Final Investigation Report on Serious Incident to M/s Jet Airways aircraft VT-JEK at London Heathrow Airport on 30.08.2016

COMMITTEE OF INQUIRY - VT-JEK

(Raje Bhatnagar)
Assistant Director, AAIB
Member, CoI -VT-JEK

(Dr. Jitender Loura)
Assistant Director, AAIB
Chairman, CoI-VT-JEK

Foreword

In accordance with Annex 13 to the Convention on International Civil Aviation Organization (ICAO) and Rule 3 of Aircraft (Investigation of Accidents and Incidents), Rules 2012, the sole objective of the investigation of an incident or accident shall be the prevention of incidents and accidents and not apportion blame or liability.

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 future incidents /accidents could lead to erroneous interpretations.

Glossary

AAIB,UK	Air Accidents Investigation Branch ,U.K
AAIB	Aircraft Accident Investigation Bureau, India
ADS-B	Automatic Dependence Surveillance-Broadcast
AGL	Above Ground Level
AIP	Aeronautical Information Publication
ANOMS	Heathrow Noise and Track Keeping System
AOP	Air Operator Permit
ASDA	Accelerate-Stop Distance Available
ASMGCS	Advanced Surface Movement Guidance and Control System
ATCO	Air Traffic Control Officer
ATD	Actual Time of Departure
ATM	Assumed Temperature Method
ATIS	Automatic Terminal Information Service
ATSI	Air Traffic Services Investigations
AUW	All Up Weight
CDU	Control and Display Unit
C of A	Certificate of Airworthiness
C of R	Certificate of Registration
CLD	Clearance Delivery Unit
COI	Committee of Inquiry
CPL	Commercial Pilot License
DFDR	Digital Flight Data Recorder
EFB	Electronic Flight Bag
FMC	Flight Management Computer
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
IFR	Instrument Flight Rule
LVP	Low Visibility Procedure
MDS	Multistatic Dependence Surveillance System
MHz	Mega Hertz
MTOW	Maximum Take Off Weight
NATS	National Air Traffic Services, UK
NLR	Netherlands Aerospace Centre
NOTAM	Notice to Airmen
OPT	On-board Performance Tool
PIC	Pilot In Command
Pax.	Passenger
QFE	Query: Field Elevation
QNH	Query: Nautical Height
R/T	Radio Telephony
SMC	*Surface Movement Control*
TODA	Take off Distance Available
TODR	Take Off Distance Required
TO/GA	Take Off/ Go Around
TORA	Take off Run Available
VR	Rotate Speed
VHF	Very High Frequency
UTC	Co-ordinated Universal Time

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Final Report on Serious Incident to M/s Jet Airways Ltd. B777-300, VT-JEK at London Heathrow Airport on 30.08.2016

1. Aircraft	
Type	: B777-300
Nationality	: Indian
Registration	: VT-JEK
2. Owner/ Operator	: M/s Jet Airways
3. Pilot – in –Command	: ATPL Holder
Extent of injuries	: Nil
4. First Officer	: CPL Holder
Extent of injuries	: Nil
5. Place of Incident	: London Heathrow Airport
6. Date & Time of Incident	: 30th August 2016, 20:30 UTC
7. Last point of Departure	: London Heathrow Airport
8. Point of intended landing	: CSI Airport, Mumbai
9. Type of operation	: Schedule Operation
`	
10. Crew on Board	: 02+13
Extent of injuries	: Nil
11. Passengers on Board	: 231
Extent of injuries	: Nil
12. Phase of operation	: Take- off
13. Type of Occurrence	: Serious Incident (Late take-off)

(ALL TIMINGS IN THE REPORT ARE IN UTC)

SYNOPSIS:

On 30th August 2016, M/s Jet Airways aircraft B777-300 registration VT-JEK departed from runway 27L of London Heathrow airport at 20:30 UTC. The aircraft departed from an intersection departure S4E and did not use the full length for take-off which could have been used from the north of the aerodrome after crossing the runway 27L. As per the initial report received from Air Accidents Investigation Branch (AAIB), U.K, the aircraft crossed the airfield boundary at approximately 13 feet AGL and an adjacent road at 30 feet AGL. This event has been treated as Serious Incident by AAIB, UK and handed over to AAIB, India for further investigations.

Ministry of Civil Aviation constituted a committee of inquiry vide Notification No. Av-15013/16/2016-DG to investigate the cause of the Serious Incident under Rule 11 (1) of Aircraft (Investigation of Accidents and Incidents), Rules 2012 comprising of Dr. Jitender Loura Assistant Director of Operations (AAIB) as Chairman and Shri Raje Bhatnagar, Assistant Director of Airworthiness (AAIB) as member.

1. FACTUAL INFORMATION

1.1 History of the flight

Jet Airways aircraft B777-300 was operating a Commercial Air Transport flight from London Heathrow Airport to Chhatrapati Shivaji Airport in Mumbai, India with 231 passengers and 15 crew on board. The aircraft departed from stand 407 and the runway in use was Runway 27L (Figure 1).

Figure 1: London Heathrow Airport south of Runway 27L

There were two NOTAMs relevant to the departure of the flight, both due to work in progress: Taxiway S east of Taxiway V was unavailable (including Link 41 and holding point S1), as was the entry to Runway 27L via holding points S3/SB3. Consequently, the flight was required to enter the runway and takeoff via entry point S4 (E or W), or to cross Runway 27L and enter the runway via one of the taxiway intersections on the north side (NB1, N2E, N2W, or N3). The Heathrow ATC tape transcript reveals that:

I. At **2010:00** JAI117 contacted Heathrow Delivery for their clearance, advising they were on Stand 407 and in receipt of ATIS *"Information November".* ***ATIS N stated that SB3 was closed but S4 was available for departure.*** The pilot was issued with their departure route and transponder code.

II. Then at **2010:20** the pilot was asked if they required the full length for departure, to which the pilot replied ***"Negative, S4 acceptable".*** They were then advised to expect an *"S4E intersection departure*" which was acknowledged by the pilot.

III. At **2011:30** the pilot reported ready (for push), was again advised by Heathrow Delivery to *"Expect S4E intersection departure"*, and instructed to hold position, and was then transferred to Heathrow Ground.

IV. The pilot contacted Heathrow Ground at **2012:00** requesting push and start, which was approved and the pilot was instructed to face north.

V. At **2018:40** the pilot requested taxi and was instructed to *"follow greens and hold S4E"* which was correctly read back by the pilot.

VI. At **2022:20** the pilot was instructed to *"continue round the corner to S4E and then contact Tower 118.5*" which again was read back correctly by the pilot.

VII. At **2023:05** the pilot called Heathrow Tower and was instructed to *"hold at S4E and I will call you back. It'll be around ten minutes at the moment"*, which was correctly read back by the pilot.

VIII. At **2033:48** the tower controller instructed the pilot *"behind departing Indonesia Garuda 777 from the full length, via S4W line up Runway 27 Left behind".*

IX. The pilot read back the clearance but advised the controller that they were *"holding short 27 Left at S4E"*, to which the controller did not correct themselves but added *"Thank you, I'll give you the green lights very shortly".*

X. At **2034:40** the controller cleared the aircraft for take-*off: "(c/s) from S4E, Runway 27 Left clear takeoff. Wind 180°/ 5 kts".* The pilot repeated the clearance *"from S4E cleared for take-off Runway 27 Left (c/s)"*.

XI. The aircraft was transferred to London Control at **2037:25.**

1.1.1 Information from NATS, ATC Heathrow

I. Since 18th February 2016 a project has been underway at Heathrow Airport to refurbish and enable Link 41 and Taxiway Sierra, east of Taxiway Victor for larger aircraft operations. This removed access to the runway from Hold S1 during the whole of the works period. To allow the installation of new stop bars on the taxiway between Tango and Victor, the green centre line lighting had been removed, and therefore, and due to the removal of taxiway guidance lighting, Holds S3/SB3 were not available during those periods when there was a requirement to use airfield ground lighting (i.e. night and LVPs).

II. Unless there were any short-notice changes to the operational status of the aerodrome from the published data in the UK Aeronautical Information Publication (AIP) and the variations issued by NOTAM by the Aerodrome Operator at Heathrow, the ATCOs were not required to remind pilots of aircraft wishing to access Runway 27 Left from the south-side areas, as to the non-availability of the holding points east of S4 during this period. However, for tactical

purposes, pilots were being asked if they required full length departure. Full length departures were available and required the aircraft to cross the runway onto the north-side of Runway 27L. Heathrow Delivery was responsible for determining the pilot's requirements, to allow for the planning of taxi-routes and facilitating runway crossing.

III. The pilot of the B773 had clearly stated that they were able to accept a departure from the intersection S4E.

IV. ATSI obtained a printout from the Heathrow Noise and Track Keeping System (ANOMS) which showed the B773 having just passed a height of 30ft approaching the western perimeter road. A review of the Aerodrome Chart and the AIP entries for Heathrow shows assessed aerodrome obstacles (trees) as high as 31ft. ***[The ANMOS height data is not as accurate as the information supplied by Boeing. That is why the Boeing data was used in the AAIB final report and not the ANMOS data when showing the height at which the aircraft crossed the end of the runway.]***

Figure 2 : ANMOS Plot of JAI 117

V. When considering the reported heights of the aircraft, the following information has been obtained from both Heathrow and NATS engineers, together with a report from the Netherlands Aerospace Centre (NLR), which was commissioned earlier this year to complete a verification of the Heathrow Noise and Track Keeping System. NLR compared the raw

data received and displayed from the NATS source with separate ADS-B data in the same period.

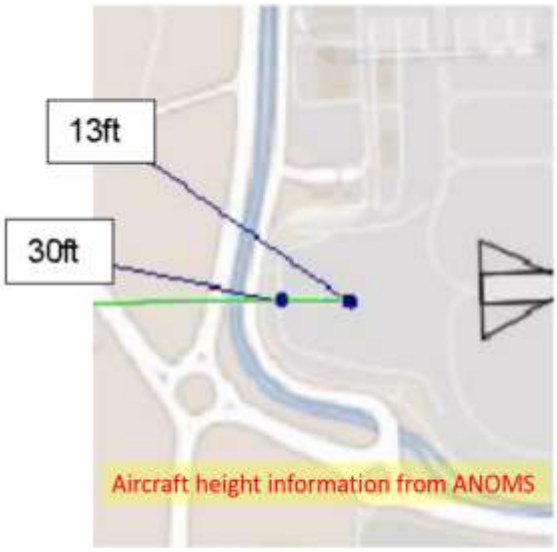


Figure 3(a) Noise Monitor

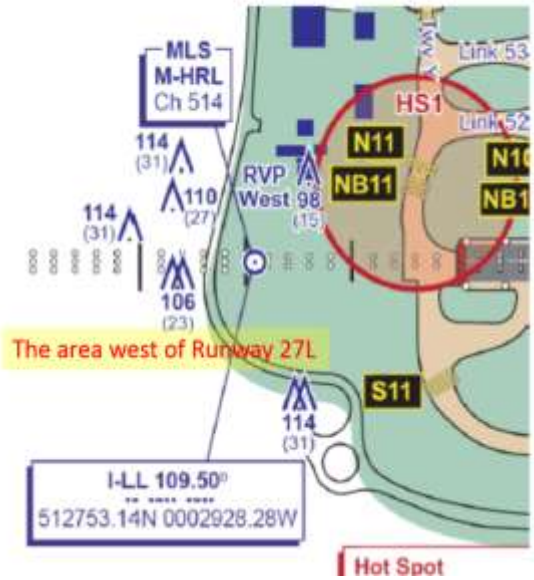


Figure 3(b) Aerodrome Obstacles

VI. Accuracy of the data supplied by this system is subject to the following:

- Aircraft Mode-S transponders report pressure altitude, against a standard QNH of 1013. The accuracy of such systems could not be determined although they must be capable of reporting in 25ft intervals.
- Accuracy of the receiving radar/processor - the ANOMS is supplied with data via an Asterix Cat-62 NATS radar feed, accurate to +/-25ft in this instance.
- Accuracy of the display system – in this case ANOMS – verified by NLR to be accurate to an *average* per flight of -55 to +40ft, with a maximum difference of -35 to 120ft.

VII. ATSI reviewed the ASMGCS radar for the period 1945 – 2045 UTC, noting which of those aircraft which were based on the south side of Runway 27L, elected to take an S4 intersection departure, and those which crossed to the north side to take full length. Also, snapshots were taken of the first point an altitude was recorded by the ASMGCS for a departing aircraft, (all of whom took full-length departures.) This gave a broad picture of the point of rotation of each aircraft. Only those results which show a similar type (Boeing 777) are included in this report.

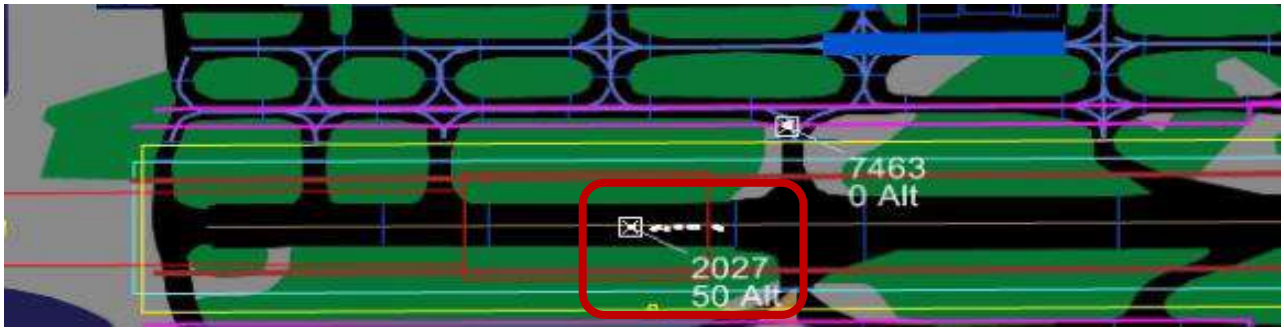


Figure 4(a): Departing **BAW 77 (B772)**

Figure 4(b): **JAI 117 (B77W) Lined up**

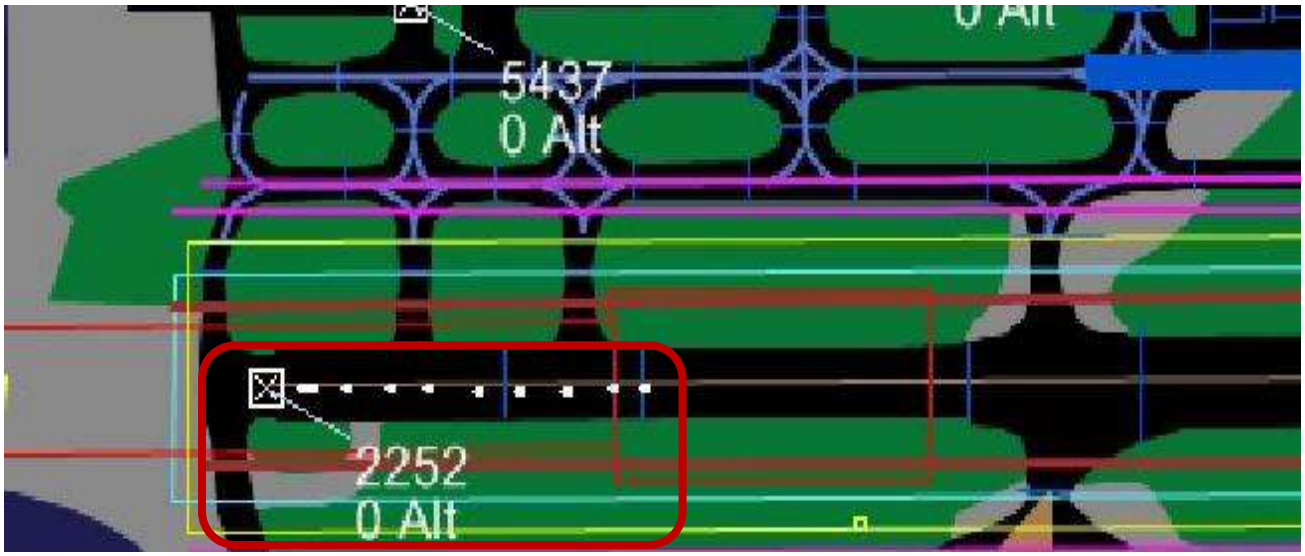


Figure 4(c): **JAI 117 (B77W) approaching threshold**

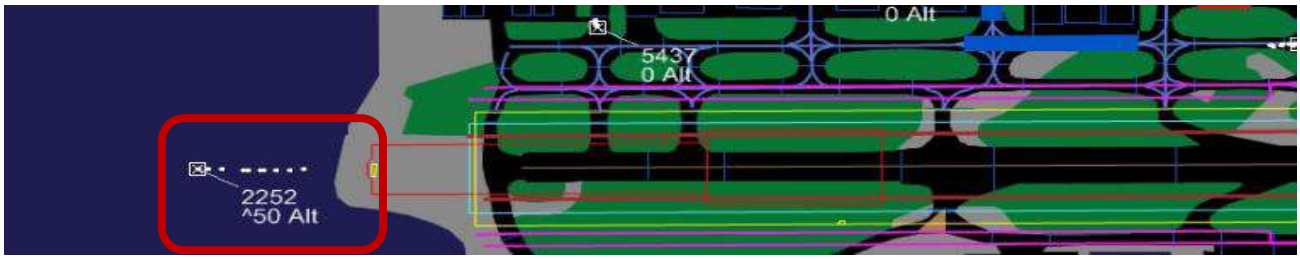


Figure 4(d): **JAI 117 (B77W) airborne**

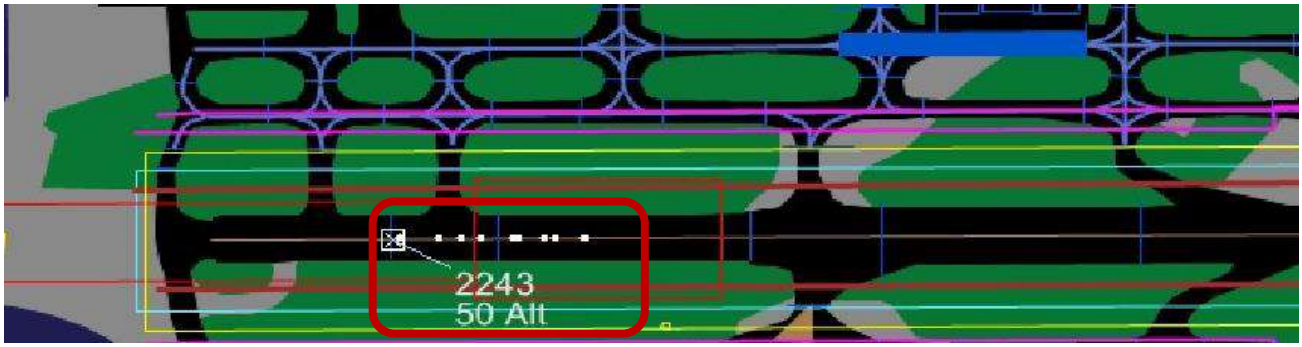


Figure 4(e): **JAI 121 (B77W) - another aircraft airborne**

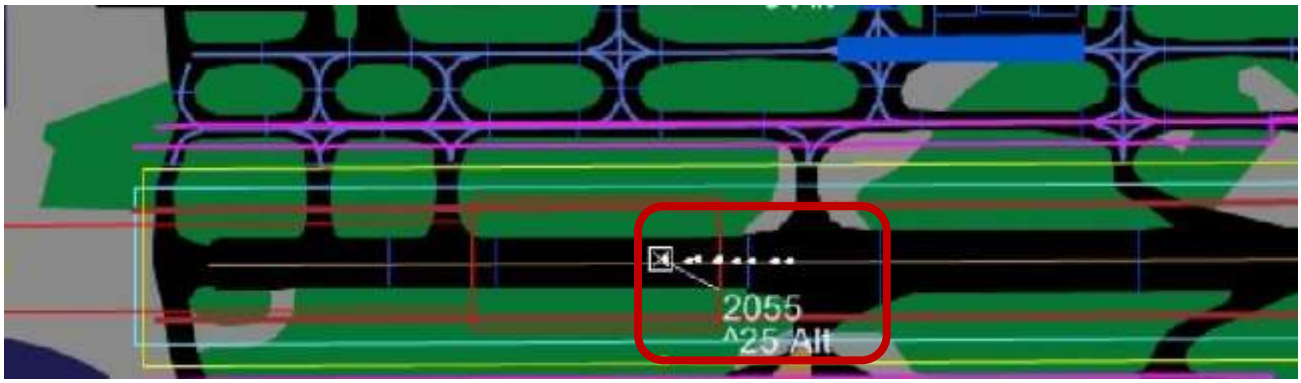


Figure 4(f): **AAR 552 (B772) airborne**

VIII. During the period of observation, only one other aircraft was observed to take the S4 intersection (an A320). Three other aircraft elected to cross to the north side for a full length departure, an A346, an A332 and another B77W belonging to the same operator as the subject aircraft.

IX. Using an ADS-B Multistatic Dependence Surveillance System (MDS) as its source, ASMGCS data is believed to be accurate to within 7.5m laterally however, height is reported

as pressure altitude and although reported by the system in 25ft intervals, accuracy could not be determined.

1.1.2 Information from the crew

As part of her pre-flight duties, the co-pilot used the aircraft's Electronic Flight Bag (EFB) On-board Performance Tool (OPT) to check whether the estimated takeoff weight was below the aircraft performance-limited maximum takeoff weight (MTOW) from intersection S4W. The calculation showed that the MTOW for a takeoff from S4W would be 318,646 Kgs using rated thrust (Figure 5). The takeoff weight was 296,885 Kgs and so a takeoff from S4W was not performance-limited.

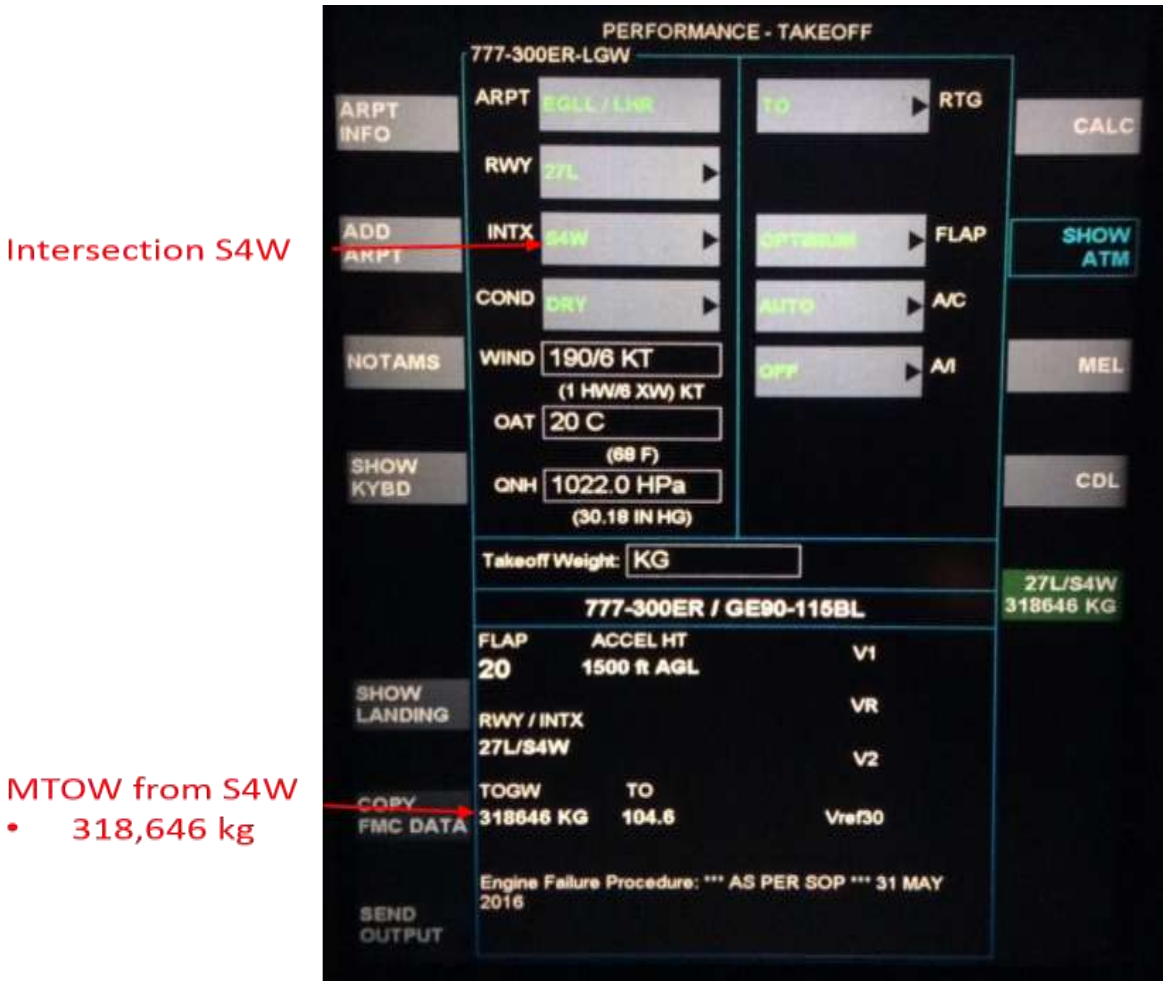


Figure 5: OPT calculation of MTOW from intersection S4W

When the load sheet arrived, each pilot ran the performance calculation again using the actual TOW to establish takeoff speeds and the thrust setting for the takeoff. When the crew cross-checked the output from their respective OPTs, however, it became apparent that the commander had calculated aircraft performance from the first four intersections on the north side of Runway 27L (NB1, NB2E, NB2W, and NB3 in Figure 1) whereas the co-pilot had used S4W. The commander had done this by selecting the "FIRST 4" option from the OPT intersection drop-down menu rather than using the "S4W" option (Figure 6). **The Co-Pilot changed the option in her OPT to match the commander's option and did not select S4W again.**

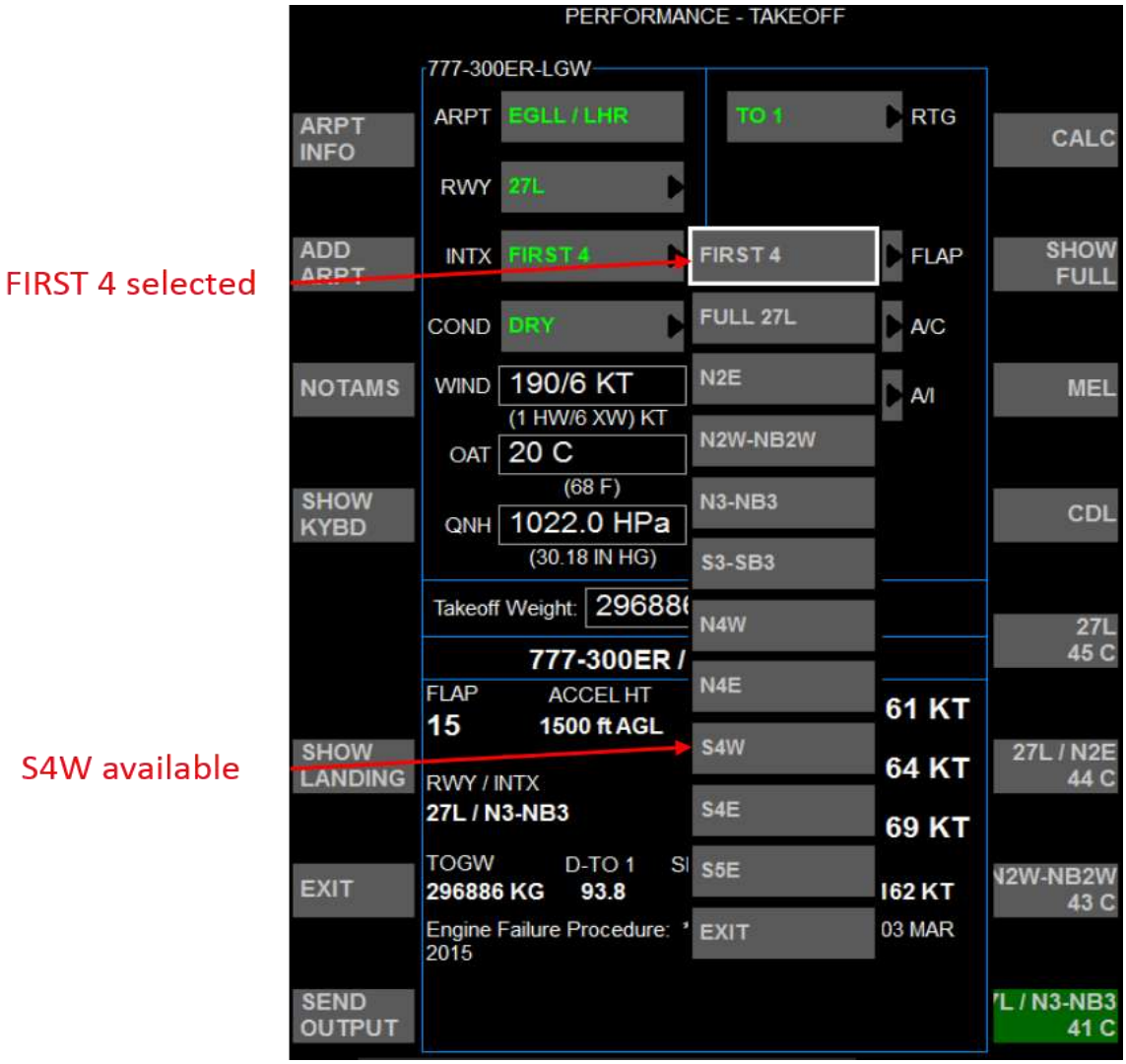


Figure 6: OPT drop-down menu for Runway 27L intersection

During the takeoff, as the aircraft approached Vr, the commander noticed the runway centreline lighting change from all-white to alternating red-and-white lights. This occurs with 900 m of runway remaining. The co-pilot commented that the commander's rate of rotation **"was a bit faster than normal".**

1.1.3 Takeoff performance – on-board calculation

1.1.3.1 Thrust management

Rated thrust is the maximum thrust that an aircraft's thrust management system will allow the engines to produce. Airliners regularly takeoff using thrust settings below rated thrust because doing so reduces engine servicing costs, increases engine life and improves engine reliability. Thrust management systems commonly use two methods to calculate and set reduced thrust:

a. De-rated thrust using fixed de-rate settings which, on the Boeing 777, are referred to as TO 1 or TO 2 (10% and 20% reduction from rated thrust respectively).
b. Assumed temperature method (ATM) whereby thrust is limited by assuming a temperature for the performance calculation which is higher than the actual outside air temperature. This temperature is shown as SEL TEMP on the OPT performance calculation output (Figure 7).

The EFB OPT calculates takeoff performance for a given set of aircraft and environmental conditions. The OPT may be used to calculate the maximum takeoff weight (MTOW) possible from a given runway/taxiway intersection (Figure 1). It may also be used to calculate optimum settings for thrust and flaps when the actual takeoff weight is known. In this case, it also calculates takeoff speeds V_1, V_R and V_2. Performance information is entered into the Flight Management Computer (FMC) through the keypad on the Control and Display Unit (CDU). The FMC commands the selected takeoff thrust when the TO/GA switch is pushed.

1.1.3.2 Takeoff performance calculation

The commander selected FIRST 4 on the EFB OPT and, although four performance calculations were performed by the OPT, the default output showed the result for a takeoff using the full length of the runway (Figure 7). The takeoff weight used for the calculation, obtained from the load sheet, was 296,886 kg and the weather used by the crew to calculate aircraft performance, obtained from ATIS N, was: wind from 190° at 6 kts, a temperature of 20°C and a QNH of 1022 hPa.

Figure 7: OPT output used for the takeoff

The calculation showed that, for a takeoff from the full length of Runway 27L, the takeoff power setting to be entered into the FMC was 'D-TO 1 SEL TEMP 45° C'. This corresponded to a reduction from rated power of 10% plus a further reduction entered into the FMC using an assumed temperature of 45°C.

The takeoff speeds were: V_1 = 163 kts, V_R = 167 kts and V_2 = 171 kts.

1.1.3.3 Takeoff performance – regulatory requirements

The takeoff distance required (TODR) on a dry runway is the longest of the following distances:

a. 115% of the distance with all engines operating from the start of the takeoff to the point at which the aeroplane is 35 ft above the runway (also known as the screen height).

b. The distance from the start of the takeoff point at which the aeroplane is 35 ft above the runway assuming failure of the critical engine occurs at a point corresponding to the decision speed (V_1).

1.1.4 The operator's SOPs

The operator's SOPs required a departure briefing to be given by the Pilot Flying (PF) as soon as practicable '*so as not to interfere with the final takeoff preparation'* (Annexure I). During the briefing the PF would review the ATIS and read aloud unspecified '*Takeoff Data inputs'* and the PM would verify that the same data was input on his/her OPT.

On receipt of the Load and Trim sheet (load sheet) the SOPs required crews to check that the TOW entered in the Control and Display Unit (CDU) was the same as the TOW on the load sheet, enter the TOW into the OPT, and select CALC to perform the performance calculation. There was no explicit requirement before selecting CALC to check whether any of the data entered at the time of the departure briefing had changed, such as the intersection being used for takeoff.

Once the OPT performance calculation was complete, the SOPs required the commander to read aloud the assumed temperature thrust setting (SEL TEMP), the flap setting and the takeoff speeds. The co-pilot was required to crosscheck the results, read out any discrepancies and enters the information into the CDU. There was no requirement for the commander to read aloud from the OPT the runway and intersection used for the performance calculation or the fixed de-rate setting e.g. D-TO 1 (Figure 7).

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	Nil	Nil	Nil
SERIOUS	Nil	Nil	Nil
~~MINOR~~/NONE	(02+13)	231	Nil

1.3 Damage to aircraft: Nil

1.4 Other damage: Nil

1.5 Personnel information

1.5.1 Pilot in command

Age	45 Yrs
License	ATPL
Date of License Issue and Valid up to	25/08/2009 & 24/08/2020
Category	Aero plane
Class	Multi Engine Land
Endorsements as PIC	B737-700/-800/-900, B777-300 ER
Date of FRTOL issue & validity	30/07/1992 to 09/09/2021
Date of Med. Exam & validity	11/04/2016 to 13/10/2016
Date of last Refresher/Simulator	14/03/2016
Simulator Training for Critical Emergencies	Last IR on 15/02/2016 & PPC on 10/08/2016.
Total flying experience	13436:57 Hrs
Total Experience on type	943:19 Hrs
Total Experience as PIC on type	943:19 Hrs
Total flying experience during last 01 Year	430:33 Hrs
Total flying experience during last 180 days	209:26 Hrs
Total flying experience during last 30 days	32:29 Hrs
Total flying experience during last 07 Days	21:39 Hrs
Total flying experience during last 24 Hours	09:19 Hrs
Rest period before the flight	23.58 Hrs

1.5.2 Co-pilot

Age	32Yrs
License	CPL
Date of License Issue and Valid up to	20/12/2007 & 19/12/2017
Category	Aero plane
Class	Multi Engine Land
Endorsements as PIC	B737-700/-800/-900, B777-300 ER
Date of Endorsement as PIC on type	N/A

Date of FRTOL issue & validity	20/12/2007 to 19/12/2017
Date of Med. Exam & validity	21/01/2016 to 08/10/2017
Simulator Training for Critical Emergencies	last IR on 20/05/2016 PPC on 19/02/2016.
Total flying experience	2446:50 Hrs
Total Experience on type	1198:26 Hrs
Total Experience as PIC on type	N/A
Total flying experience during last 01 Year	290:06 Hrs
Total flying experience during last 180 days	235:24 Hrs
Total flying experience during last 30 days	46:22 Hrs
Total flying experience during last 07 Days	15:12 Hrs
Total flying experience during last 24 Hours	09:19 Hrs
Rest period before the flight	23:58 Hrs

1.6 Aircraft information

The Boeing 777 is a family of long-range wide-body twin-engine jet airliners developed and manufactured by Boeing Commercial Airplanes. It is the world's largest twinjet and has a typical seating capacity of 314 to 396 passengers, with a range of 5,240 to 8,555 nautical miles (9,704 to 15,844 km). Commonly referred to as the "Triple Seven", its distinguishing features include the largest-diameter turbofan engines of any aircraft, six wheels on each main landing gear, fully circular fuselage cross-section, and a blade-shaped tail cone. Developed in consultation with eight major airlines, the 777 was designed to replace older wide-body airliners and bridge the capacity difference between Boeing's 767 and 747.

The aircraft is certified in Normal (Passenger) category, for day and night operation under VFR & IFR. The maximum operating altitude is 43100 feet and the maximum Laden weight (MTOW) is 337926 Kgs. The Aircraft length is 73.9 meters, wingspan is 64.8 meters and height of this aircraft is 17.9(minimum) to 19.7(maximum) meters. The distance between main wheels is 11 meters. The Engine Ground Clearance is 0.812(minimum) to 0.9398 (maximum) meters.

Boeing 700-300ER aircraft, VT-JEK (MSN 35165) had been manufactured in year 2008. The aircraft is registered under Category 'A' and the Certificate of registration No. 3708.The

Certificate of Airworthiness Number 4017/6790 under "NORMAL category" subdivision Passenger / Mail / Goods was issued by DGCA. The specified minimum operating crew is two and at the time of incident the Certificate of Airworthiness was current.

The Aircraft was holding a valid Aero Mobile License No. A-006/WRLO-08 at the time of serious incident. This aircraft was operated under Scheduled Operator's Permit No S-6A which was valid up to 12.02.2018. As on 30.08.2016, i.e. the day of serious incident, the aircraft's left and right engine's serial Number and hours/cycles logged are:

1. Right Hand (RH) Engine: ESN 906359 TSN/CSN 37863 hours / 4683 cycles
2. Left Hand (LH) Engine : ESN 906494 TSN/CSN 30300 hours / 3796 cycles

The B777-300ER aircraft and its engines are being maintained as per the maintenance programme consisting of calendar period/ flying hours or cycles based maintenance as per maintenance programme approved by Regional Airworthiness office.

Accordingly, the last major inspection C1 Check was done on 16/05/2016 and A24 Check was done on 17/08/2016. The aircraft was last weighed on 03/12/2012 and the weight schedule was prepared and duly approved by the office of Director of Airworthiness, DGCA. Prior to the incident flight the weight and balance of the aircraft was well within the operating limits. All the concerned Airworthiness Directive, mandatory Service Bulletins, DGCA Mandatory Modifications on this aircraft and its engine has been complied with as on date of serious incident.

1.7 Meteorological information:

An Aviation Routine Weather Report (METAR) was posted at 09:20 PM local time. The airplane lifted off at approximately time 09:36 PM local time (20:36 Greenwich Mean Time [GMT]). The METAR stated the following:

METAR EGLL 302020Z AUTO 20009KT 150V230 9999 NCD 19/12 Q1022 NOSIG

The METAR report indicated that the winds were on average from 200 degrees at 9 knots, varying between 150 to 230 degrees, with an unlimited ceiling. The wind data resolved into components when referenced to the runway heading (true heading = 270 degrees) would result in a 3-knot headwind and an 8-knot left crosswind. The temperature was reported as 19 degrees Celsius and the air pressure was 30.18 inches of Mercury (in Hg).

1.8 Aids to navigation

All the aids to navigation including Heathrow Delivery frequency (121.975 MHz), Heathrow Ground Frequency (121.700 MHz), Heathrow Aerodrome Control frequency (118.500 MHz) and SMGCS were reported working normal

1.9 Communications

During the period of occurrence, the aircraft JAI 117 (B77W) was in contact with Heathrow ATC on Aerodrome Control Tower frequency 118.500 MHz. There was always two way communications between the ATC and the aircraft.

1.10 Aerodrome information

Heathrow Airport (also known as London Heathrow Airport) (IATA: LHR, ICAO: EGLL) is a major international airport in London, United Kingdom. Heathrow is the second busiest airport in the world by international passenger traffic (surpassed by Dubai International in 2014), as well as the busiest airport in Europe by passenger traffic, and the seventh busiest airport in the world by total passenger traffic. In 2016, it handled a record 75.7 million passengers, a 1.0% increase from 2015. In the 1950s, Heathrow had six runways, arranged in three pairs at different angles in the shape of a hexagram with the permanent passenger terminal in the middle and the older terminal along the north edge of the field; two of its runways would always be within 30° of the wind direction. As the required length for runways has grown, Heathrow now has only two parallel runways running east–west. These are extended versions of the two east–west runways from the original hexagram.

The UK AIP lists the following declared distances for Runway 27L, which was the Runway in use on the day of serious incident as below:

Runway	TORA	TODA	ASDA	Remarks
27L	3658 m	3658 m	3658 m	3658 m
27L	2589 m	2589 m	2589 m	Take-off from intersection with S4E

1.11 Flight recorders

The Heathrow Advanced Surface Movement Guidance and Control System's (ASMGCS) radar recordings, the R/T transcripts of Heathrow Delivery, Ground and Tower controllers and DFDR/QAR data of the subject aircraft was analyzed for investigation purpose.

1.12 Wreckage and impact information

There was no damage to either of the aircraft or to any ground facilities.

1.13 Medical and pathological Information

The cockpit crew of M/s Jet Airways had undergone pre-flight medical check prior to the flight and the same was found to be negative.

1.14 Fire

There was no fire.

1.15 Survival aspects

The incident may or may not be survivable, had there been a rejected take off for any reason(s).

1.16 Tests and research Nil

1.17 Organizational and management information

M/s Jet Airways is an Indian registered Schedule airline. It operates scheduled flights to both domestic and international sectors. The Flight Safety Department is headed by Chief of Flight Safety approved by DGCA. M/s Jet Airways has a fully established Operations training facility for the pilots.

1.18 Additional information

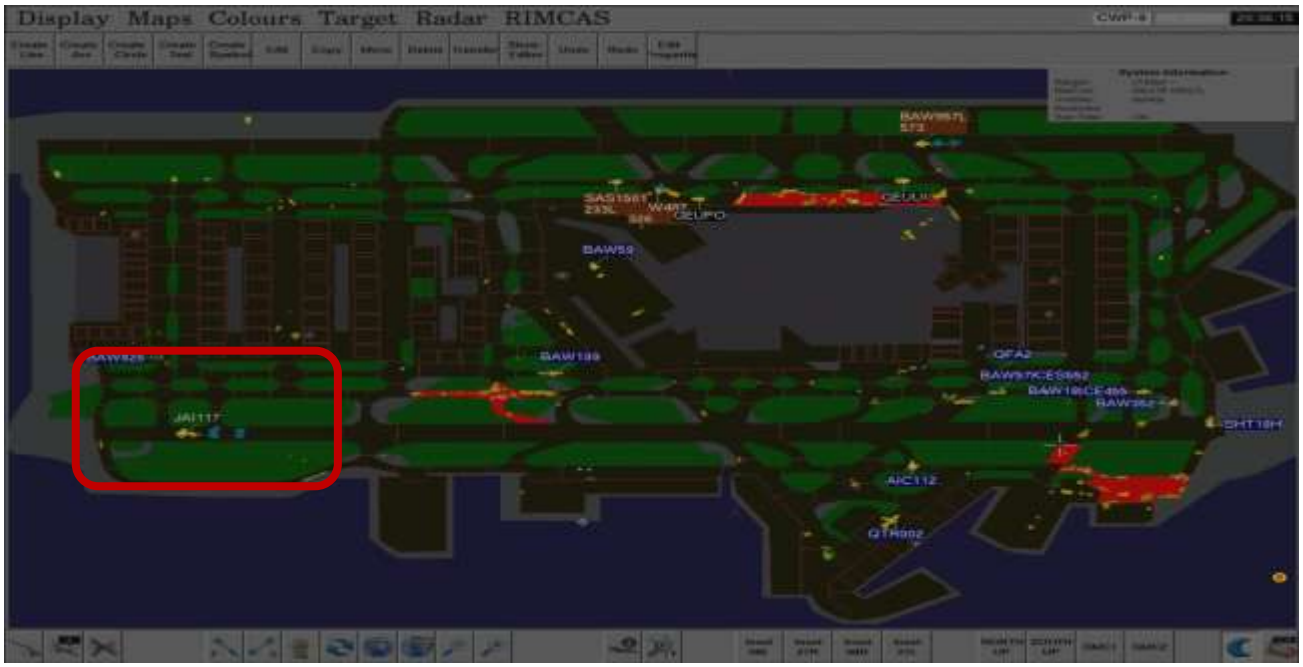


Figure 8: Heathrow ASMGCS Radar Display showing JAI 117

1.19 Useful and Effective Techniques Nil

2. ANALYSIS

2.1 Takeoff performance

M/s Jet Airway's aircraft took off from intersection S4E on Runway 27L using performance information (power setting, flap setting and takeoff speeds) appropriate for a takeoff from intersection N1 (full length). ***The manufacturer found that, for the aircraft to meet all regulatory performance requirements, the takeoff distance required was 3,349 m whereas the takeoff distance available from intersection S4E was 2,589 m.*** The aircraft lifted off within the takeoff distance available but:

a. Did not meet regulatory requirements for the all-engine, continued takeoff case.
b. Would not have been able to reject the takeoff and stop in the runway remaining following an engine failure just below V_1.
c. Would not have been able to continue the takeoff while meeting regulatory requirements following an engine failure just above V_1.

2.2 Boeing's Analysis:

2.2.1 QAR Data Analysis

The provided QAR data are non-time-aligned, which means that each parameter has lost its original timestamp. These data are buffered and output in "clusters" of data, corresponding to common sample rates. Then, post-processing tools evenly distribute the data samples throughout each sample interval (one second in this dataset) based on sample rate, without knowledge of when that event actually occurred on the airplane. For example, a parameter that is recorded at 4 samples per second (sps) will have the recorded data points evenly distributed at 0.0, 0.25, 0.5, and 0.75 seconds within a given second. As a result, there may be an error in time when comparing recorded data points to GMT and to other parameters. Thus, caution should be exercised when interpreting these data.

Time history plots of the pertinent longitudinal and lateral-directional parameters are attached in Annexure II [page i to vi]. The QAR data show the airplane configured for a flaps 15 takeoff, at a takeoff gross weight of 654,080 pounds (LB) [Annexure II], and center of gravity of 31%. The stabilizer was positioned at -2 degrees which was within the takeoff green band. The certified maximum takeoff weight is 745,000 LB. The takeoff runway was Runway 27L (RWY 27L) at LHR based on the recorded latitude/longitude coordinates (not shown) and magnetic heading (Annexure II). The throttles were advanced from the forward idle position at time 1230 seconds and the engines began to spool up. The airplane turned to the left and was aligned with the runway heading by time 1231 seconds (Annexure II). Around the time of auto throttle engagement at time 1237 seconds, the engines stabilized at approximately 55% N1 before spooling up to the takeoff N1 of 92.2% by time 1243 seconds (Annexure II). The takeoff thrust was de-rated as indicated by a DERATE_1_TM discrete (not shown). Rotation was initiated at approximately time 1273.5 seconds with a slight pull of the column at a computed airspeed of 165 knots (Annexure II). The rotation speed (VR) was recorded at 167 knots. At time 1274.5 seconds, while still on ground, a more aggressive pull of the column occurred and the airplane pitch attitude started to increase. The airplane lifted off at approximately time 1278.5 seconds, as indicated by the main gear tilt discrete parameters transition to TILT, at a pitch attitude of approximately 8 degrees and computed airspeed of 180 knots (Annexure II). The airplane reached a climb rate of approximately 2500 feet/minute at time 1287.5 seconds and maintained a

pitch attitude of 14 degrees. Just after liftoff, the bank angle was maintained at near wings level (Annexure II) until a left turn was initiated at time 1302 seconds (Annexure II).

2.2.2 Ground Track Analysis

A ground track was generated to show the airplane's path during the takeoff roll and initial climb out (Annexure II). RWY 27L has a length of 12,001 feet and a width of 164 feet. Longitudinal and lateral distances were calculated using the recorded inertial data: ground speed, drift angle, and heading. The distances were then referenced to the runway based on the airplane's turn onto the runway from Taxiway S4E. The airplane was estimated to have aligned with the runway centerline at 4000 feet beyond the runway threshold (8001 feet of runway remaining).

The ground track shows the airplane entering RWY 27L from Taxiway S4E. The analysis indicates that the takeoff was initiated at a distance of approximately 4286 feet beyond the runway threshold (7715 feet of runway remaining) at auto throttle engagement and the engines spooled up to the takeoff N1 of 92.2% at 4600 feet beyond the runway threshold. Rotation initiation occurred just prior to VR at 10,185 feet beyond the threshold and liftoff occurred at approximately 11,690 feet beyond the threshold. As the airplane climbed over the end of the runway, at 12,001 feet beyond the runway threshold, the center radio altitude parameter (shown on plot) was at 16.4 feet. The other two radio altimeter parameters, left and right (not shown), had values of approximately 16.6 feet and 17 feet, respectively. At the perimeter road, which was approximately 13,215 feet beyond the runway threshold, the center radio altitude parameter and left radio altitude were both at a value of approximately 112 feet and the right radio altitude value was 118 feet.

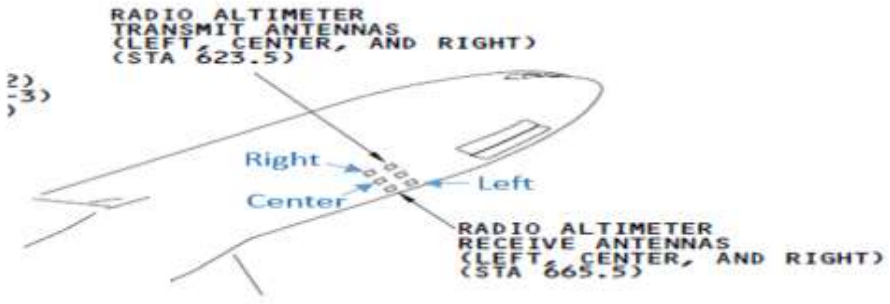


Figure: 9 showing Radio Altimeter Parameter

Annexure II shows the QAR recorded latitude and longitude data (in yellow) on a Google Earth image of LHR starting at push back from the terminal through the takeoff roll and liftoff. The data confirmed that the airplane taxied onto RWY 27L using Taxiway S4E.

2.2.3 Performance Analysis

The outside air temperature (OAT) at the time of the event was reported by the METAR as 19 degrees Celsius (66 degrees Fahrenheit) with a pressure of 30.18 in Hg. The pressure altitude recorded by the QAR was -140 feet just prior to the takeoff. The reported OAT used by the crew from the load sheet was 20 degrees Celsius with a pressure of 30.18 in Hg. A performance analysis of the required field length was produced using the following parameters for the takeoff conditions of the event: METAR reported winds, OAT of 19 degrees Celsius, and a runway pressure altitude of -140 feet. The analysis indicated that the climb limited takeoff weight was 653,640 LB, which is approximately 400 LB lower than the recorded takeoff weight. The climb limited weight was close enough to the recorded takeoff weight and can be accounted for by adjusting the conditions (temperature, runway pressure altitude, etc.) slightly. The analysis resulted in a required field length for dispatch of approximately 11,000 feet and is based on a balanced decision speed (V1). The actual (non-factored) all-engine go takeoff distance would be 8472 feet with a calculated distance to liftoff of 7393 feet. The actual takeoff distance for an engine-out case would be 9828 feet with a calculated distance to liftoff of 8094 feet.

The ground track analysis (Annexure II) shows that the takeoff was initiated at approximately 4286 feet beyond the runway threshold, which left 7715 feet of runway available (RWY 27L = 12,001 feet). ***Liftoff occurred approximately 7404 feet from takeoff initiation (11,690 feet from the runway threshold), just 311 feet from the end of the runway.*** To meet the required runway field length for dispatch, ***the takeoff run should have started no farther than approximately 1001 feet from the runway threshold. The airplane did not meet the 35 feet screen height requirement when crossing the end of the runway and would not have had enough runway distance available to perform a rejected takeoff (RTO).***

Boeing concluded that ***the very low takeoff was the result of using Taxiway S4E onto RWY 27L which did not allow for enough runway distance available for the takeoff to meet the takeoff performance requirements at the takeoff thrust setting. The center radio altimeter showed the***

airplane at an altitude of 16 feet at the end of the runway and at 112 feet radio altitude at the airport perimeter road which was 13,215 feet from the threshold of RWY 27L.

2.3 UK CAA Air Traffic Services Investigation

The UK CAA Air Traffic Services Investigation (ATSI) unit carried out an investigation into this event using information from the **Heathrow Noise Monitoring System (ANOMS)**. Data from ANOMS suggested that the aircraft might have been below 30 ft agl when beyond the paved surface of Runway 27L in an area containing obstacles up to 31 ft (Figure 10). ***[The ANMOS height data is not as accurate as the information supplied by Boeing. That is why the Boeing data was used in the AAIB final report and not the ANMOS data when showing the height at which the aircraft crossed the end of the runway.]***

Figure 10: Aircraft height given by ANOMS and obstacles to the west of Runway 27L(UK AIP)

A comparison of ANOMS height information with aircraft-derived Mode S ADS-B data, taken from an earlier study, estimated the accuracy of ANOMS height information to be '*no worse than ±55 ft'*. The ATSI report made the following recommendation:

> ***'A risk assessment [should] be considered jointly by both the Heathrow Aerodrome Authority and NATS ATC on the likelihood and impact of a similar incident reoccurring, with a view to revising the usage of intersection departures for aircraft above a certain size'.***

2.4 The operator's SOPs

The operator's SOPs required a departure briefing to be given by the Pilot Flying (PF) as soon as practicable '*so as not to interfere with the final takeoff preparation'*. During the briefing the PF would review the ATIS and read aloud the '*takeoff data inputs',* and the PM would verify that the same data was input on his/her OPT.

On receipt of the Load and Trim sheet (load sheet) the SOPs required crews to carry out the procedure shown in Annexure I. A crew would ensure that the TOW entered in the Control and Display Unit (CDU) was the same as the TOW on the load sheet, enter the TOW into the OPT, and select CALC to perform the performance calculation. There was no explicit requirement before selecting CALC to check whether any of the data entered at the time of the departure briefing had changed, such as the intersection being used for takeoff. There was, however, a requirement to '*Individually check EFB calculation'* and call out any discrepancies.

After the pilots checked their own OPT calculation, the captain would read aloud the OPT output while the First Officer entered the information into the CDU.

Company SOPs separated the calculation of aircraft takeoff performance into two discrete procedures without an explicit check that data entered during the first procedure (the departure briefing) was still valid and appropriate during the second (after receipt of the load sheet).The operator confirmed that, after the crew selected FIRST 4 on the OPT, although four performance solutions were available corresponding to the first four intersections, the default output was used to programme the CDU for departure. The default output provided performance information for a departure from N1 (Runway 27L full length).The operator reviewed its SOPs and concluded that they did not trap data input errors e.g. using the incorrect runway intersection or environmental conditions, or selecting the incorrect thrust de-rate. It issued SOP Revision 1 on 1st September 2016 to address these deficiencies.

3. CONCLUSIONS

3.1 Findings

1. The medical of both the cockpit crew members of Jet Airways, JAI117 was valid. The crew of Jet Airways JAI117 has undergone pre-flight medical checks including BA test which was negative.
2. At 2010 hrs the co-pilot contacted Heathrow Delivery stating that she had ATIS Information N. ATIS N stated that SB3 was closed but S4 was available for departure.

After receiving the flight's departure clearance, she was asked ***"DO YOU REQUIRE THE FULL LENGTH OF THE RUNWAY FOR DEPARTURE?"*** The co-pilot replied ***"NEGATIVE, SIERRA FOUR ACCEPTABLE"*** and was told to expect a "SIERRA FOUR ECHO INTERSECTION DEPARTURE". At 2012 hrs, VT-JEK was cleared to push back from stand 407 and start engines after which it taxied to holding point S4E. VT-JEK was cleared to takeoff from S4E at 2034 hrs.

3. VT-JEK took off from runway intersection S4, as briefed by the crew, but used performance figures calculated for intersection N1 (Runway 27L full length). Consequently, regulatory takeoff performance requirements were compromised.
4. Heathrow ATC correctly verified that the pilot of subject aircraft could accept an intersection departure, and that position was mentioned a total of 7 times by ATC and correctly read back by the pilot on each occasion.
5. Sufficient information had been published by the Aerodrome Authority on the non-availability of full-length departures from the southern holding points for Runway 27L.
6. For an all-engine go takeoff, at the event conditions, the estimated required field length would be 9387 feet with distance to liftoff at 8222 feet. The Airplane Flight Manual (AFM) distance to V1 was 6578 feet. If a RTO was initiated at V1, there would be 2809 feet of runway available for stopping.
7. For a balanced V1, one engine inoperable (OEI), the required field length would be 10,989 feet at the event conditions. The AFM distances to V1 was 6634 feet and to liftoff was 9020 feet. The climb performance with an engine inoperative is 2.4%.
8. After reviewing the ATIS, the Departure Briefing SOP required the crew to read out '*Takeoff Data inputs'* before entering those data into the OPT, but the procedure did not specify which '*Takeoff Data inputs'* were required and there was no requirement to nominate the runway or intersection to be used. The SOP following receipt of the load sheet ensured that the OPT based its takeoff performance calculation on the actual, rather than estimated, TOW but there was no explicit step to check that data input as part of the departure briefing was still valid or appropriate to the current circumstances. From a procedural perspective, there appeared to be no assurance that an incorrect or invalid entry into the OPT made at the departure briefing would be corrected before the performance calculation was made.

9. The commander calculated aircraft takeoff performance from the first four intersections of Runway 27L (***using the default OPT output corresponding to the full length***), whereas the co-pilot calculated performance (correctly) for a takeoff from intersection S4W. Even though there was no requirement to read aloud the runway and intersection used by the OPT for the performance calculation, the discrepancy was nevertheless identified during the post-calculation crosscheck of OPT output. This provided an opportunity for the crew to agree the correct intersection but the co-pilot changed her OPT entry to match that of the commander and the opportunity was lost probably due to the fact that Commander was much senior to the Co-pilot.
10. It is the responsibility of the pilot to determine the suitability of an intersection departure for their aircraft and none of the subject Pilots have ever departed from SW4 intersection departure before the day of the serious incident.
11. The available evidence suggests that the departing aircraft completed a late rotation which, in comparison with previous departures of similar aircraft types, placed it at a significantly lower height as it left the airfield.
12. The aircraft manufacturer carried out an analysis of the takeoff using data from the aircraft's Quick Access Recorder (QAR) and the environmental conditions used by the crew for the performance calculation.
13. After the TO/GA switch was pressed, the auto throttles increased engine rpm to the reference value of 92.2% N1 (this value is shown in Figure 7 beneath 'D-TO 1'). The pilot began to rotate the aircraft at 165 kt with a slight pull of the control column followed by a 'more aggressive' pull one second later. The aircraft lifted off the runway at 180 kts.
14. The manufacturer calculated that ***rotation was initiated with 556 m of runway remaining and lift off occurred with 97 m remaining***. As the aircraft passed the end of the runway, the three radio altimeters recorded heights above the surface of 16.4 ft, 16.6 ft and 17 ft respectively.
15. The manufacturer's performance analysis indicated that, for the actual takeoff weight and environmental conditions of the day:

a. *The **Takeoff Distance Required (TODR) was 3,349 m**. The Takeoff Distance Available **(TODA) was 2,589 m** for a departure from S4E (3,658 m for a takeoff using the full length of the runway*). **(i.e.760 meters of runway was short for the departure)**

   Note: TODR includes the distance it takes for the aircraft to climb to 35 ft agl.

b. The aircraft did not meet the 35 ft screen height requirement at the end of the runway.

c. The aircraft would not have enough runway distance available to perform a rejected takeoff manoeuvre (RTO) from close to V_1.

16. The manufacturer concluded that the use of a power setting appropriate for a takeoff using the full length of Runway 27L, while actually taking off from intersection S4E, 'did not allow for enough runway distance available for the takeoff to meet the takeoff performance requirements'.

17. ***M/s Boeing also concluded that the center radio altimeter showed the airplane at an altitude of 16 feet at the end of the runway and at 112 feet radio altitude at the airport perimeter road which was 13,215 feet from the threshold of RWY 27L.***

18. The SOPs required a crosscheck of OPT output, which revealed that different performance calculations had been carried out. However, the crew did not resolve why they had selected different intersections for the calculation, thereby preventing the error from being trapped. Data validation immediately before the performance calculation might have prevented the two pilots from calculating takeoff performance from different intersections.

19. Following the serious incident, the operator amended its SOPs to make it more likely that data-entry errors would be noticed.

3.2 Probable cause of the Serious Incident

Wrong selection of aircraft take- off performance by the Commander despite the Co-pilot selecting the right take-off performance initially but the commander overruled her take-off performance selection.

3.3 Contributory Factors

The first time initiation of **SW4 intersection departure** by the crew (both Commander and Co-pilot).

4. SAFETY RECOMMENDATIONS

1. M/s Jet Airways (India) Limited to amend its Standard Operating Procedure for "*Departure Briefing*" to specify the takeoff data to be input into the Electronic Flight Bag On-board Performance Tool.
2. M/s Jet Airways (India) Limited to amend its Standard Operating Procedure for "*On receipt of Load and Trim sheet*" to ensure that:
   a) Before the performance calculation is made, data entered into the Electronic Flight Bag On-board Performance Tool is valid and appropriate to the current circumstances.
   b) The runway and intersection used for the performance calculation, and the power setting required for the takeoff, are read aloud from the OPT and crosschecked.
3. M/s Jet Airways (India) Limited to require its crews to call out and resolve discrepancies identified between the output of the commander and co-pilot's Electronic Flight Bag On-board Performance Tool before entering data into the Control and Display Unit.
4. The crew shall be imparted corrective training on CRM, simulator similar exercise besides theory classes for the intersection takeoff.
5. All the crews of M/s Jet Airways and other Indian airlines shall undergo one simulator exercise of this sort during next simulator training.

22.02.18.

(Raje Bhatnagar)
Assistant Director, AAIB
Member, CoI to VT-JEK

(Dr. Jitender Loura)
Assistant Director, AAIB
Chairman, CoI to VT-JEK

Place: New Delhi
Date: 22/02/2018

Annexure- 1

Operator's SOP for the Departure Briefing

Departure Briefing - PF

The Departure briefing shall be completed as soon as practicable, so as not to interfere with the final takeoff preparation. The briefing shall include the following:

EFB OPT TAKE OFF DATA	Review ATIS & Read out Take off Data inputs. PM verifies that same data is input on his/her OPT
TAXI*	Expected Taxi Route & Holding Point NOTAMS if any.
SID	Chart Briefing, FMC & MCP Settings NADP, if any.
REJECT TAKE OFF	Review Procedure
EVACUATION	Review Procedure
ENGINE FAILURE AFTER V1	Review Procedure, Thrust management in case of Derate Take Off. Special EO.
AIR TURN BACK	Discuss strategy vis a vis fuel Jettison/ Overweight Ldg. Checklist

Additional briefing items may be required when applicable. These may include:

ADVERSE WEATHER	LVP Taxi , LVTO if required , Anti-ice use Review Windshear Recovery
MEL/CDL	Effect on Operation of the Flight
DGR/ PERISHABLE CARGO	ERG Brief, Cargo Compartment Temp. setting
OBSERVER BRIEFING	Task sharing during normal and non normal operations

Operator's SOP after receipt of the Load and Trim sheet

On receipt of Load and Trim sheet,

Log the time of receipt of trim sheet

Log the time of receipt of "All On Board" report from ground staff and Cargo Doors Closed (OM A 8.1.8.3.2.)

Captain	First Officer
ZERO FUEL WEIGHT(L&T)- Read out aloud	ZERO FUEL WEIGHT Enter into FMC CDU
TAKE OFF WEIGHT(L&T)- Read out aloud	Crosscheck with GROSS WEIGHT on FMC CDU
TAKE OFF WEIGHT Enter into EFB OPT TOW box and Select CALC *	TAKE OFF WEIGHT Enter into EFB OPT TOW box and Select CALC*
CG(L&T) - Read out aloud	CG –Enter into CDU CRUISE CG- Enter into CDU (obtained by subtracting 10 from CG)
Individually check EFB Calculation **	Individually check EFB Calculation**
SEL TEMP, FLAPS AND V SPEEDS(EFB OPT)- Read out aloud from OPT	SEL TEMP, FLAPS AND V SPEEDS (EFB OPT)- Crosscheck on OPT** Enter into CDU

* If due to equipment unavailability, only one takeoff calculation is possible, then the parameters used for calculation must be checked by the other crew member.

** Call out discrepancies, if any.

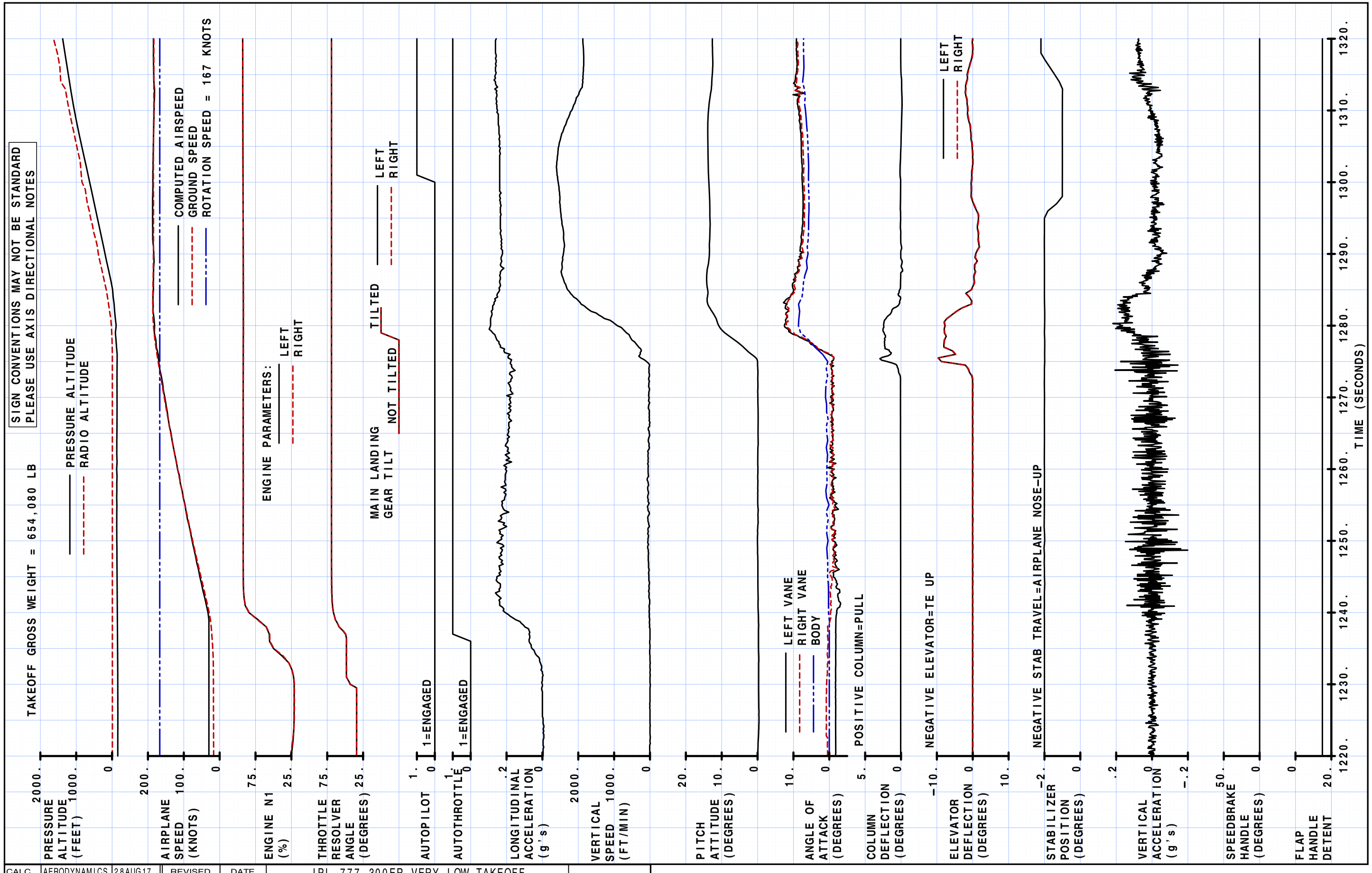
First officer shall record all applicable data into OFP Take Off Page.

Take Off Data : Briefing format

Captain	First Officer
	Select THRUST LIM page Read out from CDU
VERIFY T/O N1, SEL TEMP . against OPT data	TO MAX OR DERATE 10 SELECT TEMPERATURE_____
Verify PACK config. If 'APU to PACK', then verify APU mode armed	PACKS ON/OFF OR APU TO PACK
Verify N1 against OPT data	N1 _____ CLB 1 OR CLB2 ARMED Select TAKEOFF Page
Verify FLAP Setting against OPT Data Verify V1, VR, V2 against OPT Data Verify ACCL HT against OPT Data	FLAPS_____ V1___VR___V2____ STAB_UNITS Select next page ACCELERATION HT_____FT
Announce " TAKEOFF DATA CONFIRMED"	

Annexure –II

Page i - vi



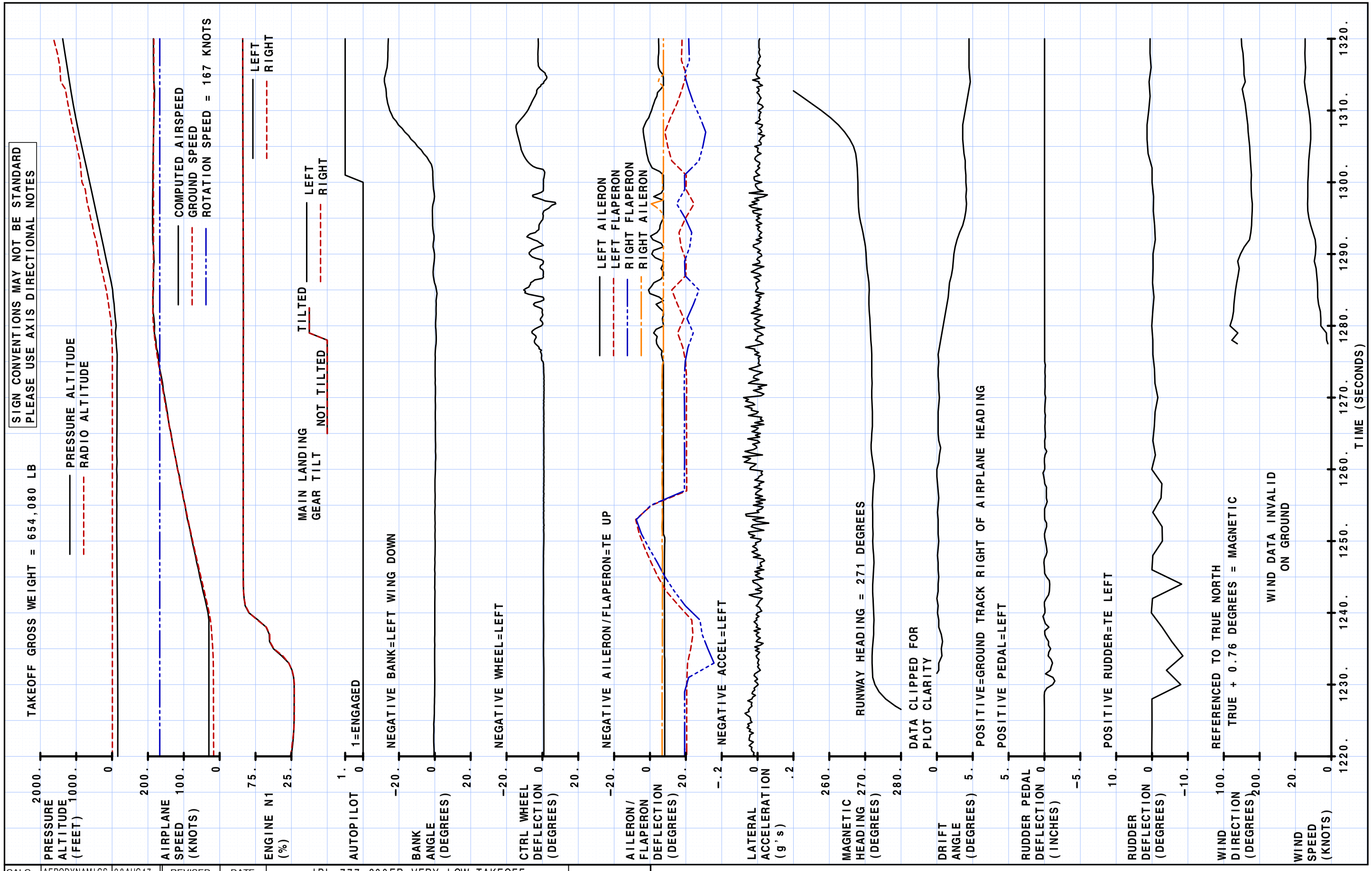
CALC	AERODYNAMICS	28AUG17	REVISED	DATE	JPL 777-300ER VERY LOW TAKEOFF 30AUG2016 -- NON-TIME-ALIGNED QAR DATA LONGITUDINAL PARAMETERS
CHECK					
APPD					
APPD					

WD770/VT-JEK

FIGURE 1

BOEING PROPRIETARY

THE BOEING COMPANY



CALC	AERODYNAMICS	28AUG17	REVISED	DATE
CHECK				
APPD				
APPD				

JPL 777-300ER VERY LOW TAKEOFF
30AUG2016 -- NON-TIME-ALIGNED QAR DATA
LATERAL-DIRECTIONAL PARAMETERS

WD770/VT-JEK

FIGURE 2

BOEING PROPRIETARY

THE BOEING COMPANY

SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES

TAKEOFF GROSS WEIGHT = 654,080 LB

PRESSURE ALTITUDE (FEET): 300. / 100. / -100.
- PRESSURE ALTITUDE
- RADIO ALITITUDE

AIRPLANE SPEED (KNOTS): 190. / 170. / 150.
- COMPUTED AIRSPEED
- GROUND SPEED
- ROTATION SPEED = 167 KNOTS

ENGINE N1 (%): 100. / 90.

THROTTLE RESOLVER ANGLE (DEGREES): 75. / 65.
ENGINE PARAMETERS: LEFT, RIGHT

MAIN LANDING GEAR TILT: 1. / 0
TILTED
NOT TILTED
LEFT
RIGHT

AUTOPILOT: 1. / 0 — 1=ENGAGED

AUTOTHROTTLE: 1. / 0 — 1=ENGAGED

LONGITUDINAL ACCELERATION (g's): .2 / 0

VERTICAL SPEED (FT/MIN): 2000. / 1000. / 0

PITCH ATTITUDE (DEGREES): 20. / 10. / 0

ANGLE OF ATTACK (DEGREES): 10. / 0
- LEFT VANE
- RIGHT VANE
- BODY

COLUMN DEFLECTION (DEGREES): 5. / 0 — POSITIVE COLUMN=PULL

ELEVATOR DEFLECTION (DEGREES): -10. / 0 / 10. — NEGATIVE ELEVATOR=TE UP
LEFT
RIGHT

STABILIZER POSITION (DEGREES): -2. / 0 — NEGATIVE STAB TRAVEL=AIRPLANE NOSE-UP

VERTICAL ACCELERATION (g's): .2 / 0 / -.2

SPEEDBRAKE HANDLE (DEGREES): 50. / 0

FLAP HANDLE DETENT: 20. / 0

1270. 1272. 1274. 1276. 1278. 1280. 1282. 1284. 1286. 1288. 1290.
TIME (SECONDS)

CALC	AERODYNAMICS	28AUG17	REVISED	DATE
CHECK				
APPD				
APPD				

JPL 777-300ER VERY LOW TAKEOFF
30AUG2016 -- NON-TIME-ALIGNED QAR DATA
LONGITUDINAL PARAMETERS - ZOOM-IN

WD770/VT-JEK

FIGURE 3

BOEING PROPRIETARY

EXPORT CONTROLLED ECCN: 9E991

BOEING PROPRIETARY

JPL 777-300ER VERY LOW TAKEOFF
30AUG2016 -- NON-TIME-ALIGNED QAR DATA
LATERAL-DIRECTIONAL PARAMETERS - ZOOM-IN

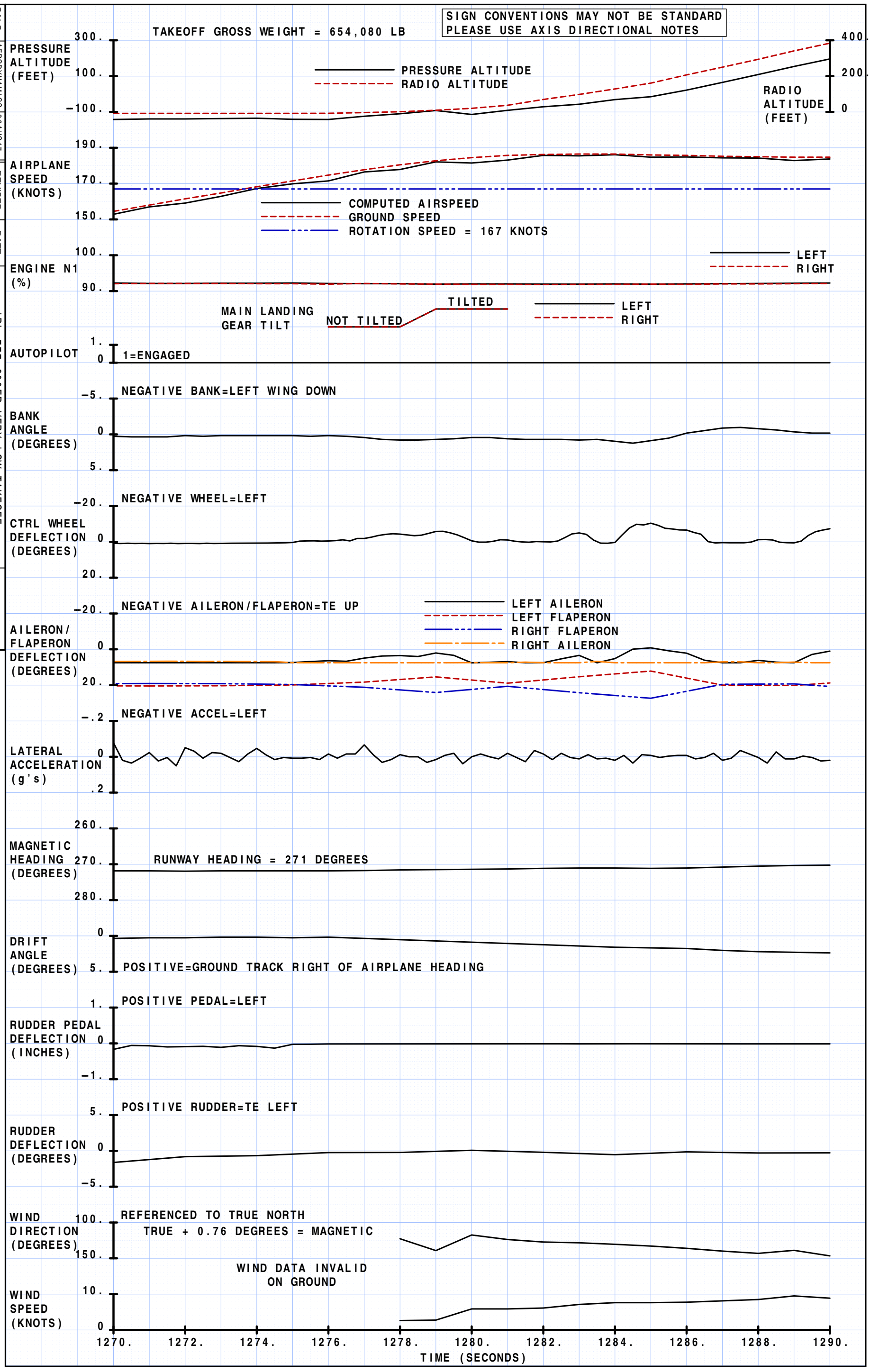
	CALC	AERODYNAMICS	28AUG17
APPD	CHECK		
APPD	APPD		
		REVISED	
		DATE	

WD770/VT-JEK

FIGURE 4

PAGE

THE BOEING COMPANY



THE BOEING COMPANY

SIGN CONVENTIONS MAY NOT BE STANDARD
PLEASE USE AXIS DIRECTIONAL NOTES

TAKEOFF GROSS WEIGHT = 654,080 LB

RADIO ALTITUDE (FEET) 200. 150. 100. 50. 0

MAIN LANDING GEAR TILT — NOT TILTED / TILTED — LEFT — RIGHT

112 FEET

16 FEET

AIRSPEED (KNOTS) 200. 100. 0

COMPUTED AIRSPEED
GROUND SPEED
ROTATION SPEED = 167 KNOTS

ENGINE N1 (%) 75. 25.

ENGINE PARAMETERS: LEFT — RIGHT

THROTTLE RESOLVER ANGLE (DEGREES) 70. 60. 50. 40. 30. 10.

A/T ENGAGED

PITCH ATTITUDE (DEGREES) 0

COLUMN DEFLECTION (DEGREES) 5. 0 — POSITIVE COLUMN=PULL

ELEVATOR DEFLECTION (DEGREES) −10. 0 — NEGATIVE ELEVATOR=TE UP — LEFT — RIGHT

VERTICAL SPEED (FEET/MIN) 2000. 0

TAXIWAYS: S1 S3 S4E S4W S5E S5W S6 S7 S11

END OF RUNWAY

AIRPORT PERIMETER ROAD

CALCULATED LATERAL DEVIATION FROM RWY CENTERLINE (FEET) −200. −100. 0 100.

−1000. 0 1000. 2000. 3000. 4000. 5000. 6000. 7000. 8000. 9000. 10000. 11000. 12000. 13000. 14000. 15000.

CALCULATED LONGITUDINAL DISTANCE FROM RWY 27L THRESHOLD (FEET)

CALC	AERODYNAMICS	11AUG17	REVISED	DATE
CHECK				
APPD				
APPD				

JPL 777-300ER VERY LOW TAKEOFF
30AUG2016 -- NON-TIME-ALIGNED QAR DATA
GROUND TRACK ANALYSIS

WD770/VT-JEK

FIGURE 5

BOEING PROPRIETARY

REV

EXPORT CONTROLLED ECCN: 9E991

PAGE

CALC	AERODYNAMICS	11AUG17	REVISED	DATE	JPL 777-300ER VERY LOW TAKEOFF 30AUG2016 -- NON-TIME-ALIGNED QAR DATA GOOGLE EARTH MAP - LATITUDE/LONGITUDE	WD770/VT-JEK
CHECK						FIGURE
APPD					**BOEING PROPRIETARY**	6
APPD						