A : 82:30 hrs
- CRM Refresher Validity : 30 April, 2013

(b) First Officer (FO)

- Date of Birth : 30 April, 1958
- CPL No : 2934 (A)
- Medical Validity Date : 31 May, 2012
- Total Flying Experience : 2832:00 hrs
- Flying Hrs on B737-200 : 750:00 hrs
- Flying Hrs on B737-236A : 82:00 hrs
- CRM Refresher Validity : 28 February, 2014

1.6 **Aircraft Information.** The Boeing 737-236A (Reg # AP-BKC) aircraft was inducted on the inventory of M/s Bhoja Air in January, 2012. The detailed aircraft and engine related data is appended below:

1.6.1 **Aircraft.**

- Aircraft Make and Model : Boeing 737-236A
- Manufacture Serial No : 23167
- Aircraft Inducted in Bhoja Air : January, 2012
- Registration Marking : AP-BKC
- Aircraft Line Number : 1074
- Year of Manufacture : 1985
- Total Hours at Induction : 46863.56
- Total Flight Hours at Crash : 46933.06
- Total cycles at Induction : 37783
- Total Flight Cycles at Crash : 37824
- Total hours/Cycles flown with Bhoja : 69.10 / 41

1.6.2 **Engines Information.** The details of engines installed at the time of crash are as below:

	ENGINE # 1 (Left)	ENGINE # 2 (Right)
Engine Type and Model	JT8D-15A	JT8D-15A
Engine Serial Number	700469	709211
Total Hours at Induction	33666	49398
Total Cycle at Induction	19483	36615
Total Hours at Crash	33724.20	49456
Total Cycles at Crash	19521	36653

1.6.3 The daily inspection / servicing of mishap aircraft was carried out on 20th April, 2012 prior to the departure of Flight BHO-213 and no defect was recorded. No anomaly in the aircraft system performance was recorded before and during the flight till mishap aircraft impacted the ground 4.2 nm short of runway 30 at BBIAP, Islamabad.

1.7 **Meteorological information.**

1.7.1 On 20th April, 2012 the weather around OPRN was forecasted to be cloudy with chances of thunderstorm and rain. The same was passed in advance through TAFs. Duty Met Officer issued weather warning for thunderstorm rain at 1430 hrs on 20th April 2012 for OPRN which was initially valid from 1500 till 1800 hrs and later was extended. It included 1-2/8 CB at or above 2500 feet AGL with reduction trend of surface visibility from 3-1 km or even less in precipitation and wind 20-40 kts QNT 65 kts or more for BBIAP Islamabad and 50 km around.

1.7.2 The detailed Meteorological analysis is given in subsequent paragraphs.

1.8 **Navigation Aids Availability.** Boeing 737-236A aircraft was equipped with serviceable ADF, VOR / DME, ILS and GPS 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 Availability.** Boeing 737-236A 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 **Type of Fuel used.** The aircraft was refuelled with JET A1 fuel. The sample of the fuel taken from the source was tested for contamination. The Fuel Test report did not reveal any abnormality.

1.11 **Impact Information.** The wreckage site was situated 4.2 nm short of runway 30 BBIAP, Islamabad near a small and thinly populated village named Hussain Abad. The terrain was generally undulating and terraced agricultural land. The main wreckage was confined to an area of 1400 ft x 446 ft in line with runway 30. The Main Landing Gears (MLGs) were the first to impact the ground indicating their extended state. The aircraft structural disintegration started immediately after the ground impact. Shortly after initial ground contact, the aircraft struck a steeply sloped terrace ~5 meters high which resulted in significant structural breakup of the aircraft structure.

1.12 **Aids to Navigation.** Following navigation aids were available and serviceable at BBIAP Islamabad prior to the crash of ill fated Flight BHO-213.

OPRN 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/DME 30	Dots/Dashes	335 MHZ / CH40X	H24	333639.92N 0730629.53E	-	
LLZ ILS CAT I	IRN	110.3 MHZ	H24	333728.90N 0730451.72E		
LLZ-TDME		CH-40X	H24	DITTO	513.09M	←
VOR/DME	RN	112.1 MHZ / CH 58X	H24	333621.39N 0730733.37E	504.47M	

1.13 **Communications.** Following communication facilities were available and serviceable.

OPRN AD 2.18 ATS COMMUNICATION FACILITIES

Service designation	Call sign	Frequency	Hours of operation	Remarks
1	2	3	4	5
APP	Islamabad APP	124.9 MHZ	H24	Primary frequency
APP	Cherat APP	125.6 MHZ	H24	Primary frequency
TWR	Chaklala Tower	123.7 MHZ	H24	Primary frequency
	"	121.5 MHZ	H24	Emergency Frequency
	"	119.7MHZ	H24	Secondary Frequency ←
	Islamabad APP	125.5 MHZ	H24	Secondary Frequency
ATIS	ATIS	129.6 MHZ	H24	
BS	Radio Pakistan	1150 KHZ	HX	
G/A/G	Radio	5601 KHZ	H24	
G/A/G	Radio	2923 KHZ	H24	

1.14 **Aerodrome information**

1.14.1 The northeast of BBIAP Islamabad is covered by a hilly terrain. The highest Minimum Sector Altitude (MSA) is 9500 ft towards northeast and the lowest is 3600 ft towards southeast. The two prohibited areas ie OP(P)-254 and OP(P)-277 are located towards the southwest and northeast of BBIAP, Islamabad respectively.

1.14.2 Airfield layout includes one main runway with no parallel or operational secondary surfaces. BBIAP Islamabad ATC Tower is manned by CAA and PAF Controllers to provide Aerodrome Control Service for civilian and military traffic respectively. The Islamabad Radar of CAA is providing radar vectoring services to arriving and departing aircraft in the designated airspace. The CAA as well as PAF controllers handling the air traffic at BBIAP, Islamabad are qualified and certified to undertake this activity in their specific area of responsibility. The following is the Jeppesen chart for the ILS DME RWY-30.

OPRN/ISB
CHAKLALA INTL

JEPPESEN 23 MAY 03 (11-1)

ISLAMABAD, PAKISTAN
ILS DME Rwy 30

ATIS	ISLAMABAD Approach	CHERAT Approach	CHAKLALA Tower
129.6	124.9 ❶	125.6	119.7 123.7

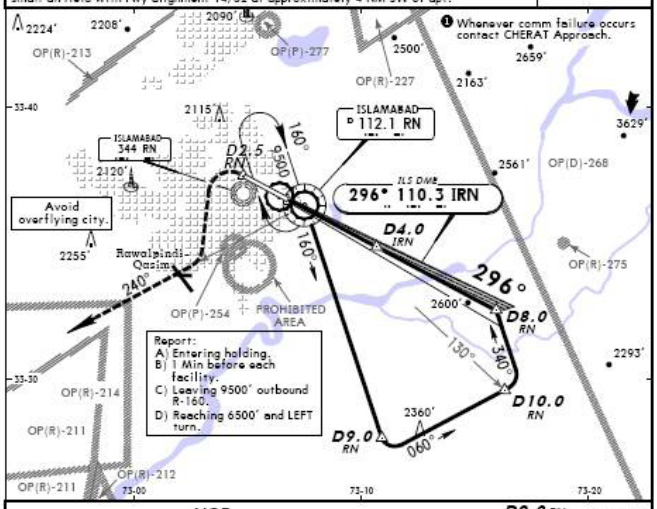
LOC IRN	Final Apch Crs	GS D4.0 IRN	ILS DA(H)	Apt Elev 1668′
110.3	296°	2938′ (1282′)	1965′ (309′)	RWY 1656′

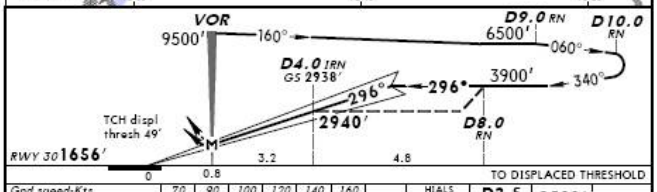
MISSED APCH: Climb to D2.5 RN, then turn LEFT climbing to 9500′ outbound on R-240 RN and contact ATC.

Alt Set: hPa(IN on req) Rwy Elev: 59 hPa Trans level: FL 140 Trans alt: 12000′

1. ILS DME reads zero at rwy 30 displaced threshold. 2. WARNING: Do not mistake small airfield with rwy alignment 14/32 at approximately 4 NM SW of apt.

MSA RN VOR: 7700′ 9500′ 5200′ 3600′ (090°–180°–270°–360°)





Gnd speed-Kts	70	90	100	120	140	160
ILS GS 3.00° or LOC Descent Gradient 5.2%	377	484	538	646	753	861
MAP at VOR						

HIALS PAPI | D2.5 RN | 9500′ LT | RN on 112.1 R-240

JAR-OPS

STRAIGHT-IN LANDING RWY 30

	ILS DA(H) 1965′ (309′) FULL	ILS DA(H) 1965′ (309′) ALS out	LOC (GS out) MDA(H) 1970′ (314′)	LOC (GS out) MDA(H) 1970′ (314′) ALS out
A	RVR 800m	RVR 1200m	RVR 900m	RVR 1500m
B			RVR 1000m	
C				RVR 1800m

CIRCLE-TO-LAND

Max Kts	MDA(H)	VIS
100	2410′ (742′)	1500m
135	2410′ (742′)	1600m
180	2510′ (842′)	2400m

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	122 (T) 120 (M)	3292 x 46	77/F/C/X/T Bitumen	333721.41N 0730508.49E	THR 506M / 1660 FT
30	302 (T) 300 (M)			333639.32N 0730642.38E	THR 505 M / 1657 FT

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
12	0.15% up till 1981 M from displaced THR	229	-	-	-
30	0.5% up till 762 M from displaced THR then .15%	213	-	-	-
Remarks: THR RWY 12 displaced 274 m. THR RWY 30 displaced 274 m. LCN 68 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 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
12	SALS 518 M LIH	GREEN	PAPI Left/3°	-	2743 M 30 M WHITE LIL	2743 M 60 M WHITE LIL. Last 600 M yellow	RED	Additional Stand by RWY edge lights. Sequence flasher	PAPI Max range 3 NM. Strobe LGT
30	PALS 900 M LIH	GREEN	PAPI Left/3°	-			RED		-

1.15 **Medical and Pathological Information.** The body / remains of Captain were identified by his family members on the night of 20th April, 2012 at Pakistan Institute of Medical Sciences (PIMS), Islamabad. As per the PIMS management input, the body parts / remains of Captain were handed over to the family by Police & District Administration and post mortem was not conducted on the request of legal heirs. Whereas, the remains of FO were identified by DNA profiling on 26th April, 2012. After the autopsy body parts / remains were handed over to the family members by District Administration.

1.16 The DNA samples of onboard personnel were taken by PIMS medico-legal experts. The bodies of 118 passengers were identified by their relatives through personal belongings / personal identification and handed over to the relatives by local police. The remains / body parts of 09 passengers were identified through DNA profiling / matching and were handed to their family members by District Administration.

1.17 **Fire.** Pre-impact in-flight fire indications were neither reported by the Captain / FO of ill fated aircraft nor were observed by the Investigation Team Members at the crash site. However, post impact ground fire was observed at the wreckage site.

1.18 **ATC Tower / Approach Radar Tape Extracts.** ATC Tower / Approach Radar Tape Extracts were retrieved for detailed analysis.

1.19 **Mishap Flight CVR and FDR Data Retrieval**

1.19.1 Following the occurrence, the investigation team along with rescue parties reached the crash site. The FDR was identified and recovered from the crash site, however the CVR was located by CDA staff and handed over by Chairman Capital Development Authority (CDA) to the then Investigation In-charge (IIC) Gp Capt Mujahid Islam (late) on 22nd April, 2012.

1.19.2 IIC along with Technical Investigators proceeded to NTSB, USA facility for downloading of the recorded data on both the modules.

1.19.3 The FDR was received on 07th May, 2012 by the NTSB with following details:

- Recorder Manufacturer / Model : Allied Signal SSUFDR-RQUS
- Recorder Serial Number : 6989

1.19.4 **Recorder Condition**

1.19.4.1 As per the NTSB report, the FDR and CVR recorders had suffered moderate impact damages. However, the memory modules were removed from the units at NTSB facilities and the respective data was successfully downloaded.

1.19.4.2 After the downloading of CVR and FDR data, detailed analyses were carried out at USA with the assistance of NTSB investigators. It was carried out while keeping major focus to retrieve any information which can assist and help in ascertaining all possible operational and technical aspects along with other factors (if any) related to specifically cockpit crew in handling of aircraft after encountering weather and abnormal situation. The CVR data comprised about 30 minutes recording which was listened and pertinent calls and the conversation amongst the cockpit crew and Radar / ATC controllers or the cockpit crew and cabin crew were documented and analysed in detail. The data when correlated with the time and compared with the FDR recorded data helped in re-enacting the entire sequence of events prior to the aircraft ground impact. As a whole, the vital FDR and CVR data helped the investigation team to ascertain various facts / factors which could have directly or indirectly contributed towards the causation of accident.

1.20 **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 accident.

1.21 **Useful 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.

2. Analyses

2.1 **Operational Analysis.** The operational analysis in the proceeding paragraphs is based on the data collected from various sources inclusive of FDR, CVR, wreckage and expert agencies' inputs:

2.1.1 The mishap Flight BHO-213 was the first evening scheduled flight of Bhoja Air from Karachi to Islamabad.

2.1.2 At JIAP, Karachi the start up, push back and taxi remained un-eventful. The mishap aircraft took off at 17:05:30 hrs for destination and climbed to FL310 en-route to Islamabad.

2.1.3 The FDR data was available for last 26 hours.

2.1.4 The FDR data indicated the engagement of Autopilot command A at 17:05:50 hrs.

2.1.5 The aircraft (systems and sub-systems along with both engines) response was consistent with each other and as per the design performance parameters of JT8D-15A aero-engines.

2.1.6 The flight climb profile was consistent with a normal climb and at 17:27:00 hrs the MA levelled off at FL310.

2.1.7 At 18:08:04.7 hrs, the cockpit crew monitored the Lahore ATIS broadcast and were well aware of the overall weather picture.

2.1.8 At 18:08:05.6 hrs, Captain came on PA system and announced "it will be cloudy weather and thundery activity is also there and let's see. Wahan ja kar dkhtay hein kaisa weather hai *(we will go there and see how is the weather there)*. Temperature 25^0 hai wahan *(there temp is* 25^0*).* Jab ham pohanchen gay to ho sakta hai keh barish bhi ho to Insha Allah tala abhi thori der main Lahore nazar aay ga *(when we reach there may be it would be raining anyway God willing after some time we will see Lahore on our right).*

2.1.9 At 18:08:31.7 hrs, Captain continues with the route brief about the cities along the way.

2.1.10 At 18:08:50.3 hrs, Captain briefs the FO that he had briefed the passengers of light turbulence ahead.

2.1.11 At 18:09:15.1 hrs, Captain astonishingly questions the runway 18L in use at AIIAP, Lahore and FO informs him that wind is from 230^0. Captain responds that the winds are blowing from unusual direction at Lahore.

2.1.12 At 18:09:58 hrs, FO informs the Captain that Lahore has a weather warning for dust thunderstorm up to 2030 hrs.

2.1.13 At 18:10:14 hrs, Captain sings in a traditional qawali tone / style "Sadi kismat which chain say jina likh day *(Let there be peace in my life also)".*

2.1.14 At 18:10:32.5 hrs, Captain and FO discussed Lahore as first alternate and Peshawar as second alternate.

2.1.15 At 18:15:01.8 hrs, Captain tells the cabin crew (flight attendant) while referring to weather radar, to inform the passengers, if the same weather persists at Islamabad, there will be lot of bumps. Captain was foreseeing a bad weather conditions while approaching BBIAP, Islamabad.

2.1.16 From 18:15:24.8 hrs till 18:17:05 hrs, Captain and FO discussed landing procedures for runway 12 and 30 at BBIAP, Islamabad including circle to land procedure.

2.1.17 At 18:17:53.2 hrs, Captain sings few lines of traditional Punjabi song “Sanoo nahar wali pul tay bula kay” *(you called us on the canal bridge)* and FO comments laughingly.

2.1.18 At 18:18:17.9 hrs, FO asked the Captain “Sir Peshawar ka bhi lay loon” *(Sir should I take Peshawar weather).*

2.1.19 At 18:18:19.4 hrs, Captain said “na na na Allah malik hay” *(No God will help us).* Probably Captain wanted to avoid diversion.

2.1.20 At 18:19:41.9 hrs, Captain said “Oh ho ho, yeh to pura hai yar” *(Oh my God this is all over).* Probably at this particular moment, Captain at a distance observed the squall line weather.

2.1.21 At 18:20:26.9 hrs, FO asked Captain “Sir descent kitna rakhan gay?” *(Sir what would be the descent?)* and again asked “hundred”.

2.1.22 At 18:20:31.7 hrs, Captain replied “Ah – hah”. At this moment Captain was probably pre-occupied due to the bad weather in front and not listening to FO attentively.

2.1.23 At 18:20:38.4 hrs, Lahore Approach called “Bhoja 213 approaching position MATIN, pilots discretion descent (flight) level 200, report leaving (flight level) 310”.

2.1.24 At 18:21:12.1 hrs, FO told Captain that he had put the seat belt sign “ON” and simultaneously a single chime similar to cabin sign change was heard.

2.1.25 At 18:21:21.6 hrs, flight attendant made announcement first in Urdu and then in English about the seat belt sign “ON” due to the possibility of turbulence.

2.1.26 At 18:21:22.7 hrs, FO informed Lahore Approach “Bhoja 213 leaving ah 310 for 200” and subsequently added “we will call you INDEK Bhoja 213”.

2.1.27 The flight commenced descent with Engine Pressure Ratios (EPRs) to approximately 1.0 which is consistent with flight idle setting.

2.1.28 At 18:22:00.5 hrs, Captain told FO “aik hazar honay do. Aik hazar honay do” (let it descend through one thousand feet. Let it descend through one thousand feet).

2.1.29 At 18:22:09.9 hrs, FO asked Captain “Sir, lights ON kar lain apni *(sir put your lights on).*

2.1.30 At 18:22:29.3 hrs, FO told Captain “Sir, QNH standby par 1009 laga lain *(Sir put 1009 on your standby).*

2.1.31 At 18:22:43.9 hrs, FO told Captain “Sir, one is one, aha both to Islamabad”.

2.1.32 At 18:22:47.2 hrs, Captain asked “both of them?”

2.1.33 At 18:23:42.5 hrs, Captain humming sound is heard.

2.1.34 At 18:23:54.6 hrs, Captain humming sound is heard again. Probably it is indicative of the anxiety of Captain about prevalent approaching weather.

2.1.35 At 18:23:56.2 hrs, FO told Captain “Ham say thora aagay lagta hai” *(it seems to be slightly ahead of us).* The cockpit crew worried about the weather and their apprehensions along with their state of mind, determined to land at BBIAP, Islamabad as it was the Bhoja Air first flight in the evening on Khi – Isb – Khi sector.

2.1.36 At 18:23:59.3 hrs, Captain asked FO “Kia?” *(What?)*.

2.1.37 At 18:24:00.5 hrs, FO told Captain “yeh ah C-B” *(this ah C-B).*

2.1.38 At 18:24:03.1 hrs, FO told Captain “nahin yeh to eighty par baitha hua hay” *(no it is sitting at 80 miles).* FO is also observed participating actively in the interpretation of changing weather picture / conditions.

2.1.39 At 18:24:05.8 hrs, Captain said “kia? han han” *(what? yes, yes).* Probably it is also indicative of mental pre occupation of Captain.

2.1.40 At 18:24:17.9 hrs, FO informed Captain “cabin descending, descent and approach checklist please”.

2.1.41 At 18:24:22.4 hrs, Captain told FO “yeh series hai, acha” *(this is a series, okay).*

2.1.42 At 18:24:26.8 hrs, FO acknowledged as by saying yes to Captain briefing.

2.1.43 At 18:24:27.7 hrs, Captain continues the briefing to FO “iss ko squal line kahtay hain” *(it is known as squall line).* Captain was seemed worried about the severity of weather in-front, however, they were not very clear about the exact location of the squall line at this particular moment.

2.1.44 At 18:24:29 hrs, FO told Captain “Sir, anti ice”.

2.1.45 At 18:24:38 hrs, FO told Captain “Temperature is minus nine sir”.

2.1.46 At 18:24:43.9 hrs, FO carried out his cockpit checklist actions.

2.1.47 At 18:24:58 hrs, Captain told FO “main speed barha raha hoon, 280 kts kar raha hoon” *(I am increasing the speed, I am taking it to 280 kts)* and FO acknowledged it. The speed was increased to 280 kts as it is the OEM recommended speed for turbulence.

2.1.48 At 18:25:03.2 hrs, Captain told FO “kuch agar ho gia to ham iss ko, we will maintain this theek hai na” *(if anything happens then we will maintain this okay)* and FO acknowledged it by saying “right sir”.

2.1.49 At 18:25:49.6 hrs, FO clears his throat (sound is heard) and told Captain “yeh paray ga” *(this will affect us).* The FO analysis of weather at this particular time is that they were most likely to enter the squall line / bad weather area.

2.1.50 At 18:25:54.1 hrs, FO again told Captain “yeh wala lagay ga, hain na sir?” *(this one will affect, isn’t it sir).* FO is sharing his concerns with Captain and indicating his analysis of encountering the bad weather en-route to BBIAP, Islamabad.

2.1.51 At 18:25:57.5 hrs, Captain told FO “chakar mar kay aain” *(take a round and come back).* Captain had also realized the severity of the weather / presence of squall line and wanted to avoid entering the bad weather but intended to continue for destination.

2.1.52 At 18:26:05.2 hrs, Captain suddenly said “ooohhh”. Probably after experiencing some turbulence he said this.

2.1.53 At 18:26:19.4 hrs, Captain told FO “iss ko call day keh permission to change over to the route” *(give him a call that permission to change over to the route).*

2.1.54 At 18:26:23.2 hrs, FO coordinates with Lahore Approach and at 18:26:40.5 hrs coordinates with Islamabad Approach for approaching INDEK.

2.1.55 At 18:26:54.1 hrs, Islamabad Approach identified Bhoja 213 and cleared flight to Islamabad via POMAR ONE FOXTROT arrival and informed to expect vector ILS runway 30. Flight was also cleared to descend to 9500 ft on QNH 1009 when ready. The said instructions were acknowledged by FO at 18:27:09.4 hrs.

2.1.56 At 18:27:20.6 hrs, Captain said “idhar say nikal jayen gay” *(we will go from this side).*

2.1.57 At 18:27:21.4 hrs, Islamabad Approach asked Captain “and ahhh Bhoja asslam o alaikum *(greetings)* if able can you give us ahh weather brief on Islamabad?”

2.1.58 At 18:27:28.8 hrs, Captain briefed Islamabad Approach “yah, it is a squall line through out from the (ah) almost it is going from 19 miles (ah) from the western side that is the (ah) my heading is 300^0 ....and there is no gap...to come inside, so is it possible that I go and come from the (ah) west?”

2.1.59 At 18:28:02.6 hrs, Islamabad Approach apprised Captain “Bhoja 213 (ah) radar is not observing any gap towards west, however I am observing some kind of gap (ah) between radial 160^0 to radial 220^0.

2.1.60 At 18:28:17.3 hrs, FO told Captain “theek hay na, iss main say nikal lain na, yeh 160^0 say 220^0 yahan tak” *(it is right you go through from 160^0 to 220^0 up to here).* From the abovementioned discussion between radar controller and captain it was evident that they both considered the prevalent weather covering BBIAP, Islamabad approach and there was apparently small gap for BHO-213 to penetrate the squall line.

2.1.61 At 18:28:22.5 hrs, Captain told Islamabad Approach “(ah) that is (ah) very small one, let me try on that one han”. As per operator Operational (Ops) Manual (approved by CAA Pakistan), Bhoja aircraft should avoid

thunderstorm by at least 5 to 10 nm. Captain intentionally continued for destination while disregarding the documented procedures.

2.1.62 At 18:28:27.4 hrs, Islamabad Approach acknowledged by saying “roger”.

2.1.63 At 18:28:32.4 hrs, Captain commented “yeh...iss pay ja sakta hoon” (this, I can go on this).

2.1.64 At 18:28:35.7 hrs, FO acknowledged and suggested to Captain “ji (yes), iss ko kaheen sir radar vector hamen kara day” (tell him he should give us radar vectors).

2.1.65 At 18:28:39.8 hrs, Captain asked Islamabad Approach “ahhh... is it possible if I turn just now on a heading of uhm 040^0, there is some gap”.

2.1.66 At 18:28:53.2 hrs, Islamabad Approach told Captain “040^0 from present position might not be feasible because ahhh because of the close proximity of Tilla range...however touching position ah INDEK you can turn right on to heading 040^0 and ah confirm from 040^0 heading you will be intercepting direct for final runway 30”. Captain acknowledged by saying yes at 18:28:59.2 hrs.

2.1.67 At 18:29:17.1 hrs, FO suggested to Captain again “issay kahen keh hameain radar vector day” *(tell him he should give us radar vector).*

2.1.68 At 18:29:18.3 hrs, Captain requested Islamabad Approach “...can you give me radar vectoring because there is small gap but that will be in between the almost thund---C-Bs?”

2.1.69 At 18:29:28.9 hrs, Islamabad Approach asked the Captain “ah understand are you picking up any weather ah towards southeast of Islamabad ah at a distance of about ah 10 to 15 miles”.

2.1.70 At 18:29:41.1 hrs, Captain told Islamabad Approach “ah nah negative, till 40 miles there is no not at all”.

2.1.71 At 18:29:45.1 hrs, Islamabad Approach advised Captain “roger, you can turn right onto heading 360^0 vectors ILS runway 30. Pilot discretion descent 6500 ft”.

2.1.72 At 18:29:52.7 hrs, Captain acknowledged the Islamabad Approach and added “yes you are right uhm I can come because till 40 miles there is nothing, it is all towards the northern side”. Islamabad Approach also acknowledged by saying “affirm sir”.

2.1.73 At 18:30:19.1 hrs, Captain and FO discussed their altitude to descend and then FO confirmed clearance of descend to 6500 ft from Islamabad Approach.

2.1.74 At 18:30:31.0 hrs, Captain and FO selected few settings and acknowledged to each other.

2.1.75 At 18:30:34.9 hrs, Captain told FO “yar larki ko kah do in ko bitha dain” *(tell the girl to make them sit).*

2.1.76 At 18:30:45.9 hrs, FO announced on PA system “cabin crew take positions for landing please”. The cockpit crew probably were experiencing lot of

turbulence at this particular moment and FO mistakenly made announcement for cabin crew to take positions for landing when actually they were still descending for 6500 ft.

2.1.77 At 18:31:05.8 hrs, Captain suddenly said “what”. Probably Captain realized the mistake of FO and showed his concern over the announcement.

2.1.78 At 18:31:08.1 hrs, FO suggested to Captain “yeh hammain right pay nikalna chahiyeh idher” *(we should come out to the right here).* FO suggested to Captain after his interpretation of weather picture that probably they should go towards right to avoid bad weather area.

2.1.79 At 18:31:10.4 hrs, Captain said “nahin, nahin, jana hi nahi hay ham nay, idhar land karna hay” *(no no we don’t have to go there, we have to land here).* It is evident from Captain’s remarks that he had made up his mind to land at destination irrespective of prevalent weather conditions during approach to BBIAP, Islamabad.

2.1.80 At 18:31:15.0 hrs, Captain told Islamabad Approach “Mukhtar very nice, it was very nice whatever you told me”.

2.1.81 At 18:31:20.5 hrs, Islamabad Approach thanked Captain as acknowledgement.

2.1.82 At 18:31:31.7 hrs, Islamabad Approach exchanged greetings with Captain while telling him his name as Mukhtar and asked him how he is.

2.1.83 At 18:31:34.9 hrs, Captain asked Islamabad Approach “oy sir khariat say hain *(hey sir you are well)* thank you very much God bless you”. At this particular time, it appeared that cockpit crew became relaxed and comfortable.

2.1.84 At 18:31:38.5 hrs, Islamabad Approach told Captain that he was talking to him after a very long gap and Captain laughed.

2.1.85 At 18:31:45.6 hrs, Captain told Islamabad Approach “bari achchi Masha Allah very nice actually yeh main nay ghalat kar diya tha *(very good by the grace of God, very nice actually I did it wrong).* I was going quite far away.”

2.1.86 At 18:31:52.0 hrs, Islamabad Approach briefed Captain and said “laikin sir main dekh raha tha keh uss side pay zara weather hay yeh shaid beech mein zara thora sa area zara clear banta hey *(but in between on the other side this was the only clear which was slightly clear),* laikin iss heading kay uopar bhi *(but on this heading as well)* after another about thirty miles you might intercept ah little bit of precipitation till intercepting the localizer”.

2.1.87 At 18:32:06.9 hrs, Captain told Islamabad Approach “very nice Masha Allah *(by the grace of God),* I just used to get it once I was in the abroad, such beautiful weather, very nice”.

2.1.88 At 18:32:20.2 hrs, FO while carrying out his cockpit checks told Captain of aircraft crossing 10, 000 ft of altitude.

2.1.89 At 18:32:24.8 hrs, FO asked Captain to keep the gasper ON or OFF which was replied by Captain as “han? (what?) ON karo (let it be ON)”.

2.1.90 At 18:32:31.0 hrs, Captain shared his apprehension of weather conditions with FO and said “bara zoor iss nay diya, aisay ghabrai huway they hum *(it has kept us under pressure and we were afraid for nothing)”.* At this particular moment Captain seemed to be quite relaxed and comfortable as far as the prevalent weather conditions were concerned.

2.1.91 At 18:32:41.6 hrs, Captain said to probably the jump seat occupant “yeh teri ammi ki wajah say hai *(it is because of your mother)”.* The occupant on jump seat was a non operating cabin crew travelling on mishap flight accompanying his mother to his home station. This individual in no way had any contribution to the causation of accident.

2.1.92 At 18:32:48.5 hrs, Captain again said to probably the jump seat occupant Ámmar cigarette pee raha ji, ji han *(Ammar is smoking, yes he is)”* and it was followed by a laughter and then Captain at 18:32:56.1 hrs said “mera kiya jata hay *(how does it affect me)”*.

2.1.93 At 18:33:37.7 hrs, Captain briefed and asked FO “sara north pay hay dekho na, wo dekh rahay hain? Bijli chamak rahi hay *(look all of it is in the north, can you see that? It is lightening)”* and FO acknowledged by saying “sir”. Till now the Flight BHO-213 had encountered turbulence but had not entered the bad weather.

2.1.94 At 18:33:45.5 hrs, Captain shared a joke with FO in Punjabi dialect “hoon bahir say ji tussi jao” and FO laughed in reply.

2.1.95 At 18:33:48.3 hrs, FO asked the Captain about levelling off and in reply immediately Captain said “acha pahlay batana tha *(okay you should have told me earlier)”*.

2.1.96 At 18:33:56.2 hrs, Islamabad Approach cleared the flight to continue descent to 5500 ft and the instructions were acknowledged by FO.

2.1.97 After this various sounds eg stretching and electronic fluctuations were heard on CVR recording for few seconds.

2.1.98 At 18:34:49.4 hrs, Captain told FO “ILS my side, ILS number one”.

2.1.99 At 18:34:54.8 hrs, FO told the Captain “final course is set sir, minimas are set, speeds are set”. According to the SOPs requirement neither ATIS ISB was obtained by the cockpit crew nor the formal approach briefing was conducted by the Captain. However, FO reminded the Captain for setting of minimas for the landing.

2.1.100 At 18:35:00 hrs, the flight levelled off at 5,500 feet pressure altitude and glide slope deviation A became active.

2.1.101 The altitude of 5,500 feet was maintained for 80 seconds and during this time both engines responded normal.

2.1.102 The aircraft maintained Indicated Airspeed (IAS) Speed mode on descent through 4500 feet with autopilot and auto throttle engaged.

2.1.103 At 18:35:03.3 hrs, FO informed Captain “recheck speed 133, 138, 148”.

2.1.104 At 18:35:06.5 hrs, Islamabad Approach gave instructions to the flight and said “Bhoja 213 after five miles descend 3900 ft” and the said clearance was acknowledged by FO which indicates that Captain was PF and FO was PNF at this time and everything appeared normal in the cockpit.

2.1.105 At 18:35:36.1 hrs, there was first a laughter and then suddenly Captain said “wo gia *(that has gone)”.* Probably some lightening / weather phenomenon occurred which was observed and referred by the Captain.

2.1.106 At 18:35:39.6 hrs, Islamabad Approach gave weather update of BBIAP, Islamabad and said “Bhoja 213 surface wind at Islamabad ah is varying between 180^0 to 270^0,10 kts and ah sometimes gusting to 20 kts and runway condition is wet, light drizzle is ah uhm going on, braking action not known” and Captain acknowledged it by saying “thank you very much, sir”.

2.1.107 At 18:36:06.7 hrs, Captain asked FO “3900 na (3900 ft ok)” and FO acknowledged by saying yes sir.

2.1.108 At 18:36:36.0 hrs, Captain commented on weather and told FO “yeh khulta nahin hay aur *(it does not open anymore)*” and probably FO did not understand due to which Captain repeated again “yeh khulta nahin hay aur *(it does not open anymore)*”*.*

2.1.109 At 18:36:38.5 hrs, FO replied and said “ yeh jo hay na ahh *(this one ahh)*, 10 miles, 15 miles darmian main hai yeh goodarh *(the problem is in between 10 and 15 miles),* hamarah abhi 14 hai miles *(we still have 14 miles to go)”.* At this particular moment squall line was at 10 to 15 miles away from aircraft and the aircraft was at 14 DME from BBIAP, Islamabad.

2.1.110 At 18:36:45.8 hrs, Captain said “uh exactly overhead hai *(it is exactly overhead)”.* Captain is confirming to FO that the squall line is exactly overhead BBIAP, Islamabad.

2.1.111 At 18:36:50.2 hrs, FO shared with Captain “so...we are likely to get very close to it”. It can be deduced from above discussion of cockpit crew that they had no confusion of their ending up very close to the squall line / prevalent adverse weather conditions.

2.1.112 At 18:36:55.3 hrs, Captain suddenly said “we are already, wo hit kar gia hay hamain *(it has already hit us)”* and then at 18:36:58.0 hrs, Captain again said “ussi waqat hit karay ga hamain *(it will hit us at that time)”.* Probably at this particular time, they experienced precipitation which alarmed the Captain however, after few seconds he realized that the severity of squall line was still close to the aerodrome.

2.1.113 At 18:36:59.1 hrs, Captain said “one to go” and it was acknowledged and checked by FO.

2.1.114 At 18:37:15.1 hrs, FO commented on prevalent weather and said “jab ham turn Karen gay na idhar to it get ah thora intense *(when we will turn this side then it will ah get slightly intense).*

2.1.115 At 18:37:18.8 hrs, Captain suddenly said “haaa dark ho gia *(haaa it has become dark)”.* Now by this time, cockpit crew was very clear that they were actually entering the squall line / bad weather conditions but did not take a

decision as per Bhoja Air (CAA approved) Operational Manual to discontinue the approach to the destination.

2.1.116 At 18:37:25.2 hrs, radio altimeter alarm is heard. At this time the aircraft was passing through 2500 ft above ground level (AGL).

2.1.117 At 18:37:26.5 hrs, Captain said “checked”.

2.1.118 At 18:37:28.9 hrs, Captain said “airspeed reaching 210 kts, flaps one” and it is acknowledged by FO.

2.1.119 At 18:37:38.6 hrs, Islamabad Approach asked flight “Bhoja 213 continue descend 3600 ft standby correction, Bhoja 213 descend 3600 ft standby for the final turn” and the clearance is acknowledged by FO.

2.1.120 At 18:37:50.2 hrs, FO asked Captain about the flaps.

2.1.121 At 18:37:52.4 hrs, sound of three wailer is heard which is also similar to auto pilot disconnect and at this particular moment FDR data confirmed the disengagement of autopilot.

2.1.122 At 18:37:53.2 hrs, Captain suddenly said “oops yeh kia kar dia main nay?” *(oops what have I done?)” At* 18:37:56.1 hrs, Captain repeated again “yeh main nay kia kar dia?” *(what have I done?)” and then laughed.* Probably Captain said this due to his selection of manual flying mode / disengagement of autopilot and then he engaged the auto pilot again.

2.1.123 At 18:38:00.0 hrs, Captain (in a worried tone) told Islamabad Approach “it is exactly on top”. At this particular time, the flight had actually ended up in the active bad weather cell.

2.1.124 In IAS Speed mode, the auto throttle modulates thrust to maintain the cockpit crew selected IAS on the Mode Control Panel (MCP). The auto throttle remained engaged during final approach.

2.1.125 The pitch mode transitioned between V/S mode and Level Change mode several times prior to leveling off at altitude of 3600 feet.

2.1.126 At 18:38:06 hrs, after passing through 4000 ft of altitude (2000 ft radio altitude), the flaps transitioned from flaps UP to flaps 1.

2.1.127 At 18:38:07.5 hrs, Islamabad Approach advised mishap flight “Bhoja 213 turn left heading 340^0, cleared ILS runway 30, report established” and the clearance was acknowledged by FO.

2.1.128 At 18:38:08 hrs, slats were extended to mid position. Additionally, during this time, the leading edge flaps transitioned to the full extended position.

2.1.129 At 18:38:10 hrs, the landing gear lever was selected to down position. The aircraft landing gear were selected to down position when the aircraft had not turned on the intercept heading for the ILS approach.

2.1.130 At 18:38:13 hrs, as the aircraft approached the target altitude, the autopilot transitioned into Altitude Select mode. At the same time, while in Heading

Select mode, a left turn was initiated to intercept the localizer. The aircraft maintained an approximate 20^0 bank angle during the turn.

2.1.131 The Heading Select mode was de-selected while in the middle of the turn, and no recorded roll mode was engaged for the next 10 seconds. At this particular time, it is felt that Captain de-selection of heading select mode indicates his lack of confidence on automation.

2.1.132 At 18:38:16 hrs, the aircraft started to roll left till approximately 20^0 to 23^0 angle of bank followed by a momentary right roll to approximately 15^0. Subsequently the aircraft again roll left to approximately 30^0 angle of bank.

2.1.133 At 18:38:24.7 hrs, FO told Captain "speed 220" and immediately Captain responded by saying "haan? *(what?)"*. At 18:38:27.4 hrs, FO again repeated his information of speed 220 kts. The airspeed of aircraft with flaps to 1 position is supposed to be 190 kts, however, it was 30 kts higher than the recommended speed.

2.1.134 At 18:38:29.1 hrs, Captain in highly surprised tone asked FO "220, oh shit yeh kia hua yar? *(oh shit what has happened?*" Captain realized that with auto-throttle engaged the speed of aircraft should not have increased to 220 kts, however, probably he could not correlate the variation of aircraft speed to the presence of wind shear.

2.1.135 At 18:38:31 hrs, the thrust was increased as the aircraft began to level off at the target altitude (~ 3600 feet pressure altitude). Ten seconds later, the autopilot transitioned to Altitude Hold mode that was likely selected on the MCP.

2.1.136 At 18:38:34.0 hrs, FO informed Captain to turn left 340^0 as they had been cleared for ILS. The cockpit crew turned left to intercept the localizer with flaps at position 1 and landing gears down.

2.1.137 At 18:38:35.8 hrs, Captain seemingly in extreme anxiety said "oh". At this time probably the intercept heading of 340^0 for the ILS approach had been delayed.

2.1.138 At 18:38:37.4 hrs, sound of light to moderate precipitation began and simultaneously Captain said "oh shit". The precipitation continued with varying intensity, until end of the recording / aircraft ground impact. At this particular moment, the aircraft was flying through the active weather cell. FO was also seemed unaware and ignorant of the severity of weather & its implications and did not recommend discontinuation of the approach.

2.1.139 At 18:38:39.3 hrs, FO asked Captain "should I give you both on ILS"?

2.1.140 At 18:38:41.3 hrs, Captain asked FO "han yeh garhbarh hai, yeh kuun nahi hua *(yes there is a problem, why it has not happened?)"* Captain seemed to be extremely pre occupied and worried about the flight parameters variations and bad weather effects on the flight at that particular moment.

2.1.141 At 18:38:43.4 hrs, FO informed Captain "both on ILS?" and Captain replied "han ILS day do mujhay *(yes give me the ILS)"* in a highly low energy tone and with pre occupied mind.

2.1.142 At 18:38:45.8 hrs, FO told Captain “auto armed”. The cockpit crew had the autopilot and auto-throttle engaged.

2.1.143 At 18:38:48 hrs, the glide slope deviation B became active and tracked similarly with glide slope deviation A until the end of the recorded data.

2.1.144 At 18:38:49 hrs, after leveling off at 3600 feet pressure altitude, with Heading Select mode engaged, VOR/LOC was Armed. The aircraft rolled back to the right, and the aircraft began to approach the localizer beam as evidenced by the localizer deviation moving towards zero.

2.1.145 At 18:38:55 hrs, the Approach mode was engaged. However, the G/S Arm mode was not recorded, but selection of Approach mode engages G/S Arm mode during normal operation.

2.1.146 After asking Captain, FO extended flaps from flaps 1 to flaps 5 at 18:38:54.6 hrs and the stabilizer was trimmed approximately 2 units nose-up.

2.1.147 At 18:38:56 hrs, the localizer deviation reached zero deviation and the aircraft rolled out of the left bank back to approximately 10^0 right bank. During the roll right, the autopilot reached its maximum control wheel authority (~ 25 degrees).

2.1.148 At the same time, the aircraft approached the glide slope beam from below, and the glide slope deviation began to move towards zero.

2.1.149 At 18:39:05 hrs, the aircraft rolled right to approximately 10^0.

2.1.150 At 18:39:09 hrs, autopilot command B was also engaged which is consistent with a dual autopilot approach.

2.1.151 At 18:39:13.4 hrs, FO informed Captain “localizer is right…VOR/LOC captured”. The Flare Arm gets engaged 23 seconds after the following conditions are satisfied: VOR/LOC Engage and G/S Engage and radio altitude < 1500 feet. During these 23 seconds, a number of system tests and checks are performed prior to Flare Arm engagement.

2.1.152 For the event flight, Flare Arm did not engage during the final approach prior to both autopilot channels disengaging at 18:39:33 hrs.

2.1.153 At 18:39:15 hrs the pitch attitude of aircraft increased from about 0^0 to 9^0 and till the end of the FDR data, the aircraft remained in approximately 5^0 to 20^0 right angle of bank.

2.1.154 The autopilot transitioned to G/S Engage mode around time 18:39:16 hrs at approximately 175 knots computed airspeed, and the aircraft began its final approach, descending on the glide path. The glide slope deviation reached zero and was maintained for several seconds. According to the procedures, at G/S capture the aircraft should have been in landing configuration of flaps 30^0 with landing gears down. However, only flaps 5 were selected and the auto throttle maintained the recommended / selected speed of around 170 kts.

2.1.155 Between time 18:39:16 hrs and 18:39:21 hrs, calculated vertical winds showed the aircraft encountered an increasing downdraft. As it entered this descending air mass, the pitch attitude increased and computed airspeed

decreased as the autopilot attempted to maintain the glide slope beam. The aircraft had to pitch up and, consequently, lose airspeed, to maintain the glide path. These are the indications that the aircraft had entered into a downdraft.

2.1.156 At 18:39:21.5 hrs, a sound of rapid increase in precipitation intensity from moderate to extreme was observed on CVR recording. This elevated intensity in precipitation remained for next 26.5 seconds.

2.1.157 At 18:39:25 hrs, radio altitude decreased from 1,900 feet AGL to 900 feet AGL within 4 seconds while pitch attitude increased from 6^0 nose up to 12^0 nose up. During this time the computed airspeed decreased from 180 kts to 173 kts. At 18:39:26.2 hrs, GPWS Alarm "Wind shear - Wind shear - Wind shear" was recorded. Both the cockpit crew did not take any remedial action as per Boeing procedures (FCOM / QRH) with the auto-throttle and autopilot engaged. It was found that during the simulator training sessions, the cockpit crew was not exposed to wind shear training / exercises. It was observed that the customized QRH / FCOM were also not available at Bhoja Air on the day of accident. The actions of Boeing 737-200 and Boeing 737-236A are different as per both the QRH / FCOM**.**

2.1.158 At 18:39:28.6 hrs, Captain was heard yelling in extreme anxiety and desperation "no …no". The cockpit crew still did not take any remedial action to recover out of unsafe set of conditions despite getting specific warnings of wind shear.

2.1.159 In the same extreme anxiety and desperation FO shouted "go around, go around" at 18:39:29.3 hrs, but no action was taken by the Captain (PF), and FO (PNF) also did not take over the controls of aircraft to initiate a go around. It appeared that Captain and FO were not sure about the behavior of the aircraft in automation mode during wind shear conditions due to their lack of formal training during simulator sessions. While going through the records of FO, it was observed that an extension in respect of recurrent simulator training which was due in February, 2012 was granted for two months on 09 March, 2012 by CAA Pakistan as per the existing rules and regulations in vogue. Furthermore, his previous simulator session was carried out on B737-200 simulator in August, 2011 which did not include the automated flight deck, as was the case of mishap aircraft.

2.1.160 The downdraft dissipated (vertical winds changed from approximately -40 feet per second [fps] to -10 fps), resulting in a change in angle of attack and the observed spikes in longitudinal acceleration and normal load factor.

2.1.161 Longitudinal acceleration and normal load factor reached a maximum of 0.2 g's and 1.4 g's, respectively. Nose-down column was commanded, and the pitch attitude decreased to its previous level ($\sim 5^0$) over the next few seconds.

2.1.162 At 18:39:33 hrs, the aircraft deviated left of the extended runway centerline, eventually reaching a maximum of 2 dots localizer deviation and 5^0 to 10^0 right bank angle was commanded to return the aircraft to zero deviation (autopilot maximum authority is 8^0 of bank).

2.1.163 Both autopilot channels got disconnected at around 18:39:33 hrs and the subsequent FDR data is consistent with the aircraft being flown under manual control, however, the auto-throttle remained engaged in IAS Speed mode.

Therefore, the auto-throttle continued to command thrust to track the airspeed selected on the MCP, but the autopilot stopped commands to the flight control surfaces. Probably the autopilot channels got disconnected due to the aircraft deviation beyond the autopilot maximum authority limits.

2.1.164 Following autopilot disconnect, there was no control wheel activity recorded for approximately 6 seconds and no control column activity for approximately 8 seconds. The cockpit crew was probably in a state of confusion and unsure of remedial actions to be taken to get out of unsafe set of conditions, as the aircraft was still observed flying with auto-throttle in engaged mode.

2.1.165 During this period of control inactivity, the aircraft deviated below the glide slope, and the pressure altitude and pitch attitude decreased while approximately 160 knots computed airspeed was maintained.

2.1.166 At 18:39:37.1 hrs, Islamabad Approach cleared Bhoja 213 to contact BBIAP, ATC Tower which was acknowledged by FO on the reminder of Captain “channel kar lo na *(deal with the channel)”*. FO appeared to be highly pre occupied due to severe weather conditions / precipitation and the aircraft encountering wind shear along with complete confusion in the cockpit to recover out of unsafe set of conditions. This was the last recorded communication of Captain with FO whereas the aircraft impacted ground after 21 seconds at 18:40:00.3 hrs.

2.1.167 At 18:39:41.9 hrs, Terrain Awareness Warning System (TAWS) alarm “Whoop, Whoop, Whoop” was recorded. The aircraft was in close vicinity of the ground and the cockpit crew did not carry out the recommended Boeing QRH / FCOM procedures, as remedial actions required after TAWS alarm.

2.1.168 At 18:39:42 hrs, the pitch attitude decreased from approximately 5^0 nose up to around 0^0.

2.1.169 At 18:39:42.9 hrs, FO informed BBIAP ATC Tower that they were maintaining this frequency. The FO was busy giving calls to the BBIAP tower instead of assisting Captain or taking over controls of the aircraft. It appeared that the FO was not proficient and trained to handle the prevalent abnormal situation.

2.1.170 During this period thrust also decreased since the auto-throttle was still engaged in IAS Speed mode, thrust commands were input to maintain the airspeed selected on the MCP.

2.1.171 The aircraft encountered another descending air mass. This downdraft gradually increased over 15 seconds, reaching a maximum of approximately 50 fps. The rate of descent increased rapidly, however after encountering this second downdraft cockpit crew again did not take required remedial actions which confirmed their ignorance on recovery procedures.

2.1.172 At around 18:39:43.0 hrs, a TAWS alarm “(Whoop) Pull up, (Whoop, Whoop) Pull up” was recorded. The Captain responded with a nose-up column input. However, pressure altitude and thrust continued to decrease.

2.1.173 With the auto-throttle engaged and autopilot disengaged, the aircraft in flaps 5 and landing gears down configuration, failure of the cockpit crew to

undertake the Boeing recommended procedures to respond TAWS warning, aggravated the existing unsafe / dangerous conditions.

2.1.174 At approximately 18:39:47 hrs, the downdraft dissipated, rapidly decreasing from 50 fps to close to zero fps in less than 4 seconds. This resulted in a rapid increase in angle of attack of the aircraft, which activated the stick shaker for almost 2 seconds. It appeared that Captain was making desperate control column inputs to come out of the TAWS "pull up" warning regime. As a result, the aircraft achieved nose up attitude with flaps 5, landing gears down and auto-throttle engaged position, thus aircraft ended up in stalling regime.

2.1.175 During this period, the longitudinal acceleration and normal load factor (vertical acceleration) both rapidly increased, reaching maximums of 0.25 g's and 1.7 g's, respectively.

2.1.176 A nose down column input was commanded in response to the stick shaker (the stick nudger likely also engaged), this nose-down column input command continued until the end of the data. It appeared that Captain lowered the nose down to get out of stick shaker regime however, proper and complete Boeing recommended stall and recovery procedures were not carried out.

2.1.177 The pitch attitude changed from approximately 2^0 nose up to a maximum of approximately 12^0 nose down over 8 seconds. During the initial rapid pitch down, normal load factor reached 0.45 g's. The aircraft went into a critical unusual attitude of 12^0 nose down in close proximity of the ground.

2.1.178 The pressure altitude continued to decrease while thrust remained at a low level (~ 40-45 percent engine N1) in order to maintain the computed airspeed. At 18:39:45 hrs, the power on both engines was reduced to 1.0 EPR (flight idle) and remained at 1.0 EPR for the remainder of the recorded data.

2.1.179 The ground proximity warning momentarily ceased before activating again until the end of data.

2.1.180 At 18:39:46.8 hrs, ATC Tower cleared the mishap flight for landing "Bhoja 213 check wheels down and locked, wind 180^0 to 270^0 10 kts, rain runway 30 cleared to land", however, the aircraft never acknowledged this call. It appeared that due to the complete confusion and chaos in the cockpit, the crew never responded the call of ATC tower.

2.1.181 At 18:39:48.3 hrs, sound of wailer tones similar to auto pilot disconnect was recorded on CVR which continued till end of recording. This indicated that the Captain lacked the automation knowledge and experience due to which he was unable to silence the continuous wailer tone by pressing the autopilot disconnect switch on the control column. In addition during this time warning of "wind shear, wind shear, wind shear" was recorded.

2.1.182 At 18:39:49.0 hrs, the CVR recording indicated decrease in precipitation intensity and decreased intensity remained constant till end of CVR recording.

2.1.183 At 18:39:49.0 hrs, both left and right stick shakers indicated "Operative" for approximately one second. As the Captain was struggling with the control column to recover out of unsafe set of conditions, he again exceeded the

critical angle of attack of aircraft which resulted in activation of the stick shakers for one second.

2.1.184 At 18:39:52.2 hrs, FO shouted in desperation and extreme anxiety “stall warning, let’s get out”. It appeared that Captain was making desperate attempts to recover out of dangerous situation but was not following the Boeing recommended remedial actions. At the same time, FO was also not taking over the controls of aircraft in order to initiate a go around indicating his lack of system knowledge, experience and confidence.

2.1.185 At 18:39:54.4 hrs, the ground proximity warning again came on “pull up (whoop, whoop), pull up (whoop, whoop), pull up (wh*), (whoop whoop) pull...” and it remained till the end of the recorded data.

2.1.186 From 18:39:49 hrs till 18:39:51, a significant variation in vertical acceleration was recorded from + 1.7 to +0.4 g’s and pitch attitude decreased from 2^0 nose up to 8^0 nose down.

2.1.187 At 18:39:54.4 hrs, when the ground proximity warning was active “Pull up (Whoop - Whoop), Pull up (Whoop, Whoop), Pull up (Whoop, Whoop), Pull--” was recorded, the bank angle increased to the right, and the aircraft returned to the extended runway centerline prior to the end of data.

2.1.188 The aircraft appeared to pitch up to at least 0^0 at the end of the data while traveling at 215 knots computed airspeed, which is consistent with the wreckage / ground scar information that indicated the aircraft contacted the ground on main landing gears first.

2.1.189 Boeing records indicate that a stick nudger was installed on the event aircraft. The stick nudger is designed to activate (push the control column forward) at the same time stick shaker activates. However, the stick nudger activation in this event would have been brief (at the most 2 seconds) and then would have returned to a no-load position over 2 seconds following stick shaker de-activation.

2.1.190 Based on the Stall Warning System functional test in the Boeing 737-200 Aircraft Maintenance Manual (AMM), the force on the control column increases by approximately 20 pounds over 5.6 +/- 0.6 seconds when the stick nudger activates. At the most, control column force would have increased approximately 7 pounds during stick nudger activation in this event.

2.1.191 At 18:39:57.1 hrs, FO was observed shouting in desperation / anxiety and telling Captain “go around, go around sir, go around”. Neither the Captain nor the FO followed Boeing recommended remedial procedures / actions due to their lack of knowledge, training and experience to handle this type of abnormal situation. This resulted in the unfortunate flight to impact the ground.

2.1.192 The CVR last recorded data finished at 18:40:00.3 hrs.

Boeing Ground Track Analysis

2.1.193 At Boeing Facility, a ground track was generated to show the aircraft’s flight path during the approach. The longitudinal and lateral distances were calculated using a combination of integrated inertial data (ground speed, drift

angle, heading), glide slope / localizer deviation, and airport information (glide slope and localizer antenna location, etc).

2.1.194 The distances were then orientated by estimating a final position of the recorded data, based on the initial aircraft impact location, in order to evaluate the aircraft's trajectory.

2.1.195 The analysis showed that the aircraft deviated a maximum of 0.2 nautical miles to the left of the extended runway centre line. The aircraft encountered both the downdrafts during the deviation to the left. Additional wind information was also provided (with the inclusion of headwind and crosswind relative to the aircraft heading) and it was observed that the aircraft initially impacted the ground approximately 4.24 nautical miles from the Runway 30 threshold just to the right of the extended runway centre line.

Boeing Kinematic Consistency (KINCON) Analysis

2.1.196 A kinematic consistency analysis was conducted by Boeing on the provided FDR data. KINCON is used to correct inherent inconsistencies often present in FDR and QAR data because of sample rate differences, multiple independent data sources, and the presence of instrumentation biases. The KINCON process uses integrated acceleration data to ensure basic inertial parameters such as altitude, ground speed, and drift angle are compatible and comparable. The output is a kinematically consistent set of data with acceleration biases removed, allowing calculations of wind data and ground track information.

2.1.197 KINCON was used to generate the calculated data shown in the plots. Since the standard inertial parameters, ground speed and drift, were not available in the FDR data, KINCON used recorded glide slope deviation, localizer deviation, and the ILS transmitter locations on the ground to produce a ground track. From the matches of glide slope and localizer Deviation, a ground speed could be integrated from the recorded accelerations with instrumentation biases removed. With this calculated ground speed, winds could also be generated. However, the accuracy of the KINCON analysis is hindered because of missing data, so some assumptions were required in the calculation of the winds. Since vane angle of attack was not recorded, an aerodynamic angle of attack had to be estimated from a total lift build-up from simulator data. This lift build-up used the assumption of zero elevator deflection and used an approximate thrust contribution calculation, which was small during this particular segment of flight. Using these assumptions, the vertical wind magnitude may differ slightly from what was actually present, but the shape of the vertical wind should be the same.

2.1.198 An additional assumption made in the calculation of the horizontal wind components was that of zero rudder deflection. There was no rudder pedal movement, but yaw damper can command +/- 2 degrees of rudder. The assumption of zero rudder deflection likely made a small difference in the wind calculations, but the rudder deflection is used in the calculation of aerodynamic sideslip angle, which affects the calculation of the wind direction and magnitude.

Boeing Simulation Analysis

2.1.199 The Boeing 737-200 desktop engineering simulation was used to re-create the last 70 seconds of the flight. The simulation offers the flexibility to drive the simulation control positions with FDR data and/or use mathematical pilot models to produce the desired aircraft state/flight path.

2.1.200 The simulation was set up with initial conditions (e.g. weight, speed, etc.) and control/throttle inputs similar to the recorded FDR inputs. The simulation was driven with the FDR column position, control wheel position, flap detent, and Engine Pressure Ratio (EPR).

2.1.201 Additionally, the simulation was driven with the FDR stabilizer position, but with a 20 nose-up bias. Mathematical pilot models were used on the column position and control wheel position to assist in matching the pitch attitude and bank angle, respectively.

2.1.202 The simulation winds (both vertical and horizontal) were driven with KINCON calculated winds. A 20 nose-up bias was used on the stabilizer position for two reasons. First, when originally driving the simulation with the FDR stabilizer position, a Center of Gravity (CG) at the aft limit and beyond (~ 30 percent) was required to match the data closely using the FDR gross weight, which seemed unreasonable. It was also reported that the stabilizer position was measured as 8.5 units when found in the wreckage, which differed from the last recorded stabilizer position by 2.5 units nose-up.

2.1.203 Additionally, weight and balance information from the event takeoff was provided which indicated that the recommended takeoff stabilizer trim was 5.25 units (CG = 19.1 percent), which was close to 1 unit higher (in the nose-up direction) than the recorded stabilizer position at takeoff (~ 4.4 units). Thus, it seemed that the FDR stabilizer position could have been erroneous and so a bias was applied. Increasing the simulation stabilizer position by 2 units (degrees) reduced the CG to a more reasonable value of 20 percent, which represents a mid-CG configuration.

2.1.204 The resulting simulation rudder deflection is due to yaw damper activity only, responding to the driven KINCON calculated winds. The matches of control wheel position, true heading, and drift angle were likely affected by the assumptions made during the KINCON process in calculating the winds (zero rudder, etc). However, when the simulation was driven with the FDR data, the resulting flight path closely matched the FDR flight path for all longitudinal and lateral-directional parameters evaluated, confirming the aircraft's motion was due to the recorded control inputs and calculated atmospheric conditions.

Boeing Analysis of Cockpit crew Actions after Encountering Severe Weather Conditions

2.1.205 In response to the ground proximity warning annunciation and stick shaker activation, the cockpit crew did not increase thrust as expected, and the auto-throttle remained engaged until the end of data. These actions did not adhere to the procedures provided in the Boeing 737-200 Quick Reference Handbook (QRH).

2.1.206 In the Ground Proximity Warning System (GPWS) Response section, the following procedures are stated for a GPWS warning involving PULL UP or TERRAIN (assumed annunciations):

- Disconnect autopilot.
- Disconnect auto-throttle.
- Aggressively apply maximum thrust.
- Simultaneously roll wings level and rotate to an initial pitch attitude of 20^0.

Note: *Maximum thrust can be obtained by advancing the thrust levers to the takeoff or go-around limit. If terrain contact is imminent, advance thrust levers full forward.*

2.1.207 In the Approach to Stall or Stall Recovery section of the QRH, the following procedures are outlined to be performed immediately at the first indication of stall (buffet or stick shaker):

- Hold the control column firmly.
- Disconnect autopilot and auto-throttle.
- Smoothly apply nose down elevator to reduce the angle of attack until buffet or stick shaker stops. Nose down stabilizer trim may be needed.
- Roll in the shortest direction to wings level if needed.
- Advance thrust levers as needed.

2.1.208 The crew did not disconnect the auto-throttle and thrust was never advanced in these two situations. Advancing thrust would have helped the aircraft maintain the proper flight path.

Summary

2.1.209 The aircraft encountered a storm cell during approach which was capable of producing strong downdrafts. The mishap flight encountered two downdrafts reaching maximum of 40 and 50 fps, respectively. The second downdraft gradually increased over 15 seconds as the aircraft descended from 3500 feet pressure altitude to approximately 2500 feet pressure altitude. While in this downdraft, both autopilot channels were observed disconnected, but the auto-throttle remained engaged. For approximately 6 seconds following autopilot disconnect, no control wheel activity was recorded and no physical control column activity was recorded for approximately 8 seconds. During this period of control inactivity altitude, pitch attitude, and thrust continued to decrease. A ground proximity warning sounded, which resulted in the Captain commanding nose-up control column inputs, but thrust and altitude continued to decrease while airspeed started to increase. The downdraft dissipated, resulting in a rapid increase in angle of attack which momentarily activated the stick shaker. In response to the stick shaker, the cockpit crew commanded nose-down column and the stick nudger activated

for almost 2 seconds. The Captain commanded nose-down control column inputs continued until the end of the data. The thrust remained at a low level and pitch attitude decreased to approximately 12^0 nose down, resulting in an increase in airspeed and further decrease in altitude prior to the end of data.

2.1.210 The analysis showed that when the simulation was driven at Boeing facility with the FDR data, the resulting flight path closely matched the FDR flight path which confirmed that the aircraft's motion was due to the recorded control inputs and calculated atmospheric conditions.

2.1.211 Therefore, cockpit crew ineffective management of thrust, altitude, and flight path in turbulent atmospheric conditions resulted in ground impact short of the runway.

2.1.212 The investigation team discussed at length the factors which could have contributed towards ineffective management of thrust, altitude, and flight path by the cockpit crew despite knowing the associated dangers while operating aircraft into such a weather phenomenon. For these reasons the cockpit crew's history and their professional competence at various stages of their flying career were specifically focused to find out all possible factors which could have directly or indirectly contributed towards this type of ineffective management by both the Captain and FO.

Cockpit crew History, Flying Experience and Medical Fitness

2.1.213 **The Captain**. He was born on 15th February, 1954. He belonged to village Babari Banda, Post Office Billitang, Distt Kohat but he was residing at Malir Cantt, Karachi with his family.

2.1.214 As per the medical investigation / analysis, the Captain was fit to undertake the mishap scheduled flight (refer Medical Analysis).

2.1.215 He was issued ATPL # 948 initially on 26th March, 1996 which was renewed and valid up to January, 2013.

2.1.216 He possessed valid medical Class 1 till 30th September 2012. He possessed valid IRA-ME on Boeing 737/100-200 aircraft till January, 2013.

2.1.217 He possessed a very rich flying experience of military as well as commercial aircraft.

2.1.218 He had served as a Captain of Boeing 737-200 in Shaheen Air International (SAI) before joining Bhoja Air.

2.1.219 He was selected for Boeing 737-400 ground training in one of the batch of cockpit crew. However, he was taken off from the said training due to his past flying experience of semi-automated aircraft. It was felt at the supervisory levels of SAI that he may not be able to manage the automated flight deck effectively, efficiently and safely. As a reaction to discontinuation of his Boeing 737-400 aircraft training in SAI, he decided to leave the SAI and join Bhoja Air. It is important to note that mishap Bhoja Air Boeing 737-236A variant aircraft was equipped with automated flight deck.

2.1.220 **The First Officer (FO).** He underwent his secondary education at Cadet College Hassan Abdal and then joined PAF as a cadet where his performance

remained above average during his training before commencement of his flying training.

2.1.221 During his initial flying training, he suffered from airsickness problem which adversely affected his flying performance and resulted in his under confident behaviour in flying profession.

2.1.222 FO possessed a valid CPL # 2934 renewed up to July, 2012.

2.1.223 FO remained an under confident individual and could just perform average during his stay as first officer in Shaheen Air International (SAI).

2.1.224 At SAI, he got the chance to fly with Captain. First Officer found refuge in the fatherly personality of the Captain who also started to provide him the required shelter.

2.1.225 When Captain decided to leave SAI and join Bhoja Air, FO probably again felt insecure and under confident. He left SAI after flying his last flight on 15th January, 2012 before joining Bhoja Air.

Violation of Flight Duty Time Limitation (FDTL)

2.1.226 Bhoja Air had inducted sufficient number of cockpit crew for smooth flying operations.

2.1.227 It was found that the CAA Pakistan approved rules and regulations in respect of FDTL were adhered to. Therefore, the cockpit crew of mishap aircraft was not observed exposed to any undesired stress / fatigue prior to the flight as a result of FDTL violation.

Cockpit Crew Selection and Induction System in Bhoja Air

2.1.228 The investigation team probed this area in detail to analyze the selection and induction of cockpit crew into Bhoja Air. Bhoja Air selected and appointed an ex-PIA Captain as Director Operations Bhoja Air, possessing rich experience of management and civil flying. He was made responsible for the selection and smooth induction of all cockpit crew in Bhoja Air. The selection of cockpit crew was done by him along with Managing Director (Ex-PIA Engineer) and at times GM Flight Operations input was also sought.

2.1.229 Bhoja Air was asked by investigation team to submit the copy of cockpit crew selection and induction system policy. Bhoja Air Management forwarded only the cockpit crew (Captain, First Officer and Cadet Pilots) selection criterion as appended in Ops Manual; however, there was no specific policy on cockpit crew selection and induction system.

Cockpit Crew Training and Skill Competence Level at Bhoja Air to Handle Automated Flight Deck

2.1.230 Bhoja Air planned the ground schooling of newly inducted cockpit crew for Boeing 737-200 series. The services of another experienced ex-PIA Captain as ground instructor were hired to educate / train the cockpit crew before their departure for simulator training to South Africa. As per the input of GM (Ops) Bhoja Air all the cockpit crew attended these scheduled ground training /

aircraft systems lectures and successfully completed their ground schooling phase.

2.1.231 Bhoja Air was asked by investigation team to submit the copy of entire ground schooling curriculum and training schedules of cockpit crew. Bhoja Air Management forwarded only the transition ground schooling as appended in Ops Manual; however, the mishap aircraft was the advanced version of Boeing 737-200 series ie Boeing 737-236A which was equipped with automated flight deck. The ground schooling curriculum of Bhoja Air for cockpit crew did not include the automation of Flight deck. Bhoja Air did not submit the detailed ground schooling programmes as requested by the investigation team.

2.1.232 It was observed that Boeing 737-200 which was taught during ground schooling and Boeing 737-236A being inducted in Bhoja Air were completely two different variants of Boeing 737 series. In the case of former variant, it is equipped with semi automated flight deck whereas the latter one with automated flight deck.

2.1.233 The information with regards to automation capabilities of aircraft which was to be acquired by Bhoja Air, was not in the knowledge of cockpit crew even after the formal ground schooling which also did not cover the variant training of Boeing 737-236A. It is evident that Bhoja Air cockpit crew ground schooling did not cater for the automation of Boeing 737-236A aircraft.

2.1.234 It is a considered fact that cockpit crew who is not equipped with satisfactory level of ground knowledge about all the onboard equipment and its effective and efficient utilization ie automation management after encountering severe weather conditions, would be highly unsafe and vulnerable to serious and fatal procedural mistakes in managing the flight deck of aircraft.

Cockpit Crew Flying Performance Monitoring System at Bhoja Air

2.1.235 FO did not undergo six monthly recurrent simulator training and Bhoja Air requested for an extension which was granted for a period of two months by CAA Pakistan as per existing rules / regulations. Bhoja Air did not have an established monitoring system to critically track the cockpit crew performance at organizational level.

2.1.236 It is important to note that the variance type training as per the IATA and CAA Pakistan rules & regulations and Boeing recommended training was not conducted prior to scheduling of FO on regular passenger flights. FO was never exposed to automated flight deck management in simulator as no simulator training was conducted in his case, which is one of the primary reason of inaction by FO to recover out of unsafe set of conditions during the entire abnormal flight conditions.

2.1.237 Captain underwent his recurrent simulator training in South Africa, Comair Johannesburg on 24th January, 2012. During the simulator evaluation conducted by South African Flight Instructor, following observations were made:

- Automation is relatively new to Captain in the simulator and should be practiced in future training.

- It is recommended Bhoja Air fully incorporate the new Boeing Recommended Procedures.

2.1.238 During the simulator check session in most of the mandatory exercises including precision approaches, localizer tracking and glide slope tracking and flight deck management, the Captain was assessed as "Satisfactory with Briefing" (SB).

2.1.239 A total of seven "SBs" were recorded in the CAAF-628 during this simulator check session which indicated Captain's marginal performance in a relatively new automated environment.

2.1.240 Additionally, the South African instructor's recommendation regarding incorporation of new Boeing Recommended procedures for an automated aircraft were not implemented as Bhoja Air did not have the customized QRH and FCOM for Boeing 737-236A aircraft**.**

2.1.241 Bhoja Air neither had any cockpit crew performance monitoring system nor made Captain to undergo any additional training regarding automated flight deck management this was inferred, as no supporting documentation evidences were provided by Bhoja Air in response to a formal letter by investigation team.

Cockpit Crew Scheduling / Pairing as Captain and First Officer

2.1.242 The flying of Captain and FO at Bhoja Air was analysed in detail. It was observed that out of total 23 flights of Captain, during 16 flights, FO was his cockpit crew member.

2.1.243 The specific aspect of Bhoja Air managing the scheduling of cockpit crew was discussed at length within the investigation team members from human behaviour point of view. The normal human psyche is that when ever two individuals come in contact with each other quite often, they tend to come very close to each other. They start to understand each other requirements and can predict each other behaviours which may result in increased level of frankness between them, thus neglecting and overlooking QRH, FCOM, Ops Manual and Boeing recommended instructions / procedures. At times, they start to rely on each other to an extent that very critical decisions are also not taken by one individual and it is expected that the other will take the required actions, thus violating the basic essence of CRM.

2.1.244 This is specifically alarming in aviation industry and can result into fatal mistakes. That is why, the flight crew is made to undergo Crew Resource Management (CRM) courses. CRM course grooms the cockpit crew to challenge his colleague if it is observed that he is taking an incorrect action / decision or not taking a specific action / decision for the safe conduct of flight. In extreme cases, the other cockpit crew is supposed to take over the controls of aircraft to ensure safe conduct of flight regardless of flying experience and seniority of the other individual.

2.1.245 One of the main factors of FO inaction in the cockpit is the shelter provided by the Captain to him. They had not carried out their formal approach briefing because they were too comfortable with each other and never challenged each other. The ATIS Islamabad was never obtained by the cockpit crew despite visible severe weather conditions prevailing around BBIAP, Islamabad. It is also evident that despite knowing the dangers associated with wind shear and aircraft stalling, FO kept reminding Captain who was PF, to go around but never took over the controls of the aircraft to execute a go around / missed approach or take required actions as per FCOM / QRH.

Cockpit Crew Interpretation and Understanding of Weather Picture / Information

2.1.246 The cockpit crew had all the pertinent and relevant data / information about the prevalent weather en-route and at the destination. They were very clear as far as the prevalent weather conditions were concerned. They had been discussing the entire weather picture in the later half of the flight. Captain was observed educating the FO on the presence of squall line en-route to destination. However, despite observing very small gap between the active weather cells, they still continued with the flight, entered active weather cell and violated the Bhoja Air Ops Manual instructions / procedures.

Cockpit crew Decision to Continue for Destination

2.1.247 Cockpit crew at first place never obtained ATIS Islamabad and got the weather update from radar controller BBIAP, Islamabad. The presence of squall line en-route to BBIAP, Islamabad was observed and discussed in detail amongst the cockpit crew. It was also discussed that there was hardly any gap between the active weather cells en-route to BBIAP, Islamabad but still continued their flight to destination and did not take the decision to divert to the alternate aerodrome as it was the evening inaugural flight of Bhoja Air on Karachi – Islamabad sector.

Cockpit Crew Performance and Behaviour Evaluation after Encountering Abnormal Weather Conditions during Last Phases of Flight

2.1.248 Prior to joining Bhoja Air, Captain had no experience and exposure of managing an automated flight deck. It is important to note that the wind shear as well as TAWS exercises were not imparted to the Captain during his simulator training in South Africa for Boeing 737-236A aircraft. Therefore, he was neither exposed to these particular exercises nor trained for applying wind shear / TAWS warning recovery techniques while managing an automated flight deck.

2.1.249 On the other hand, FO was due for his six monthly simulator training for Boeing 737-200 aircraft in February, 2012 and an extension was sought by Bhoja Air for a period of two months for his recurrent simulator requirement. The extension in simulator training for FO was granted by CAA, Pakistan without knowing that he was about to fly an automated flight deck, as this information was not provided to Flight Standard Directorate, CAA Pakistan by Bhoja Air management / supervisors.

2.1.250 As both the cockpit crew were not properly trained and groomed to handle such abnormal situations (exposure to wind shear / TAWS alarms) while flying

an automated flight deck, they were confused in the cockpit and not familiar with the Boeing recommended remedial actions. They did not carry out the Boeing recommended procedures to get out of unsafe set of conditions.

Evaluation of Terrain Awareness Warning System (TAWS) / Enhanced Ground Proximity Warning System (EGPWS)

2.1.251 At the time of operational inspection of Boeing 737-236A aircraft (Reg # ZS-OLB which was later registered in Pakistan as AP-BKC) for induction in Bhoja Air fleet, it was equipped with Terrain Awareness Warning System (TAWS) Sandel Avionics ST3400. This system was installed during Check 4C inspection carried out in South Africa before the aircraft was brought to Pakistan by Bhoja Air. The Sandel Avionics ST3400TAWS has six modes:

- Excessive Descent Rate
- Excessive Closure to Terrain
- Altitude Loss after Takeoff
- Unsafe Terrain Clearance
- Excessive Deviation Below the Glide Slope
- Advisory Callouts

2.1.252 The wind shear warning is not given by Sandel Avionics ST3400 TAWS. Therefore, while carrying out the Supplementary Type Certificate (STC) for installation of TAWS, wind shear warning capability of Enhanced Ground Proximity Warning System (EGPWS) MK-VII made by Honeywell (already installed on the aircraft), was retained. This system was capable of generating “reactive wind shear warning”.

2.1.253 The aircraft was operationally inspected by CAA Flight Standard Inspector at Johannesburg, South Africa. It was observed and documented that EGPWS / TAWS check could not be successfully carried out as the aircraft was parked inside the hangar (unsatisfactory).

2.1.254 It was noted that although the CAA Pakistan Flight Standard Inspector was qualified but was not having on type experience ie Boeing 737-200 series, therefore he could not monitor / observe the automation of flight deck. Subsequently flight standard also could not keep a close watch on the Bhoja Air cockpit crew competence skill level to manage automated flight deck as Simulator Recurrent Training Evaluation (CAAF-628) was not seen / monitored by Flight Standard Directorate.

2.1.255 The detailed inspection observations at South Africa were communicated to Bhoja Air by Flight Standard Directorate. Subsequently, the observations made by Flight Standard Directorate were addressed and compliance / confirmation by Bhoja Air was sent to CAA Pakistan**.**

2.1.256 The TAWS Sandel Avionics ST3400 along with wind shear warning capability of Enhanced Ground Proximity Warning System (EGPWS) MK-VII worked perfectly as per the design parameters / features. According to ICAO

Annex 6 (Part-I) all turbine engine aeroplanes of maximum certified take off mass in excess of 5700 kg shall be equipped with a GPWS.

2.1.257 While carrying out the detailed investigation of the requirement for EGPWS / GPWS / TAWS / Wind shear warning equipment onboard the aircraft, it was observed that US Department of Transportation Federal Aviation Administration Master Minimum Equipment List for Boeing 737 series, M/s PIAC, M/s Shaheen Air International and M/s Bhoja Air Boeing 737 series aircraft could be dispatched for flight without, the GPWS and wind shear warning system (predictive or reactive), being serviceable as per their respective Minimum Equipment List (MEL).

2.1.258 However, the mishap aircraft had both the TAWS and wind shear warning system (reactive) serviceable during the flight and operated as per the design parameters of the equipment.

Aircraft System Failure / Incapacitated Cockpit Crew

2.1.259 The possibility of aircraft system failure and cockpit crew incapacitation was studied in detail and it was observed that:

2.1.260 Technical investigation / analysis confirmed that all systems, accessories and both engines were functioning normal, till the aircraft impacted the ground.

2.1.261 The cockpit crew never announced any emergency or abnormal conditions related to the aircraft systems / sub-systems.

2.1.262 The cockpit crew were conversing till the last second before the crash which confirms that the cockpit crew status was normal and not incapacitated during last phases of flight.

Lack of Situational Awareness (SA)

2.1.263 The mental formulation and retention of the detailed picture of references and conditions, is called situational awareness (SA). The cockpit crew needs to be well orientated all the time with the entire environment around them. Due to various reasons and factors, at times the cockpit crew starts to have degradation in mental picture formulation and retention, which is called lack of situational awareness.

2.1.264 In case of Bhoja Air crash, it was observed that both the cockpit crew till the ground impact of aircraft remained well orientated and were correctly identifying the unsafe and prevalent hazardous conditions.

Procedural Error

2.1.265 In aviation industry, there are set rules / regulations and procedures devised and implemented by the regulatory authority as well as the operator for the safe conduct of flights. The procedures for the specific type of aircraft are spelt out by the manufacturers and are to be religiously followed and implemented by the operators for the safe flight of aircraft. Captain while managing the final phases of mishap aircraft, was observed not adhering and following the operator (CAA approved) as well as manufacturer recommended rules / regulations and procedures to get out of unsafe and dangerous set of

conditions. So the procedural error and ineffective management of flight deck by the Captain as well as the FO's inaction, contributed in the catastrophic accident.

Cockpit crew Non-Conformance of QRH, FCOM and Operational (Ops) Manual.

2.1.266 The critical violation of procedures was observed with regard to implementation and conformance of QRH, FCOM and Ops Manual recommended actions / instructions. As per the CAA Pakistan approved Ops Manual of Bhoja Air, the aircraft was supposed to remain clear of an active weather cell by 5 to 10 nm which was not followed by the cockpit crew during the conduct of ill fated flight to destination. The cockpit crew were observed not complying with any Boeing recommended FCOM and QRH remedial actions to recover out of wind shear, TAWS / GPWS warnings and stall conditions.

Crew Resource Management (CRM) Training

2.1.267 During the CRM training, the cockpit crew is educated on hazard identification, hazard management and optimum utilization of available resources. As a result of CRM training, the flight crew evolve techniques to mitigate the hazards and reduce the human errors in flying operations.

2.1.268 The documentation in respect of both cockpit crew was scrutinized in detail to find out any anomaly in the CRM training of cockpit crew. The record indicated that both the cockpit crew were qualified and had undergone Crew Resource Management (CRM) training. However, during the last phases of conduct of ill fated flight, it was observed that the cockpit crew did not follow the CRM tools / techniques to get out of unsafe set of conditions after encountering severe bad weather conditions ie FO did not take over the controls of aircraft and kept giving reminders of go around to the Captain.

2.1.269 It was important to find out the reasons of CRM failure which otherwise could have averted the accident. It was observed during the process of investigation that Captain of mishap aircraft was one of the instructional staff when FO was undergoing his initial flying training at PAF Academy as a cadet. Captain always remained a fatherly figure in the mind of the FO. Captain looked after the FO in SAI and later became a factor in his joining Bhoja Air. In Bhoja Air FO flew a total of 23 flights, 16 of which were flown with Captain. FO had an average flying experience and not undergone any simulator training of automated aircraft / flight deck management. That is why, FO kept on reminding the Captain and suggesting a go around to get out of unsafe / hazardous set of conditions after entering the severe weather, but remained reliant on Captain to take the required actions. The FO should have taken over the controls of aircraft to execute a go around once there was inadequate response / inaction by the Captain.

2.1.270 Due to the above mentioned factors and reasons, FO and Captain failed to comply with the basics of CRM training which contributed in causation of the unfortunate mishap.

Why did the Cockpit crew Fail to avert Accident

2.1.271 It was the first evening scheduled flight of Bhoja Air on sector Karachi – Islamabad which had put unnecessary and undesired pressure on the cockpit crew to continue the flight for destination. As per the CVR recording, at no time during the flight, cockpit crew discussed discontinuation of flight for the destination and diverting to the alternate airport. The cockpit crew were adamant to land at destination. On one side was the pressure of first evening flight and on the other hand the cockpit crew were trying to manage the automated flight deck of ill fated aircraft for which FO had not undergone variance type training and the Captain also had limited experience of automation, lacked knowledge about Boeing recommended procedures concerning wind shear, TAWS / GPWS warning and stall recovery along with effective and efficient automated flight deck management. The Licensing Circular (ASC) – 1 / 2000 dated 15th October, 2000 issued by CAA Pakistan also did not cover the variance type training requirement of Boeing 737-236A aircraft. The cockpit crew were observed till the aircraft ground impact, confused about handling of automated flight deck. This was due to their very low automation management experience and lack of formal simulator training to recover out of such abnormal situations.

Availability of Customized Boeing 737-236A Aircraft FCOM and QRH at Bhoja Air

2.1.272 The available FCOM and QRH with Bhoja Air for utilization with flight crew were not customized copies of Boeing 737-236A aircraft variant. Due to the non availability of customised FCOM and QRH, Captain and FO of mishap aircraft by virtue of their previous semi-automated flight deck flying experience did not have the reading material available with them to update themselves on academic knowledge of specific variant of Boeing 737-200 series ie Boeing 737-236A being flown by them in Bhoja Air.

Implementation of Standardized Flying Procedures

2.1.273 The primary responsibility of the operator is to ensure that before an aircrew is accorded status of a qualified cockpit crew, they are thoroughly trained so that they can operate the aircraft safely. The cockpit crew training makes them fully capable of handling any abnormal situation encountered either on the ground or in the air. For that, besides learning the aircraft systems, adequate practice and drills are given to the pilots, on simulators and in actual line flying. The various flight checks of the pilots include assessments in this domain.

2.1.274 In case of Bhoja Air, the Flight BHO-213 was being managed by the cockpit crew who were not professionally competent to operate the flight in the given set of unsafe / severe bad weather conditions. FO did not have formal simulator training for operating an automated flight deck, on the other hand Captain underwent simulator training in South Africa under the supervision of South African instructor and the simulator check was not monitored by Flight Standard Inspector CAA Pakistan. It is observed that during these simulator sessions Captain was not exposed to wind shear / TAWS / GPWS exercises and their recovery techniques. Due to the absence of required training, Captain kept relying on automation to provide him a solution whereas he should have followed the Boeing FCOM / QRH recommended procedures.

2.1.275 The captain while undergoing his simulator training had seven “satisfactory with brief (SB)” entries. The cockpit crew of his experience, is not expected to perform in this manner, as seven SBs grading of such experienced cockpit crew are considered as poor performance. After the arrival of Captain from South Africa, neither any specific recommended training was imparted nor his performance to manage the automated flight deck evaluated. This was a serious mistake on the part of Bhoja Air management in grooming / training of Captain.

Role of ATS in Averting the Accident

2.1.276 The investigation team had a dedicated ATS investigator to look into all available evidences and ascertain all the factors which could have directly or indirectly contributed towards the causation of the accident.

2.1.277 A thorough investigation in this particular domain was conducted. After detailed deliberations and thorough analysis it was concluded that radar controller and ATC Tower controller performed their duties as per their laid down procedures, rules and regulations. The weather picture transmitted by radar controller was also appreciated by the Captain by saying that MASHA-ALLAH *(by the grace of God)* he had guided them correctly. Therefore, any direct or indirect contribution of radar controller as well as ATC Tower Controller towards the causation of the accident is ruled out.

Bird Strike

2.1.278 The possibility of a bird strike to the aircraft or to any engine, causing damage to the engine or aircraft structure to an extent which could have resulted into the mishap aircraft crash, was also studied in detail and ruled out due to the following reasons:

2.1.279 The cockpit crew never discussed bird activity or their presence on the final approach path and the ATCO also never transmitted the presence of the birds on or around the runway or the adjoining areas especially towards the final approach flight path direction.

2.1.280 No evidence of bird impact or its remains were observed or found on any of the aircraft body parts or in the engines area.

2.1.281 On the basis of above mentioned facts, the possibility of a bird strike to the aircraft or bird ingestion into the engines causing the accident is ruled out.

Sabotage

2.1.282 Due to prevalent security situation in the country, an in-depth analysis of the aircraft wreckage was carried out to ascertain that the mishap did not occur due to some internal / external sabotage activity.

2.1.283 **External / Internal Explosive Device.** The sabotage activity was ruled out on the basis of the following:

2.1.284 The aircraft did not disintegrate or explode in the air, and no part of the aircraft structure was found from outside the general wreckage area or from the final flight path, or from the route or prior to the first ground impact point.

The complete inventory of the aircraft structure was available from within the wreckage site.

2.1.285 The cockpit voice recorder (CVR), gave complete conversation amongst the pilots and various ground agencies; even the sound of the engines and various warnings, alerting the cockpit crew during final phases of the flight were also available. The CVR neither showed any abnormal sound of explosive or aircraft disintegration, nor did the flight crew sound any concern about any onboard detonation or explosion.

2.1.286 The complete wreckage analysis did not reveal any chemical explosive deposits on any of the aircraft component / structural part.

2.1.287 Islamabad Police was requested to conduct forensic testing of wreckage for confirmation of any sabotage action. The report forwarded by them re- confirmed the absence of any evidence which could have ascertained the sabotage action being the cause of aircraft crash.

2.1.288 None of the eye witnesses gave any information related to seeing or hearing the sound of explosion prior to the aircraft ground impact or sound of any projectile being fired towards the aircraft prior to the ground impact.

Weather Analyses

2.1.289 An in-depth study was conducted by the meteorological investigation team member to find out all the factual information related to the reported / prevalent weather conditions in and around BBIAP, Islamabad prior to and at the time of accident. The relevant METARs, satellite picture of Pakistan weather, the weather relayed through ATIS and the weather announced by Approach Radar, along with weather analysis by Boeing by utilizing all available sources to ascertain the exact weather parameters on the mishap day were studied, the details are appended below:

2.1.290 **BBIAP, Islamabad and AIIAP, Lahore Reported Weather**

2.1.291 The weather observation reports at BBIAP, Islamabad on 20 April, 2012 before and after the accident are as follows:

Time UTC	Weather Report
1100	SE 16KTS VIS 6KM HAZE 1TCU030 4SCCU040 4AC100 QNH 1009 TEMP 32/13 WEATHER WNG FOR TSR valid up to 1300.
1200	SE 22KTS VIS 6KM HAZE 1TCU030 4SCCU040 6AC100 QNH 1008 TEMP 31/12 WEATHER WNG FOR TSR valid up to 1300.
1300	SW 20KTS VIS 4KM TS 1CB025 4SCCU040 6AC100 QNH 1009 TEMP 25/15 WEATHER WNG FOR TSR valid up to 1600.

2.1.292 The weather situation at alternate aerodromes was as under:

Lahore Weather

Time UTC	Weather Report
1100	SW 230/17G28KTS VIS 3500M DRDU SCT040 SCT100 QNH 1009 TEMP 32/13 TEMPO 22030KTS 2000.
1200	SW 240/18G28KTS VIS 3500M DRDU SCT040 BKN100 QNH 1009 TEMP 30/12 TEMPO 22040KTS 2000.
1300	SW 230/13KTS VIS 4000M HZ SCT040 BKN100 QNH 1010 TEMP 27/12 TEMPO 22030KTS 2000 DRDU.

Peshawar Weather

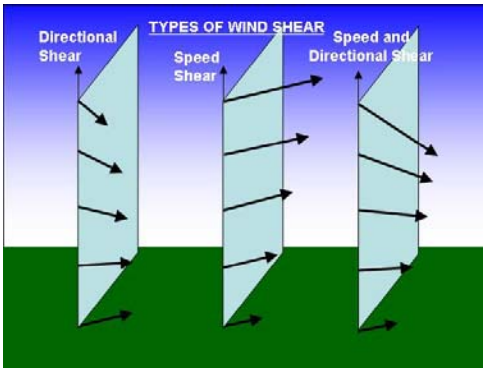
Time UTC	Weather Report
1100	SW 20KTS VIS 6KM HAZE STRA FEW030CB SCT040 BKN100 QNH 1012 TEMP 23/17
1200	SW 12KTS VIS 6KM HAZE STRA FEW030CB SCT040 BKN100 QNH 1011 TEMP 21/18
1300	SW 16KTS VIS 4KM HAZE STRA FEW030CB SCT040 BKN100 QNH 1011 TEMP 21/18

2.1.293 The following weather warnings were issued for Islamabad region on the day of accident:

Time in UTC	Weather Warning
1200 (METAR)	WX WNG FOR TSRA OVER OPRN AND 50KM AROUND DURING THE PERIOD OF 20-1000Z UPTO 20-1300Z SURFACE WIND NE-NW 20-40KT QNT 65KT OR MORE SURFACE VISIBILITY 3 TO 1 KM OR LESS DUE TO PPTN MORDERATE / SEVERE TURBULENCE MAY ACCURE 1-2/8 CB AT 2500FT ABOVE GROUND LEVEL PROB 70%)
1300 (METAR)	(OUR PREVIOUS WX-WNG FOR TSRA OVER OPRN AND 50KM AROUND IS FURTHER EXTENDED UPTO 20-1600Z. S/WIND NW-NE 20-40KT QNT 65KT OR MORE. S/VIS MAY REDUCE 3-1KM OR LESS IN PPTN MOD/SEV TURB MAY OCCURE IN 1-2/8CB AT 2500FT AGL PROB 70%=)
1400 (METAR)	WX WNG FOR TSRA OVER OPRN AND 50KM AROUND DURING THE PERIOD OF 20-1600Z TO 20-1900Z=

2.1.294 As the CVR recording revealed exposure of mishap flight to wind shear, therefore this specific phenomenon was studied in detail to see its contribution towards causation of occurrence.

2.1.295 **Wind Shear.** Wind shear is a micro scale meteorological phenomenon in which sudden and drastic changes in wind direction and speed take place with altitude over a short distance. It is usually associated with a microburst that often occurs in the vicinity of thunderstorms resulting in conditions that can cause rapid changes in lift and hence the attitude / altitude of the aircraft.



2.1.296 Generally, the winds travel horizontally, but under certain conditions in thunderstorms and frontal system, wind shear will travel in a vertical direction, causing up and downdrafts. Microburst wind shear is an extremely violent downward blast of air that hits the ground and radiates outward with its sharp shifts in wind speed.

2.1.297 **What is a Downburst?** A downburst is a rapid down-rush of air in the downdraft caused by hail storm or heavy rain. As the pocket of cooler air hits the ground, it spreads out in all directions.

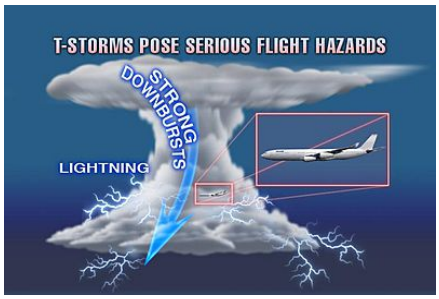


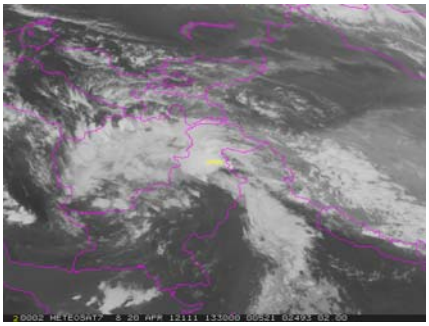
Illustration of a Microburst

Tree damage from a downburst

2.1.298 **Boeing Weather Analysis**

2.1.299 Boeing also provided a weather analysis of all available weather data. The details of Boeing Weather Analysis is discussed below:

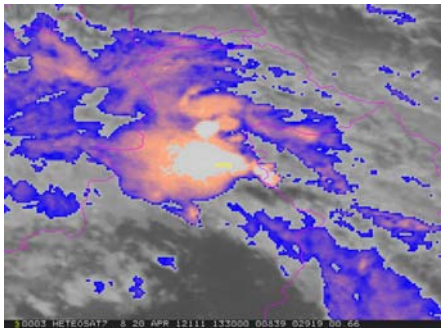
2.1.300 **Infrared Satellite Imagery.** At 13:30 UTC on 20 April 2012 the Meteosat7 infrared satellite image showed following picture of the regional area.



13:30 UTC 20 April 2012 Meteosat7 infrared satellite image

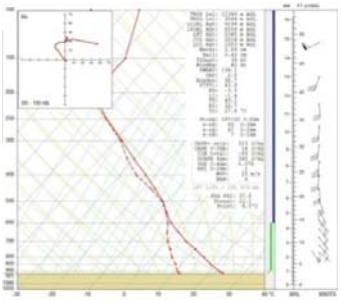
2.1.301 According to the above mentioned weather picture, BBIAP Islamabad (OPRN) was covered by a large canopy of bright white (cold topped) clouds. This cloud system appeared to be a convective system given the round shape and tight cloud gradient seen on the southern edge.

2.1.302 **Colour Enhanced IR Satellite.** The enhanced colour satellite imagery of Meteosat7 infrared satellite for 18:30 PST on 20 April 2012 image also highlighted areas of deep convective clouds. The colour scheme used to identify the most intense (cold deep cloud tops) as bright white. BBIAP, Islamabad sat under deep convective clouds at the time of the accident.



2.1.303 **Surface observations for BBIAP Islamabad for 20 April 2013.** The surface observation between 1800 and 1900 PST, the temperature dropped from 77 to 68 degrees Fahrenheit (F), the dewpoint temperature increased from 59 to 61 degrees F, winds were from 230^0 at 20 knots, the visibility reduced from 2.5 to 1.9 miles and thunderstorms were reported. Note the significant wind speeds at 1610 and 1720 PST when 34 knots were reported. Also, wind direction was quite variable over several hour period going from south east to south west to north east between 1700 and 2000 PST, which is likely due to convective downdraft / outflow influences.

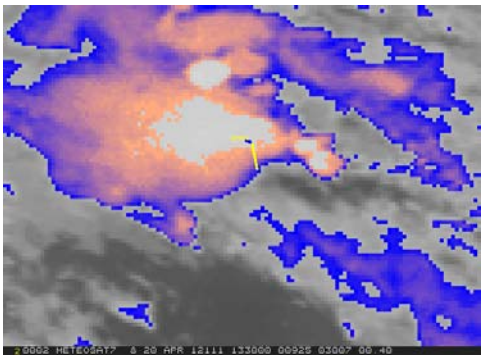
2.1.304 **GDAS model atmospheric sounding OPRN 1700 PST.** The GDAS model atmospheric sounding was carried out for 1700 PST BBIAP Islamabad. The model appears to be resolving a convective cloud environment that is characterized by a dry sub-cloud layer (ie high based convection). The surface inflow to the convective system had a temperature / dew point spread of 35^0 Fahrenheit (90F/55F), which results in an inverted-V type sounding and the potential for **Model Atmospheric Sounding**



strong convective downdrafts. Also, the downdraft convective available potential energy (a parameter called DCAPE) can be used to assess downdraft strength potential. There was 348 J/kg of DCAPE on this sounding. DCAPE values can be converted to theoretical downdraft magnitude potential which results in 40-50 knots of potential downdraft in this case.

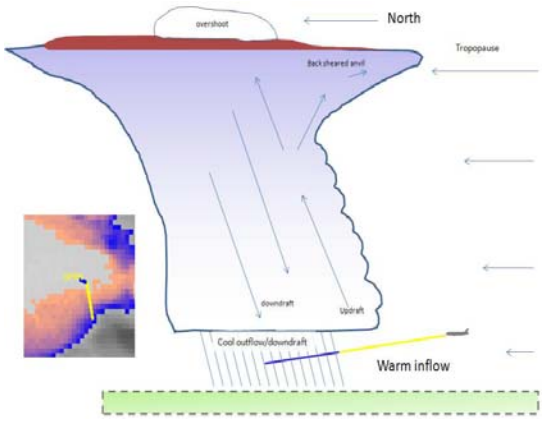
2.1.305 **Weather Summary.** After a detailed analysis of infrared satellite imagery, surface observations and model derived thermodynamic profiles, it has been concluded that high based thunderstorm activity was present at Islamabad during this accident event. Surface observations showed thunderstorms with gusty and variable winds associated with the convective system. Wind speeds were reported between 20 and 34 knots while the convective system was in the vicinity. Also, a theoretical downdraft strength potential of 40-50 knots was derived from the thermodynamic profile. Given these facts, this accident occurred in an environment with a high probability of producing strong downdrafts and / or near-ground wind shear.

2.1.306 The final segment of the flight (yellow / blue) over the colour enhanced IR satellite image from 18:30 PST. The colour have been arranged so that blue / beige are associated with cirrus anvil clouds below the tropopause and white is where the deepest convective clouds have penetrated into the tropopause and / or stratosphere. Enhanced white areas are associated with the deepest convective clouds and greatest potential for heavy precipitation generation. The flight path has been colour coded such that the yellow segment represents warm recorded outside temperatures and the blue segment represents cold recorded temperatures. The transition from warm air to cool air occurred under the deep convective cloud and likely represents an evaporatively cooled downdraft.



Plot of Flight Segment

2.1.307 **Conceptual Model of Convective Cloud.** The conceptual model cross section of the convective cloud is shown below. Due to increasing southerly winds with height, the convective cloud would have been vertically sheared towards the north with height. As the aircraft entered the convective system from the south, they would have likely flown under the back sheared anvil cloud (blue and beige areas) while in warm inflow. Then as they continued to enter the convective system, they would have entered the downdraft region. Given the high cloud bases on this day, there was potential for considerable sub-cloud evaporative cooling resulting in significant cold downdraft production. Therefore deteriorated weather condition was one of the factor in the causation of this accident.



2.1.308 **Boeing Atmospheric Analysis**

2.1.309 A weather analysis was conducted by the Atmospheric Physics Group at Boeing USA to determine whether the conditions were conducive to generating downdrafts of the magnitude observed in the calculated data. After an analysis of infrared satellite imagery, surface observations, and model-derived thermodynamic profiles, it was concluded that high-based thunderstorm activity was present in Islamabad at the time of the accident. Surface observations showed thunderstorms with gusty and variable winds associated with the convective system. Wind speeds between 20 and 34 knots were reported while the convective system was in the vicinity. Also, a theoretical downdraft strength potential of 40-50 knots (68-84 fps) was derived from the thermodynamic profile. Given these facts, the accident occurred in an environment with a high probability of producing strong downdrafts.

Renewal of Bhoja Air Regular Public Transport (RPT) Licence

2.1.310 M/s Bhoja Air was initially awarded the Regular Public Transport (RPT) Airlines Licence No 020/92 for one year from 14 November, 1992, after processing the application with laid down procedures in vogue at that time. The terms and conditions of the airlines licence were also conveyed to them with the licence. The airline continued her operations till year 2000. Later their licence was repeatedly renewed on M/s Bhoja Air's request as per CAA's Pakistan procedures. From time to time, the licence renewal requirements continued to change. All these requirements / formalities as per National Aviation Policy 2000, Civil Aviation Rules 1994 and related Air Navigation Orders were implemented and complied before the renewal of RPT (airlines) licence of Bhoja Air. The Bhoja Air RPT (airlines) Licence No 020/92 dated 21 October, 1998 was renewed on 14th September, 2011 by CAA Pakistan for period from 15th November, 2010 till 14th November, 2011 and 15th November, 2011 till 14th November, 2012 as per CARs 1994.

Issuance of Air Operations Certificate (AOC)

2.1.311 After meeting all the requirements of CAA, Pakistan as per the existing rules and regulations in vogue, the Air Operation Certificate was issued vide AOC # AOC-025/12-AL dated 02nd March, 2012 valid till 31 December, 2012.

Issuance of Certificate of Airworthiness "C of A"

2.1.312 After meeting all the requirements of CAA Pakistan as per the existing rules and regulations in vogue, the ill fated aircraft was issued C of A vide CAAF-009-AWRG-1.1 S No 756/1 on 15 February, 2012. It was observed that the C of A was signed by Competent Authority on 15th February, 2012 whereas the pre-requisites of technical inspections / evaluations for issuance, were verified on 27th February, 2012. That is why its validity was granted from 27th February, 2012 till 26th February, 2013.

2.2 Technical Analysis

History of Aircraft (Boeing 737-236A)

2.2.1 The aircraft B737-236A, S. No. 23167 was manufactured on 07 January, 1985 and was fitted with two Pratt & Whitney (PW) JT8D-15A engines and an Auxiliary Power Unit (APU) GTCP-129 of Honeywell.

2.2.2 The aircraft was initially delivered to British Airways in January, 1985 with Registration No. G-BKYI and remained with British Airways till June 1999. During this period of about 14 years, the aircraft flew 25245:31 Hours and 21744 Cycles without any major defect history.

2.2.3 In, June 1999 the aircraft was sold to M/s Comair and registered in South Africa with Registration No. ZS-OLB. The aircraft rendered good service for about 12 years and accumulated 46863:56 hours and 37783 cycles while operated by the second operator. The aircraft was maintained by South Air Aviation Technical (approved by CAA, South Africa) from 09th June, 1999 to 31st December, 2010.

2.2.4 In January, 2011 the aircraft was grounded as serviceable because of change of fleet by Comair and was put in storage in Johannesburg (South Africa).

2.2.5 During storage, it was being maintained as per Maintenance Planning Document (MPD) which included a weekly ground run of engines till October, 2011.

2.2.6 Before induction into M/s Bhoja Air, under mentioned aircraft major inspection schedule was followed:

	'C' Check (Hrs)	**'D' Check (Hrs)**
Interval	3000	20000
Last Performed at	44216	33500
Next Due at	47816	53500

2.2.7 Bhoja Air purchased this aircraft in January, 2012 and got it registered in Pakistan with Registration No. AP-BKC. Bhoja Air is the third operator of this aircraft since its manufacture.

2.2.8 Before purchase, to assure air worthiness of the aircraft, major Check-4C was carried out on 13th January, 2012 at aircraft flight hours 46863.56 by Springbok Aviation Services (SAS), South Africa.

2.2.9 Boeing Ageing Airplane Corrosion Prevention & Control Programme (CPCP) was implemented during Check-4C to evaluate structural integrity as per

Original Equipment Manufacturer (OEM) requirement. Same was validated by CAA Pakistan acceptance team.

2.2.10 During Check-4C at South Africa, Supplementary Type Certificate (STC-02997AT) for Boeing 737 aircraft was carried out by SAS. As per this STC, a Sandel Avionics ST 3400 class A TAWS was installed.

2.2.11 As a pre-requisite to induction of aircraft, the acceptance was carried out jointly by representative of Pakistan Aviation Engineering Services (PAES), Flight Standards and Airworthiness Inspectors of CAA Pakistan (as per the approved checklist of CAA Pakistan) at Johannesburg, South Africa. A total of 28 discrepancies were noticed during that acceptance inspection on 12th January, 2012. All these discrepancies were cleared by SAS at Johannesburg and same were verified by CAA Pakistan after arrival of aircraft at Karachi.

2.2.12 Bhoja Air "Aircraft Maintenance Schedule (AMS)" was approved by Directorate of Airworthiness (DAW), CAA Pakistan on 02nd March, 2012.

2.2.13 As per the aircraft log book Engineering Change Order (ECO – BHO-737-001) was carried out to change cabin configuration from 100 to 118 seats on 10th March, 2012 at Karachi.

2.2.14 After issuance of AOC and C of A in respect of mishap aircraft to Bhoja Air, the aircraft commenced scheduled domestic operations with effect from 29th March, 2012.

2.2.15 The aircraft flew 69 hours and 41 Cycles during service with Bhoja Air from 25th January, 2012 (Date of Ferry) till it crashed on 20th April, 2012.

2.2.16 During service with Bhoja Air, routine maintenance checks S1, S2 and S3 were performed as per the Maintenance Schedule approved by Air Worthiness, CAA Pakistan. The details of these checks are given in subsequent paragraphs.

2.2.17 **Transit Check (1-S).** It is to be performed at all stations where the flight is in transit.

2.2.18 **Pre Flight Check (2-S).** It is to be performed prior to first flight of each day and at station where flight will terminate and have minimum of 6 hrs ground time. All checks of 1-S will also be included in it.

2.2.19 **Layover Check (3-S).** It is to be performed every 45 flight hours from previous 3-S check. All checks of 1-S and 2-S will also be included in it.

2.2.20 The last check 3-S was carried out on 13th April, 2012 and last check 2-S on 20th April, 2012.

2.2.21 During all the above mentioned maintenance checks, no anomaly was observed in serviceability and reliability status of the aircraft structure, engines, or components.

2.2.22 The record of the time changed components was thoroughly scrutinized. All systems' components and their related parts were found within life limits.

History of Engines

2.2.23 At the time of induction into Bhoja Air, two engines of Pratt & Whitney (P&W) make and model JT8D-15A were installed on the aircraft. The Serial No 709210, TSN 47607 hrs and CSN 38971 was installed on left hand side (No. 1 position) whereas Serial No. 709211, TSN 49398 hrs and CSN 36615 was installed on right hand side (No. 2 position).

2.2.24 After induction into Bhoja Air and before starting routine operations, Left Engine S. No. 709210 was removed as serviceable for compliance of Service Bulletin (SB) No. JT8DA6431 which warranted High Pressure Compressor (HPC) disk inspection for corrosion. As replacement Engine S. No. 700469, TSN 33666 hrs and CSN 19483 was installed on left side (No 1 Position).

2.2.25 The Log Books of both the Engines S. No. 700469 and S. No. 709211 indicate that these two engines had been performing satisfactorily since commencement of scheduled flight operations by Bhoja Air on 29th March, 2012.

2.2.26 **Wreckage Examination and Analysis.** The onsite analysis of the wreckage revealed that:

2.2.27 At the first impact point, right MLG outboard wheel's 7 inches and inboard wheel's 5 inches deep dug marks were found at 5.6 feet from the wreckage centre line towards right side and 21 feet before the 1st ridge, indicating that the right Main Landing Gear (MLG) hit the ground first. The aircraft was probably in a slight right bank at the time of hitting the ground.

2.2.28 Left MLG outboard wheel's 6 inches and inboard wheel's 8 inches deep dug marks were found at 5.6 feet from the wreckage centre line towards left side and 20 feet before the 1st ridge, indicating that left MLG hit the ground after right MLG had already hit.

2.2.29 After first impact marks of both MLGs, there were marks in the shape of small ditches of both engines and aircraft belly dragging on ground. The ditches of right engine, left engine and belly were 12, 14 and 4.5 inches deep respectively.

2.2.30 Physical examination of both the engines' parts did not point toward any evidence of engines' failure or internal / external fire prior to impact. The compressor blades of both the engines were found bent and broken in direction opposite to their normal rotation and mud was also found sucked inside both the engines, which are clear indications of normal engines' operation at the time of aircraft ground impact.

2.2.31 The wreckage was thoroughly examined and inspected for possible lightening strike. However, in metallic structural parts, no pits, burn marks or small circular holes were observed. Similarly, in composite (non-metallic) structural parts, no signs of discoloration, burns, puncture or de-lamination were found. Hence, it could be concluded that there was no lightening strike on the aircraft before ground impact.

2.2.32 The efforts were made to locate the static dischargers however; all the onboard static dischargers could not be recovered. The recovered static

dischargers were observed damaged due to ground impact and broken from their mounting retainers. The mounting was found without any electric burning marks. Neither metal was observed fused due to lightening nor any pitting in the static discharger retainers.

2.2.33 The wreckage was thoroughly examined for hail strike on its structural parts. However, no such indentation marks were observed on any of the parts which could have confirmed the hail storm.

2.2.34 **Reconstruction of Aircraft.** After completion of onsite wreckage examination, identification of the flight path and documentation of the wreckage distribution, the wreckage was moved to BBIAP, Islamabad. The wreckage was laid out at BBIAP, Islamabad in the simulated pattern as found at the crash site. All aircraft parts were regrouped for reconstruction of mishap aircraft to ascertain integrity of aircraft structure, engines and all related systems. However, no anomaly was observed and following possible causes of crash were ruled out.

2.2.35 **Bird Hit.** No bird impact mark / remains were found on any of the aircraft body parts or inside the engines.

2.2.36 **In-Flight Structural Failure.** All structural parts were inspected and their completeness / integrity before ground impact was verified. No signs of external or internal damage before ground impact were observed.

2.2.37 **In Flight Fire.** The detailed examination of the wreckage did not reveal any sign of in-flight fire.

2.2.38 **Sabotage.** The wreckage was critically examined for evidence of sabotage however, it was ruled out as the aircraft did not disintegrate or explode in the air, and no part of the aircraft structure was found from outside the general wreckage area or from the route along the final flight path behind the first ground impact point. The complete inventory of the aircraft parts was available within the wreckage. The CVR transcript revealed normal conversation amongst the flight crew. The CVR also neither showed any abnormal sound of explosive or aircraft disintegration, nor did the pilots show any concern about any detonation or explosion.

2.2.39 **Salient points of Examination and the Analyses.** The detailed examination and analyses of the wreckage along with FDR / CVR data was conducted and the salient points from analyses are appended below:

- *The aircraft disintegrated due to high ground impact loads.*
- *The fractured aircraft parts did not have any pre-impact fire signatures.*
- *The evidence of fire on some of the aircraft parts indicated that those were affected by the post impact ground fire.*
- *The engines appeared to be operating normally and within expectation up to the crash event.*

2.3 ATS Analysis

2.3.1 In order to analyze the role of Air Traffic Services (ATS) in this accident, the facts pertaining to this domain were considered, by segregating them into various essential activities of ATS and determine the specific areas which

could have contributed directly or indirectly towards the causation of the accident. The possible activities related to ATS could be divided into the following domains:-

- Role of ATS (Radar or Non-Radar)
- Role of Radar in ATS (General)
- Role of Radar in Bad Weather Conditions
- Organizational Responsibilities

Role of ATS (Radar / Non Radar)

2.3.2 Pakistan being signatory of Chicago Convention for the provision of air traffic services follows the standard ATS rules and regulations specified by the ICAO in its Annexes and documents. The following objectives of ATS are extracted from ICAO Annex 11.

2.3.3 The objectives of air traffic services shall be to:

- Prevent collisions between aircraft;
- Prevent collisions between aircraft on the manoeuvring area and obstructions on that area;
- Expedite and maintain an orderly flow of air traffic;
- Provide advice and information useful for the safe and efficient conduct of flights;
- Notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required.

Air Traffic Control (ATC) Service

2.3.4 ATC service is provided by ground-based controllers who direct aircraft on the ground and in the air. The primary purpose of ATC systems worldwide is to separate aircraft to prevent collisions, to organize and expedite the flow of traffic, and to provide information and other support for pilots for safe conduct of flights. Preventing collisions is referred to as separations, which is a term used to prevent aircraft from coming too close to each other by use of lateral, vertical and longitudinal separation minima. ATC is providing additional services in the form of advice and information to pilots for the safe conduct of flight, it may be weather and navigation related information or any other information. The services provided to aircraft whether it is procedural or radar on the basis of charter given by the ICAO is uniform all over the world.

2.3.5 ATC service is provided throughout Pakistan in selected airspaces and ATS routes. The service is available to all users (private, military, and commercial aircraft) when flying in designated airspaces or at designated ATS routes. When controllers are responsible for separating some or all aircraft, such airspace is called "controlled airspace" in contrast to "uncontrolled airspace" where aircraft may fly without the use of air traffic control service. Depending on the type of flight and the class of airspace, ATC may issue instructions that pilots are required to follow, or merely flight information (in some countries known as advisories) to assist pilots operating in the airspace. In all cases, however, the pilot in command has final responsibility for safety of the flight,

and may deviate from ATC instructions in emergency or to avoid severe / adverse weather areas.

Role of Radar in ATS (General)

2.3.6 Radar controller is an air traffic controller providing air traffic control service to aircraft by the use of surveillance facilities (radar). The purpose of using radar in the provision of ATC service is to achieve the following extra benefits with regard to the objective of ATS:-

- Reduction in conventional separation
- Reduction in track miles of the aircraft
- Monitoring the phases of flight and clearances
- Expeditious flow of air / ground movement of aircraft
- Provision of navigational assistance
- Provision of weather related information

2.3.7 All over the world, ATC radars receive echoes of higher moisture contents in atmosphere, in the form of clutters. Although, technically, it is possible that an echo could be associated with birds, volcanic ash, etc. Even then controllers tell pilots the location of significant areas of moisture in the form of clutter on radar scope when it appears that it may affect the aircraft's flight path. Controllers also provide assistance in the form of course deviations when requested by the pilot. Although the weather picture presented on ATS surveillance radar is always not very accurate as these radars are not meant for weather purposes even then the information is shared with pilots just to caution the pilot, otherwise the weather radar onboard the aircraft is more accurate / sophisticated and is capable of scanning the predicted route / flight path of the aircraft. Hence pilots on the basis of weather radar picture available to them, select and fly the safest possible tracks in coordination with ATC to avoid significant weather prevalent areas. The radar controller on duty provided standard ATC service to ill-fated Flight BHO-213 as per ICAO documents Doc 4444, Annex 11 and directory of duties. There was no breach of procedures observed during the course of investigations from ATS point of view. Aerodrome information including weather information was being broadcast through ATIS and it was observed that as per the CVR transcript cockpit crew of Flight BHO-213 never selected and monitored the ATIS being broadcasted by BBIAP, Islamabad, however ATIS AIIAP, Lahore was monitored by the cockpit crew during flight. The radar controller owing to inclement weather conditions around BBIAP, Islamabad guided the aircraft on the basis of weather picture available to him on the radar scope which was also appreciated by the Captain of aircraft during flight. There was no contrast or deviation to international standards which was observed by the investigation team.

Role of Radar in Bad Weather Conditions

2.3.8 ICAO specifies in its documents that Controllers are required to provide the most appropriate advice / information to pilots of an aircraft requesting navigational assistance when avoiding areas of adverse weather conditions. The following are the guide lines which are to be followed in weather avoidance scenarios:

Information regarding Adverse Weather

2.3.9 Information should be issued to the affected aircraft in sufficient time to permit the pilot to decide on an appropriate course of action when an aircraft appears to penetrate in an area of adverse weather, including that of requesting advice on how best to circumnavigate the adverse weather area, if so desired.

Note: *Depending on the capabilities of the ATS surveillance system, areas of adverse weather may not be presented on the situation display. An aircraft's weather radar will normally provide better detection and definition of adverse weather than radar sensors in use by ATS.*

2.3.10 When vectoring an aircraft for circumnavigating any area of adverse weather, the controller should ascertain that the aircraft can be returned to its intended or assigned flight path within the coverage of the ATS surveillance system and, if this does not appear possible, inform the pilot of the circumstances.

Note: *Attention must be given to the fact that under certain circumstances the most active area of adverse weather may not be displayed.*

2.3.11 The cockpit crew should notify the concerned ATS unit and request clearance to deviate from track, advising, when possible, the extent of the deviation expected, expressed in new heading and for how long the cockpit crew intends to proceed on the deviation. When the pilot initiates communications with ATC, a rapid response may be obtained by stating "WEATHER DEVIATION REQUIRED" to indicate that priority is desired on the frequency and for ATS response. When necessary, the pilot should initiate the communications using the urgency call "PAN PAN" (preferably spoken three times). The pilot shall inform ATC when weather deviation is no longer required, or when a weather deviation has been completed and the aircraft has returned to its cleared route.

2.3.12 In order to achieve the basic objectives of ATS (Radar), radar controller requires Position indications (tracks) and map on the Radar scope. The weather information available to radar controller on the radar scope is additional information to caution the aircraft about the weather phenomena in a particular area, otherwise the objectives of ATS do not hold controller responsible for separating aircraft from severe weather activity at any phase of flight as stated in above paragraphs, aircraft are advised / cautioned on the basis of weather information if available on radar and the depicted picture of weather is passed to the concerned / affected aircraft so that pilot can analyze the severity and strength of weather activity with the help of aircraft weather radar as the aircraft weather radar could provide more accurate weather picture and its strength to the cockpit crew. Pilots always select a proper and safe course of action and get necessary clearances from concerned ATS unit. The aircraft are normally cleared on the requested tracks in weather avoidance situations or alternate safe routes are suggested by ATS units to avoid danger / restricted areas. Whenever cockpit crew in any circumstances considers the ATS cleared track / route in-appropriate, they may ask for other suitable track as the final responsibility of the safety of the flight lies with the captain of the aircraft as per ICAO Annex 2. Air traffic controllers provide flight information to aircraft; it is the pilot to take best possible decision in the interest of safety of the aircraft on the basis of information provided to him, however, by international rules and regulations controllers are not involved in

decision making process whether to continue for destination or divert to alternate airport.

2.3.13 The Flight BHO-213 was the only aircraft in the area, so the full attention was given to the aircraft and radar controller remained in touch with the aircraft till last moment. The Flight BHO-213 was provided the available weather information / briefing. The captain of Flight BHO-213 at one stage appreciated the controller, upon passing useful weather briefing to him.

2.3.14 The Captain requested radar controller to circumnavigate through the narrow gap of CB cells, whereas radar controller was not picking up any active weather cells on radar scope between radial 160^0 to 220^0. In order to clear the confusion and be sure of the actual prevalent weather conditions between the above mentioned radials, the radar controller asked the cockpit crew to confirm any weather activity towards southeast of Islamabad at a distance of about 10 to 15 nm. Radar controller on confirmation from the Captain that southeast of Islamabad is clear of weather till 40 nm, provided radar vectors to carry out an ILS approach RWY 30. The aircraft was never circumnavigated around CB cells by the radar controller. Moreover the Captain after turning onto heading 360^0 again confirmed that the area ahead of the aircraft is clear of weather and the actual weather is in the north of BBIAP, Islamabad.

2.3.15 The cockpit crew of Flight BHO-213 may have used their best judgment on the basis of information provided by the radar controller and the onboard weather picture available to them. Moreover, cockpit crew may have used the option of discontinuing on the heading advised by the radar controller, if it was not clear of weather for the safe conduct of flight. The detailed analysis on cockpit crew mutual discussions on weather en-route to BBIAP, Islamabad and their handling of particular situation is given in Operational Analysis part of the investigation. Radar controller did not have any information on the presence of wind shear in the vicinity of BBIAP, Islamabad during the final approach of ill fated Bhoja Air aircraft as per the available weather information.

Organizational Responsibilities

2.3.16 BBIAP Islamabad is a joint user airport being used by both Civil Aviation Authority (CAA) Pakistan and Pakistan Air Force (PAF). The approach control service is provided by CAA radar whereas the aerodrome control service is provided jointly by CAA and PAF qualified controllers under a formal letter of agreement as per ICAO requirement to avoid any confusion. The qualified CAA radar controllers are deployed for the purpose of providing radar and procedure approach control service in a pre-defined area around BBIAP, Islamabad. On the day of accident, instrument approaches on both the RWY-12 / 30 were available for landing. There are number of restricted / prohibited / danger areas around BBIAP, Islamabad, which compel controllers and pilots to remain within a specified airspace, even in severe weather scenarios.

2.4 Meteorological Analysis

2.4.1 On 20th April, 2012 the weather around OPRN was forecasted to be cloudy with chances of thunderstorms and rain. The same was passed in advance through TAFs. Duty Met Officer issued weather warning for thunderstorm rain

at 1430 hrs on 20th April, 2012 for OPRN which was initially valid from 1500 hrs till 1800hrs and subsequently extended. It included 1-2/8 CB at or above 2500 feet AGL with reduction trend of surface visibility from 3-1 km or even less in precipitation and wind to be 20-40 kts QNT 65 kts or more for BBIAP Islamabad and 50 km around.

2.4.2 METARs revealed that the destination (OPRN) had a thunderstorm warning with 1/8 TCU and alternate AIIAP, Lahore (OPLA) had DRW warning with no sig clouds at the time of departure of Bhoja Air. All the Met reports in the shape of TAFs, Mets and Species were timely delivered by the concerned departments. The existing TCU at destination was converted into CB at 1251 hrs and was promptly reported by Duty Forecasting Officer but by then the ill fated aircraft was already en-route to OPRN. The comparison of three hours MET reports of Islamabad is given below:-

Time in UTC	Weather Report
1100	SE 16KTS VIS 6KM HAZE 1TCU030 4SCCU040 4AC100 QNH 1009 TEMP 32/13 WEATHER WNG FOR TSR valid up to 1300.
1200	SE 22KTS VIS 6KM HAZE 1TCU030 4SCCU040 6AC100 QNH 1008 TEMP 31/12 WEATHER WNG FOR TSR valid up to 1300.
1300	SW 20KTS VIS 4KM TS 1CB025 4SCCU040 6AC100 QNH 1009 TEMP 25/15 WEATHER WNG FOR TSR valid up to 1600.

2.4.3 As per the flight plan of Flight BHO-213 Lahore was kept as alternate aerodrome, in case pilots decide to divert due to unfavourable landing conditions at destination they might go to the alternate aerodrome submitted in the flight plan. The weather situation at alternate aerodromes was as per following detail.

AIIAP, Lahore Weather

Time in UTC	Weather Report
1100	SW 230/17G28KTS VIS 3500M DRDU SCT040 SCT100 QNH 1009 TEMP 32/13 TEMPO 22030KTS 2000
1200	SW 240/18G28KTS VIS 3500M DRDU SCT040 BKN100 QNH 1009 TEMP 30/12 TEMPO 22040KTS 2000
1300	SW 230/13KTS VIS 4000M HZ SCT040 BKN100 QNH 1010 TEMP 27/12 TEMPO 22030KTS 2000 DRDU

BKIAP, Peshawar Weather

Time in UTC	Weather Report
1100	SW 20KTS VIS 6KM HAZE STRA FEW030CB SCT040 BKN100 QNH 1012 TEMP 23/17
1200	SW 12KTS VIS 6KM HAZE STRA FEW030CB SCT040 BKN100 QNH 1011 TEMP 21/18
1300	SW 16KTS VIS 4KM HAZE STRA FEW030CB SCT040 BKN100 QNH 1011 TEMP 21/18

2.4.4 As per satellite imagery en-route from Karachi till 50 NMs short of Islamabad had no significant weather; however thereafter it had heavy moisture contents. As per radar information the final path of R/W 30 at OPRN was blocked due to embedded Cb with the probability of hail.

2.4.5 **Meteorological Office Information**

1. Associated MET Office	ISLAMABAD
2. Hours of service *MET Office outside airport operational hours*	H24
3. Office responsible for TAF preparation Periods of validity	Islamabad (09,12,18,24 HR)
4. Type of landing forecast *Interval of issuance*	MET REPORT, 01 HR
5. Briefing/consultation provided	Personal consultation (P), telephone (T), self briefing (D)
6. Flight documentation *Language(s) used*	Charts (C), Cross sections (CR), abbreviated plain language text (PL), Tabular forms (TB), English

7. Charts and other information available for briefing or consultation	Surface analysis (S), Upper air analysis (current chart)-U_{85}, U_{70}, U_{50}, U_{30}, U_{20}, Prognostic upper chart P_{85}, P_{70}, P_{50}, P_{40}, P_{30}, P_{20}. W (significant weather chart), SWH Significant weather high chart, SWM significant weather medium chart, SWL significant weather low
8. Supplementary equipment available for providing information	WXR, receiver for satellite picture (APT), Self Briefing Terminal, Telefax
9. ATS units provided with information	ISLAMABAD APPROACH/ TWR
10. Additional information (limitation of service, etc.)	Phone: (92) (51) 50502267. Fax: (92) (51) 9280036. RWY visual range (RVR) not avbl.

2.4.6 In order to analyze the role of prevailing weather conditions in this accident, the facts pertaining to this domain were considered by segregating them into various sources of data sets to determine all the possible factors which could have contributed in the causation of the crash. The possible data sources can be divided into following four segments.

- Numerical Weather Products (NWP) Outputs
- Satellite Products
- Radar Data
- Organizational Responsibilities

2.4.7 **Numerical Weather Products.** On 20th April 2012, well marked westerly wave was present over central part of Pakistan up to 200hpa (30,000 ft) injecting cool air from northwest whereas there was strong feeding of warm moisture from Arabian Sea up to 500 hpa (18000 ft). High value of Relative Humidity (RH) profile depicts that moisture was mainly driven by these winds from Arabian Sea to the upper half of country. Scattered rainfall of moderate to high intensity was recorded over most parts of Khyber Pakhtoon Khaw (KPK) and upper Punjab. Heavy rains generated hill torrents in parts of northern Punjab that caused damages to roads as well which was being reported by media.

2.4.8 NWP data support development of intense convective storms in northern parts of country including Kohat, Mianwali, Rawalpindi-Islamabad, Chakwal

Jhelum regions and forecasters rightly picked the information for issuing a thunderstorm warning for the period.

2.4.9 The interaction of two air masses (cool northwesterly & warm southerly) duly supported by orography of the region resulted in severe thunderstorms activity which ultimately yielded strong updrafts and downdrafts before the decay of the system.

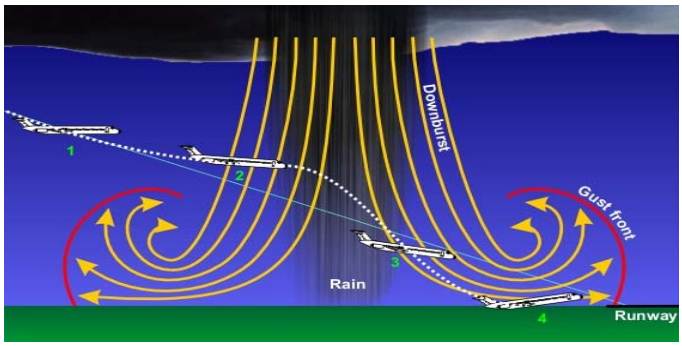
2.4.10 It is quite evident from the synoptic analysis that a strong westerly trough was affecting over the country especially in the central and northern parts at 500 hPa. Moreover, the high transport of moisture flux from the Arabian Sea along the eastern border of Pakistan, therefore the relative humidity (%) shaded in the northeast parts of the country was very high (80-90%) on 20th April, 2012 at all the selected time slots. Concentration of RH at 1200UTC and 1500UTC was at peak en-route as well as around Islamabad Airport and couple with high instability resulted in severe thunderstorms associated with gusty winds and heavy rainfall as depicted by satellite and radar imageries as well.

2.4.11 At 1200UTC it is noted that the wind barb indicated the maximum wind approximately 45-50 knots flowing en-route to BBIAP, Islamabad and also the potential is high impact weather phenomena is the highest all along the site of incident.

2.4.12 The mean wind shear was plotted for 1100UTC, 1200UTC, 1300UTC, and 1400UTC for the model domain of 3km horizontal grid spacing.

2.4.13 The data analysis depicted strong wind shear and convergence approached from Southwest en-route to BBIAP Islamabad from 1100UTC and it became worst / very severe between 1300UTC to 1400UTC. Moreover, during this time (1300-1400UTC) strong downdraft and convergence was quite evident from the model output. Generally, maximum wind downdraft accompanied with precipitation makes the weather more severe and threatening. The deep convergence produced the convection and contributed severe thunderstorm development. Wind shear is considered the critical feature of weather, which becomes the main cause of severe thunderstorms. From the analysis of above data, it is deduced that severe updrafts and downdrafts (microburst) were the main feature of weather during 1300-1400UTC on 20th April, 2012 around BBIAP, Islamabad.

2.4.14 **Microburst.** Microburst is the most violent form of downdraft from a thunderstorm. It is characterized by an intense and localized descent of cool air, causing a sudden outflow of horizontal winds above the ground with a typical horizontal extent of a few kilometres.



2.4.15 An aircraft flying through a microburst may first encounter an increasing headwind and lift, then a downdraft from above the aircraft, followed by an increasing tailwind and sink. To overcome the adverse effect of the microburst, the pilot needs to take timely corrective actions as recommended by the manufacturer to ensure aircraft safety.

Satellite products

2.4.16 Satellite imageries also depicted similar pattern of weather from 0900UTC when the severe weather development started over central KPK. The system first migrated slowly towards east and then northeast.

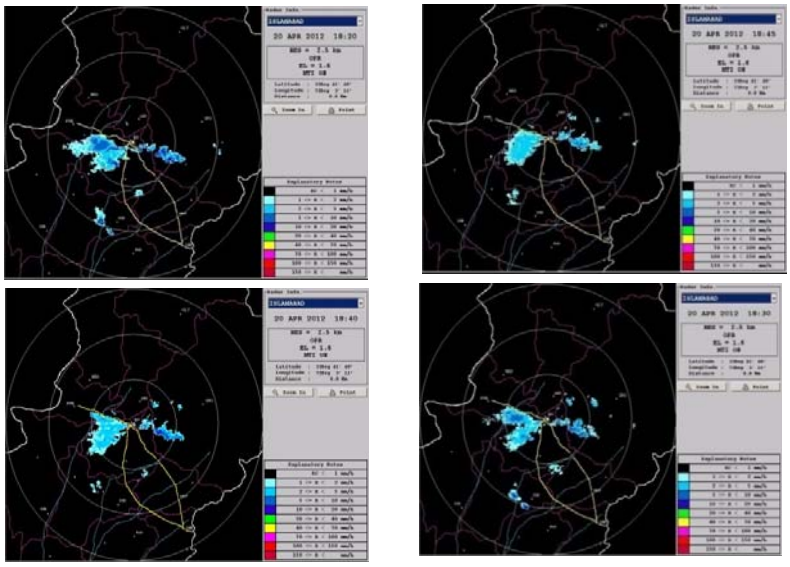
2.4.17 At 1301UTC, the core was southwest of BBIAP, Islamabad whereas at 1401UTC, it engulfed the entire region of Islamabad-Rawalpindi, Mangla (Jehlum) and up north.

2.4.18 To further focus into the weather system, infrared imageries received at 1315UTC and 1345UTC were also analyzed in detail. Satellite data depicted that severe high impact weather activity was approaching airfield at 1315 UTC and engulfed en-route & BBIAP between 1315-1345 UTC .

Radar data

2.4.19 Radar echoes of weather system depict frontal weather activity that generated severe turbulence and caused high wind shears that were responsible for the microburst.

2.4.20 Radar echoes from 1820 PST to 1845 PST of 20th April 2012 inserted above depicted that weather activity over BBIAP and east of Islamabad & Kashmir was more severe and embedded Cb clouds producing updrafts and downdrafts were mapped by radar system during the period.



Weather related Organizational Responsibilities

2.4.21 In fact all the set procedures were adopted by various stake holders. Met Flight folder was issued to Flight BHO-213 from Met Office Karachi that contained METARs, TAFs, Warnings, Satellite Imagery, significant weather chart and wind charts. Significant weather chart, METARs, TAFs etc were a

meaningful source of information to caution the pilots about disturbed weather in northern parts of country (Lahore-Islamabad).

2.4.22 Weather updates were continuously provided to Islamabad Approach Radar Controller by Meteorological Department BBIAP, Islamabad and the same was communicated by Islamabad Approach Radar Controller to Flight BHO-213 when it contacted for the purpose. In fact, at 1327UTC, Flight BHO-213 appreciated the radar controller for weather observation provided to him by saying “it was very nice whatever you told me”.

Summary

2.4.23 Satellite image analysis and its animation depicted that Flight BHO-213 encountered severe weather system (high impact).

2.4.24 NWP products fairly depicted that severe wind shear caused severe thunderstorms resulting in updrafts and downdrafts. NWP atmospheric sounding depicted severe convective cloud environment which is characterized by a dry sub-cloud layer (i.e. high convection near the surface). The surface inflow to the convective system had a temperature / dew point spread of 35^0 Fahrenheit (90F/55F), which indicates potential for strong convective downdrafts. Also, its Downdraft Convective Available Potential Energy (DCAPE) value is more than 300 J/kg. Such a high DCAPE has the potential to produce a downdraft of more than 40 knots. Therefore sounding of Islamabad confirms the development of Cb clouds and thunderstorms activity with vertical winds more than 40 knots.

2.4.25 The surface observation reports before and at the time of Bhoja Air aircraft accident near BBIAP, Islamabad confirmed high impact weather activity (TSRA, surface winds 36 knots at 1318 UTC and TSRA, surface winds 24 knots at 1340 UTC).

2.4.26 Based on above facts, it is concluded that this accident occurred in an environment with a high probability of producing strong downdrafts coupled with strong wind shear.

2.5 Medical Analysis

2.5.1 All 127 souls on board including 06 crew members and 121 passengers sustained fatal injuries due to aircraft impact with ground. Most of the bodies were in pieces and unidentifiable. There was no evidence to support any other cause of death.

2.5.2 All the dead bodies were evacuated from the crash site. One hundred eighteen (118) bodies were identified by their relatives through personal identification or through NADRA and handed over to them by local police.

2.5.3 The human remains / parts of 09 unidentified bodies were identified by DNA profiling / matching at Kahuta Research Laboratory Hospital. All these bodies / human remains were handed over to their families by District Administration.

2.5.4 Captain was assessed for initial issue of CPL by Medical Board on 01 July 1991. Thereafter his medical record does not reveal any significant problem.

2.5.5 Last medical examination of Captain was conducted at Karachi on 12 March 2012 which was valid until 30 September 2012.

2.5.6 The post-mortem of the Captain could not be performed at Pakistan Institute of Medical Sciences (PIMS), Islamabad. The PIMS management / District Administration were informed well in time but due to sensitivity of the situation and pressurization by relatives, body was handed over on 21 April, 2012.

2.5.7 FO appeared before CAMB for initial medical examination on 16 May 2009. The examination conducted was found normal and he was given fit medical assessment.

2.5.8 In the last renewal medical examination which was valid until 31 May 2012, he was found having no significant medical problem and fit medical assessment was given.

2.5.9 The post-mortem of FO was not conducted as all body parts were mixed in each other. However, autopsy of FO was performed by a team of Medico-Legal experts of PIMS, Islamabad. The Chemical Examiner observed no poison in the body tissue samples of FO.

2.5.10 The CVR transcript also did not reveal any abnormality related to fitness or consciousness of Captain / FO, as till end of flight they were talking to each other normally.

2.5.11 Captain and FO were medically fit to undertake the scheduled flight.

2.5.12 The medical certificates of all four cabin crew were found valid at the time of accident.

3. Findings

3.1 Operational

3.1.1 As per the medical investigation / analysis, the Captain was fit to undertake the mishap scheduled flight.

3.1.2 Captain was issued ATPL (A) # 948 initially on 26 March, 1996 which was renewed and valid up to January, 2013.

3.1.3 Captain possessed valid medical Class 1 till 30 September 2012. He possessed valid IRA-ME on Boeing 737/100-200 aircraft till January, 2013.

3.1.4 FO possessed a valid CPL # 2934 renewed up to July, 2012.

3.1.5 The mishap Bhoja Air Flight BHO-213 was the first evening inaugural scheduled flight from Karachi to Islamabad.

3.1.6 The mishap flight took off at 17:05:30 hrs for destination and climbed to FL310 en-route to Islamabad.

3.1.7 The unfortunate flight remained uneventful from departure till it contacted Islamabad approach radar.

3.1.8 The FDR data was available for last 26 hours however, CVR recording was available for last about 30 minutes.

3.1.9 The aircraft systems and sub-systems along with both engines response, was consistent with the design performance parameters till the ground impact of mishap aircraft.

3.1.10 The cockpit crew monitored the Lahore ATIS broadcast and were well aware of the overall weather picture.

3.1.11 At 18:08:05.6 hrs, Captain came on PA system and announced that the present weather at BBIAP, Islamabad was cloudy along with thundery activity.

3.1.12 At 18:09:15.1 hrs, Captain astonishingly questioned the runway 18L in use at Lahore and FO informed him that wind is from 230^0. The Captain on hearing this said that the winds are from the wrong side at Lahore.

3.1.13 At 18:09:58 hrs, FO informs the Captain that Lahore has a weather warning for dust thunderstorm up to 2030 hrs.

3.1.14 At 18:10:32.5 hrs, Captain and FO discussed Lahore as first alternate and Peshawar as second alternate.

3.1.15 At 18:15:01.8 hrs, Captain told the cabin crew (flight attendant) while referring to weather radar, to inform the passengers, if the same weather persists at Islamabad, there will be lot of bumps.

3.1.16 From 18:15:24.8 hrs till 18:17:05 hrs, Captain and FO discussed landing procedures for runway 12 and 30 at BBIAP, Islamabad including circle to land procedure.

3.1.17 At 18:18:17.9 hrs, FO asked the Captain that should he take the Peshawar weather and he was told that no, God would help them.

3.1.18 At 18:19:41.9 hrs, Captain analysed the weather picture and said it was all covered by squall line.

3.1.19 At many instances it was observed that FO was asking or sharing various informations with Captain but he was found not registering the contents probably due to his pre-occupation as a result of adverse / bad weather conditions.

3.1.20 At 18:20:38.4 hrs, Lahore Approach issued descent clearance to Bhoja 213 for flight level 200.

3.1.21 At 18:21:12.1 hrs, FO told Captain that he had put the seat belt sign “ON” and flight attendant made the announcement in Urdu and English about the seat belt sign “ON” due to the possibility of turbulence.

3.1.22 The flight commenced descent with Engine Pressure Ratios (EPRs) to approximately 1.0 which is consistent with flight idle setting.

3.1.23 At 18:23:54.6 hrs, Captain appeared worried about prevalent weather towards BBIAP, Islamabad area.

3.1.24 At 18:23:56.9 hrs, FO and Captain discussed the weather picture and concluded that it appeared to be slightly ahead of destination.

3.1.25 It was observed that Captain had made up his mind for landing at BBIAP Islamabad regardless of prevalent weather conditions as it was the Bhoja Air evening inaugural flight on Karachi – Islamabad sector.

3.1.26 At 18:23:59.3 hrs, Captain and FO were again found discussing the weather picture.

3.1.27 It was observed that Captain was trying to justify his decision to continue and land at BBIAP, Islamabad as correct and FO was also observed participating actively in the interpretation of changing weather picture / conditions.

3.1.28 At 18:24:27.7 hrs, Captain continued to brief FO about the presence of squall line and appeared worried about the severity of weather in front.

3.1.29 At 18:24:58 hrs, Captain increased the speed of aircraft to 280 kts as it was the recommended speed for flying through turbulent weather conditions.

3.1.30 At 18:25:49.6 hrs, FO shared his analysis of weather picture with Captain and said that they were likely to enter the squall line / bad weather area.

3.1.31 At 18:25:57.5 hrs, Captain had also realized the severity of the weather / presence of squall line and wanted to avoid entering the bad weather area but intended to continue for destination.

3.1.32 At 18:26:23.2 hrs, FO was observed coordinating with Lahore Approach and at 18:26:40.5 hrs with Islamabad Approach while approaching INDEK.

3.1.33 At 18:26:54.1 hrs, Islamabad Approach identified Bhoja flight BHO-213 and cleared it to Islamabad via POMAR ONE FOXTROT arrival and informed to expect vector ILS runway 30. The flight was also cleared to descend to 9500 ft on QNH 1009 when ready.

3.1.34 At 18:27:21.4 hrs, Islamabad Approach asked Captain that if he could give weather brief on Islamabad.

3.1.35 At 18:27:28.8 hrs, Captain briefed Islamabad Approach that there was a squall line present throughout and no gap was observed to come inside and requested Islamabad radar if they could be permitted to approach from the West.

3.1.36 At 18:28:02.6 hrs, Islamabad Approach apprised Captain that radar was not observing any gap towards West, however a gap was observed on approach radar between radial 160^0 to radial 220^0.

3.1.37 From the abovementioned discussion between radar controller and captain it was evident that they both considered the prevalent weather covering BBIAP, Islamabad and there was apparently small gap for mishap flight BHO-213 to penetrate the squall line.

3.1.38 At 18:28:22.5 hrs, Captain told Islamabad Approach that the gap was very small one and would try on that one.

3.1.39 As per Bhoja Air Operational Manual (approved by CAA Pakistan), the aircraft would avoid thunderstorm / active weather cell by 5 to 10 nm. Captain was observed intentionally continuing for destination while disregarding and violating the documented operator Ops Manual, despite knowing the fact that the gap between the adjacent active weather cells was very small.

3.1.40 At 18:28:35.7 hrs, FO suggested to Captain that they should ask for radar vectoring.

3.1.41 At 18:28:39.8 hrs, Captain asked Islamabad Approach to turn right on heading 040^0 as he observed some gap there.

3.1.42 At 18:28:53.2 hrs, Islamabad Approach did not clear Captain for right turn due to the close proximity of Tilla range, however they were cleared for right turn after reaching INDEK position.

3.1.43 At 18:29:28.9 hrs, Islamabad Approach asked the Captain if he was picking any weather towards southeast of Islamabad at a distance of about 10 to 15 miles.

3.1.44 At 18:29:41.1 hrs, Captain replied to Islamabad Approach in negative and added that till 40 miles there was no weather at all.

3.1.45 At 18:29:52.7 hrs, Captain informed Islamabad Approach that the prevalent weather was all towards the northern side.

3.1.46 At 18:30:19.1 hrs, Captain and FO discussed their clearance to descent 6500 ft by Islamabad Approach.

3.1.47 At 18:30:34.9 hrs, Captain told FO to tell the cabin crew to brief passengers to occupy their seats. The cockpit crew probably were experiencing lot of turbulence at this particular moment and that is why Captain told FO to ask the cabin crew to brief passengers to occupy their seats.

3.1.48 At 18:30:45.9 hrs, FO announced on PA system “cabin crew take positions for landing please”. It was observed that probably FO mistakenly announced for cabin crew to take positions for landing when actually they are still descending for 6500 ft.

3.1.49 At 18:31:08.1 hrs, FO suggested to Captain that they should go towards the right. However, Captain said that no, they would not go there as they had to land at BBIAP, Islamabad.

3.1.50 It was evident from Captain’s remarks that he had made up his mind to land at destination irrespective of prevalent weather conditions during approach to BBIAP, Islamabad.

3.1.51 At 18:31:15.0 hrs, Captain appreciated Islamabad Approach and said it was very nice whatever you told me and subsequently they exchanged greetings.

3.1.52 At 18:31:45.6 hrs, Captain told Islamabad Approach that by the grace of God everything was ok and actually he was planning to go far away to avoid weather.

3.1.53 At 18:31:52.0 hrs, Islamabad Approach radar controller briefed Captain and said that he was looking for the gap and this was the only slightly clear area but even on that heading after about 30 miles cockpit crew might experience little bit of precipitation till intercepting the localizer.

3.1.54 At 18:32:20.2 hrs, the mishap flight was crossing 10,000 ft of altitude during descent.

3.1.55 At 18:32:31.0 hrs, Captain shared his apprehension about severe weather conditions with FO and said that the weather kept them under pressure whereas actually they were afraid for nothing.

3.1.56 At 18:33:37.7 hrs, Captain briefed FO about the prevalent weather that it was in the north and they were observing lightening.

3.1.57 A third person was occupying the jump seat in the cockpit. He was a non-operating cabin crew travelling on mishap flight accompanying his mother to his home station. This individual in no way had any contribution to the causation of accident.

3.1.58 Till now the mishap Flight BHO-213 had encountered turbulence but not entered the active bad weather cell.

3.1.59 At 18:33:56.2 hrs, Islamabad Approach cleared the flight to continue descent to 5500 ft and the instructions were acknowledged by FO.

3.1.60 At 18:34:49.4 hrs, Captain told FO “ILS my side, ILS number one” and FO acknowledged it by saying “final course is set sir, minimas are set, speeds are set”. According to the SOPs requirement neither ATIS ISB was obtained by the cockpit crew nor the formal approach briefing was conducted by the Captain.

3.1.61 At 18:35:00 hrs, the aircraft levelled off at 5,500 feet altitude and glide slope deviation A became active.

3.1.62 The altitude of 5,500 feet was maintained for 80 seconds and during this time both aircraft engines responded normal.

3.1.63 The aircraft maintained Indicated Airspeed (IAS) Speed mode on descent through 4500 feet with autopilot and auto throttle engaged.

3.1.64 At 18:35:03.3 hrs, FO informed Captain “recheck speed 133, 138, 148”.

3.1.65 At 18:35:06.5 hrs, Islamabad Approach issued clearance to Flight BHO-213 for further descent to 3900 ft and the said clearance was acknowledged by FO which indicates that Captain was pilot flying (PF) and FO was pilot not flying (PNF) and everything appeared just normal in the cockpit.

3.1.66 At 18:35:39.6 hrs, Islamabad Approach gave weather update of BBIAP, Islamabad and said that surface wind at Islamabad was varying between 180^0 to 270^0,10 kts and sometimes gusting to 20 kts and runway condition was wet, light drizzle was going on and braking action was not known. Captain acknowledged it by saying “thank you very much, sir”.

3.1.67 At 18:36:36.0 hrs, Captain commented on weather and told FO it was not likely to open anymore and probably FO did not understand due to which Captain repeated again.

3.1.68 At 18:36:38.5 hrs, FO told Captain about his understanding of weather that the problem was in between 10 & 15 miles and they still had 14 miles to go. It is considered that at this particular moment squall line was 10 to 15 miles away from aircraft and the aircraft was at 14 DME from BBIAP, Islamabad.

3.1.69 At 18:36:45.8 hrs, Captain confirmed to FO that the squall line is exactly overhead BBIAP, Islamabad.

3.1.70 At 18:36:50.2 hrs, FO shared with Captain that they were likely to get very close to it. It can be deduced from the cockpit crew discussion that they had no confusion of their ending up very close to the squall line / prevalent adverse weather conditions.

3.1.71 At 18:36:58.0 hrs, Captain told FO that it would hit them at that time. Probably at that particular time, they experienced precipitation which alarmed the Captain.

3.1.72 At 18:36:59.1 hrs, Captain said “one to go” and it was acknowledged and checked by FO.

3.1.73 At 18:37:15.1 hrs, FO commented on prevalent weather by saying when we turn then it would get slightly intense.

3.1.74 At 18:37:18.8 hrs, Captain suddenly said that it had become dark. Now by this time, cockpit crew is very clear that they were actually entering the squall line / bad weather conditions but did not take any action / decision to discontinue the approach to the destination.

3.1.75 At 18:37:25.2 hrs, radio altimeter alarm was heard. At that time the aircraft was passing through 2500 ft above ground level (AGL).

3.1.76 At 18:37:28.9 hrs, Captain said “airspeed reaching 210 kts, flaps one” and it was acknowledged by FO.

3.1.77 At 18:37:38.6 hrs, Islamabad Approach asked Bhoja Air Flight BHO-213 to continue descent to 3600 ft and standby for the final turn. This clearance was acknowledged by FO.

3.1.78 At 18:37:52.4 hrs, sound of three wailer was heard which was similar to auto pilot disconnect.

3.1.79 At 18:37:53.2 hrs, Captain suddenly said twice that what had he done and then laughed. Probably Captain said this due to his selection of manual flying mode / disengagement of autopilot and then he engaged the auto pilot again.

3.1.80 At 18:38:00.0 hrs, Captain (in a worried tone) told Islamabad Approach “it is exactly on top”. At this particular time, the flight had actually ended up in the active bad weather cell.

3.1.81 In IAS Speed mode, the auto throttle modulates thrust to maintain the crew-selected IAS on the Mode Control Panel (MCP). The auto throttle remained engaged during final approach.

3.1.82 The pitch mode transitioned between V/S mode and Level Change mode several times prior to levelling off at altitude of 3600 feet.

3.1.83 At 18:38:06 hrs, after passing through 4000 ft of altitude (2000 ft radio altitude), the flaps transitioned from flaps UP to flaps 1.

3.1.84 At 18:38:07.5 hrs, Islamabad Approach advised mishap flight to turn left on heading 340^0, cleared the aircraft for ILS runway 30 and asked to report established on final approach. This clearance was acknowledged by FO.

3.1.85 At 18:38:08 hrs, slats were extended to mid position. Additionally, during this time, the leading edge flaps transitioned to the full extended position.

3.1.86 At 18:38:10 hrs, the landing gear lever was selected to down position.

3.1.87 At 18:38:13 hrs, as the aircraft approached the target altitude, the autopilot transitioned into Altitude Select mode. At the same time, while in Heading Select mode, a left turn was initiated. The aircraft maintained an approximate 20^0 angle of bank during the turn.

3.1.88 The Heading Select mode was de-selected while in the middle of the turn, and no recorded roll mode was engaged for the next 10 seconds. At this particular time, it is felt that Captain de-selection of heading select mode indicates his lack of confidence on automation.

3.1.89 At 18:38:24.7 hrs, FO told Captain that the speed of aircraft was 220 kts and immediately Captain responded in surprise by saying “what?”.

3.1.90 At 18:38:27.4 hrs, FO again repeated his information of 220 kts of airspeed. It is important to note that the airspeed of aircraft with flaps to 1 position is supposed to be 190 kts, however, it was 30 kts higher than the recommended speed which indicates that the aircraft was already in the weather conditions where wind shear was probably present.

3.1.91 At 18:38:24.7 hrs, Captain in highly surprised tone asked FO, “220 kts, oh shit what has happened”. Captain realized that with auto-throttle engaged the speed of aircraft should not have increased to 220 kts.

3.1.92 At 18:38:31 hrs, the thrust was observed increasing as the aircraft began to level off at the target altitude (~ 3600 feet pressure altitude) and simultaneously autopilot transitioned to Altitude Hold mode.

3.1.93 At 18:38:34.0 hrs, FO informed Captain that they had been cleared for left turn to 340^0 and ILS runway 30.

3.1.94 The aircraft turned left to intercept the localizer with flaps at position 1 and landing gears down. In this configuration the aircraft was exposed to limited manoeuvrability due to higher drag component.

3.1.95 At 18:38:37.4 hrs, sound of light to moderate precipitation began and simultaneously Captain said “oh shit”. The precipitation continued with varying

intensity, until end of the CVR recording / aircraft ground impact. At this particular moment, the aircraft had actually entered the active weather cell.

3.1.96 At 18:38:39.3 hrs, FO asked Captain that should he give him both on ILS. It appeared that the FO is unaware and ignorant of the severity of weather and its implications, instead of recommending to discontinue the approach, he was busy in carrying out the cockpit checks.

3.1.97 At 18:38:41.3 hrs, Captain told FO that there was something wrong and why it had happened? Captain seemed to be extremely pre occupied and worried about the flight parameters variations and bad weather effects on the flight at that particular moment.

3.1.98 At 18:38:43.4 hrs, FO informed Captain “both on ILS?” and Captain told FO to give him the ILS in a highly low energy tone and apparently with pre occupied mind.

3.1.99 At 18:38:45.8 hrs, the cockpit crew had already the autopilot and auto-throttle engaged and the glide slope deviation B became active and tracked similarly with glide slope deviation A until the end of the recorded data.

3.1.100 At 18:38:49 hrs, after levelling off at 3600 feet pressure altitude, with Heading Select mode engaged, VOR/LOC was “Armed”. The aircraft rolled back to the right, and the aircraft began to approach the localizer beam as evidenced by the localizer deviation moving towards zero.

3.1.101 At 18:38:55 hrs, the Approach mode was engaged.

3.1.102 After asking Captain, FO extended flaps from flaps 1 to flaps 5 at 18:38:54.6 hrs and the stabilizer was trimmed approximately 2 units nose-up.

3.1.103 At 18:38:56 hrs, the localizer deviation reached zero.

3.1.104 At the same time, the aircraft approached the glide slope beam from below, and the glide slope deviation began to move towards zero.

3.1.105 At 18:39:09 hrs, autopilot command B was also engaged which is consistent with a dual autopilot approach.

3.1.106 At 18:39:13.4 hrs, FO informed Captain that VOR/LOC was captured.

3.1.107 The Flare Arm gets engaged 23 seconds after the following conditions are satisfied: VOR/LOC Engage and G/S Engage and radio altitude < 1500 feet. During those 23 seconds, a number of system tests and checks are performed prior to Flare Arm engagement.

3.1.108 For the event flight, Flare Arm did not engage during the final approach prior to both autopilot channels disengaging at 18:39:33 hrs.

3.1.109 At 18:39:15 hrs the pitch attitude of aircraft increased from about 0^0 to 9^0 and till the end of the FDR data, the aircraft remained in approximately 5^0 to 20^0 right angle of bank.

3.1.110 The autopilot transitioned to G/S Engage mode around time 18:39:16 hrs at approximately 175 knots computed airspeed, and the aircraft began its final approach, descending on the glide path.

3.1.111 The glide slope deviation reached zero and was maintained for several seconds. According to Ops Manual, with G/S captured, the aircraft should have been in landing configuration (flaps 30^0 with landing gears down). However, only flaps 5 were selected and the auto throttle maintained the recommended / selected speed of around 170 kts.

3.1.112 Between time 18:39:16 hrs and 18:39:27 hrs, calculated vertical winds show the aircraft encountered an increasing downdraft, as it entered this descending air mass, the pitch attitude increased and computed airspeed decreased as the autopilot attempted to maintain the glide slope beam. The thrust was increased during this time but was not sufficient to counter the airspeed loss.

3.1.113 At 18:39:21.5 hrs, a sound of rapid increase in precipitation intensity from moderate to extreme was observed on CVR recording. This elevated intensity in precipitation remained for next 26.5 seconds.

3.1.114 At 18:39:25 hrs, radio altitude decreased from 1,900 feet AGL to 900 feet AGL within 4 seconds while pitch attitude increased from 6^0 nose up to 12^0 nose up. During this time the computed airspeed decreased from 180 kts to 173 kts.

3.1.115 At 18:39:26.2 hrs, EGPWS Alarm “Wind shear - Wind shear - Wind shear” was recorded. Both the cockpit crew did not take any remedial action as per Boeing recommended FCOM and QRH procedures, the auto-throttle and autopilot remained engaged. It is evident that the cockpit crew were confused and not clear about the recommended procedures to be followed after encountering wind shear.

3.1.116 The mishap aircraft was equipped with Terrain Awareness Warning System (TAWS), Sandel Avionics ST3400 and Enhanced Ground Proximity Warning System (EGPWS) MK-VII made by Honeywell. TAWS and EGPWS had the capability to provide various terrain awareness warnings and reactive wind shear warning respectively. The onboard reactive wind shear warning functioned as designed, but the flight crew did not respond with the appropriate recovery manoeuvres; autopilot and auto throttle off, full throttle applied. The inappropriate response is attributable to the lack of training and familiarity with the non-normal condition.

3.1.117 It was observed that during the recurrent simulator training sessions of Captain, he was not exposed to wind shear training / exercises whereas FO never underwent the simulator training for this variant of Boeing 737-236A.

3.1.118 At 18:39:28.6 hrs, Captain was heard yelling in extreme anxiety and desperation “no …no” but was observed not taking any remedial action to recover out of unsafe set of conditions despite getting specific warnings of wind shear.

3.1.119 In the same extreme anxiety and desperation FO shouted “go around, go around” at 18:39:29.3 hrs, but no action was observed by the Captain or the

FO (PF and PNF) of initiating a go around and taking over the controls of aircraft.

3.1.120 It appeared that Captain and FO were not sure about the behaviour of the aircraft in automation mode during wind shear conditions due to their lack of knowledge and formal training.

3.1.121 The downdraft dissipated [vertical winds changed from approximately -40 feet per second (fps) to -10 fps], resulting in a change in angle of attack and the spikes were observed in FDR recorded data regarding longitudinal acceleration and normal load factor.

3.1.122 Both autopilot channels got disconnected at around 18:39:33 hrs and the subsequent FDR data is consistent with the aircraft being flown under manual control, however, the auto-throttle remained engaged in IAS Speed mode. Probably the autopilot channels got disconnected due to the aircraft excessive deviation in severe weather; however, the explanation for the autopilot disconnect cannot be identified with certainty.

3.1.123 Following autopilot disconnect, there was no control wheel activity recorded for approximately 6 seconds and no control column activity for approximately 8 seconds. The cockpit crew was probably in a state of confusion and unsure of remedial actions to be taken, to get out of unsafe set of conditions, as the aircraft was still observed flying with auto-throttle engaged.

3.1.124 During this period of control inactivity, the aircraft deviated below the glide slope, and the pressure altitude and pitch attitude decreased while on average approximately 160 knots computed airspeed was maintained.

3.1.125 At 18:39:37.1 hrs, Islamabad Approach cleared flight BHO-213 to contact BBIAP, ATC Tower which was acknowledged by FO on the reminder of Captain.

3.1.126 FO appeared to be highly pre-occupied due to extremely bad weather conditions / severe precipitation and the aircraft encountering wind shear along with complete confusion in the cockpit to recover out of unsafe set of conditions.

3.1.127 The last recorded communication of Captain with FO was 21 seconds prior to the aircraft ground impact at 18:40:00.3 hrs.

3.1.128 At 18:39:41.9 hrs, TAWS Alarm “Whoop, Whoop, Whoop” was recorded. The aircraft was in close vicinity of the ground and the cockpit crew did not carry out the recommended Boeing QRH / FCOM procedures for this TAWS alarm.

3.1.129 At 18:39:42 hrs, the pitch attitude decreased from approximately 5^0 nose-up to around 0^0.

3.1.130 At 18:39:42.9 hrs, FO informed BBIAP ATC Tower that they were maintaining ATC Tower frequency.

3.1.131 FO appeared to be ignorant of the dangerous set of conditions as the aircraft was encountering wind shear and TAWS alarms. The FO was busy giving calls to the BBIAP tower instead of assisting Captain or taking over

controls of the aircraft. It is evident that the FO was not proficient enough to handle the prevalent abnormal situation.

3.1.132 During this period thrust also decreased since the auto-throttle was still engaged in IAS Speed mode to maintain the airspeed selected on the MCP.

3.1.133 The aircraft encountered another descending air mass. This downdraft gradually increased over 15 seconds, reaching a maximum of approximately 50 fps. The rate of descent increased rapidly, however after encountering this second downdraft also, cockpit crew again did not take required remedial actions which confirmed their ignorance of recovery procedures.

3.1.134 At around 18:39:43.0 hrs, a ground proximity warning annunciation "(Whoop) Pull up, (Whoop, Whoop) Pull up" was recorded. The Captain responded with a nose-up column input. However, pressure altitude and thrust continued to decrease.

3.1.135 With the auto-throttle engaged and autopilot disengaged, the aircraft in flaps 5 and landing gears down configuration, failure of the cockpit crew to undertake the Boeing recommended procedures to come out of TAWS warning, aggravated the existing unsafe / dangerous conditions.

3.1.136 At approximately 18:39:47 hrs, the downdraft dissipated, rapidly decreasing from 50 fps to close to zero fps in less than 4 seconds. This resulted in a rapid increase in angle of attack of the aircraft, which activated the stick shaker for almost 2 seconds.

3.1.137 It appeared that Captain was making desperate control column inputs to come out of the TAWS "pull up" warning regime. As a result, the aircraft achieved nose up attitude with flaps 5, landing gears down and auto-throttle engaged position, thus aircraft ended up in stalling regime.

3.1.138 During this period, the longitudinal acceleration and normal load factor (vertical acceleration) both rapidly increased, reaching maximums of 0.25 g's and 1.7 g's, respectively.

3.1.139 A nose-down column input was commanded in response to the stick shaker (the stick nudger likely also engaged), this nose-down column input command continued until the end of the data.

3.1.140 Captain lowered the nose of aircraft to get out of stick shaker regime however, proper and complete Boeing recommended stall and recovery procedures were not carried out.

3.1.141 The pitch attitude changed from approximately 2^0 nose-up to a maximum of approximately 12^0 nose-down over 8 seconds.

3.1.142 Captain had taken the aircraft to a critical unusual attitude by lowering the nose of aircraft to 12^0 so close to the ground in order to recover out of stall.

3.1.143 The pressure altitude continued to decrease while thrust remained at a low level (~ 40-45 percent engine N1) in order to maintain the computed airspeed, however the speed increased due to the steep dive of 12^0.

3.1.144 At 18:39:45 hrs, the power on both engines power reduced to 1.0 EPR (flight idle) and remained at 1.0 EPR for the remainder of the recorded data.

3.1.145 The ground proximity warning momentarily ceased before activating again until the end of data.

3.1.146 At 18:39:46.8 hrs, BBIAP ATC Tower cleared the mishap flight for landing. The cockpit crew never acknowledged this call.

3.1.147 At 18:39:48.3 hrs, sound of wailer tones similar to auto pilot disconnect was recorded on CVR which continued till end of recording.

3.1.148 Due to the lack of automation knowledge and experience, Captain was unable to silence the continuous wailer tone by pressing the autopilot disconnect switch on the control column. During this time warning of “wind shear, wind shear, wind shear” was recorded.

3.1.149 At 18:39:49.0 hrs, the CVR recording indicated decrease in precipitation intensity and decreased intensity remained constant till end of CVR recording.

3.1.150 At 18:39:49 hrs, both left and right stick shakers indicated “Operative” for approximately one second. As the Captain was struggling with the control column to recover out of unsafe set of conditions, he again exceeded the critical angle of attack of aircraft which resulted in activation of the stick shakers for one second.

3.1.151 At 18:39:52.2 hrs, FO shouted in desperation and extreme anxiety “stall warning, let’s get out”. It appeared that Captain was making desperate attempts to recover out of dangerous situation and the FO was only shouting and not taking over the controls of aircraft in order to initiate a go around.

3.1.152 At 18:39:54.4 hrs, the audio ground proximity warning again came on “pull up (whoop, whoop), pull up (whoop, whoop), pull up (wh*), (whoop whoop) pull...” and it remained till the end of the recorded data.

3.1.153 From 18:39:49 hrs till 18:39:51, a significant variation in vertical acceleration was recorded from + 1.7 to +0.4 g’s.

3.1.154 It was evident that Captain was making desperate control column input for survival without adopting / following Boeing recommended procedures and the FO was of no help at all in the cockpit, as he himself lacked the system knowledge, procedures and automation experience.

3.1.155 At 18:39:54.4 hrs, the ground proximity warning recorded “Pull up (Whoop - Whoop), Pull up (Whoop, Whoop), Pull up (Whoop, Whoop), Pull--”.

3.1.156 At 18:39:57.1 hrs, FO was observed shouting in desperation / anxiety and telling Captain “go around, go around sir, go around”. Neither the Captain nor the FO followed Boeing recommended procedures / actions due to their lack of knowledge, training and experience to handle this type of abnormal situation and resulted in the unfortunate flight to impact the ground.

3.1.157 The aircraft appeared to pitch up to at least 0^0 at the end of the data while flying at 215 knots computed airspeed, which is consistent with the wreckage / ground scar information that indicated the aircraft contacted the ground on

main landing gears first, at a distance of 4.24 nm from runway 30 threshold, just to the right of the extended runway centerline.

3.1.158 The CVR last recorded data finished at 18:40:00.3 hrs.

3.1.159 The Boeing simulation facility was used to re-create the last 70 seconds of the flight.

3.1.160 The analysis showed that the resulting flight path closely matched the FDR flight path. This confirms that the aircraft's motion was due to the recorded control inputs and calculated atmospheric conditions.

3.1.161 Boeing also conducted detailed analysis of cockpit crew actions after encountering severe weather conditions, the main points are appended below:

3.1.162 In response to the ground proximity warning annunciation and stick shaker activation, the cockpit crew did not increase thrust as expected, and the auto-throttle remained engaged until the end of data. These actions did not adhere to the procedures provided in the Boeing 737-236A Quick Reference Handbook (QRH).

3.1.163 In the Ground Proximity Warning System (GPWS) Response section, the following procedures are stated for a GPWS warning involving PULL UP or TERRAIN (assumed annunciations):

- Disconnect autopilot.
- Disconnect auto-throttle.
- Aggressively apply maximum thrust.
- Simultaneously roll wings level and rotate to an initial pitch attitude of 20^0.

3.1.164 In the Approach to Stall or Stall Recovery section of the QRH, the following procedures are outlined to be performed immediately at the first indication of stall (buffet or stick shaker):

- Hold the control column firmly.
- Disconnect autopilot and auto-throttle.
- Smoothly apply nose down elevator to reduce the angle of attack until buffet or stick shaker stops. Nose down stabilizer trim may be needed.
- Roll in the shortest direction to wings level if needed.
- Advance thrust levers as needed.

3.1.165 The cockpit crew did not disconnect the auto-throttle and thrust was never advanced in these two situations. Advancing thrust would have helped the aircraft to maintain the proper flight path.

3.1.166 Boeing detailed analysis concluded that cockpit crew ineffective management of thrust, altitude, and flight path in turbulent atmospheric conditions resulted in ground impact short of the runway.

3.1.167 A detailed study / investigation was conducted to ascertain all factors which could have directly or indirectly contributed towards ineffective management of thrust, altitude and flight path or automated flight deck management, in turbulent atmospheric conditions. The details are appended in following paragraphs.

3.1.168 Captain served in Shaheen Air International (SAI) before joining Bhoja Air as a Captain of Boeing 737-200 aircraft.

3.1.169 Captain was selected for Boeing 737-400 aircraft ground training. However, he was taken off from the said training by supervisory levels of SAI due to his past flying experience of semi-automated aircraft.

3.1.170 As a reaction to discontinuation of his Boeing 737-400 aircraft ground training in SAI, he decided to leave the SAI and join Bhoja Air. It is important to note that mishap Bhoja Air Boeing 737-236A aircraft was equipped with automated flight deck.

3.1.171 The FO was an ex-PAF officer who during his initial flying training suffered from airsickness problem which adversely affected his flying performance and resulted in his under confident behaviour in flying profession because of which his performance remained just average during his flying career in PAF.

3.1.172 FO remained an under confident individual and could just perform average during his stay as first officer in SAI.

3.1.173 At SAI, FO got the chance to fly with Captain and found refuge in the fatherly personality of the Captain, who also started to provide him the expected shelter.

3.1.174 When Captain decided to leave SAI and join Bhoja Air, FO also left SAI and joined Bhoja Air.

3.1.175 It was found that the CAA Pakistan approved rules and regulations in respect of FDTL were adhered to and the cockpit crew of mishap aircraft was not observed exposed to any undesired stress / fatigue / unrest prior to the flight as a result of any FDTL violation.

3.1.176 In Bhoja Air, Director Operations (an ex-PIA Captain) was made responsible for the selection and smooth induction of all cockpit crew.

3.1.177 The selection of cockpit crew was done by Director Operations along with Managing Director and at times GM Flight Operations input was also sought.

3.1.178 Bhoja Air was asked by investigation team to submit the copy of cockpit crew selection and induction system policy. However, nothing was received by the investigation team in response to a formal letter on the subject till final investigation report writing, implying that no such policy existed in the organization.

3.1.179 Bhoja Air hired the services of another experienced ex-PIA Captain to educate the cockpit crew before their departure for simulator training to South Africa and all the cockpit crew attended these scheduled ground training / aircraft systems lectures.

3.1.180 Bhoja Air was asked by investigation team to submit the copy of entire ground schooling curriculum and training schedules of cockpit crew. However, nothing was received by the investigation team in response to a formal letter on the subject till final investigation report writing.

3.1.181 It is important to note that Boeing 737-200 taught during ground schooling and Boeing 737-236A being inducted in Bhoja Air were two different variants of Boeing 737 series.

3.1.182 The information with regards to automation capabilities of aircraft was not in the knowledge of cockpit crew even after the formal ground schooling as the ground schooling did not cater for the automation of aircraft.

3.1.183 FO did not undergo six monthly recurrent simulator training and Bhoja Air requested for an extension which was granted for a period of two months by CAA Pakistan as per existing rules / regulations.

3.1.184 It was observed that Bhoja Air did not have an established monitoring system to critically track the cockpit crew performance at organizational level.

3.1.185 It is important to note that the aircraft variance type training as per the IATA and CAA Pakistan rules & regulations and Boeing recommended training was not conducted prior to scheduling of FO on regular passenger flights.

3.1.186 FO was never exposed to automated flight deck management in simulator, which is one of the primary reason of inaction by FO to recover out of unsafe set of conditions during the entire abnormal flight conditions.

3.1.187 During the simulator evaluation of Captain conducted by South African flight inspector, following observations were made:

- Automation is relatively new to Captain Khan in the simulator and should be practiced in future training.

- It is recommended Bhoja Air fully incorporate the new Boeing Recommended Procedures.

3.1.188 It was observed that during the simulator check session in most of the mandatory exercises including precision approaches, localizer & glide slope tracking and flight deck management, the Captain was assessed as “Satisfactory with Briefing (SB)”.

3.1.189 A total of seven “SBs” were recorded in the CAAF-628 during this simulator check session which indicated Captain’s marginal performance in a relatively new automated environment.

3.1.190 Bhoja Air did not incorporate the new Boeing Recommended procedures for an automated aircraft as per the recommendation of South African flight inspector.

3.1.191 Bhoja Air did not have the customized QRH and FCOM for Boeing 737-236A aircraft**.**

3.1.192 Bhoja Air did not evolve / implement cockpit crew performance monitoring system, as no supporting documentation evidences were provided by Bhoja Air after receipt of formal letter by investigation team on the subject.

3.1.193 The flying of Captain and FO at Bhoja Air was analysed in detail. It was observed that out of total 23 flights of Captain, during 16 flights FO flew as his cockpit crew member.

3.1.194 The cockpit crew had not carried out their formal approach briefing and never challenged each other contrary to the CRM training.

3.1.195 The ATIS Islamabad was not obtained by the cockpit crew despite visible severe weather conditions prevailing around BBIAP, Islamabad.

3.1.196 Despite knowing the dangers associated with wind shear and aircraft stalling, FO kept reminding Captain who was PF, to go around but never took over the controls of the aircraft to execute a missed approach / go around or take required actions as per FCOM / QRH / Ops Manual.

3.1.197 The cockpit crew had all the pertinent and relevant data / information about the prevalent weather en-route and at the destination.

3.1.198 Captain was observed educating the FO on the presence of squall line en-route to destination. However, despite observing very small gap between the active weather cells, they still continued with the flight, entered active weather cell and violated the CAA approved Bhoja Air Ops Manual procedures.

3.1.199 The cockpit crew observed hardly any gap between the active weather cells en-route to BBIAP, Islamabad but still continued their flight to destination and did not take the decision to divert to the alternate aerodrome.

3.1.200 During recurrent simulator training, Captain was never exposed to the wind shear as well as TAWS exercises / recovery techniques for managing an automated flight deck of Boeing 737-236A aircraft.

3.1.201 FO was granted an extension in simulator training by CAA, Pakistan without knowing that he was about to fly an automated flight deck, as information was not provided to Flight Standard Directorate, CAA Pakistan by Bhoja Air management / supervisors.

3.1.202 Both the cockpit crew were not properly trained and groomed to handle such abnormal situations (exposure to wind shear / TAWS alarms) while flying an automated flight deck.

3.1.203 Captain was relying on the automation of aircraft to get them out of unsafe set of conditions, instead of getting out of automated modes and manually executing the Boeing recommended remedial actions.

3.1.204 FO and Captain were observed flying together as cockpit crew for more than 69% of their flying at Bhoja Air implies that scheduling / pairing of cockpit crew was not being monitored by various supervisory tiers at organizational level.

3.1.205 It was observed that as per Master Minimum Equipment List (MMEL) for Boeing 737 series approved by US Department of Transportation Federal

Aviation Administration and Minimum Equipment Lists (MELs) of M/s PIAC, M/s Shaheen Air International and M/s Bhoja Air approved by CAA Pakistan for Boeing 737 series, the aircraft could be dispatched for flight without the GPWS / TAWS and wind shear warning system (predictive or reactive) being serviceable. However, the mishap aircraft had both the TAWS and wind shear warning system (reactive) serviceable during the flight and operated as per the design parameters of the equipment.

3.1.206 The cockpit crew were conversing, remained well orientated and were correctly identifying the unsafe and prevalent hazardous conditions around them which confirms that they were normal and not in-capacitated.

3.1.207 FO and Captain failed to comply with the basics of CRM training.

3.1.208 FO had not undergone variance type training and Captain had limited experience of automation, lacked knowledge about Boeing recommended procedures concerning wind shear & TAWS warnings and stall recovery along with effective and efficient automated flight deck management.

3.1.209 The cockpit crew were observed till the aircraft ground impact, looking for some sort of refuge in automation, assuming that automation can get them out of these unsafe / prevalent adverse weather conditions.

3.1.210 The available FCOM and QRH with Bhoja Air were not customized copies of Boeing 737-236A aircraft.

3.1.211 It is concluded that radar controller and ATC Tower controller performed their duties as per their laid down procedures, rules and regulations. The weather picture transmitted by radar controller was also appreciated by the Captain before intercepting the localizer for runway 30 BBIAP, Islamabad.

3.1.212 The wreckage evidence and data show that the accident airplane did not experience a pre-flight fire or explosion, an encounter with birds, or a mechanical or structural failure before impact.

3.1.213 After a detailed analysis of infrared satellite imagery, surface observations and model derived thermodynamic profiles at Boeing Facility, it has been concluded that the weather conditions at the time of the accident were conducive to produce strong down drafts and wind shear like condition.

3.2 Technical Findings

3.2.1 Bhoja Air inducted Boeing 737-236A aircraft from South Africa (Comair) in January, 2012.

3.2.2 Before induction, major inspection Check-4C was done and all other pre-requisites of independent inspection by CAA Pakistan were accomplished. The aircraft was taken on registry of Pakistan and allotted Registration No. AP-BKC.

3.2.3 The aircraft had no outstanding snag or inspection on 20th April, 2012.

3.2.4 After induction, the aircraft flew 69 hrs with Bhoja Air without encountering any abnormality.

3.2.5 The aircraft was serviceable in all respects to undertake the scheduled Flight BHO-213 from Karachi to Islamabad.

3.2.6 The aircraft was equipped with number of systems' performance indications and onboard warning systems including Terrain Awareness Warning System (TAWS) to provide information and prompt audio and / or visual warning to the cockpit crew.

3.2.7 The aircraft was properly serviced before mishap flight as per the approved Aircraft Maintenance Schedule.

3.2.8 The aircraft start-up, taxi and take off were uneventful.

3.2.9 The aircraft did not encounter any system / sub-system malfunction throughout the fateful flight from take off until the ground impact.

3.2.10 The mishap aircraft impacted the ground with its landing gear extended and flap position 5 which is normally used only during takeoff.

3.2.11 There was no in-flight structural failure or fire in any of the aircraft structural part or the engines.

3.2.12 Both the engines were operating normal at the time of ground impact.

3.2.13 The aircraft was not subjected to bird hit, sabotage, hail storm or lightening strike.

3.2.14 It was confirmed from FDR and CVR data analyses that the aircraft had no technical problem in any of the system or sub-system, and responded normally to all commands of cockpit crew, auto pilot and auto throttle.

3.3 **ATS Findings**

3.3.1 Approach Radar Controller was experienced and dully rated to perform Approach Control Service.

3.3.2 Air Traffic Control clearances, instructions and weather related information were dully passed to the mishap aircraft.

3.3.3 Radar controller and Captain of ill fated aircraft used at times non-standard communication during flight.

3.3.4 The Radar controller provided all the required information and assistance to the Flight BHO-213 for their approach to BBIAP, Islamabad as per ICAO standard and recommended procedures.

3.3.5 The cockpit crew of Flight BHO-213 did not announce any difficulty in handling of aircraft during any stage of flight till crash of aircraft.

3.3.6 Neither the radar nor control tower had the information regarding presence of wind shear on final approach track RWY 30 to forewarn the mishap aircraft.

3.3.7 The cockpit crew never acknowledged the landing clearance issued by tower controller and subsequent repeated calls to the aircraft.

3.3.8 After observing no response from aircraft and confirmation of absence of blip on radar scope, tower controller initiated the off airport aircraft crash actions.

3.4 Meteorological Findings

3.4.1 Satellite image analysis and its animation depicted that the mishap Flight BHO-213 encountered severe weather system (high impact) during final phases of her flight.

3.4.2 NWP products depicted that severe thunderstorms resulted in updrafts and downdrafts.

3.4.3 The maximum wind shear was produced between 1300UTC and 1400 UTC.

3.4.4 NWP atmospheric sounding depicted severe convective cloud environment that is characterized by a dry sub-cloud layer (high convection near the surface). The surface inflow to the convective system had a temperature / dew point spread of 35^0 Fahrenheit, which indicated potential for strong convective downdrafts. Also, its Downdraft Convective Available Potential Energy (DCAPE) value is more than 300 J/kg. Such a high DCAPE has the potential to produce a downdraft of more than 40 knots. Therefore sounding of Islamabad confirmed the development of Cb clouds and thunderstorms activity with vertical winds more than 40 knots.

3.4.5 Surface observation reports before and at the time of crash at BBIAP, Islamabad confirmed high impact weather activity (TSRA, surface winds 36 knots at 1318 UTC and TSRA, surface winds 24 knots at 1340 UTC).

3.4.6 The weather conditions at the time of the accident were conducive to producing strong down drafts and wind shear like conditions.

3.5 Medical Findings

3.5.1 Both the cockpit crew were medically fit to undertake the scheduled flight of Bhoja Air.

3.5.2 The CVR transcript also did not reveal any abnormality related to fitness or consciousness of Captain / FO, as till end of flight they were talking to each other normally.

3.5.3 No poison was observed in the body tissue samples of FO.

3.5.4 The medical report of Captain and FO did not reveal any other cause of death.

3.5.5 The cause of death is established as aircraft ground impact.

4. Conclusion

4.1 Factors Leading to the Accident

4.1.1 The aircraft accident took place as a result of combination of various factors which directly and indirectly contributed towards the causation of accident. The primary causes of accident include, ineffective management of the basic flight parameters such as airspeed, altitude, descent rate attitude, as well as

thrust management. The contributory factors include the crew's decision to continue the flight through significant changing winds associated with the prevailing weather conditions and the lack of experience of the crew to the airplane's automated flight deck.

4.1.2 The reasons of ineffective management of the automated flight deck also include Bhoja Air's incorrect induction of cockpit crew having experience of semi automated aircraft, inadequate cockpit crew simulator training and absence of organizational cockpit crew professional competence and monitoring system.

4.1.3 The incorrect decision to continue for the destination and not diverting to the alternate aerodrome despite the presence of squall line and very small gaps observed by the Captain between the active weather cells is also considered a contributory factor in causation of the accident.

4.1.4 The operator's Ops Manual (CAA Pakistan approved) clearly states to avoid active weather cells by 5 to 10 nm which was violated by the cockpit crew is also considered a contributory factor in causation of the accident.

4.1.5 FO possessed average professional competence level and was due for his six monthly recurrent simulator training for Boeing 737-200 aircraft (equipped with a semi-automated flight deck). Bhoja Air requested an extension for his recurrent simulator training on 07th March, 2012. As per the existing laid down procedures of CAA Pakistan, two months extension was granted for recurrent simulator training on 09th March, 2012. The extension was granted for Boeing 737-200 aircraft, whereas the newly inducted Boeing 737-236A aircraft was equipped with automated flight deck. It is important to note that Bhoja Air did not know this vital piece of information till their cockpit crew went for simulator training to South Africa. This critical information regarding automation of the newly inducted Boeing 737-236A was not available with Flight Standard Directorate CAA, Pakistan as the information was not provided by the Bhoja Air Management.

4.1.6 Therefore it is observed that due to the ignorance of Bhoja Air Management and CAA Pakistan, the said extension in respect of FO for simulator training was initially requested by former and subsequently approved by the latter. This resulted in absence of variance type training conformance of FO because of which he did not contribute positively in recovering the aircraft out of unsafe set of conditions primarily due to lack of automation knowledge, proper training and relying on captain to take remedial actions. This is also considered as one of the contributory factors in causation of accident.

4.1.7 The Captain's airline flying experience on semi automated flight deck aircraft and his selection for automated aircraft without subsequent training and monitoring to enhance his professional competence and skill, is one of the factors in causation of the accident.

4.1.8 None of the cockpit crew member challenged the decision of each other to continue for the destination despite violation of Ops Manual instructions which is against the essence of CRM training.

4.1.9 After experiencing the extremely adverse weather conditions, the cockpit crew neither knew nor carried out the Boeing recommended QRH and FCOM / Ops

Manual procedures to handle the abnormal set of conditions / situations due to non availability of customized Boeing documents for Boeing 737-236A (advanced version of Boeing 737-200 series).

4.2 **Finalization**

4.2.1 The ineffective automated flight deck management in extreme adverse weather conditions by cockpit crew caused the accident. The ineffective automated flight deck management was due to various factors including; incorrect selection of cockpit crew on account of their inadequate flying experience, training and competence level for Boeing 737-236A (advanced version of Boeing 737-200 series), absence of formal simulator training in respect of FO for handling an automated flight deck, non-existence of cockpit crew professional competence / skill level monitoring system at operator level (Bhoja Air).

4.2.2 The cockpit crew incorrect decision to continue the flight for destination and non- adherence to Boeing recommended QRH and FCOM remedial actions / procedures due to non-availability of customized aircraft documents (at Bhoja Air) for Boeing 737-236A (advanced version of Boeing 737-200 series) contributed towards the causation of accident. The inability of CAA Pakistan to ensure automated flight deck variance type training and monitoring requirements primarily due to incorrect information provided by the Bhoja Air Management was also a contributory factor in causation of the accident.

5. **Safety Recommendations**

5.1 CAA, Pakistan is to ensure the following:

(a) The 100% monitoring of cockpit crew simulator training (initial / recurrent) by Flight Standard Inspectors.

(b) Strict monitoring of flight crew proficiency along with their recurrent training compliances at operator level.

(c) Strict compliance of her directives / instructions by all operators.

(d) To devise mechanism for close monitoring / tracking of simulator training waivers / extensions of the cockpit crew.

(e) The availability of all customized applicable aircraft documents with the operator before issuance / approval of operations specifications.

(f) The conduct of aircraft variance type ground and simulator training and submission of compliance report to CAA Pakistan by the operators prior to formal start of flying duties by cockpit crew.

5.2 CAA, Pakistan is to study the following for implementation:

(a) Devise mechanism for 100 % coverage of aircraft inspections in respect of new inductions / registrations by Flight Standard Inspectors who possess type rating on the specific aircraft.

(b) The inclusion of wind shear, TAWS (EGPWS) and stall recovery exercises as mandatory items in the Pilot Proficiency Check (PPC) during simulator training sessions.

(c) Review the Licensing Circular (ASC) –1 / 2000 (issue one) dated 15 October, 2000 for inclusion of Boeing 737-236A aircraft variance type training.

(d) Devise mechanism for strict monitoring / performance evaluation of newly launched operator's flight crew.

(e) The inclusion of flight crew scheduler for formal certification to ensure required competence level of scheduler.

(f) The inclusion, of mandatory serviceability of EGPWS / GPWS / TAWS / Wind shear warning system (predictive or reactive) for all turbine-engined aeroplanes of a maximum certified take off mass in excess of 5700 kg or authorized to carry more than nine passengers, in the MEL of all operators.

(g) The availability and integration of Low Level Wind Shear (LLWS) warning system with Automatic Weather Observation System (AWOS) at all airports.

(h) Review the existing Certificate of Airworthiness (C of A) issue and validation procedure by competent authority.

(i) The implementation of automated flight crew scheduling system by all operators.

(j) The submission of selection and induction procedure / policy of all flight crew by the operators for formal approval by CAA, Pakistan.

(k) The conduct of regular flight safety meetings and submission of their respective proceedings to CAA Pakistan.

5.3 All operators in Pakistan are to ensure the following:

(a) The procurement of customized applicable aircraft documents for the approval of CAA Pakistan prior to the launch of flying operations.

(b) The strict implementation of Operational Manual (CAA Pakistan approved) by the flight crew.

(c) The conduct of aircraft variance type ground and simulator training and submission of compliance report to CAA Pakistan prior to formal start of flying duties by cockpit crew.

(d) To re-emphasize on cockpit crew the importance of strict compliance to Ops Manual, FCOM and QRH instructions / OEM recommendations.

(e) To devise mechanism where cockpit crew share their views freely with appropriate supervisory levels for highlighting deficiencies in their training for safe conduct of flights.

(f) To devise mechanism for close monitoring / tracking of simulator training waivers / extensions of the cockpit crew.