FINAL INVESTIGATION REPORT ON RUNWAY EXCURSION TO M/s AIR INDIA EXPRESS LTD BOEING 737-800 NG AIRCRAFT VT-AXT ON 10/07/2018 AT MUMBAI

GOVERNMENT OF INDIA
O/o, DIRECTOR AIR SAFETY, WESTERN REGION,
NEW INTEGRATED OPERATIONAL OFFICE COMPLEX,
SAHAR ROAD, VILE PARLE (EAST), MUMBAI-400099

OBJECTIVE

This investigation is conducted in accordance with the provisions of Aircraft (Investigation of Accidents and Incidents) Rules, 2017 of India.

The sole objective of this investigation is the prevention of accidents and incidents and not to apportion blame or liability.

FOREWARD

This document has been prepared based upon the evidences collected during the investigation, opinion obtained from the experts and laboratory examination of various components. Consequently, the use of this report for any purpose other than for the prevention of accidents or incidents could lead to erroneous interpretations.

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ABBREVIATIONS

A/c	Aircraft
SMGCS	Surface Movement Guidance & Control System
ADF	Automatic Direction Finder
AIEL	M/s Air India Express Ltd
Aircraft	Incident aircraft
AME	Aircraft Maintenance Engineer
AMM	Aircraft Maintenance Manual
AOC	Air Operator Certificate
ARC	Airworthiness Review Certificate
ASDA	Accelerate Distance Available
ATC	Air Traffic Control
ATIS	Air Traffic Information Services
ATPL	Air Transport Pilot's License
CAS	Calibrated Air Speed
CB	Cumulonimbus clouds
CSI	Cycles Since Inspection
CSIA	Chhatrapati Shivaji International airport, Mumbai
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DGCA	Director General of Civil Aviation, India
DME	Distance Measuring Equipment

DP	Dew Point
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration, United States of America
FBL	Feeble
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FDTL	Flight and Duty Time Limitations
FIM	Fault Isolation Manual
FMS	Flight Management System
FO	Co-Pilot/ First Officer
FRTO	Flight Radio Telephone Operator
IATA	International Air Traffic Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IR	Instrument Rating
IST	Indian Standard Time
LDA	Landing Distance Available
LIH	Light Intensity High
LH	Left Hand

MEL	Minimum Equipment List
NEF	Non-Essential Equipment and Furnishing
NOTAM	Notice to Airmen
Operator	AOP holder of the incident aircraft
OVC/OC	Overcast
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
PPC	Pilot Proficiency Check
QNH	Pressure setting to indicate elevation
RA	Radio Altitude
RADAR	Radio Detection and Ranging
RH	Right Hand
ROD	Rate of Descent
SCT	Scattered
TCAS	Traffic Collision Avoidance System
TORA	Take-off Run Available
TODA	Take-off Distance Available
Tower	ATC Tower
TSI	Time Since Inspection
TSN	Time Since New

UTC	Coordinated Universal Time
VABB	Mumbai Airport
VFR	Visual Flight Rules
VGA	Vijayawada Airport
VOBZ	Vijayawada Airport
VOR	Very high frequency Omni Range
WBAR	Wing bar

FINAL INVESTIGATION REPORT ON RUNWAY EXCURSION TO M/s AIR INDIA EXPRESS LTD BOEING 737-800 NG AIRCRAFT VT-AXT ON 10/07/2018 AT MUMBAI

1.	**Aircraft**	**Type**	Boeing 737-800 NG
2.		**Nationality**	Indian
3.		**Registration**	VT-AXT
4.	**Owner**		M/s Golden State Aircraft LLC Wilmington Trust, Rodney Square North, 1100 North Market Street, Wilmington, Delaware 19890-0001, USA
5.	**Operator**		M/s Air India Express Ltd Air India Building, 21st Floor, Nariman Point, Mumbai- 400021, India
6.	**Pilot In- Command**		Airline Transport Pilot's License Holder
7.	**Extent of Injuries**		Nil
8.	**Date and Time of Incident**		10/07/2018, 09:20 hrs
9.	**Place of Incident**		Mumbai
10.	**Geographical location of site of Occurrence (Lat. Long.)**		19°04'49.4"N, 72°52'36.2"E
11.	**Last point of Departure**		Vijayawada, India
12.	**Intended Place of Landing**		Mumbai, India
13.	**No. of Passengers On-Board**		82
14.	**Type of Operation**		Schedule, Passenger
15.	**Phase of Operation**		Landing
16.	**Type of Incident**		Runway Excursion

All timings in this report are in UTC.

SYNOPSIS:

On 10st July 2018, M/s Air India Express Ltd Boeing 737-800 aircraft VT-AXT was involved in runway excursion incident during landing while operating flight IX - 213 (VOBZ-VABB).

Aircraft chocked off at 07:33 hrs from Vijayawada. The flight was uneventful till 50 ft of approach at Mumbai where the aircraft was slightly high on threshold. Runway in use at CSIA, Mumbai was Runway 14. Moderate rain was forecasted in the Meteorological report. Wind was reported as 270 degrees 12 knots and visibility was reported as 2200 meters at Mumbai. Considering the runway length available and the prevailing weather conditions the auto brakes were selected on maximum braking. Landing distance calculations were made well in time. The aircraft profile in approach was normal. The flare started at threshold and continued for 14 seconds as the aircraft was slightly high on power and there was a tail wind component of approximately 08 knots. Aircraft touched down approximately 962 meters from runway 14 threshold at 09:20 hrs. The runway was contaminated with water patches due prevailing moderate rain. After 03 seconds of touchdown, Engine # 2 thrust reversers were deployed but the Engine # 1 thrust reversers remained in transit since touchdown and did not deploy. First Officer immediately called out about failure of thrust reverser and not to use full reverser & use maximum Manual braking. Realizing that there could be controllability issue, PIC put the Engine # 2 thrust reversers to IDLE by lowering engine power. Power of both the engines was immediately reduced. Simultaneously recognizing that the braking action was not sufficient and the aircraft was not decelerating enough as expected, crew decided to apply manual braking. Auto brakes were disconnected and crew applied manual brakes. PIC also asked First Officer to assist him in applying maximum manual brakes to decelerate the aircraft. The rudder was utilized to effectively maintain the directional control of the aircraft. Aircraft crossed the end of Runway 14 in the landing roll by approximately 5 meters before coming to a halt on the paved surface. Later, aircraft vacated Runway via Taxiway E1 on its own power under guidance of Follow Me vehicle and parked on stand V29 at 09:40 hrs (chocks on). No human injury was reported in the incident.

Director General of Civil Aviation ordered the investigation of the incident by appointing Inquiry Officer vide order no. DGCA-15018(03)/2/2018-DAS dated 13th July 2018 under Rule 13(1) of The Aircraft (Investigation of Accidents and Incidents) Rules 2017. The incident was caused due to prolonged flare wherein nearly 40% of the available landing distance was consumed followed by failure of Engine # 1 thrust reverser due to defective thrust reverser middle & lower actuator. Dynamic aquaplaning and prevalent weather conditions were contributory factors to the incident.

1. FACTUAL INFORMATION:

1.1 History of Flight:

M/s Air India Express Ltd Boeing 737-800 NG aircraft VT-AXT, was scheduled to operate flight no. IX-213 (sector Vijayawada - Mumbai) on 10th July 2018 at 05:00 hrs with 89 persons on-board including 02 cockpit crew, 04 cabin crew and 01 AME. The aircraft was under the command of PIC (ATPL holder). PIC was the pilot flying and First Officer was pilot monitoring.

Both crew had reported for Flight duty at 02:10 hrs for the first sector of a two sector flight on quick turn around basis. The first sector was IX- 214 (sector Mumbai - Vijayawada). Schedule departure for the first sector flight IX- 214 was at 02:30 hrs however the aircraft departed at 04:26 hrs with MEL 25-10 NEF (Tray table cracked) and MEL 26-02-02 (Engine# 2 loop 'A' unserviceable- Engine overheat and fire protection system) active. IX- 214 landed at Vijayawada at 06:51 hrs and choked on at 06:56 hrs. IX- 214 was the first flight of the day for VT-AXT. The flight IX- 214 was uneventful and no defects were reported in this sector.

After completion of transit inspection, the aircraft chocked off at 07:33 hrs for the next sector IX- 213 (Vijayawada- Mumbai) without any relevant snag/ MEL and got airborne at 07:47 hrs.

The Before Start checklist, Before Taxi checklist, takeoff and climb operations, procedures, checklists and callouts were normal. The cruise phase was also normal.

At about 08:30 hrs the PIC read the destination ATIS report: 'Runway surface – WET, Braking action – medium, 250/10 knots, Visibility – 2200 m, Feeble rain, Clouds SCT-1000, SCT – 1500, Few CB 3000, OC – 8000, 27/25 degree C, QNH 1003 Hpa, Tempo Visibility 1500 in Moderate rain.'

The NOTAM # A1449/18 was issued for CSIA, Mumbai on 10/07/2018 notifying that 'Runway 09/27 will not be available for operations from time 14:00 hrs IST up to 15:00 hrs IST of date due Maintenance. However, Runway 14/32 is available for operation.' However, the crew were not aware about the same as it was not included in their flight folder and hence the briefing and landing distance calculations were worked out for landing on Runway 27 as per latest ATIS information.

The Descent checklist was completed and the descent commenced at about 08:39 hrs. At 08:45 hrs during changeover to Mumbai Control, ATC broadcasted that all arrivals earlier cleared for Runway 27 to now expect Runway 14 due runway change which was as per NOTAM.

The FMS and navigation were reconfigured for ILS approach Runway 14 and briefing was carried out. The required landing distance with flaps 30 configuration, Auto brakes MAX, medium braking action, approximately 04 knots tail wind (250/10 knots) and reported temperature conditions added with 1000 ft factor of safety was calculated to be 7456 ft, which was within the landing distance available for Runway 14, i.e. 8106 ft.

Subsequently, upon getting clearance for the ILS approach, the aircraft was established on ILS and reported at 7.3 miles ILS DME at 09:17 hrs. It was raining on the Approach and Mumbai Tower reported the Surface wind as 270 degree, at 12 knots, Runway surface WET. At 09:18 hrs Flaps 30 was selected and the Landing checklist was completed. At 1000 ft Radio altitude the Stabilized callout was made with Approach

lights in Sight. Subsequently, Runway edge lights & Runway was also visible. At 453 ft RA the auto pilot was disconnected. The aircraft was stabilized on ILS up to 50 ft RA.

The aircraft was at around 50ft RA at threshold. The flare started at threshold by increasing the pitch of the aircraft. The aircraft was slightly high on power with varying winds having tail wind component. After 14 seconds of flare, aircraft made firm touchdown at 09:20:30 hrs with a vertical acceleration of 1.15 g in tail wind of around 8 knots. The aircraft touch down at approximately 962 meters from runway 14 threshold at 09:20 hrs.

Auto brakes MAX being active, Speed brake lever was immediately deployed on touchdown. The runway was contaminated with water patches due prevailing moderate rain. After 03 seconds of touchdown, Engine # 2 thrust reversers were deployed but the Engine # 1 thrust reversers remained in transit since touchdown and did not deploy. There was an Amber Reverser indication in upper display unit.

First Officer immediately called out about failure of thrust reverser and not to use full reverser & to use maximum Manual braking. PIC put the Engine # 2 thrust reversers to IDLE by lowering engine power upon being realized that there could be controllability issue. Power of both the engines was immediately reduced. Simultaneously recognizing that the braking action was not sufficient and the aircraft was not decelerating enough as expected, crew decided to apply manual braking. Auto brakes were disconnected and crew applied manual brakes. PIC asked assistance of First Officer for applying maximum manual brakes to decelerate the aircraft. Aircraft crossed the last available exit taxiway E1 of Runway 14 and overrun Runway 14 end by approximately 5 meters. The aircraft halted at 12.55 meters right of the center line on the paved surface at 09:21 hrs. The rudder was utilized to effectively maintain the directional control of the aircraft. Succeeding arrival flight was instructed to carry out missed approach by tower.

After the aircraft came to halt, the First Officer informed Mumbai Tower that the aircraft was on hard surface slightly ahead of the Threshold, due Technical. As crew expressed their inability to turn and exit the Runway, the controller instructed crew to hold position until a Follow Me vehicle was sent. Later, at 09:23 hrs Follow Me vehicle and Fire Tenders # 1, 4, 5 & 6 were reported at aircraft.

The aircraft followed instructions from Tower and Follow Me vehicle and taxied via taxi way E1 on its own power. Approximately at short of taxiway N1 the Follow Me was discontinued. The aircraft arrived and parked at Stand V-29 at 09:40 hrs. The Shut down and Secure procedures and checklists were completed.

Aircraft's take-off weight was 61,421 Kg and landing weight was approximately 57,600 Kg, which was within limits.

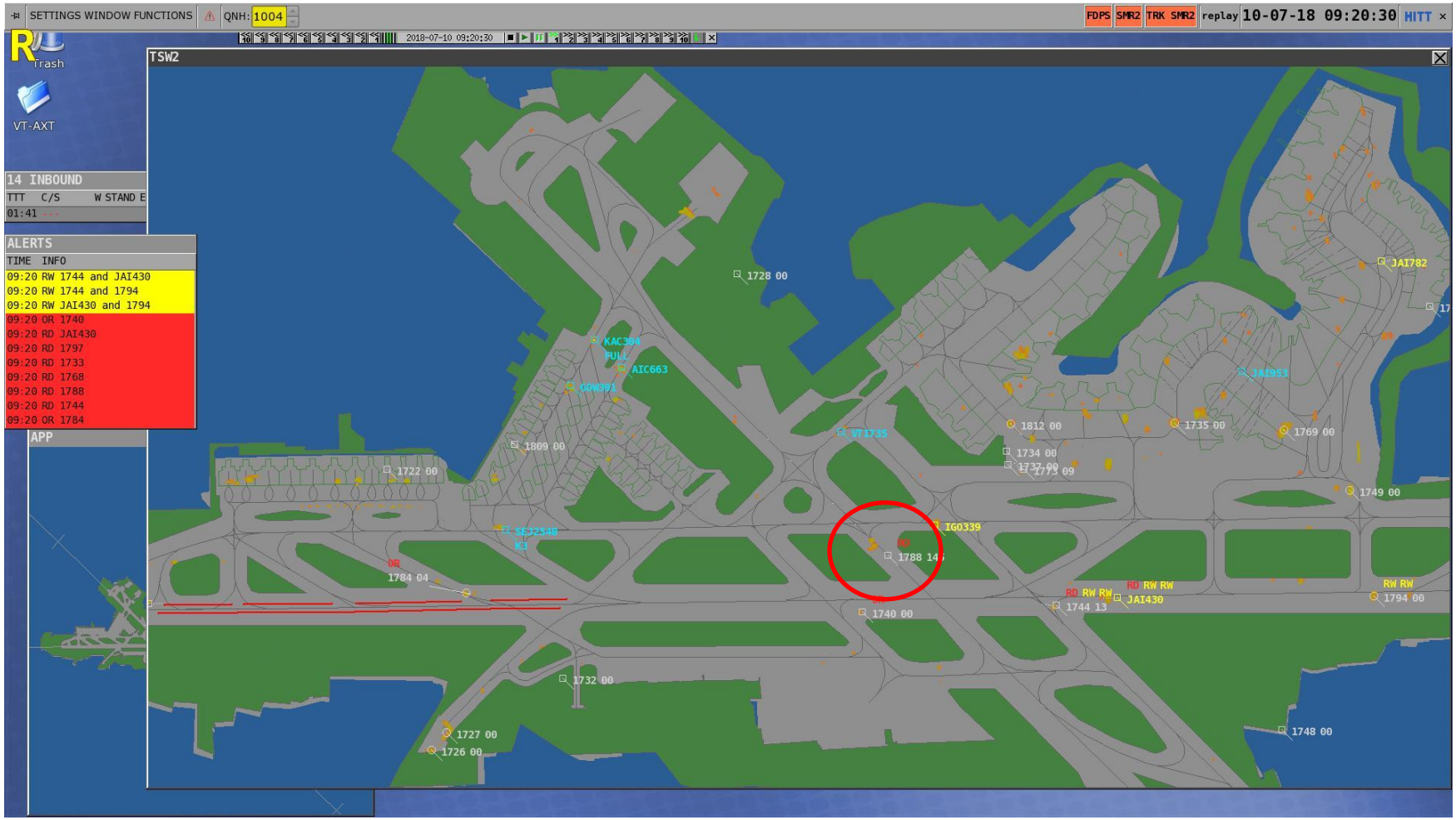


Figure # 1 SMGCS snapshot depicting the touchdown point of IX- 213

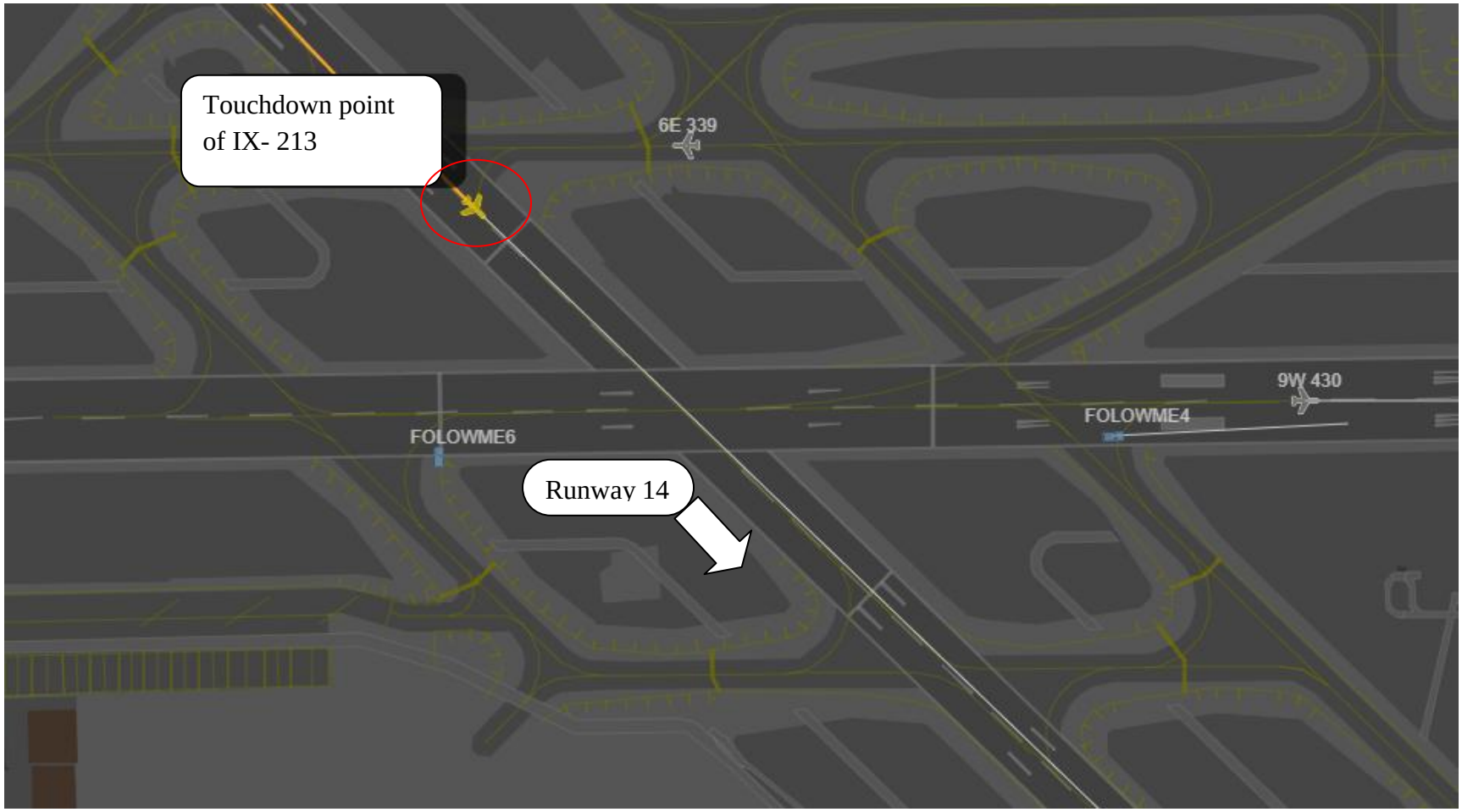


Figure # 2 Touchdown point of IX- 213 on Runway 14

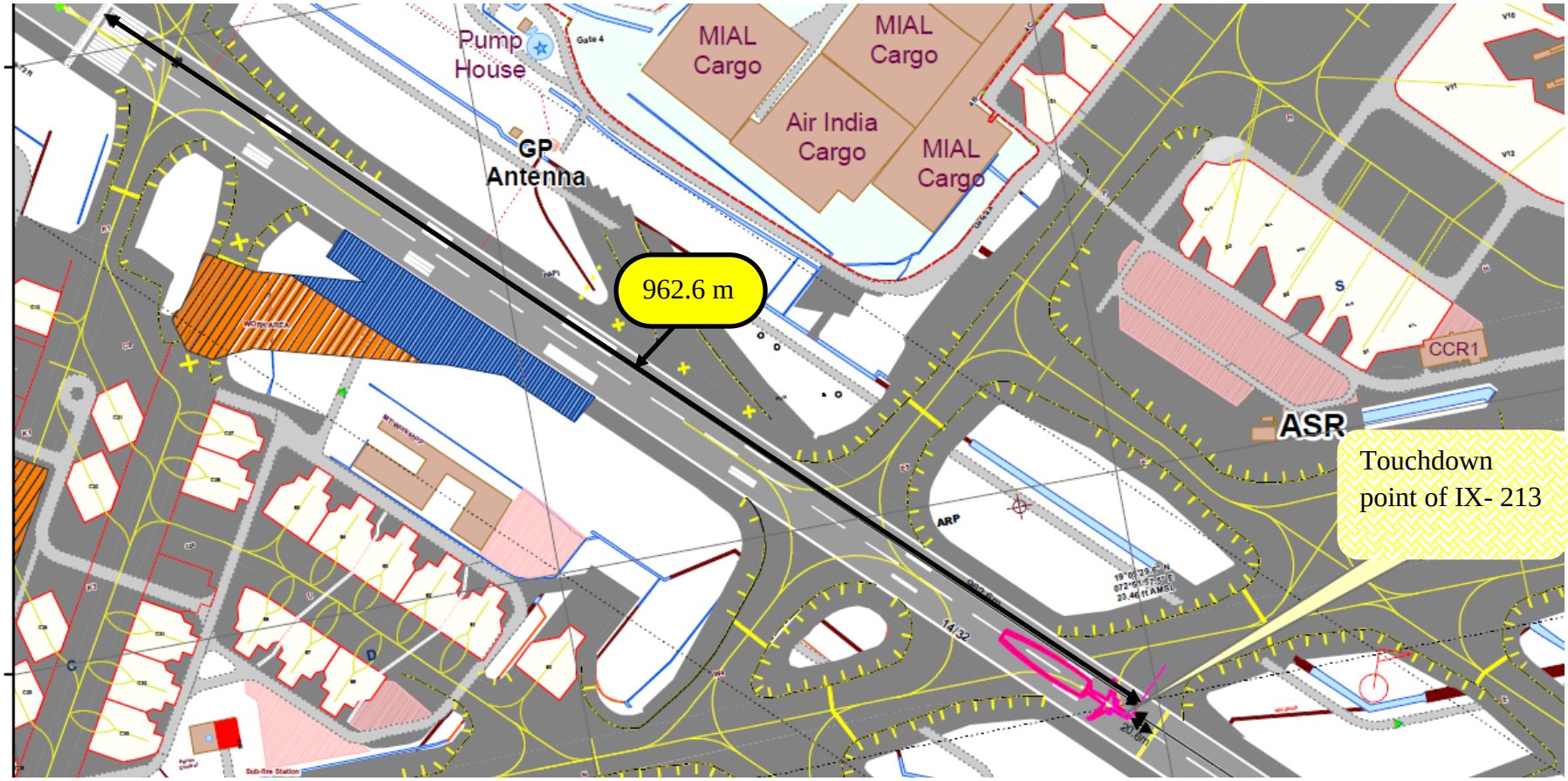


Figure # 3 Distance from threshold of Runway 14 to touchdown point= 962.6 m

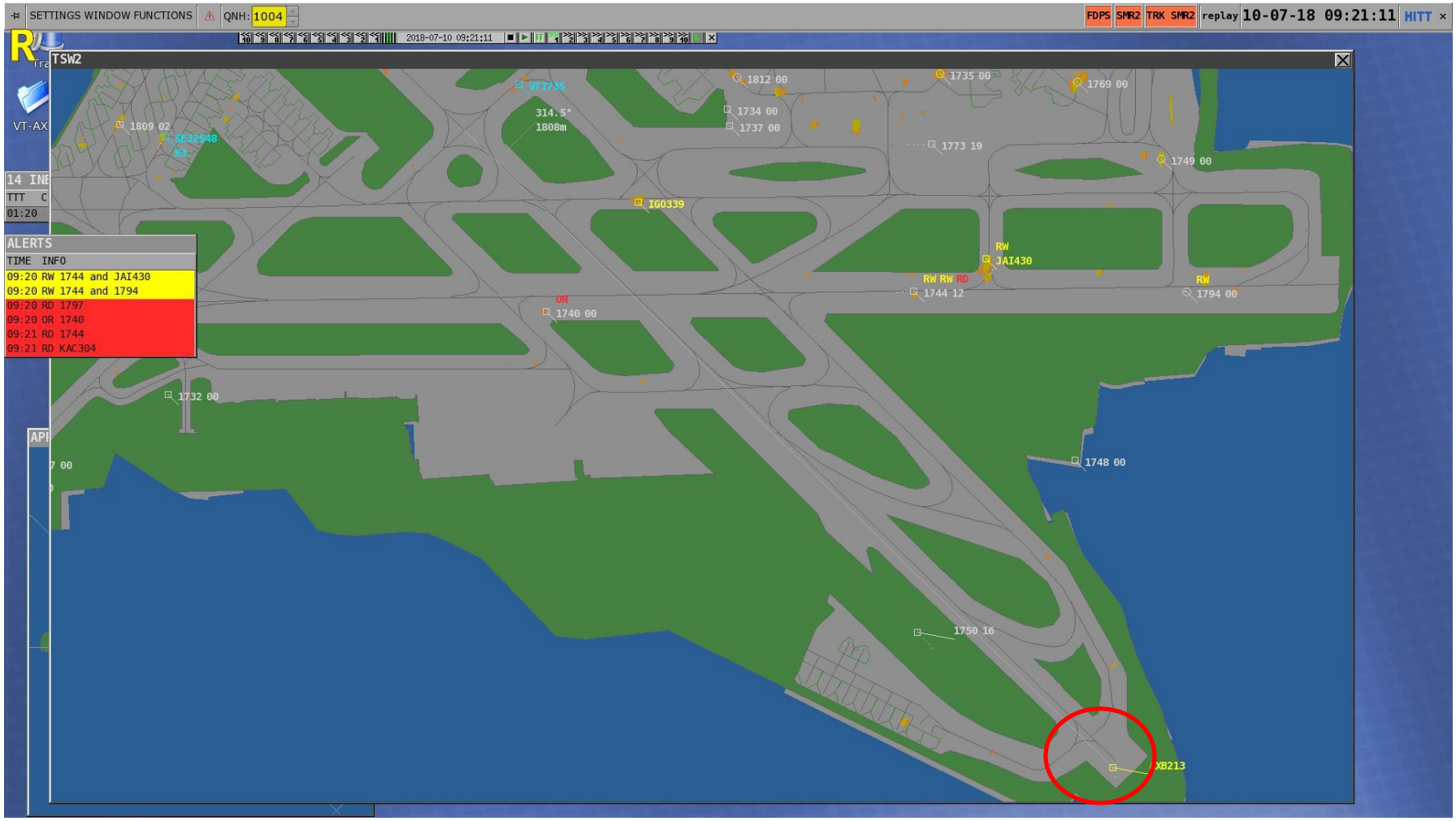


Figure # 4 SMGCS snapshot depicting the final halt point of IX- 213

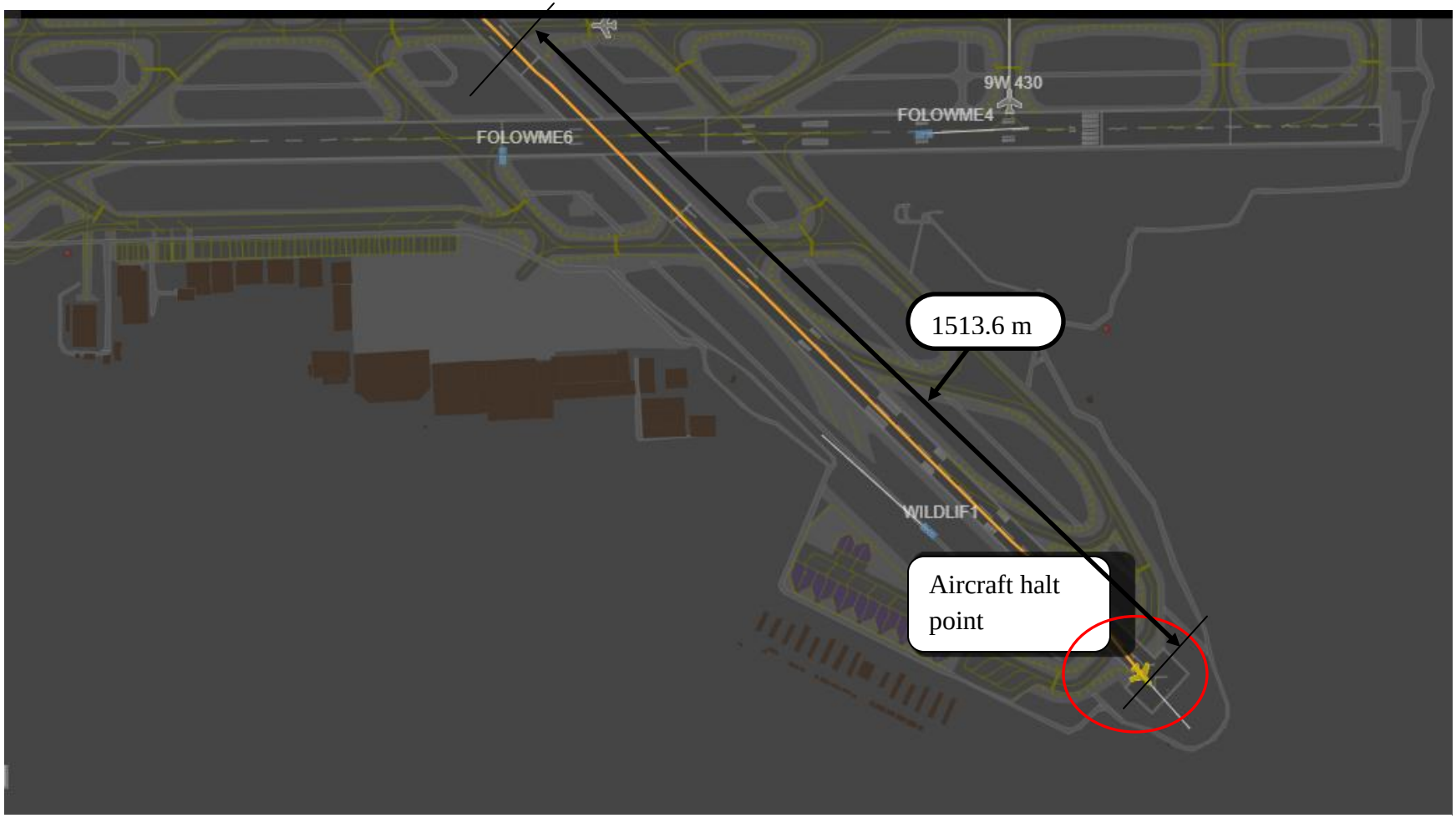


Figure # 5 IX-213 overrun the Runway 14 end and halted on paved surface after travelling 1513.6 m from touchdown

Figure # 6 Trajectory of IX- 213 depicting it vacated via taxiway E1

1.2 Injuries to Persons:

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	0	0	0
None	7	82	

1.3 Damage to Aircraft:

Tyres of Main wheel # 1 & 2 found worn out due to excessive braking action.

Figure # 7
Tyre # 1 worn out

Figure # 8
Tyre # 2 worn out

1.4 Other Damage: There was no other damage.

1.5 Personnel Information:

Pilot- In-Command:

Age	44 years Male
License	ATPL
Date of Issue	03/05/2017
Valid up to	02/05/2022
Category	ATPL
Date of Class I Medical Exam	19/07/2017
Class I Medical Valid up to	31/07/2018
Date of Issue of FRTO Licence	12/01/2010
FRTO Licence Valid up to	11/01/2020
IR/ PPC	09/06/2018

Total Flying Experience	3491 hrs
Total Flying Experience on Type	3208 hrs
Total Flying Experience in last 1 year	684 hrs
Total Flying Experience in last 6 months	356 hrs
Total Flying Experience in last 30 days	72 hrs
Total Flying Experience in last 7 days	18 hrs
Total Flying Experience in last 24 hours	04:40 hrs
Duty Time last 24 hours	05:10 hrs
Rest before the incident flight	27:28 hrs
Ratings	Boeing 737- 800, Cessna172, Duchess 76

As per operator, the PIC joined AIEL on 13/03/2013 as a trainee co-pilot and was released as First Officer on 19/03/2014. Subsequently he was upgraded to Commander on 15/04/2018; he did not have any failure or unsatisfactory report during training. PIC does not have any past incident history.

He was examined for consumption of alcohol at Mumbai at 02:11 hrs on 10/07/2018 before carrying out Mumbai- Vijayawada sector (flight no. IX - 214) and found fit for flying.

PIC was having adequate rest before he operated flight on 10th July 2018. Upon scrutiny of the records, PIC was found to be within limits of FDTL.

First Officer:

Age	62 years 01 month Male
License	ATPL
Date of Issue	22/06/2009
Valid up to	21/06/2020
Category	ATPL

Date of Class I Medical Exam	03/04/2018
Class I Medical Valid up to	24/10/2018
Date of Issue of FRTO Licence	22/06/2009
FRTO Licence Valid up to	13/08/2019
IR/ PPC	08/03/2018
Total Flying Experience	8140:41 hrs
Total Flying Experience on Type	5354:16 hrs
Total Flying Experience in last 1 year	591:47 hrs
Total Flying Experience in last 6 months	422:45 hrs
Total Flying Experience in last 30 days	76:12 hrs
Total Flying Experience in last 7 days	04:40 hrs
Total Flying Experience in last 24 hours	04:40 hrs
Duty Time last 24 hours	06:10 hrs
Rest before the incident flight	54 hrs
Ratings	Boeing 737-800

As per operator, The First Officer joined AIEL on 16/06/2008 as a trainee Captain and was released as First Officer on 09/12/2009. Prior to joining AIEL he was with Indian Air Force for 30 years. In 2013, he underwent Command upgradation training, but failed to make the grade. Subsequently he had been flying as a First Officer with the airline. FO does not have any past incident history.

He was examined for consumption of alcohol at Mumbai at 02:12 hrs on 10/07/2018 before carrying out Mumbai- Vijayawada sector (flight no. IX - 214) and found fit for flying.

First Officer was having adequate rest before he operated flight on 10th July 2018. Upon scrutiny of the records, First Officer was found to be within limits of FDTL.

1.6 Aircraft Information:

The details provided below are as on prior to the incident flight.

Aircraft Registration	VT-AXT	
Type of Aircraft	Boeing 737-800 NG	
Aircraft Serial No.	36331	
State of Manufacturing	USA	
Manufacturing year	2007	
Owner	M/s Golden State Aircraft LLC Wilmington Trust, Rodney Square North, 1100 North Market Street, Wilmington, Delaware 19890-0001, USA	
Operator	M/s Air India Express Ltd	
Certificate of Airworthiness number and issue date	2971 dated 19/07/2007	
ARC number and Validity	DDG/BLR/2971/ARC 6th/2016 Valid up to 03/09/2018	
A/c TSN / CSN	36193: 23 hrs / 12619	
Maximum All Up Weight authorized	79,015 Kg	
Minimum crew necessary	Two	
Engine Type	# 1 (LH): CFM 56-7B 27	# 2 (RH): CFM 56-7B 27
Engine Sl no.	# 1 (LH): 896634	# 2 (RH): 894358
Engine TSN/CSN	# 1 (LH): 32247:07 hrs/ 11307	# 2 (RH): 33981:18 hrs/ 12008
Main Wheel Assembly # 1	P/N: 277A6000-204, S/N: B10556 TSI/CSI: 407:27 hrs/124	
Main Wheel Assembly # 2	P/N: 277A6000-204, S/N: B24057 TSI/CSI: 455:23 hrs/138	

Last major check (Phase 81+12 months+6 months Check) carried out	On 23/06/2018 at 35963:17 hrs A/c TSN/ 12546 A/c CSN
Next schedule maintenance due at (Phase Check)	36463:17 hrs A/c TSN or 12746 A/c CSN or date 21/08/2018 whichever earlier
Aircraft Take-off Weight	61,421 Kg
Aircraft Landing Weight	57,600 Kg (approximate)
Maximum Landing Weight	66,360 Kg
Fuel On-board before Flight	10,300 Kg
Tyre pressure	205 psi (all tyres)

Thrust reverser related maintenance tasks are covered under approved schedule maintenance programme. All due scheduled maintenance tasks related to thrust reversers/ relevant system were completed before the incident flight. Thrust reverser sleeves, thrust reverser actuators and thrust reverser control valve module are the on condition maintenance items.

After completion of transit check, aircraft was released to service on 10/07/2018 at Mumbai for sector Mumbai-Vijayawada (flight no. IX- 214). Scrutiny of the maintenance records reveals that there were two MELs active when the aircraft was released to service for IX- 214, i.e. with MEL 25-10 NEF (Tray table cracked) and MEL 26-02-02 (Engine# 2 loop 'A' unserviceable- Engine overheat and fire protection system). No relevant snag was open for rectification when the aircraft was released from Mumbai for IX- 214.

Aircraft operated for Mumbai-Vijayawada sector (flight no. IX- 214) by the same set of crew and arrived in Vijayawada at 06:56 hrs with nil snag.

Before departure of the incident flight, aircraft was subjected to transit inspection. Aircraft take-off weight was 61,421 Kg and fuel on-board before departure was 10,300 Kg. The Centre of Gravity was within limits.

The flight IX- 213 was uneventful till landing, however after touchdown the Engine # 1 thrust reversers did not deploy. Pilot Defect Report of the incident flight was as follows:

'Engine # 1 thrust reverser not deployed upon landing. Auto brakes MAX. Poor braking action. Runway 14 active. Overshot runway (Runway 14 active) by 10 feet. Aircraft stopped well within paved runway surface. Remained on hard pavement area surface. Upon follow me clearance did turn back on engine power & vacated Runway 14 via E1.'

During physical inspection on arrival, AME observed Engine # 1 inboard thrust reverser stuck in mid position. Thrust reverser manually stowed. Ground thrust reverser operation carried out. It was observed that thrust reverser operation was normal but intermittently both sleeves were lagging in operation and inboard thrust reverser was getting stuck mid way during stow cycle.

Further, during physical inspection it was observed that Tyre#1 & 2 are found worn out due excessive braking. Brake wear pins (Wheel# 1, 2, 3 & 4) were found to be within the limits. Except the excessive braking worn marks, tyres # 1 & 2 and their treads were in satisfactory condition.

The aircraft was released for service on 11/07/2018 at 17:27 hrs for Mumbai- Kochi positioning flight (IX- 555) after following rectification action:

- Main wheel # 1 & 2 were replaced as per AMM task 32-45-11 as found worn out.
- On inspection found inboard sleeve not in sync with outboard sleeve. FIM task 78-34 task 802, reverser message show amber, reverser thrust lever does not move to full reverser thrust. Hydraulic leak check carried out for deploy and stow line from wheel well area to engine strut, drain line, thrust reverser flex shaft and no leak found. On inspection thrust reverser module area found with excessive hydraulic leak traces. Same replaced.
- Operations check carried out and found lock actuator not releasing the lock. Top hydraulic lock actuator replaced. Operations check carried out and found thrust reverser moving to deploy position. But not able to stow with thrust reverser lever in stow position. In the stow position, the hydraulic actuator make loud noise and gets stuck in deploy position. Suspected middle and lower hydraulic actuator fault for further snag isolation.
- Upper lock hydraulic actuator replaced as per AMM task 78-31-000-804-F00 & 78-31-400-804-F00. Installation check carried out and found satisfactory.
- Thrust reverser module engine #1 replaced as per AMM task 78-34-01-000-801-F00 & 78-34-01-400-801-F00. Post installation check carried out and found satisfactory.
- Sync shaft removed for snag isolation as per AMM task 78-31-04-000-801-F00 and found to be satisfactory. Same normalized.

- Engine # 1 inboard thrust reverser sleeve getting stuck during stow operation even after replacement of upper locking actuator and thrust reverser control valve module. Suspected middle or lower actuator faulty.
- Middle and bottom hydraulic actuator replaced as per AMM task 78-31-03.
- Thrust reverser normal operation test carried out as per AMM task 78-31-00-700-801 and found satisfactory.

After chocks off from Mumbai, the aircraft returned back to bay from taxi due 'Panel fail on Captain Communication and rubbing noise from brakes during taxi.' Following rectification was carried out:

- Captain side Navigation control panel swapped with FO side. Captain side Navigation control panel operation Normal. FO side Navigation control panel released under MEL 34-17-03-02.
- Aircraft main wheel brakes inspection carried out as per AMM task 32-41-41. Inspection found satisfactory. However, as a precaution #1 & 2 brake assembly replaced as per AMM task 32-41-41.

Subsequently aircraft was released for service on 11/07/2018 at 22:20 hrs and it completed flight Mumbai-Kochi (IX- 555) uneventfully. Post release on 11/07/2018, Pilot Defect Report for 15 sectors were scrutinized and found that the defect did not reoccur.

The following is the history of thrust reverser related snags reported by crew:

Date	Flight	Sector	Snag
09/07/18	251	Dubai-Mumbai	On landing roll # 1 reverser stuck at interlock, could not be deployed beyond interlock. Recycled. Then repeated thrust reverser thrust reverser deployment found satisfactory.
			Rectification
FIM task 78-34 task 807 Carried out. Thrust reverser normal operation test. AMM Task 78-31-00-700-801-F00 carried out, found satisfactory. EAU BITE Carried out found no fault.			

After above rectification on 09/07/2018, the aircraft operated 03 sectors till the incident flight with NIL snags reported.

1.7 Meteorological Information:

Meteorological information is provided by Indian Meteorological Department in every 30 minutes. The weather at Mumbai, as per Indian Meteorological Department, was reported as follows:

Time	0900	0930
Wind	260/ 10 Knots	270/ 10 Knots
Visibility	2200 meter	1500 meter
Clouds	SCT012 SCT018 FEW030CB OVC080	SCT012 SCT018 FEW030CB OVC080
Precipitation	FBL RA	FBL RA
Temperature	27 ºC	26 ºC
Dew Point	25 ºC	25 ºC
QNH	1003 hPa	1003 hPa
Trend	TEMPO VIS 1500M MOD RA	TEMPO VIS 1500M MOD RA

The actual weather conveyed to crew at the time of giving landing clearance at 09:18:44 hrs was as follows: Winds: 270 degrees 12 knots, Runway surface Wet.

During landing moderate rain was prevailing at the airport. Crew observed that the runway surface was contaminated with water patches due presence of moderate rains. First Officer submitted that the water available on runway was felt, after landing, to be having depth of more than 3mm. Meteorological report was available with the crew for briefing before flight.

Runway in use at CSIA, Mumbai at the time of landing was Runway 14. The aircraft landed with tail wind of approximately 8 knots.

1.8 Aids to Navigation:

Aircraft is equipped with navigation aids such as ADF, ILS, Localiser receiver, Glide path receiver, Marker receiver, VOR, DME, ATC Transponder Mode S and Weather Radar & Radio Altimeter.

Runway 14 at CSIA, Mumbai is equipped with Cat I ILS (DME collocated with glide path) and DVOR. It has also a secondary surveillance RADAR for providing route navigation services.

There were no known navigation aid difficulties reported by the crew.

1.9 Communication:

Aircraft is equipped with Very High Frequency transmitter & receiver set and High Frequency transmitter & receiver set. There was always two-way communication established between the ATC and aircraft.

1.10 Aerodrome Information:

Chhatrapati Shivaji International Airport (IATA: BOM, ICAO: VABB) is being operated, managed and developed by Mumbai International Airport Limited, a consortium led by the GVK Group. The ATC is controlled by Airports Authority of India.

The elevation of the airport is 40 ft, and it has two runways: runway 09/27, 3448 m x 60 m and runway 14/32, 2871 m x 45 m. The airport is equipped with Surface Movement Guidance and Control System.

As per the electronic Aeronautical Information Publication (e-AIP) of CSIA Airport, declared distances for runways are as under:

Runway Designator	TORA (m)	TODA (m)	ASDA (m)	LDA (m)
14	2871	2871	2871	2471
27	3448	3448	3448	2965

As per the electronic Aeronautical Information Publication (e-AIP), CSIA Airport has following Approach and Runway Lighting facility:

Runway Designator	Type, length and intensity of approach lighting system	Runway threshold lights, colour and wing bars	Length, spacing and intensity of runway edge lights
14	CAT I 740 M LIH	Green WBAR lights on each side of Runway	2871 M 60 M LIH

Aerodrome category for rescue & firefighting is CAT-10. Type of operations permitted is IFR/VFR.

There was a NOTAM # A1449/18 issued for CSIA, Mumbai on 10/07/2018 notifying that ‘Runway 09/27 will not be available for operations from time 14:00 hrs IST up to 15:00 hrs IST of date due Maintenance. However, Runway 14/32 is available for operation.’

Surface Friction Test of Runway 14 was conducted on 29/06/2018 and friction co-efficient values were found to be within the limits.

At the time of landing the Runway 14 surface was wet due presence of moderate rains and braking action was communicated as medium. Two arrivals and two departures operated on Runway14 before arrival of IX- 213 and none of the aircraft reported adverse braking action.

No adverse report for approach and runway lighting system was received for the relevant time and crew confirmed that the approach lights, runway edge lights and runway became visible well before landing.

RUNWAY 14					
EXIT TWY	E1	W1	E3	E4 RET	S/S1
DISTANCE (M)	2436	2411	2115	1573 *	1429

RET : RAPID EXIT TAXIWAY

*Distance: The distance mentioned is the distance from the runway threshold to the RET Turn off curve i.e. the point at which an aircraft starts the turn to exit the RWY

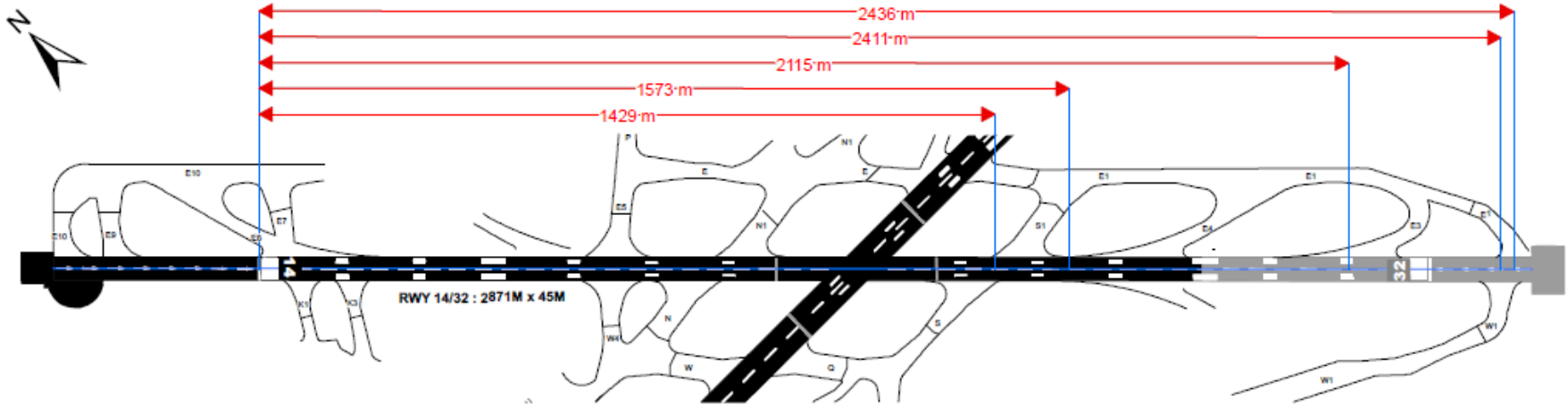


Figure # 9 Arrival Runway 14 details

1.11 Flight Recorders:

The report on CVR readout is as follows:

The CVR readout commenced at 07:37 hrs with the VGA ATIS broadcast. The Before Start checklist was carried out and the takeoff data card was prepared for VGA Runway 26. Both engines were started normally, ground equipment disconnected and the aircraft taxied out for departure after performing the Before Taxi checklist. The takeoff and climb operations, procedures, checklists and callouts were normal. The cruise phase was also normal.

At about 08:30 hrs the PIC read the destination ATIS report: 'Runway surface – WET, Braking action – medium, 250/10 knots, Visibility – 2200 m, Feeble rain, Clouds SCT-1000, SCT – 1500, Few CB 3000, OC – 8000, 27/25 degree C, QNH 1003 Hpa, Tempo Visibility 1500 in Moderate rain.' Thereafter, the Landing distance was worked out preparing for a Flaps 30 landing. The Descent preparation and Approach briefing was adequately covered through the ILS 27 chart details, Approach profile & Minimas. Descent checklist was completed and the descent commenced at about 08:39 hrs. At 08:45 hrs during changeover to Mumbai Control, ATC broadcast to all arrivals earlier cleared for Runway 27 to now expect Runway 14 due runway change. The subject flight was cleared to descend to flight level 170. The FMS and navigation was reconfigured for ILS approach Runway 14. Briefing was carried out from ILS 14 chart. Subsequently, the flight was cleared to intercept the localizer on a heading of 180 degrees and cleared for the ILS approach. The aircraft was established on ILS and reported 7.3 miles ILS DME and contacted Mumbai Tower at 09:17 hrs. Mumbai Tower reported the Surface wind as 270 degree, at 12 knots, Runway surface WET. The landing configuration with Flaps 30 was selected and the Landing checklist was completed after the Landing clearance was obtained. At 1000 ft Radio altitude the Stabilized callout was made with Approach lights in Sight. The presence of rain was assessed by 500 RA callout. The Autopilot was disengaged and the aircraft landed with a firm touchdown, going by the sound profile, and the Speed brake lever deployed on touchdown.

The First Officer called out the failure of the Thrust Reverser 3 seconds after the touchdown and called out for no full reverser & maximum manual braking. PIC asked FO for assistance in manual braking. After the aircraft came to halt, the First Officer informed Mumbai Tower that the aircraft was on paved surface slightly ahead of the Threshold, due Technical. When initially the crew advised Mumbai Ground that they were unable to turn and exit the Runway, the controller instructed crew to hold position until a Follow Me vehicle was sent.

Eventually, when the Follow Me vehicle arrived the aircraft following instructions from Tower and Follow Me vehicle was turned to the left and taxied via taxi way E1. On changeover to Mumbai Ground 121.75 taxi instructions were followed to initially Hold Short N1 where the Follow Me was discontinued. The aircraft arrived and parked at Stand V29 at 09:40 hrs. The Shut down and Secure procedures and checklists were completed and the CVR Circuit Breaker was pulled at 09:42 hrs.

Relevant portion of CVR tape transcript is reproduced below:

TIME (hrs)	FROM	CONVERSATION
9:16:47	PIC	ALT HOLD
	FO	ALT HOLD
	PIC	ALL RIGHT, VOR/LOC CAPTURED
	ATC	EXPRESS INDIA 213 SPEED 160 KNOTS
	FO	SPEED 160 KNOTS
	PIC	CHECKED
	PIC	ILS APPROACH COURSE 136 SET
	FO	136 SET. ON LOCALISER RUNWAY 14. GLIDESLOPE CAPTURED
	ATC	EXPRESS INDIA 213 ROGER REPORT ON ILS
	FO	ON ILS NOW, EXPRESS INDIA 213
	PIC	CHECKED
	ATC	EXPRESS INDIA 213 ROGER 8 MILES FROM TOUCHDOWN, CONTACT TOWER 118.1
	FO	TOWER 118.1, GOOD DAY EXPRESS INDIA 213
	PIC	ALL RIGHT GEAR DOWN, FLAPS 15
	FO	GEAR DOWN
	AREA MIKE	(RADIO ALTIMETER) 2500

TIME (hrs)	FROM	CONVERSATION
9:17:42	FO	MUMBAI EXPRESS INDIA213, GOOD AFTERNOON, ESTABLISHED ON ILS 7.3 DME
	PIC	GIVE ME IN CASE OF THE RAINS LOW OR HIGH ON THE WIPERS
	FO	SAY AGAIN?
	PIC	OK GIVE ME LOW RIGHT NOW
	ATC	EXPRESS INDIA 213 CONTINUE APPROACH ON RUNWAY 14 WIND 270 DEGREES, 12 KNOTS
	FO	CONTINUE APPROACH RUNWAY 14, EXPRESS INDIA 213
	PIC	270 14 KNOTS?
	FO	SAY AGAIN WINDS EXPRESS INDIA 213
	ATC	270 DEGREES 12 KNOTS
	PIC	12 KNOTS, ENCOUNTERING TAIL FROM THE RIGHT, FLAPS 30
	FO	FLAPS 30 SELECTED MOVING
	PIC	LANDING CHECKLIST
	FO	LANDING CHECKLIST. ENGINE START SWITCHES
	PIC	CONTINUOUS
	FO	SPEED BRAKES
	PIC	ARMED
	FO	LANDING GEAR
	PIC	DOWN
	FO	FLAPS
	PIC	30 GREEN LIGHT

TIME (hrs)	FROM	CONVERSATION
	FO	HOLDING AT LANDING CLEARANCE
09:18:44	ATC	EXPRESS INDIA 213 CLEARED TO LAND RUNWAY 14 WIND 270 DEGREES 12 KTS RUNWAY SURFACE WET
	FO	CLEAR TO LAND RWY 14 EXPRESSS INDIA 213
	PIC	ANY RAINS OVER THE FIELD?
	FO	LANDING CLERANCE
	PIC	OBTAINED
		1000 FT STABLISED, NO FLAGS, ALL LIGHTS ON , LANDING CLERANCE OBTAINED, LANDING CHECKLIST
	FO	COMPLETE
	PIC	ANY RAINS OVER THE FIELD?
	FO	SAY AGAIN
	PIC	ANY RAINS OVER THE FIELD?
	RADIO ALTIMETER	1000 (RADIO ALTI METER)
	PIC	STABLISED, NO FLAGS, ALL LIGHTS ON, APPROACH LIGHTS IN SIGHT
	FO	OK, LEADING EDGE LIGHTS VISIBLE
	RADIO ALTIMETER	500,
	FO	IT IS RAINING, NO DOUBT
	RADIO ALTIMETER	APPROACHING MINIMUMS
	AUTO PILOT	DIS ENGAGED WAILER

TIME (hrs)	FROM	CONVERSATION
	RADIO ALTIMETER	MINIMUMS
	FO	FD'S
	PIC	CHECKED
9:20:12	RADIO ALTIMETER	100,
	PIC	CHECKED
	RADIO ALTIMETER	50,40,30,20
	PIC	GO DOWN GO DOWN
	RADIO ALTIMETER	10,
9:20:30	AREA MIKE	SPEED BREAK HANDLE EXTENTION
	FO	NO NO DON'T PUT THE NOSE DOWN. OK NO NO NO FULL REVERSERS NO FULL REVERSERS .PARTIAL ONLY
	FO	MAX BRAKES SIR
	FO	LET MAX GO SIR, LET MAX BRAKES GO SIR
	PIC	OK MANUAL BRAKES
	FO	AUTO BRAKES DISARMED, MAX MAX THRUST
	FO	MAX BRAKES SIR, MAX BRAKES, MAX BRAKES SIR
	PIC	MAX MAX ASSIST ME
	FO	NO THRUST, NO THRUST, NO NO NO NO HOLD IT HOLD IT HOLD IT HOLD IT HOLD IT

TIME (hrs)	FROM	CONVERSATION
	ATC	IX 213 CONTACT GROUND 12175
	FO	STANDBY, STANDBY
9:21:07	PIC	PULL PULL
	FO	(AIRCRAFT STOPPED) REVESERS DINT COME SIR
	PIC	CONTACT
	FO	XI 213 WE ARE ON THE HARD SURFACE, BUT SLIGHTLY AHEAD OF THE THRESHOLD
	PIC	DUE TECHNICAL
	FO	DUE TECHNICAL
	ATC	XI 213 REPORT YOUR EXACT POSITION
	FO	WE ARE ON THE HARD SURFACE BUT WE HAVE CROSSED THE THRESHOLD, BUT WE ARE ON HARD SURFACE
	ATC	CONFIRM ABLE TO VACATE REUWAY
	PIC	NEGATIVE
	FO	NEGATIVE, WE CAN’T TAKE A LEFT TURN, BUT WE MIGHT DAMAGE THE
	ATC	ROGER SIR, WE ARE SENDING THE FOLLOW ME, HOLD POSITION
	FO	WE ARE HOLDING POSITION

Following are the salient observations made from FDR readout:

TIME (hrs)	EVENTS
09:17:43	RA: 2451 ft, Speed brakes armed
09:18:30	RA: 1703 ft, Flaps 30 selected, V_{REF} = 137 knots
09:19:10	RA: 1002 ft, Winds 263/21 knots, Engine # 1 & 2 at 42.1% N1, CAS 147 knots
09:19:40	RA: 491 ft, Winds 254/19 knots, Engine # 1 & 2 at 50.6% N1, CAS 143 knots
09:19:49	RA: 453 ft, Auto pilot disengaged
09:19:56	RA: 325 ft, Winds 253/18 knots, Engine # 1 at 55.9% N1 & Engine # 2 at 55.2% N1, CAS 143 knots
09:20:12	RA: 100 ft, Winds 259/14 knots, Engine # 1 at 51.5% N1 & Engine # 2 at 48.8% N1, CAS 146 knots
---	Approach up to 50 ft RA was stabilized.
09:20:16	RA: 49 ft, CAS 144 knots, Winds 258/12 knots, DME 0 (at threshold), Engine # 1 at 58.2% N1 & Engine # 2 at 59.5% N1, Pitch 0.87º, ROD 660 ft/m, Flare initiated
09:20:21	RA: 14 ft, CAS 145 knots, Winds 257/09 knots, Engine # 1 at 55% N1 & Engine # 2 at 51.5% N1, Pitch 3.5º, ROD 540 ft/m
09:20:25	RA: 09 ft, CAS 138 knots, Winds 272/10 knots, Engine # 1 at 32% N1 & Engine # 2 at 32.75% N1, Thrust IDLE, Pitch 4º, ROD 120 ft/m
09:20:30	Aircraft touchdown. Vertical acceleration 1.15g, Winds 266/12.5 knots, Ground speed 142 knots
09:20:31	Auto brakes applied, speed brakes applied, left thrust reverser in transit and remained in transit throughout
09:20:33	Right thrust reverser deployed
09:20:34	The power of Engine # 1 & 2 was reduced
09:20:37	Auto brakes disconnected and manual brakes applied
09:21:11	Ground Speed became 0. Aircraft halted.
09:40:41	Aircraft parked.
---	Lateral deviation of the aircraft was within limits throughout the approach.

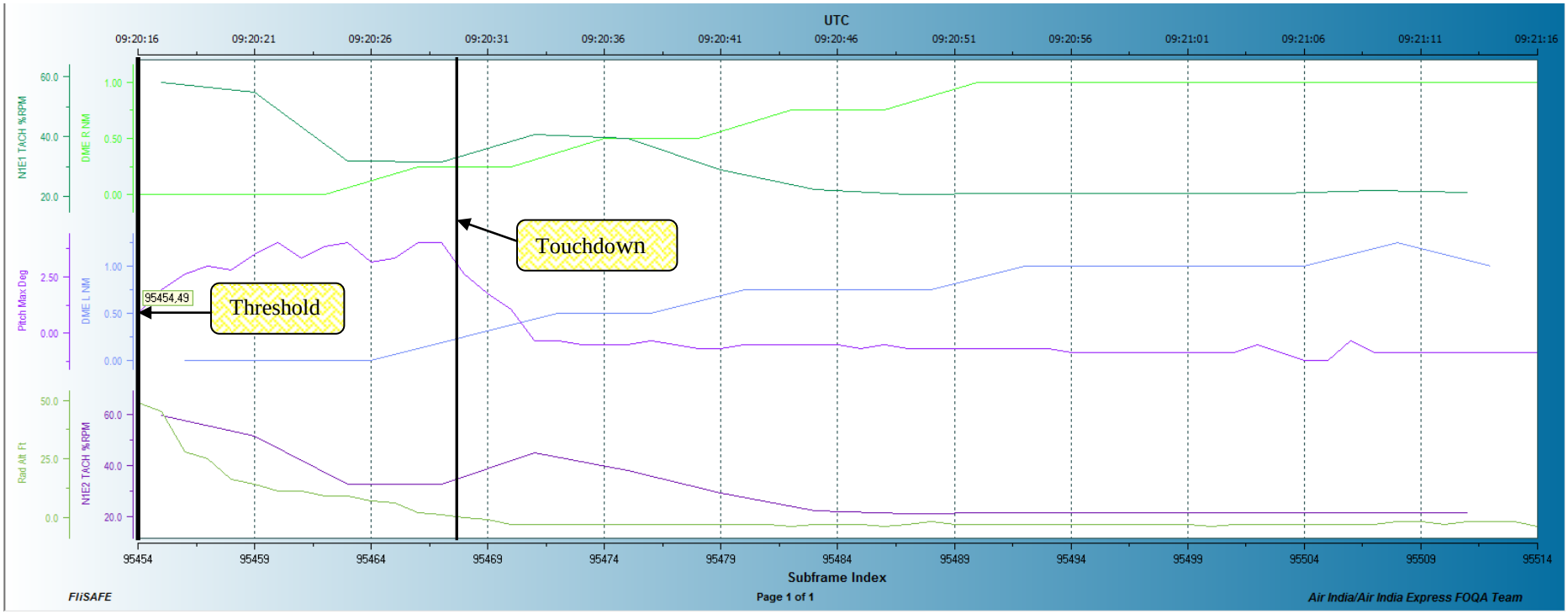


Figure # 10 Graphical representation of FDR data

(Pitch variation Vs Power Vs RA Vs DME Vs Time)

The above graph depicts that the aircraft was at around 50ft RA at threshold which was considered slightly higher than normal. As per FCTM, in normal approach the aircraft is about 30ft RA on threshold. The flare started at threshold by increasing the pitch of the aircraft. The maximum pitch recorded during flare was 4.04º, which was normal. The power from Engine # 1 & 2 was observed to be 58.2% N1 and 59.5% N1 respectively at threshold which was lowered down to IDLE,32% N1 and 32.75% N1 respectively, at 09:20:25 hrs. Subsequent to lowering the power, aircraft made firm touchdown at 09:20:30 hrs. The power was considered to be slightly higher during flare. Aircraft touched down after 14 seconds of flare at 962.6 m/ 3158 ft from the threshold. The power of Engine # 1 & 2 was immediately reduced after deployment of right thrust reverser.

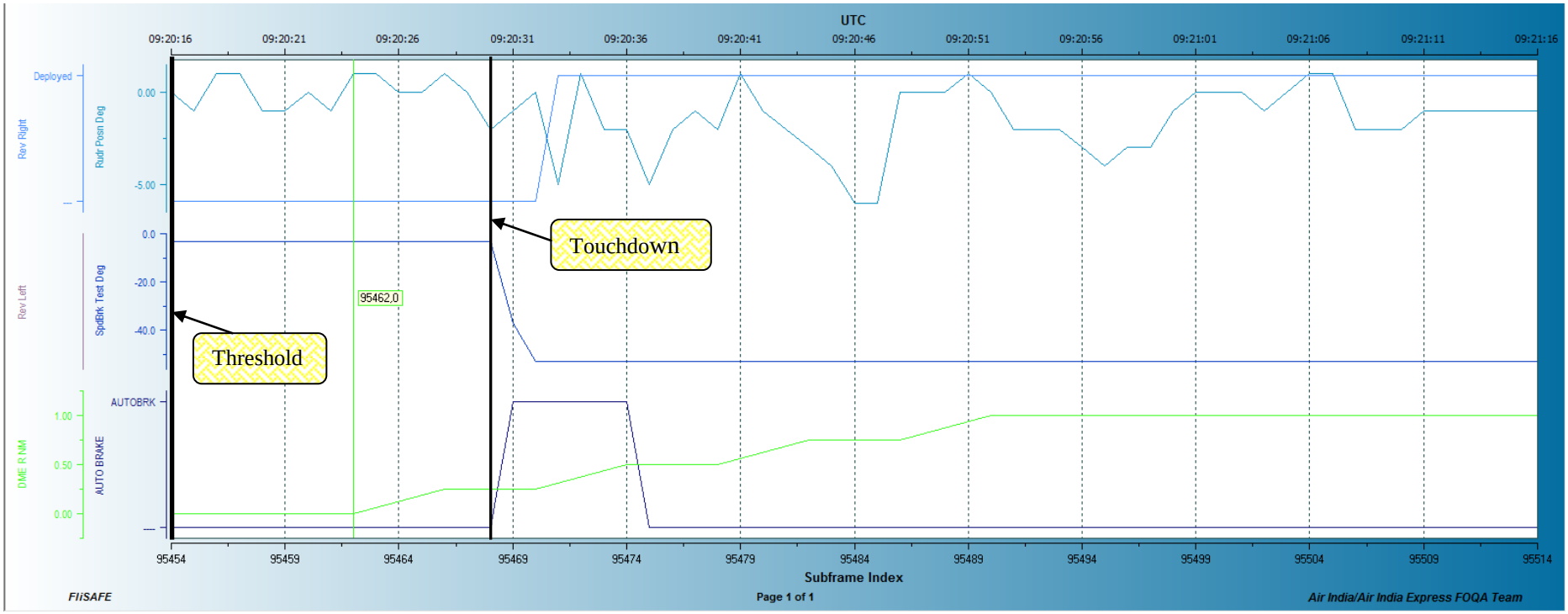


Figure # 11 Graphical representation of FDR data

(Auto brakes Vs 1 & 2 TR Vs DME Vs speed brakes Vs Rudder input Vs Time)

The above graph depicts that Auto brakes were active & speed brakes were deployed immediately after the touchdown. Right (#2) thrust reverser was deployed after three seconds of touchdown and Left (#1) thrust reverser did not deploy. Auto brakes were active for six seconds after touchdown and disconnected at 09:20:37 hrs. The rudder was utilized to effectively maintain directional control of the aircraft.

1.12 Wreckage and impact information: Nil.

1.13 Medical and pathological information: Both the crew had undergone Pre-flight medical examination before operating the flight at Mumbai and tested negative for consumption of alcohol.

1.14 Fire: There was no fire before or after the incident.

1.15 Survival Aspects: No human injuries were reported in the incident.

1.16 Tests and research:

During rectification, the following components were replaced. The removed thrust reverser actuators were tested for its serviceability at M/s Boeing facility and removed thrust reverser control valve module was tested at M/s ACE Services Pvt Ltd, Singapore (FAA/EASA approved).

Main Wheel Assembly # 1: P/N: 277A6000-204	OFF S/N: B10556
Main Wheel Assembly # 2: P/N: 277A6000-204	OFF S/N: B24057
Thrust reverser control valve module: P/N: 3810056-108	OFF S/N: 8899A
Thrust reverser upper lock actuator: P/N: 315A2801-4	OFF S/N: A0035920
Thrust reverser middle actuator: P/N: 315A2800-2	OFF S/N: A0038950
Thrust reverser bottom actuator: P/N: 315A2800-2	OFF S/N: A0038956

The replaced thrust reverser control valve module failed proof pressure test, found leak from the solenoid and failed internal leakage test. Middle and bottom thrust reverser actuators also confirmed failure.

Post rectification, aircraft was released for IX- 555 (Mumbai- Kochi) and it returned back from ramp. During rectification following brake assemblies were replaced:

Brake Assembly # 1: P/N: 2612312-1	OFF S/N: B5489
Brake Assembly # 2: P/N: 2612312-1	OFF S/N: B16188

The above mentioned brake assemblies were tested for its serviceability in M/s Air India Engineering Services Ltd shop facility and found satisfactory.

1.17 Organizational and Management Information:

M/s Air India Express Ltd is a wholly owned subsidiary of M/s Air India Ltd, operating under a separate AOC for Schedule operations. This low-cost arm of M/s Air India Ltd and is headquartered in Kochi, Kerala. M/s Air India Express Ltd is low cost international airline, providing convenient connectivity to short/medium haul international routes in the Gulf and South East Asia. M/s Air India Express Ltd operates fleet of 23 Boeing 737- 800 Next Generation (NG) aircraft.

1.18 Additional Information:

Hydroplaning/Aquaplaning:

Aquaplaning or hydroplaning by the tires of an aircraft occurs when a layer of water builds between the wheels of the aircraft and the runway surface, leading to a loss of traction that prevents the vehicle from responding to control inputs. Aquaplaning may reduce the effectiveness of wheel braking in aircraft on landing or aborting a take-off. It can occur in water depths as little as 0.1 of an inch and is dependent upon aircraft speed and tyre pressure.

The three basic types of hydroplaning are dynamic hydroplaning, reverted rubber hydroplaning, and viscous hydroplaning. Any one of the three can render an airplane partially or totally uncontrollable anytime during the landing roll.

a) Dynamic Aquaplaning:

Dynamic aquaplaning is a relatively high-speed phenomenon that occurs when there is a film of water on the Runway that is at least one-tenth inch deep. As the speed of the airplane and the depth of the water increase, the water layer builds up an increasing resistance to displacement, resulting in the formation of a wedge of water beneath the tire. When the water pressure equals the weight of the airplane, the tire is lifted off the Runway surface and stops rotating. Directional control and braking are lost.

For dynamic aquaplaning, Horne's formula is used for calculating the minimum ground speed for initiation of aquaplaning on a sufficiently wet Runway based upon tyre pressure where V = ground speed in knots and P = tyre inflation pressure in psi:

$V = 9 \times \sqrt{P}$

b) Viscous Aquaplaning:

This occurs when the Runway is damp and provides a very thin film of water which cannot be penetrated by the tyre. Viscous aquaplaning can occur at, or persist down to, much lower speeds than simple dynamic aquaplaning. Viscous aquaplaning is particularly associated with smooth surfaces such as the touch down zone of the Runway which is smoothed by rubber deposits.

c) Reverted Rubber Aquaplaning:
When reverted rubber aquaplaning occurs, the affected tyre(s) become tacky and take on the appearance of uncured rubber. It is normally the consequence of a long skid occurring on a wet Runway, during which the friction between the tyre and the wet surface boils the water and reverts the rubber. As a consequence, a seal is formed which delays water dispersal. The resulting steam then prevents the tyre from making contact with the Runway surface.

1.19 Useful or Effective Investigation Techniques: None.

2. ANALYSIS:

2.1 Engineering aspects:

Airworthiness Review Certificate of the aircraft was valid up to 03/09/2018. Aircraft TSN was 36193: 23 hrs and CSN was 12619. Last major maintenance, i.e. Phase 81+12 months+6 months Check, was accomplished on 23/06/2018 at 35963:17 hrs A/c TSN/ 12546 A/c CSN and next phase check was due at 36463:17 hrs A/c TSN or 12746 A/c CSN or 21/08/2018 whichever earlier. Aircraft was departed with valid Certificate of Release to Service on 10/07/2018.

Aircraft was subjected to Transit Inspection schedule by authorized personnel before it was released to service. Aircraft completed one sector with NIL snags before the incident flight. The incident flight was a second flight of the day. Aircraft Load & Trim sheet was prepared. Take-off weight, landing weight and Centre of Gravity were found within limits. Scrutiny of the maintenance records reveals that no scheduled maintenance was due on thrust reversers/ relevant system, no relevant snag open for rectification and no active MEL invoked with regard to relevant aircraft systems before the incident flight. There was a defect recorded about the Engine # 1 thrust reverser on 09/07/2018 and the same was rectified. The defect reported on 09/07/2018 and its rectification was not considered a contributory factor to the incident as aircraft operated for 03 sectors with NIL snags after the rectification on 09/07/2018 before the incident flight.

No abnormality was noticed by the crew during the flight IX- 213 except the Engine # 1 thrust reverser deployment failure and poor braking action. There was an Amber reverser indication in upper display unit as Engine # 1 reverser did not deploy and was in transit immediately since touchdown. The auto brakes MAX was used for six seconds after touchdown and later maximum manual braking was used by crew.

During physical inspection on arrival, it was noticed that the brake wear pins were found within limits and the tyre treads were in satisfactory condition except the

excessive braking worn marks. Brakes # 1 & 2 were replaced after the aircraft returned back from the ramp in the next sector due to rubbing noise was reported by the crew during taxi. Both the replaced brakes were tested in shop and found to be serviceable and satisfactory.

Landing distance required calculation for CSIA, Mumbai Runway 14 for Flaps 30 and Medium reported braking action as per FCOM:

Braking configuration Max Manual		5710 ft
Adjustments	Weight adjustment for 58,000 Kg	-518 ft
	Standard Altitude adjustment for 1000 ft	170 ft
	Winds adjustment for 266/12.5 knots (approximately tail wind of 8 knots present at touchdown)	856 ft
	Temperature adjustment for 26ºC	176 ft
	Approach speed adjustment for 5 knots above V_{REF}	200 ft
	Reverse thrust adjustment for no reverser	1280 ft
Total landing distance required		7874 ft

Actual distance aircraft travelled before coming to halt: 1513.6 m/ 4965.8 ft

Landing distance required in prevailing weather conditions for the landing aircraft configuration without thrust reverser was calculated to be 7874 ft. However, the aircraft stopped after travelling 4965.8 ft from touchdown which substantiate that the brakes were effective enough.

Therefore, serviceability of the brakes was not considered as a factor to the incident.

During rectification and further shop tests/ investigations it was ascertained that the Engine # 1 thrust reverser did not deploy fully/ stuck in transit because of the defective thrust reverser middle actuator & thrust reverser lower actuator. As per the record, the thrust reverser snag did not reoccur on aircraft for the period of next 15 sectors after the rectification.

As the Engine # 1 thrust reverser failed to deploy, crew were constrained to put the Engine # 2 thrust reverser to IDLE in order to maintain the directional control of the aircraft. This resulted in non-availability of thrust reversers after landing in the prevailing weather conditions wherein tail winds of approximately 08 knots & moderate

rains were present. The failure of deployment of Engine # 1 thrust reverser resulted in increase in landing distance required and hence contributed to the incident.

The aircraft was considered airworthy and serviceable before the incident flight.

2.2 Operational aspects:

Both the crew members were medically fit, had valid license, had adequate rest and found to be within FDTL limits before they operated flight on 10/07/2018. Medical fitness & FDTL of the crew was not a factor to this incident.

IX-213 was scheduled to depart at 05:00 hrs but departed at 07:33 hrs after quick turn around. Delay of 02:33 hrs was not a factor to this incident as the delay was due to delay in arrival from the originating sector.

The Before Start checklist, Before Taxi checklist, takeoff and climb operations, procedures, checklists and callouts were normal. The cruise phase was normal. Top of descent checklist was also followed and landing distance calculations were worked out considering Runway 27 active. Later after getting information on runway change, it was again worked out for Runway 14. The non-availability of NOTAM for runway change was not considered as a factor as revised landing distance requirement was well within the Runway 14 LDA limits and; crew reconfigured FMS & navigation and carried out briefing for the same well in time. The revised landing distance calculations were found to be correct considering the active Runway 14 and available aircraft configuration and weather conditions.

Landing checklist was completed for flaps 30 landing and 1000 ft RA stabilized call out was made. Approach lights, runway lights and runway were sighted by crew. Crew was aware about the wet runway conditions, prevailing rains and winds. Autopilot was disengaged thereafter. The aircraft was stabilized up to 50 ft RA on ILS. From the FDR data it is observed that winds below 50 ft RA were varying in terms of direction and speed both.

At 09:20:16 hrs around 50ft RA the aircraft was at threshold which was slightly higher than normal. The flare started at threshold by increasing the pitch of the aircraft with power of 58.2% N1 and 59.5% N1 available from Engine # 1 & 2 respectively. The application of power was higher than required. The pitch of the aircraft varied between 0.87º at starting of flare to its maximum value 4.04º during flare which was normal. Power of Engine # 1 & 2 was lowered down to IDLE, 32% N1 and 32.75% N1 respectively, at 09:20:25 hrs at 09 ft RA. Subsequent to lowering the power, aircraft made firm touchdown at 09:20:30 hrs. The vertical speed of the aircraft was observed to be normal. Aircraft took 09 seconds from threshold (around 50 ft RA) to reach 09 ft RA and further 05 seconds from 09 ft RA to touchdown. Higher power application during flare combined with varying winds having tail wind component lead to flaring the

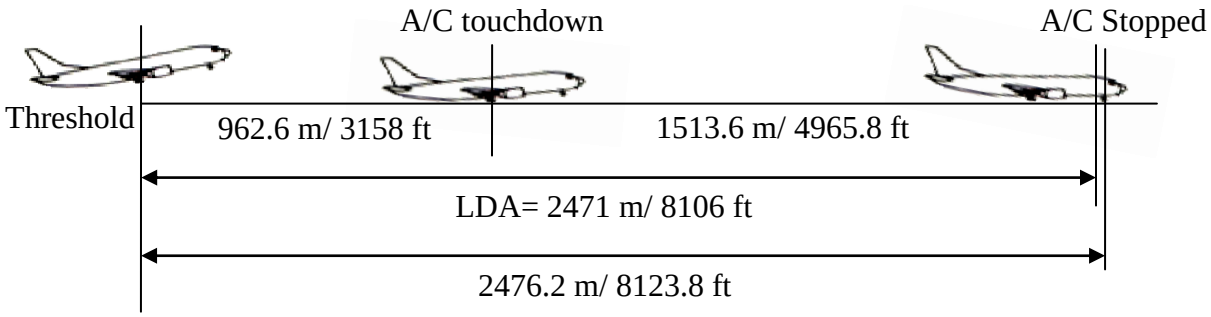
aircraft for 14 seconds. As a result, aircraft touched down at 962.6 m/ 3158 ft from threshold, with vertical acceleration of 1.15g. 962.6 m of runway was covered during flare which is considered as a prime contributory factor to the incident. Lateral deviation of the aircraft was within limits throughout the approach.

Crew action of putting Engine # 2 thrust reverser to IDLE by reducing both the engine powers post identification of Engine # 1 thrust reverser failure upon touchdown was correct in order to maintain the directional control of the aircraft.

Further, crew realized after touchdown that the runway was contaminated with water patches due to rain. Crew felt that the deceleration rate of aircraft was not as desired and took decision of using maximum manual brakes. The decision to use maximum manual brakes was correct in order to get the desired deceleration considering the contaminated runway surface, prevailing tail wind and absence of thrust reverser.

Both PIC and FO applied manual brakes and simultaneously the rudder input was also given to effectively maintain the directional control of the aircraft. With application of maximum manual brakes, the aircraft could be stopped on the paved surface after crossing the Runway 14 end by 5.2 meters and at 12.55 meters right of the center line.

The handing of the aircraft post touchdown with one thrust reverser failed, contaminated runway surface and prevailing tail wind conditions was satisfactory and hence it was not considered as a factor to the incident. Crew showed good CRM throughout the flight.



Total distance travelled from threshold was 2476.2m/ 8123.8 ft and aircraft crossed end of Runway 14 by around 5.2 m/ 17ft.

Figure # 12 Total distance covered by aircraft from threshold to final halt point

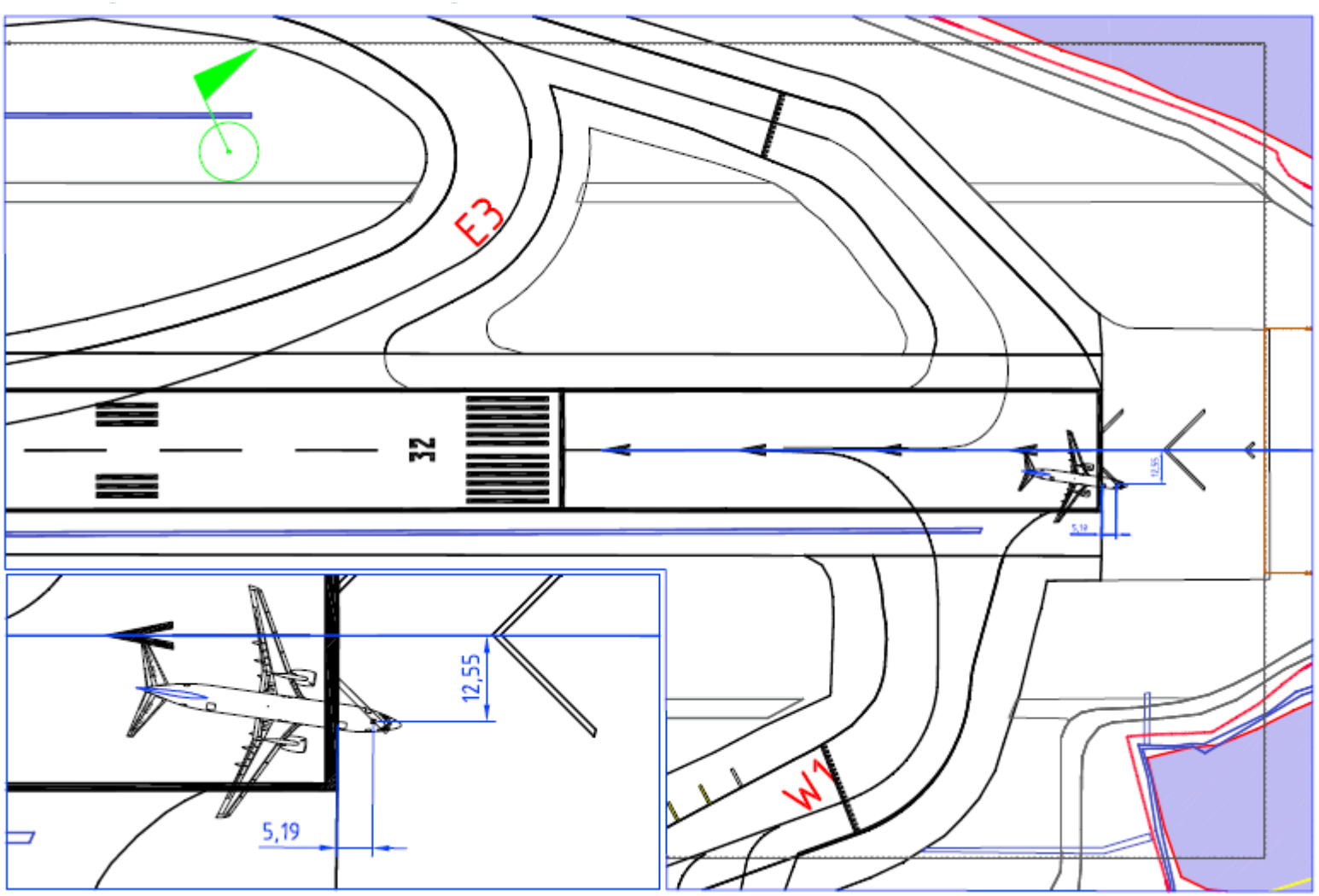


Figure # 13 Depicting the aircraft overrun the Runway 14 end by 5.19 m and halted 12.55 m right of the center line

Surface Friction Test of Runway 14 was conducted on 29/06/2018 and friction co-efficient values were found to be within the limits. Two arrivals and two departures operated on Runway14 before arrival of IX- 213 and none of the aircraft reported adverse braking action. Hence, runway surface friction was not considered as a factor to the incident.

2.3 Dynamic Aquaplaning:

Horne's formula ($V = 9 \times \sqrt{P}$) is used for calculating the minimum ground speed for initiation of dynamic aquaplaning on a sufficiently wet Runway based upon tyre pressure where V = ground speed in knots and P = tyre inflation pressure in psi.

In the incident case, the surface of Runway was wet due to moderate rain showers at the time of landing. The aircraft touched down with ground speed of 142 knots at 09:20:30 hrs and the tyre pressure of all tyres was measured to be 205 psi post incident.

Therefore, minimum ground speed for initiation of dynamic aquaplaning is $V = 9 \times \sqrt{P} = 9 \times \sqrt{205} = 128.86$ knots.

Hence, it is ascertained that there would have been dynamic aquaplaning occurred on the incident flight till the time the aircraft ground speed was above 128.86 knots.

The ground speed was recorded to be 123 knots after 05 seconds of touchdown, i.e. at 09:20:35 hrs. Therefore, it is assumed that the aircraft had encountered dynamic aquaplaning for around 05 seconds between 09:20:30 hrs to 09:20:35 hrs and probably during this time crew felt that the braking action was poor & deceleration rate of aircraft was not as desired. Subsequently at 09:20:37 hrs Auto brakes were disconnected and manual brakes were applied. Dynamic aquaplaning was considered as a contributory factor to the incident.

2.4 Weather:

The weather below 50 ft RA at CSIA, Mumbai contained varying winds in terms of direction & speed and reflected tail wind component. Runway surface was wet and moderate rains were prevalent during landing.

The flaring was initiated at 50 ft RA, i.e. at threshold, and the presence of varying winds having tail wind component adversely contributed in the duration of flaring.

Further, the presence of moderate rains lead the runway to become contaminated with water patches felt to be having more than 3mm depth. During such conditions, if the

ground speed of aircraft is higher than the minimum ground speed for initiation of dynamic aquaplaning, then the dynamic aquaplaning occurs.

As the ground speed of the aircraft at the time of landing, i.e. 142 knots, was greater than the minimum ground speed for initiation of dynamic aquaplaning, i.e. 128.86 knots, it is assumed that the aircraft had encountered dynamic aquaplaning at touchdown. The aircraft ground speed was more than minimum ground speed for initiation of dynamic aquaplaning for around 05 seconds from touchdown. Hence, it is assumed that the dynamic aquaplaning was present from time of touchdown and lasted for around 05 seconds. Probably due to dynamic aquaplaning crew felt poor deceleration rate immediately after touchdown.

The prevalent weather affected the duration of flare and developed a condition wherein dynamic aquaplaning was encountered. Hence, weather was considered as a contributory factor to the incident.

2.5 Circumstances Leading to the Incident:

Flight IX-213 was departed from Vijayawada in airworthy condition with PIC as pilot flying and FO as pilot monitoring. Appropriate procedures and checklists were followed up to the descent phase. The landing distance was worked out for Runway 27 as per the latest ATIS information. On the course of descent, the notification of runway change was received by the crew from ATC due NOTAM. Accordingly, the landing briefing, FMS & navigation configurations and calculations were again worked out for Runway 14. Landing checklist was completed and aircraft was configured for flaps 30 landing with MAX Auto brakes and speed brakes armed. On getting the clearance, ILS was also captured and approach commenced. After 1000 ft RA stabilized call out approach lights, runway edge lights and runway became visible. The auto pilot was disconnected. Aircraft was stabilized in the ILS approach up to 50 ft RA and crew were aware about the wet runway condition due moderate rain, wind direction & speed reflecting tail wind component. At 50 ft RA the aircraft was slightly high on approach at threshold where the flare normally begins. The flare started at threshold with increase in pitch attitude of aircraft but with the power application higher than required. There was a presence of varying winds below 50 ft RA with tail wind component. The flare continued for the 09 seconds with the power application higher than required. After 09 seconds of flare the power was reduced to IDLE. After 05 seconds of reducing the power aircraft touched down firmly on the runway surface with vertical acceleration of 1.15g. The pitch attitude and rate of descent were observed to be satisfactory during flaring. Total 14 seconds were spent in flaring the aircraft from threshold to touchdown point due to higher power application and presence of varying winds having tail wind component. During these 14 seconds 962.6 m/ 3158 ft of the runway was passed. Immediately after touching down the auto brakes and speed brakes were applied. Left

thrust reverser did not deploy due to failure of middle and lower thrust reverser actuators and right thrust reverser was deployed after 03 seconds from touchdown. FO called about failure of thrust reverser immediately and right thrust reverser was brought back to IDLE by reducing the power of both the engines in order to maintain directional control. Meantime, the aircraft was assumed to have encountered dynamic aquaplaning for first 05 seconds from touchdown when MAX auto brakes were being applied. Probably during these 05 seconds crew felt that the braking action was poor and they immediately disengaged the auto brakes and decided to apply maximum manual brakes. The directional control of the aircraft was being maintained by the rudder inputs. Application of maximum manual brakes by both PIC & FO could stop the aircraft on paved surface at a distance of 1513.6 m/ 4965.8 ft from the touchdown point, which was 5.2m/ 17 ft beyond the Runway 14 end and towards 12.55m right of the center line. The aircraft then taxied to bay V-29 under the guidance of Follow Me vehicle on its own power.

3. CONCLUSION:

3.1 Findings:

- Airworthiness Review Certificate of the aircraft was valid up to 03/09/2018.
- Aircraft was departed with valid Certificate of Release to Service on 10/07/2018. The aircraft was considered airworthy and serviceable before the incident flight.
- The defect reported on 09/07/2018 and its rectification was not a contributory factor to the incident.
- Delay of 02:33 hrs in departure of incident flight was not a factor to this incident as delay was attributed to the delay in operating originating sector.
- Both crew members had valid licenses while operating incident flight.
- Medical fitness & FDTL was not a factor to this incident.
- Crew followed standard procedures and checklists in all phases of flight.
- NOTAM for change in runway was not available with crew however the same was not a factor to this incident.
- Configuration of aircraft for landing was correct as per briefing and landing calculations.
- The aircraft was stabilized up to 50 ft RA on ILS.
- Lateral deviation of the aircraft was within limits throughout the approach.
- Aircraft was at 50ft RA on threshold, slightly higher than normal.
- Winds below 50 ft RA were varying in terms of direction and speed both.
- The flare started at threshold and lasted for 14 seconds due to higher power application and presence of varying winds having tail wind component.
- The pitch attitude and rate of descent were observed to be satisfactory during flaring.

- Aircraft touched down firmly at 962.6 m/ 3158 ft from threshold. 962.6 m of runway was covered during flare which was a prime contributory factor to the incident.
- Vertical acceleration of the aircraft at touchdown was 1.15g.
- Engine # 1 reverser did not deploy on touchdown because of the defective thrust reverser middle actuator & thrust reverser lower actuator. The failure of deployment of Engine # 1 thrust reverser resulted in increase in landing distance required and hence contributed to the incident.
- Crew action of putting Engine # 2 thrust reverser to IDLE post identification of Engine # 1 thrust reverser failure upon touchdown was correct.
- The aircraft was assumed to have encountered dynamic aquaplaning for first 05 seconds after touchdown and probably due to same crew experienced poor braking action after touchdown. Dynamic aquaplaning has contributed to the incident.
- The decision to use maximum manual brakes was correct.
- Both PIC and FO applied manual brakes to decelerate aircraft.
- Serviceability of the brakes was not a factor to the incident.
- Rudder input was used to effectively maintain the directional control of the aircraft post touchdown.
- Aircraft overrun Runway 14 end by 5.2 meters and halted at 12.55 meters right of the center line on the paved surface. Total distance travelled by the aircraft from threshold was 2476.2m.
- The handing of the aircraft post touchdown was satisfactory and was not a factor to the incident.
- Runway surface friction was not a factor to the incident.
- Prevalent weather at the time of landing was a contributory factor to the incident.
- Crew shown good CRM throughout the flight.
- The aircraft taxied to bay V-29 under the guidance of Follow Me vehicle on its own power.

3.2 Causes:

- The incident was caused due to prolonged flare wherein nearly 40% of the available landing distance was consumed followed by failure of Engine # 1 thrust reverser due to defective thrust reverser middle & lower actuator.
- Dynamic aquaplaning and prevalent weather conditions were contributory factors to the incident.

4. SAFETY RECOMMENDATIONS:

- As both the involved cockpit crew had already undergone the corrective training suggested by DGCA Hqrs post incident, no further recommendations are made.

(Pathik Vaghela)
Inquiry Officer, VT- AXT

Date: 14/03/2019
Place: Mumbai

------END OF REPORT-----