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AAIA

Air Accident Investigation Authority

Deviation from Intended Flightpath Inflight

Investigation Report

Serious Incident to

Boeing 787-8, ET-ASG

Waypoint RIVER of Hong Kong

18 July 2019

03-2023

AAIA Investigations

Pursuant to Annex 13 to the Convention on International Civil Aviation (Annex 13) and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Cap. 448B), the sole objective of the investigation and the Investigation Report is the prevention of accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

The Chief Inspector ordered an inspector's investigation into the serious incident in accordance with the provisions in Cap. 448B.

This serious incident Investigation Report contains information of an occurrence involving a Boeing 787-8 aircraft, registration ET-ASG, operated by Ethiopian Airlines, which occurred on 18 July 2019.

The Ethiopian Accident Investigation Bureau of Ethiopia (EAIB), being the investigation authority representing the State of Operator and the State of Registry, the National Transportation Safety Board of the United States of America (NTSB) being the investigation authority representing the State of Design and the State of Manufacture, the Civil Aviation Department of Hong Kong (CAD), Boeing and the aircraft operator, provided assistance to the investigation.

Unless otherwise indicated, recommendations in this report are addressed to the regulatory authorities of the State or Administration having responsibility for the matters with which the recommendation is concerned. It is for those authorities to decide what action is taken.

This Investigation Report supersedes all previous Preliminary Report and Interim Statements concerning this serious incident investigation.

All times in this Investigation Report are in Hong Kong Local Times unless otherwise stated.

Hong Kong Local Time is Coordinated Universal Time (UTC) + 8 Hours (hrs).

Chief Accident and Safety Investigator
Air Accident Investigation Authority
Transport and Logistics Bureau
Hong Kong
March 2023

Synopsis

At 2351 hrs on 18 July 2019, an Ethiopian Airlines Boeing 787-8 aircraft, with registration ET-ASG and flight number ETH 645, deviated from the Localizer (LOC) course during an Instrument Landing System (ILS) approach to Hong Kong International Airport (VHHH).

During the ILS approach to the then Runway (RWY) 25R[1] of VHHH, the aircraft with the autoflight system engaged, while intercepting the LOC, overshot and diverged from the LOC course towards the terrain in the north. It also descended below the Minimum Sector Altitude (MSA) of 4,300 feet (ft) until Air Traffic Control (ATC) instructed it to go around. No Enhanced Ground Proximity Warning System (EGPWS) warnings were triggered.

Following the go-around and the second approach to the same RWY, the aircraft landed uneventfully. There was no damage to the aircraft and no one was injured.

The investigation team found that this serious incident was caused by a software problem embedded in the flight control module (FCM) of the autoflight director system.

[1] Under the Three-runway system (3RS) Project, a new RWY to the north of and parallel to the original duel RWYs was being constructed at VHHH at the time of the incident. The original North RWY (RWY 07L/25R) was re-designated as the Centre RWY (RWY 07C/25C) on 2 December 2021, to prepare for the commissioning of the new North RWY in 2022, which would then be designated as the new RWY 07L/25R. The incident in this Investigation Report occurred on 18 July 2019; hence the designation of RWY 07L/25R in this Investigation Report refers to that of the original North RWY prior to its re-designation on 2 December 2021.

Contents

1. Factual Information

1.1. History of the Flight

(1) On 18 July 2019, a Boeing 787-8 (B787-8) aircraft with registration ET-ASG was operated by Ethiopian Airlines as a scheduled passenger flight from Manila Ninoy Aquino International Airport (RPLL) to VHHH.

(2) As cleared by ATC of Hong Kong, the aircraft proceeded direct to waypoint RIVER and descended to 4,500 ft for an ILS approach to the then RWY 25R of VHHH.

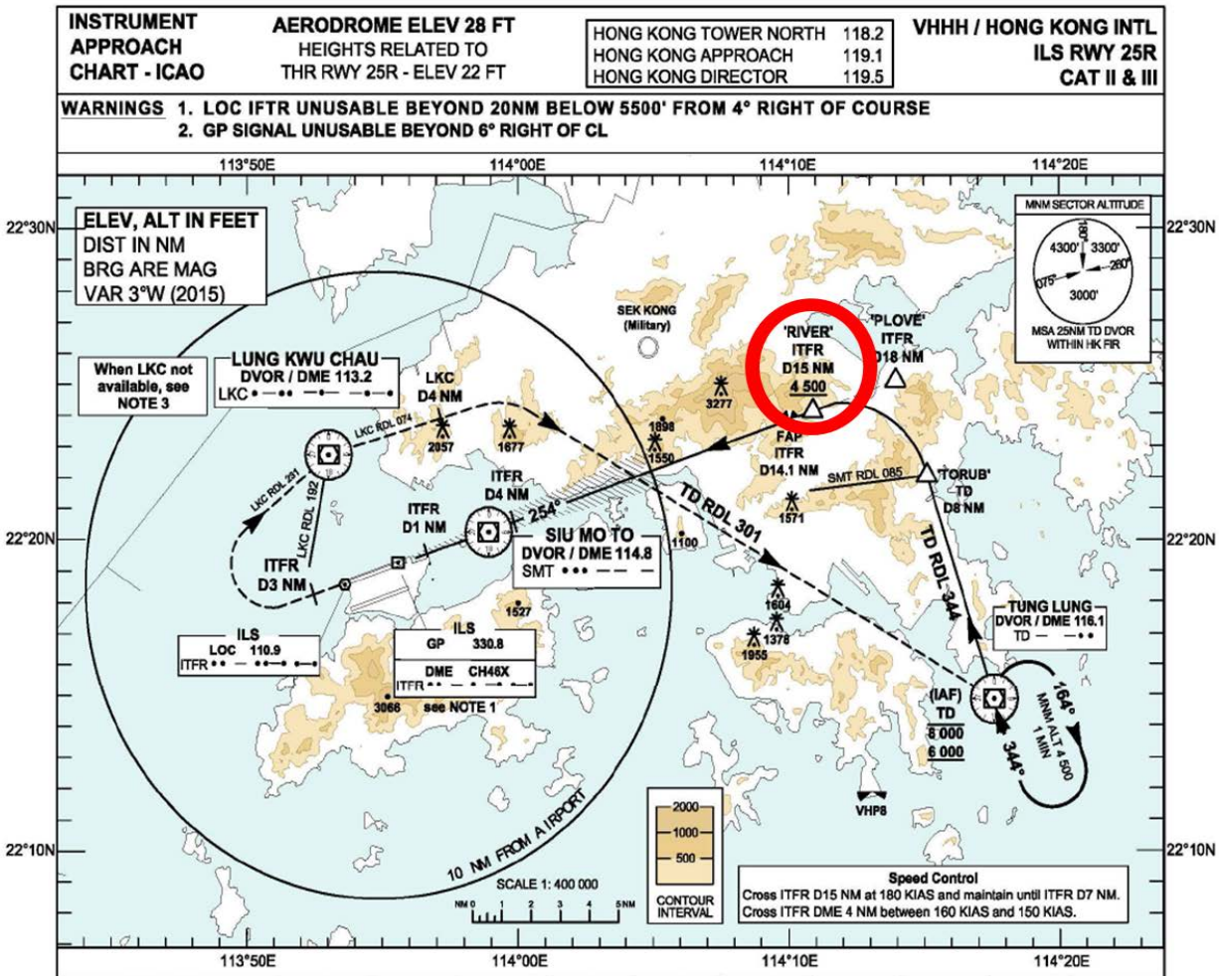

Figure 1: Instrument Approach Chart Published in Aeronautical Information Publication Hong Kong (AIP Hong Kong)

(3) The aircraft, with the autoflight system engaged, proceeded to intercept the LOC at waypoint RIVER, which was 15 Nautical Miles (NM) from the RWY, from the southeast.

(4) At 23:51:57 hrs, while the aircraft was turning left to intercept the LOC from the south, it overshot the LOC course and continued to deviate to the north towards terrain and descended below the MSA of 4,300 ft. The flight crew identified the deviation from the LOC course, and at 23:53:02 hrs, the Pilot Flying (PF) immediately disengaged the autoflight system and assumed manual control of the aircraft to climb back to MSA.

(5) On noticing the course deviation, ATC warned the aircraft of its approach towards terrain, and shortly after, at 23:53:43 hrs, instructed the aircraft to go around. No EGPWS warnings were triggered.

(6) Following the go-around and the second approach to the same RWY, the aircraft landed uneventfully.

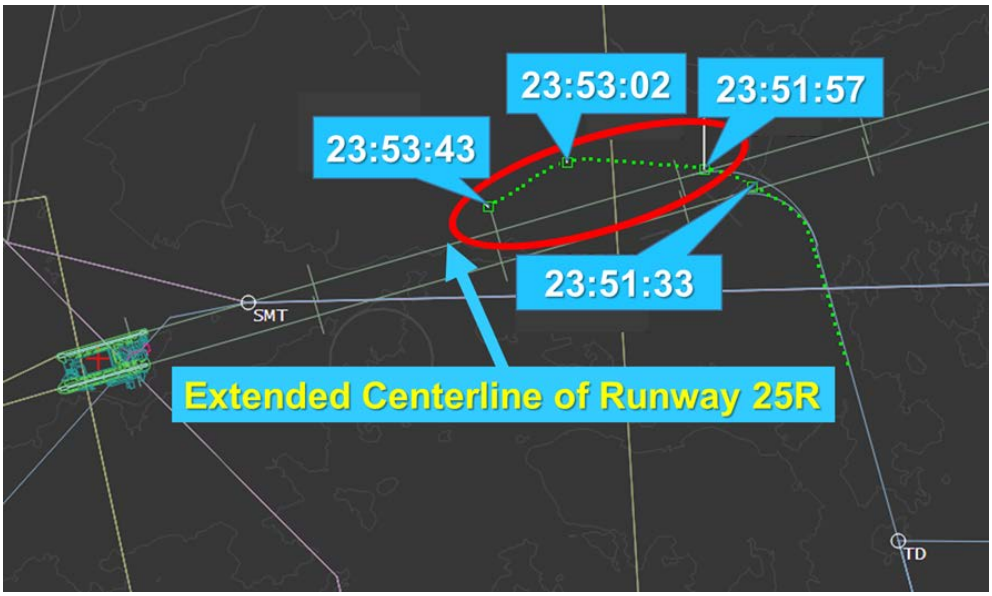

Figure 2: Radar Plot of Flight Track

1.2. Injuries to Persons

The aircraft carried 10 crew members and 225 passengers. The crew was composed of 2 pilots and 8 cabin attendants. There were no injuries to persons as a result of this occurrence.

Injuries to Persons						
Persons on board:	Crew	10	Passengers	225	Others	0
Injuries:	Crew	0	Passengers	0		

Table 1: Injuries to Persons

1.3. Damage – Aircraft

There was no damage to the aircraft.

1.4. Other Damage

No other damage was caused.

1.5. Personnel Information

1.5.1. Flight Crew

(1) The flight crew consisted of the captain and the first officer. The captain was PF in the left-hand seat. The first officer was PM in the right-hand seat.

(2) Crew licence information is in Section 7.2 Pilot Information.

1.6. Aircraft Information

1.6.1. Aircraft

The B787-8 is a wide-body twin-engine aircraft manufactured by The Boeing Company. The aircraft is powered by two General Electric GEnx-1B engines. The aircraft has been operated by Ethiopian Airlines since 2015. The aircraft held a valid Certificate of Airworthiness and a valid Certificate of Registration. Details are in Section 7.3 Aircraft Details.

1.6.2. Autopilot Flight Director System (AFDS)

(1) The AFDS consists of three autoflight computing systems and a mode control panel (MCP) to control the attitude of the Boeing 787.

(2) It provides full flight autopilot (A/P) control during the primary flight control normal mode operation. It can control all flight phases except takeoff. It includes the features of Category IIIB autoland capability and backdrive of pilot controls during A/P operation.

1.6.2.1. Display of AFDS Indication

The AFDS indication is displayed on the primary flight displays (PFDs) and head-up displays (HUDs).

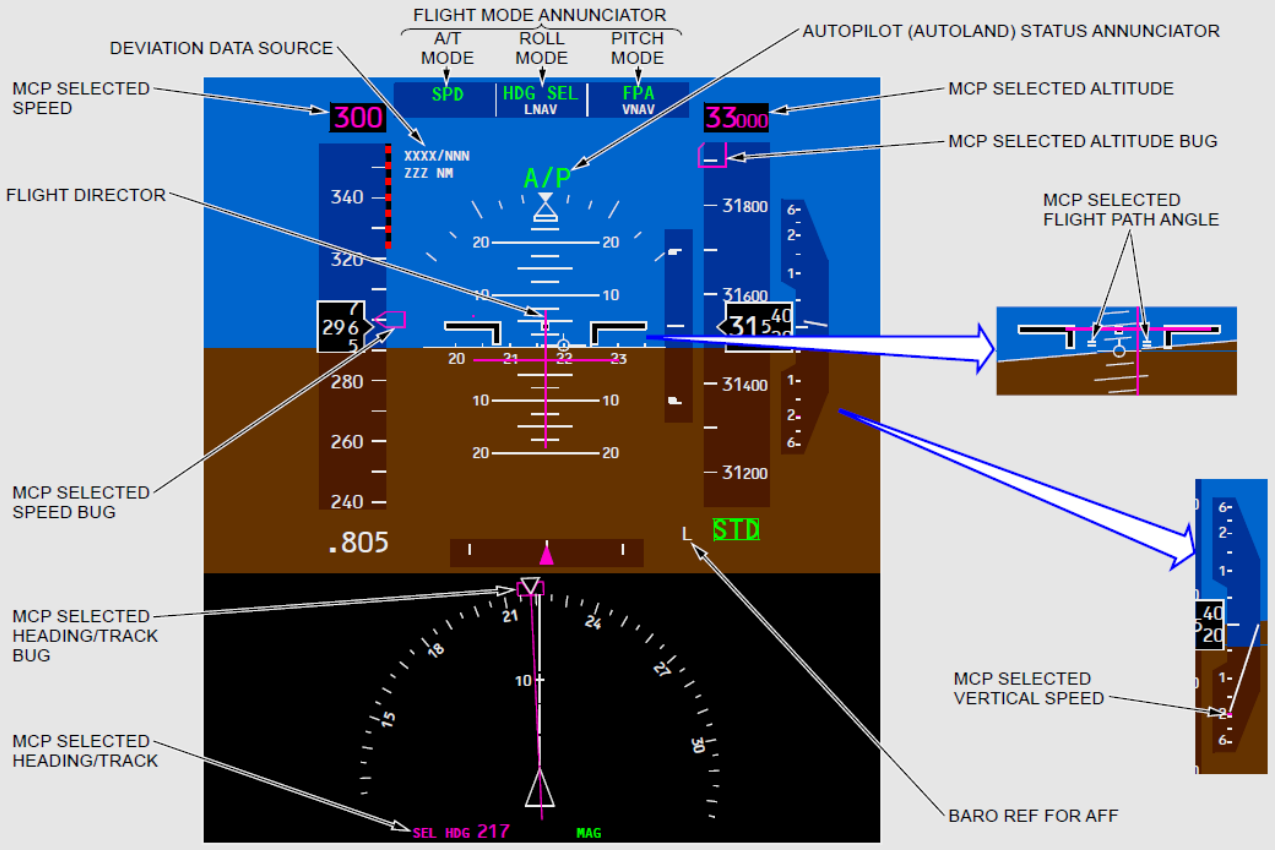

Figure 3: AFDS Indication on PFD

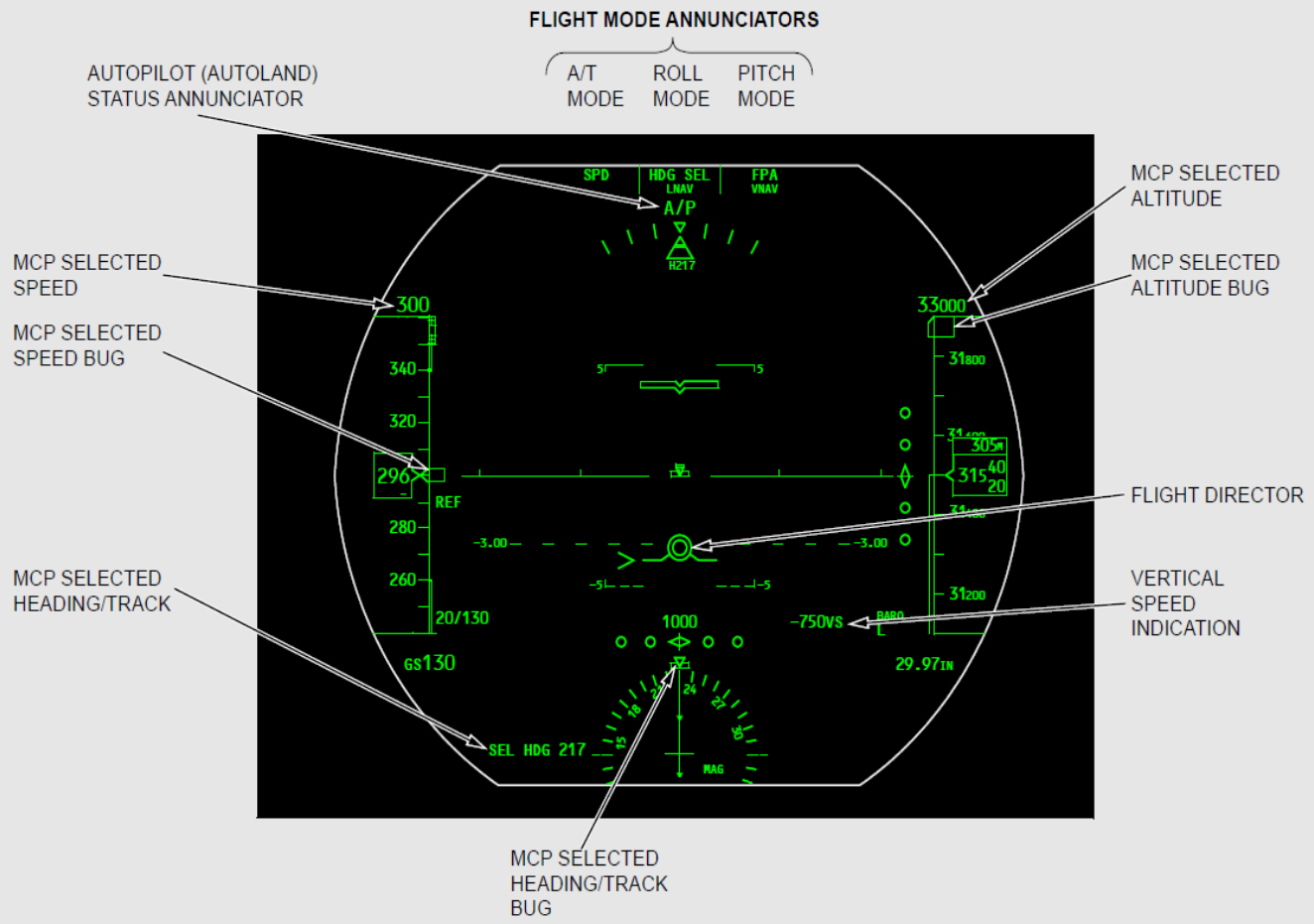

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Figure 4: AFDS Indication on HUD

1.6.2.2. MCP

The MCP provides control of the A/P, flight director, altitude alert, and autothrottle systems. The MCP is used to select and activate AFDS modes, and establish altitudes, speeds, and climb/descent profiles. Mode select switches of the MCP are shown in Figure 5.

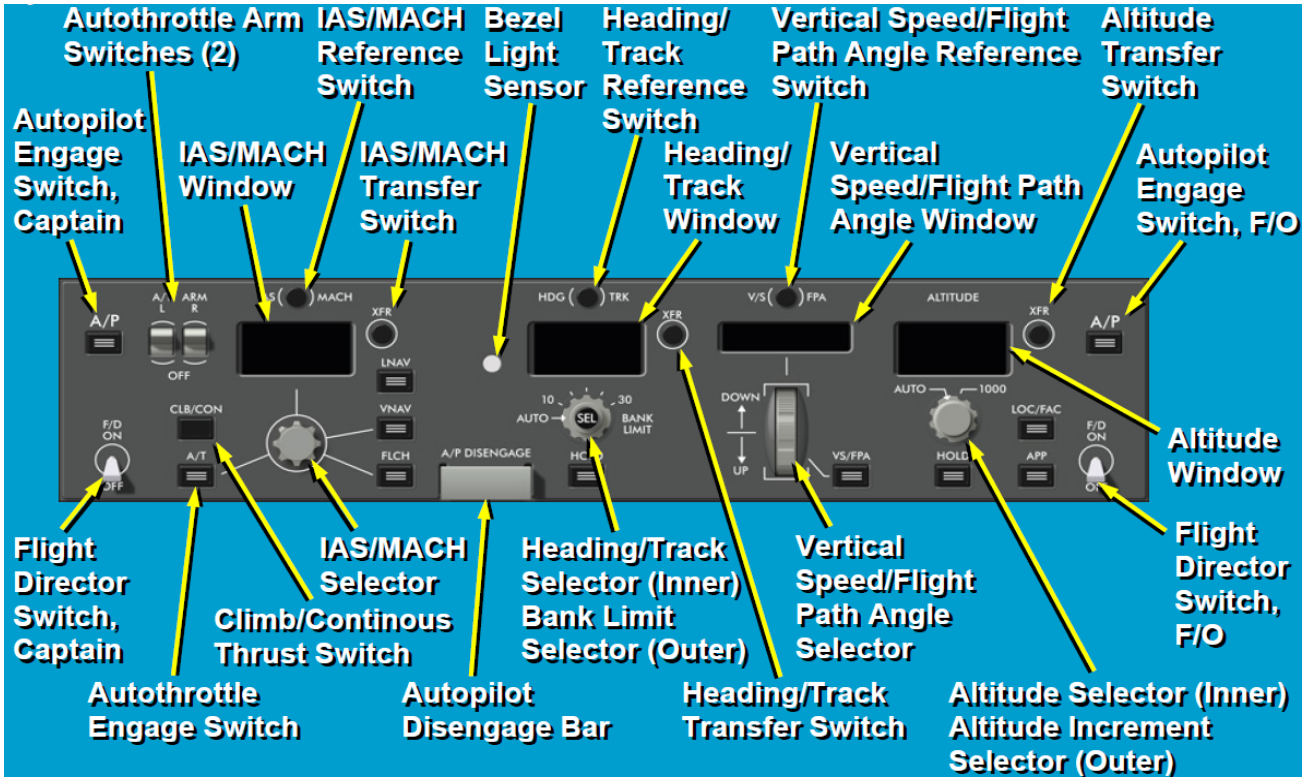

Figure 5: MCP

1.6.2.3. Flight Mode Annunciator (FMA)

(1) The FMA is located at the top of the PFD and HUD. The FMAs show the armed and engaged AFDS and autothrottle modes as follows:

(a) Autothrottle mode (left)

(b) Roll mode (centre)

(c) Pitch mode (right)

(2) The active modes are shown in “green” while the armed modes are displayed in “white” under the active modes.

(3) A line through the mode shows a mode failure.

(4) Temporary loss of data can cause a mode failure. These mode failures can be reset automatically.

(5) If there is a permanent mode failure, the pilot must select another mode.

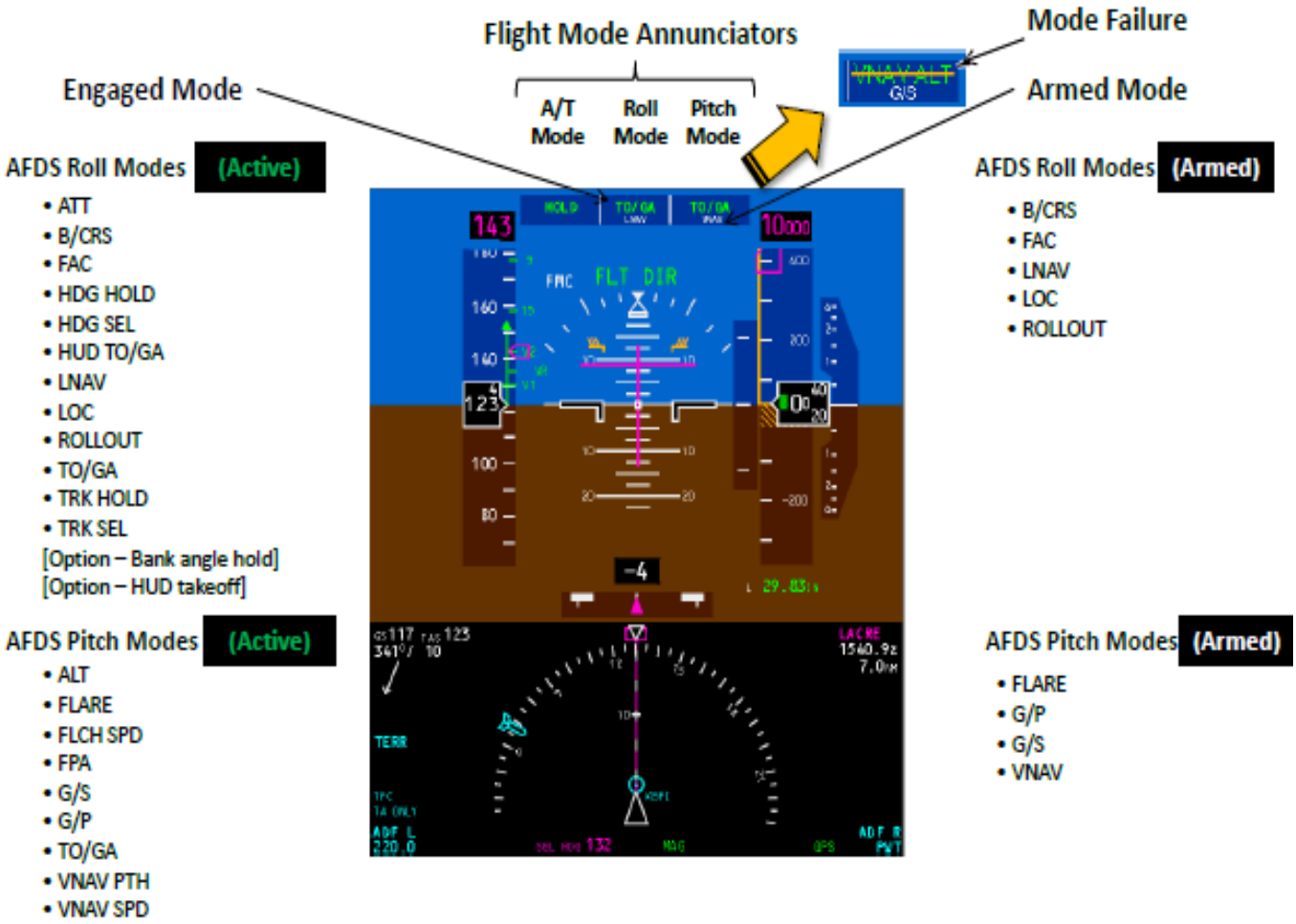

Figure 6: AFDS - FMA

(6) The AFDS does not have direct control of the flight control surfaces. The A/P controls the flight control surfaces through the fly-by-wire flight control system.

1.6.2.4. Flight Control Electronics (FCE) Cabinets

(1) The FCE cabinets provide the calculations for the A/P, flight director, and backdrive functions.

(2) The FCE cabinets calculate control surface commands based on input signals from control columns, control wheels, rudder pedals, pitch trim switches and aircraft sensors.

(3) There are four FCE cabinets (L, C1, C2, and R). Each FCE cabinet has a power conditioning module, actuator control electronics (ACE) and a FCM. Only FCE C2 does not have an FCM.

1.6.2.5. Autoflight Function (AFF) in FCM of FCE cabinet

(1) The AFF is a software application in the FCM of each FCE cabinet. There is one copy of the AFF software in each FCM.

(2) The AFDS uses the AFF software in the three FCMs. The AFF receives crew inputs from the MCP and aircraft systems inputs from flight management function. It uses these inputs to calculate AFF pitch, roll, and yaw commands and sends A/P command data to the primary flight control function (PFCF) in the FCMs.

(3) The PFCF generates flight control surface commands and sends them to the ACE. The ACEs then send the commands to the flight control surfaces.

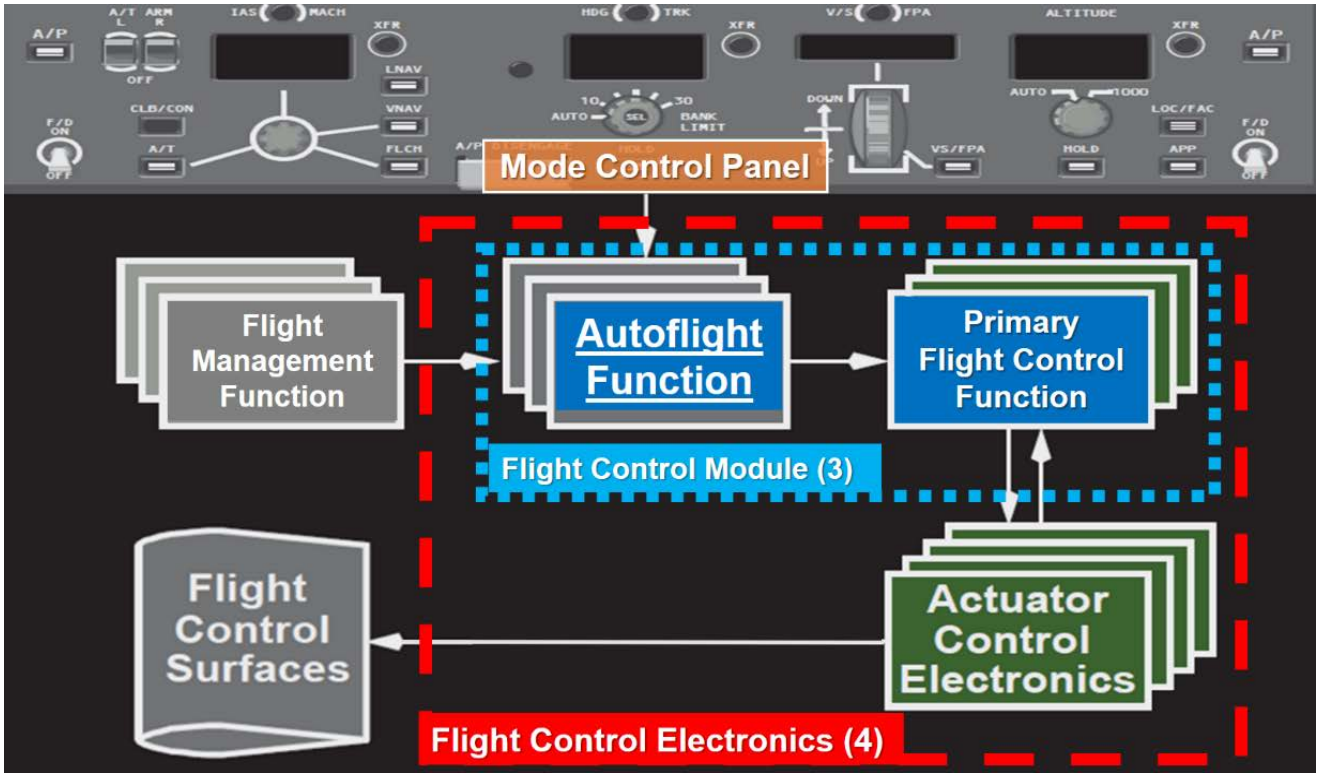

Figure 7: Schematic Diagram of AFDS

1.6.3. Consistent Localizer Capture (CLC)

(1) The AFF contains a CLC control law function. The intent of this CLC function is to begin the LOC capture turn of an ILS approach early during certain conditions to avoid or reduce trajectory overshoot and subsequently transition to the LOC mode resulting in a smooth transition in a single turn toward LOC null.

(2) ILS approach LOC captures that occur too close to the RWY can result in LOC trajectory overshoots as shown in the graphic below.

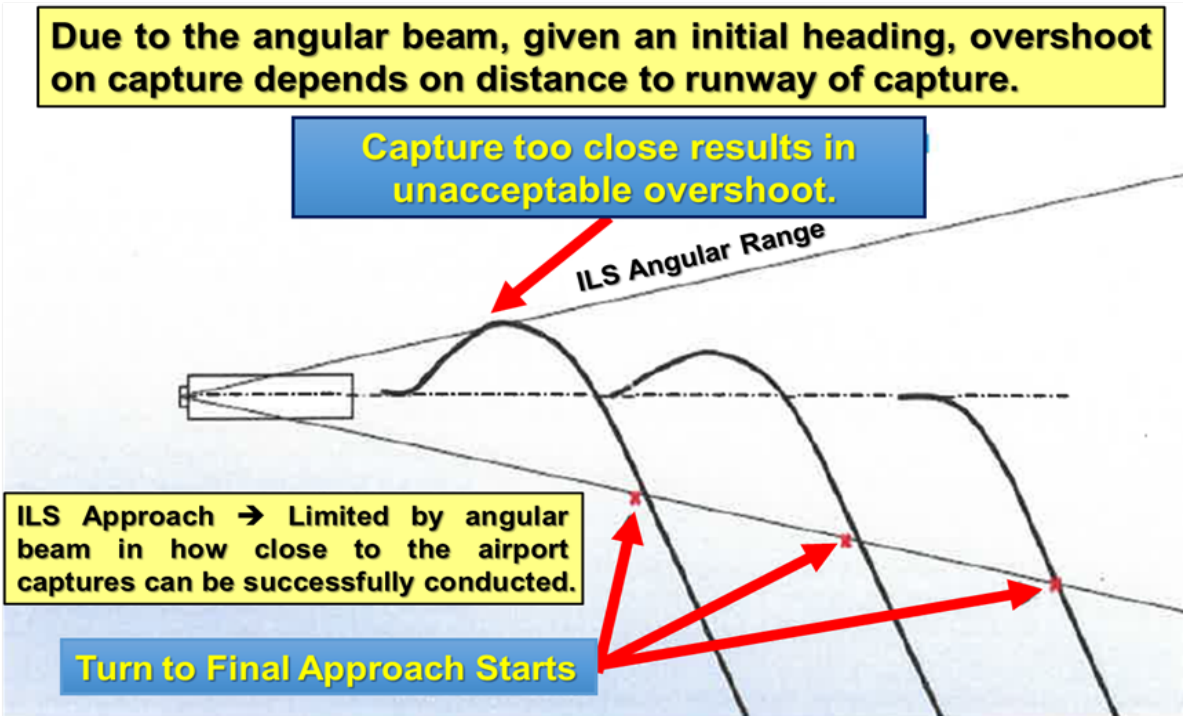

Figure 8: Effect of Intercept ILS Close to RWY

(3) The CLC mode reduces the risk of LOC course overshoot in A/P-enabled approaches that require a large turn (>40 degrees) onto the LOC course.

(4) During an ILS approach, and when tracking a LOC intercept path angle greater than 40 degrees to the RWY extension line, the CLC mode will become active prior to capturing the LOC.

(5) Using aircraft position (latitude/ longitude) and RWY information from the flight management function, CLC will turn the aircraft towards the LOC course before the LOC is within parameters for capture, in order to avoid overshoot and maximize the chance of capturing the LOC in one turn.

(6) "LOC" will be annunciated on the FMA when a CLC turn begins and remains annunciated through the transition to LOC capture.

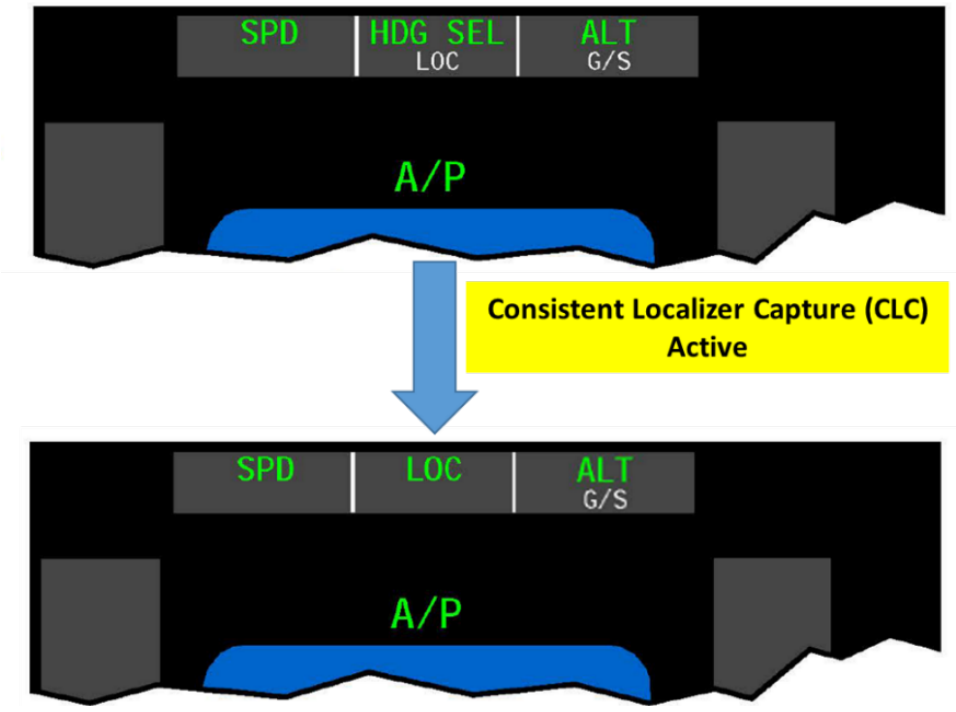

Figure 9: FMA on PFD with CLC Mode Active

(7) CLC has enough authority to turn the aircraft up to 20 degrees off of the LOC course. This results in the aircraft turning to a LOC intercept angle of approximately 20 degrees.

(8) During the turn, CLC will automatically transit to the LOC capture control law when the LOC is within parameters for capture and "LOC" will continue to be visible on the FMA.

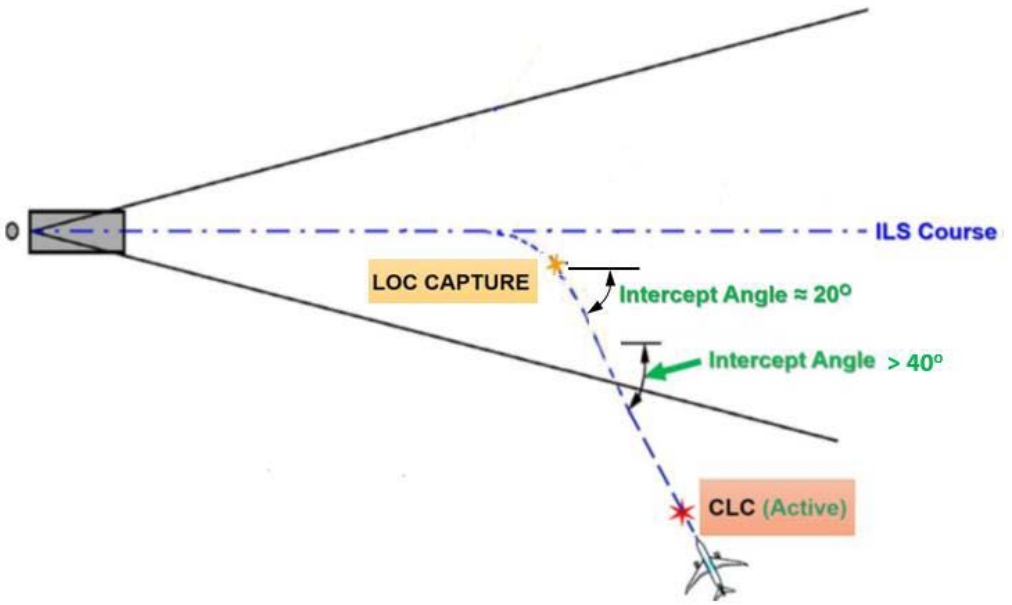

Figure 10: CLC Mode to LOC Capture Mode

1.6.4. Maintenance History

A review of the aircraft's maintenance history did not identify any defects or recent maintenance actions that could have contributed to the occurrence.

1.7. Meteorological Factors

The Meteorological Aerodrome Report (METAR) for VHHH at 2330 hrs indicated that the wind speed was 5 knots. The surface wind direction was 270 degrees. The visibility was 10 km or above. There were no clouds below 5,000 ft above mean sea level. The air temperature was 31 degrees Celsius and the dew point was 24 degrees Celsius. No significant changes in weather conditions were expected for the next two hrs.

1.8. Navigation Aids

There was no report of abnormal operation of any ground-based navigation aids or aerodrome visual ground aids at the time of the occurrence.

1.9. Communications

The aircraft was equipped with three Very High Frequency (VHF) radio communication systems that were serviceable. All communications between ATC of Hong Kong and the aircraft were recorded by ground-based automatic voice recording equipment. There was no interruption to such communications.

1.10. Aerodrome Information

Information on the VHHH is listed in Section 7.4 Aerodrome Information.

1.11. Flight Recorders

(1) The aircraft was equipped with two Enhanced Airborne Flight Recorders (EAFR), one installed at the front of the aircraft and the other at the rear. The EAFR is a multifunction crash-protected

recorder that records 25 hrs of Flight Data Recorder (FDR)[2] data and 120 minutes of Cockpit Voice Recorder (CVR)[3] audio into a solid-state memory.

(2) Both EAFRs were functional. The operator downloaded the data from the EAFRs for data analysis.

1.12. Wreckage and Impact

Not applicable in this investigation.

1.13. Medical/Pathological Information

No medical or pathological investigations were conducted as a result of this occurrence, nor were they required.

1.14. Smoke, Fire, and Fumes

There was no smoke or fire on the aircraft during the flight or after the occurrence.

1.15. Survival Aspects

No injury was reported, therefore no investigation into the survival aspects was required.

1.16. Tests and Research

Not applicable in this investigation.

[2] FDR – a device used to record specific aircraft performance parameters. The purpose of an FDR is to collect and record data from a variety of aircraft sensors onto a medium designed to survive an accident.

[3] CVR - a device used to record the audio environment in the flight deck for accident and incident investigation purposes. The CVR records and stores the audio signals of the microphones and earphones of the pilots' headsets and of an area microphone installed in the cockpit.

1.17. Organisation, Management, System Safety

1.17.1. CAD

The CAD is the regulatory authority responsible for regulating and monitoring of all matters relating to civil aviation in Hong Kong. Apart from the regulatory role in aviation safety, the CAD provides air navigation services, including ATC services, for the flights at the VHHH and in the Hong Kong Flight Information Region as designated by the International Civil Aviation Organization (ICAO). The CAD is also responsible for the safety oversight of the provision of air navigation services in Hong Kong.

1.17.2. Federal Aviation Administration (FAA)

The FAA is the regulatory authority responsible for the airworthiness and environmental certification of all aeronautical products, parts, and appliances designed, manufactured, maintained or used by persons under the regulatory oversight of the United States. It carries out the functions and tasks of the State of Design and State of Manufacture of Boeing 787 aircraft.

1.17.3. Ethiopian Airlines

Ethiopian Airlines held the Air Operator's Certificate issued by the General Civil Aviation Authority of the United Arab Emirates. The operator has been using Bole International Airport as the main base for passenger and cargo operations since 1946. The fleet consists of Airbus A350, Boeing 737, Boeing 777 and Boeing 787 aircraft types for operations.

1.18. Additional Information

1.18.1. LOC Capture Anomalies

(1) Boeing 787 operators have reported numerous events that the AFDS did not provide proper guidance to capture the LOC when intercepting the LOC at large angles (40 degrees or more).

(2) During these events, the AFDS reduced the intercept angle, but continued flying through the LOC course, even when the FMA showed "LOC" as the active roll mode.

(3) In all events, the deviation from the LOC was accurately shown by both the LOC pointer and scale on the PFD, HUD, and by the aircraft symbol on the navigation display (ND).

(4) The failure to properly capture the LOC could take place at any airport.

(5) In the reported events at Hong Kong, the aircraft initially turned toward the LOC with a 20 to 30 degrees' intercept angle, but continued flying through the LOC course on that track.

(6) It should be noted that "LOC" remained on the FMA despite the failed capture and, in some circumstances, the aircraft might begin to descend below the glideslope while the aircraft was 20 degrees offset from the LOC course.

(7) There was no indication on board the aircraft to notify the crew of the LOC capture anomalies.

1.18.2. Issuance of Related Technical Publications

(1) Based on the in-service experiences, Boeing and the FAA had published different technical publications to provide operators with up to date information on the development/availability status of product improvements.

(2) The timeline of issuance of technical publications related to LOC Capture Anomalies of the AFDS is shown in Figure 11.

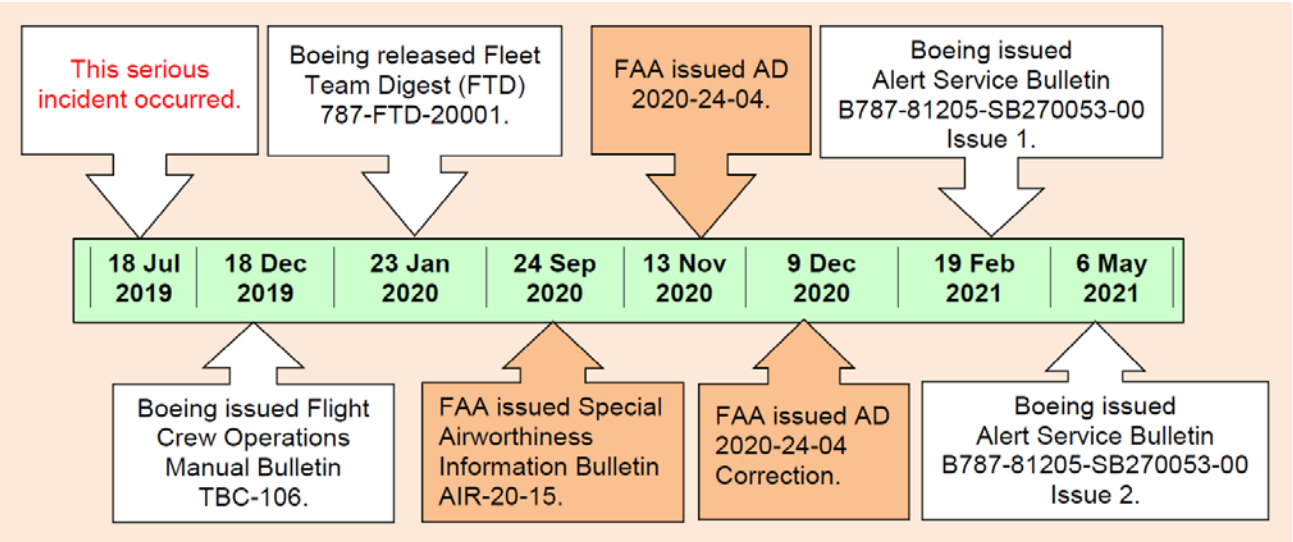

Figure 11: Timeline of Issuance of Related Technical Publications

1.18.2.1. Boeing Flight Crew Operations Manual Bulletin

(1) Boeing issued Flight Crew Operations Manual Bulletin TBC-106 (LOC Capture Anomalies) dated 18 December 2019 to inform flight crew of reports of the AFDS not capturing the LOC.

(2) Some operators reported to Boeing that the AFDS did not provide proper guidance to capture the LOC when intercepting the LOC LOC at large angles (40 degrees or more).

(3) Boeing confirmed with flight data that during these events, the AFDS reduced the intercept angle, but continued flying through the LOC course, even when the FMA indicated "LOC" as the active roll mode.

(4) In all events, the deviation from the LOC course was accurately shown by both the LOC pointer and scale on the PFD and by the aircraft symbol on the ND.

(5) Boeing had been able to reproduce the anomaly in an engineering simulator and determined the root cause. Boeing planned to correct the anomaly in FCE software blockpoint 5.1.

(6) The bulletin also provided the Operating Instructions of the AFDS to handle such LOC capture anomalies as follows:

"*When conducting an approach with a LOC-based navigation aid, monitor LOC raw data and call out any significant deviations. If AFDS performance is not satisfactory, the flight crew must intervene. Perform an immediate go around if the aircraft has not intercepted the final approach course as shown by the LOC deviation.*"

1.18.2.2. Boeing Fleet Team Digest (FTD)

(1) Boeing released FTD 787-FTD-22-20001 on 23 January 2020. The purpose of the FTD was to provide the following information:

(a) Operators were informed about the issue of LOC capture anomaly, in which A/P-engaged approaches in a specific LOC window could result in an insufficient turn towards the LOC course, resulting in the aircraft continuing to fly through the LOC course rather than properly capturing the LOC. In some circumstances, the aircraft could subsequently capture the glideslope and begin descent.

(b) The condition could occur at any airport but had been reported multiple times for approaches on ILS RWY 25R into VHHH.

(c) Boeing had opened a service-related problem investigation for this condition and the root cause had been identified and explained as follows:

"The B787 AFF contains a CLC control law that reduces the risk of LOC course overshoot in autopilot-engaged approaches that requires a large turn (40 degrees) onto the LOC course. CLC provides the B787 with ILS performance consistent with a Ground-Based Augmentation System (GBAS) Landing System (GLS) approach. Using Global Positioning System (GPS) and RWY information from the flight management function. CLC will turn the aircraft towards the LOC course before the LOC is within parameters for capture. In order to maximize the chance of capturing the LOC in one turn. "LOC" will annunciate on the FMA when a CLC turn begins and remain annunicated through the transition to LOC capture. Normally, CLC will automatically transition to the LOC capture control law when the LOC is within parameters to capture and "LOC" will continue to be visible on the FMA.

Boeing has received reports that suggest, depending on the geometry and groundspeed of the approach, CLC may activate for such a short time that the three FCMs fail to synchronize the engaged autopilot mode and fail to transition to the LOC capture mode. This may result in the aircraft turning to a LOC intercept angle of approximately 20 degrees and flying through the LOC on this track, rather than properly capturing the LOC. "LOC" will remain on the FMA despite the failed capture and, in some circumstances, the aircraft may begin descent down the glideslope while 20 degrees off of the LOC course."

(d) Interim actions refer to the 18-DEC-2019 Flight Crew Operations Manual Bulletin for flight crew guidance and necessary actions were introduced to prevent the anomaly from occurring.

(2) Later, the FTD was updated to inform operators that:

(a) In March 2020, Boeing selected a solution for the condition. New logic would separate the LOC entry criteria from the CLC entry criteria and also add robustness to remove time sensitivity.

(b) The FAA released Airworthiness Directive (AD) 2020-24-04 to require operators to add related flight crew procedures to the Aircraft Flight Manual (AFM) with the effective date of 18 December 2020.

(3) The final update of the FTD was released on 10 March 2021 to encourage operators to install FCE Common Block Point (CBP) 5.1 software per Boeing Alert Service Bulletin (SB) B787-81205-SB270053-00 that was released on 19 February 2021 as the final action.

1.18.2.3. FAA Special Airworthiness Information Bulletin

(1) The FAA issued Special Airworthiness Information Bulletin AIR-20-15 on 24 September 2020 to advise registered owners and operators of The Boeing Company Model 787-8, -9, and -10 airplanes of the potential for AFDS failure to capture the LOC during ILS approach.

(2) The FAA recommended that all owners and operators of affected airplanes notify flight crew of this issue and incorporate the actions outlined in the referenced Flight Crew Operations Manual Bulletin at the earliest opportunity.

1.18.2.4. FAA AD

(1) The FAA issued AD No. 2020-24-04 on 13 November 2020 to address the AFDS failing to transition to the ILS LOC beam, which could result in LOC overshoot leading to glideslope decent on the wrong heading (HDG).

(2) Combined with a lack of flight deck effects for a CLC mode failure, this condition could result in a controlled flight into terrain.

(3) As the unsafe condition was identified, mandatory measures in the form of an AD had to be issued.

(4) The FAA issued AD No. 2020-24-04 Correction dated 9 December 2020 to correct errors in AD related to certain references to the AFM.

(5) This AD required revising the existing AFM to incorporate procedures for conducting an approach with a LOC-based navigation aid, monitoring LOC raw data, calling out any significant deviations, and performing an immediate go around if the airplane

has not intercepted the final approach course as shown by the LOC deviation.

(6) The AD mandated the following changes made by Boeing in the Operating Instructions of the AFM with the effective date of 18 December 2020.

(Required by AD 2020-24-04)

Autopilot Flight Director System – Operating Instructions:

When conducting an approach with a localizer-based navigation aid, monitor localizer raw data and call out any significant deviations. If AFDS performance is not satisfactory, the flight crew must intervene. Perform an immediate go-around if the airplane has not intercepted the final approach course as shown by the localizer deviation.

Figure 12: Operating Instructions of AFDS

(7) When the FAA AD 2020-24-04 was issued, the FAA considered this AD as an interim action. The manufacturer was developing a modification that would address the unsafe condition identified in this AD. Once this modification was developed, approved, and available, the FAA might consider additional rulemaking.

1.18.2.5. Boeing Alert (SB)

(1) Boeing issued Alert SB B787-81205-SB270053-00 Issue 1 (FLIGHT CONTROLS - General – FCE CBP 5.1 Software Change) dated 19 February 2021 with a compliance time of 6 months after the issue date.

(2) This Alert SB dealt with the CLC mode failure of the AFF to capture the LOC by upgrading the software of all three FCMs.

(3) The new software addressed timing in the A/P logic for transitions from a short duration CLC mode to LOC mode and addressed consolidation of the mode between the FCMs.

(4) Also, during ILS signal fluctuations, changes in the new software reduced potential deviation from glidepath and eliminated potential misleading flight director guidance subsequent to A/P disconnect.

(5) This Alert SB was revised as B787-81205-SB270053-00 Issue 2 dated 6 May 2021 to update the effectivity.

(6) The FAA, the primary certification authority of Boeing 787 aircraft, advised the investigation team that the FAA was currently planning to issue an AD to mandate the incorporation of FCE CBP 5.1 Software modification as a requirement for all Boeing 787 aircraft.

1.19. Useful or Effective Investigation Techniques

Not applicable in this investigation.

2. Safety Analysis

The Safety Analysis provides a detailed discussion of the safety factors identified during the investigation, providing the evidence required to support the findings, contributing factors and the safety recommendations.

2.1. Flight Operations

2.1.1. Crew Qualification

The flight crew were properly licensed and medically certified in accordance with the Ethiopian Civil Aviation Authority (ECAA)'s licensing requirements, and adequately rested to operate the flight.

2.1.2. Operational Procedures

According to the flight track data, the flight crew acted promptly and effectively to return the aircraft to a safe altitude after identifying the LOC course deviation.

2.1.3. Weather

Referring to 1.7, the prevailing weather conditions were generally fine for the flight and were not a factor in the occurrence.

2.1.4. Navigation Aids

Referring to 1.8, there was no report of abnormal operation of any ground-based navigation aids or aerodrome visual ground aids.

2.1.5. Communications

Referring to 1.9, all communications between Hong Kong ATC and the aircraft recorded were clear and there was no report of a defective radio communication system in the cockpit.

2.2. Aircraft Maintenance

The investigation team did not identify any maintenance-related issue, or inherent aircraft defect that might have led to the serious incident. Aircraft maintenance was not a factor.

2.3. Flight Data Evaluation

(1) During the investigation of this occurrence, another operator encountered a similar occurrence on the B787 at VHHH on 7 September 2019. The flight data of this flight was sent to Boeing, the aircraft manufacture, for analysis. These two occurrences appeared to be identical and Boeing was able to determine the root cause.

(2) Evaluation of the flight data suggested that the CLC AFF initiated the turn towards the RWY 25R LOC, as LOC annunciated the active roll mode.

(3) After the CLC AFF had initiated the turn, the A/P transition to the LOC mode did not occur. This resulted in the aircraft HDG stabilised 20 degrees short of the LOC course and flying through the LOC course on this track, rather than properly capturing the LOC.

(4) The recorded flight data was consistent with the LOC capture anomaly of the AFDS as described in the FTD 787-FTD-22-20001.

(5) The LOC course deviation observed was due to the LOC capture anomaly of the AFDS.

(6) The FTD stipulated that the issuance of a Flight Crew Operations Manual Bulletin and related FAA AD 2020-24-04, associated with the software modification released by Boeing via Alert SB B787-81205-SB270053-00 addressed this anomaly.

2.4. Analysis of LOC Capture Anomalies

(1) Boeing was able to reproduce the anomalies experienced in Hong Kong and other events in an engineering simulator.

(2) The analysis indicated that depending on the geometry and groundspeed of the approach, CLC might activate for such a short time that the three FCMs failed to synchronize the engaged A/P roll mode.

(3) When the FCMs disagreed on the engaged roll mode, the FCM in command could remain in CLC mode and failed to transition to the LOC capture mode.

(4) This might result in the aircraft turning to a LOC intercept angle of approximately 20 degrees and flying through the LOC course on this track, rather than properly capturing the LOC.

(5) "LOC" would remain on the FMA despite the failed capture and, in some circumstances, the aircraft might begin descent on the glideslope while it was deviating 20 degrees off the LOC course.

(6) Boeing concluded that the occurrence was due to a software failure of the CLC which was a submode of the auto-flight function in AFDS.

2.5. Solution for LOC Capture Anomalies

(1) After the root cause of the LOC Capture Anomalies in AFDS had been identified and established in December 2019, Boeing planned to develop a software solution for the anomaly in FCE software CBP 5.1. In March 2020, Boeing selected a solution for the anomaly, with new software logic that would:

(a) separate the LOC entry criteria from the CLC entry criteria; and

(b) add robustness to remove time sensitivity.

(2) The change of software was committed in May 2020 and later the flight test was carried out in December 2020.

(3) Boeing released Alert SB B787-81205-SB270053-00 on 19 February 2021 to install FCE CBP 5.1 software with the compliance time of 6 months after the issue date.

(4) The new software included the changes described in 2.5(1)(a) & (b) to mitigate the LOC capture anomaly in AFDS.

(5) The new software addressed timing in the A/P logic for transition from a short duration CLC submode to LOC mode and addressed the consolidation of the mode between the FCMs.

(6) In June 2022, the FAA published a Notice of Proposed Rulemaking (NPRM)[4] (Reference Docket No. FAA-2022-0674) that proposed a new AD to mandate the incorporation of FCE CBP 5.1 software modification for all Boeing 787 aircraft.

[4] NPRM is used by FAA to give notice of an intention to change their Regulatory regime for aircraft design, production, maintenance or operation and allow interested parties the opportunity to comment before actual changes are made.

3. Conclusions

From the evidence available, the following findings are made with respect to the occurrence. These findings should not be read as apportioning blame or liability to any particular organisation or individual. Findings related to Safety issues, or system safety problems, are highlighted to emphasise their importance.

3.1. Findings

(1) The flight crew were licensed and qualified for the flight in accordance with regulations and the operator's requirements. (2.1.1.)

(2) The flight crew handled the situation of LOC course deviation in a timely manner. (2.1.2.)

(3) The weather conditions were within the limits for the flight. (2.1.3.)

(4) Ground-based navigation aids and aerodrome visual ground aids were serviceable. (2.1.4.)

(5) All communications between Hong Kong ATC and the aircraft were clear. (2.1.5.)

(6) The aircraft held a valid Certificate of Airworthiness and was maintained in accordance with the regulations. (2.2.)

(7) The LOC course deviation was due to the LOC capture anomaly of the AFDS. (2.3.)

(8) The LOC capture anomaly of the AFDS was due to the software failure of the CLC auto-flight function in AFDS. (2.4.)

(9) The software failure of the CLC auto-flight function in AFDS was addressed by Boeing Alert SB 787-27A0053 dated 19 February 2021 to install FCE CBP 5.1 software. (2.5.)

(10) In June 2022, the FAA published a NPRM (Reference Docket No. FAA-2022-0674) that proposed a new AD to mandate the incorporation of FCE CBP 5.1 software modification for all Boeing 787 aircraft. (2.5)

3.2. Cause

The LOC course deviation was caused by the software failure of the CLC auto-flight function in the AFDS. (3.1. (8))

4. Proactive Safety Actions

Whether or not AAIA identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk.
AAIA has been advised of the following proactive safety action in response to this occurrence.

4.1. Proactive Safety Actions Taken by the CAD

Throughout the course of the investigation, the CAD has been closely monitoring the situation and has taken proactive safety actions to address the issue.

4.1.1. Comprehensive Check of ILS

4.1.1.1. Ground Check of ILS

In November 2019, the CAD engaged the original system supplier of the four ILS located at the RWYs of VHHH, including the 07L, 07R, 25L and 25R ILS, to conduct comprehensive review of the performance of the ILS equipment and operations and maintenance (O&M) work. The supplier confirmed that the four ILS were in good working conditions under good O&M work and system performances were in compliance with the ICAO requirements.

4.1.1.2. Flight Check of ILS

(1) Periodic flight checks for all four ILS were carried out in May and November every year. The flight checks were conducted by the Flight Inspection Centre (FIC) of the Civil Aviation Administration of China (CAAC). All the flight checks were conducted in accordance with requirements in the CAD's Flight Inspection Manual based on the ICAO Doc 8071 - Manual on Testing of Radio Navigation Aids. There were routine flight profiles taken by the CAAC FIC all along within the concerned region in the periodic flight checks for RWY 07L & 25R ILS.

(2) The last flight checks on RWY 07L/25R ILS were conducted in May 2019, with the reports from the CAAC FIC stating that the measurements of the systems met the ICAO requirements.

(3) Noting the serious incident of ILS approach to RWY 25R since the last flight check in May 2019, the CAD had coordinated with the CAAC FIC to conduct ad-hoc flight checks for RWY 25R ILS on 6 November 2019, with initial flight from station identity code of radio navigation aids at Tung Lung (TD)[5] to waypoint RIVER to capture RWY 25R ILS LOC signals and break off around 2 NM after ILS establishment. It was confirmed that there was no issue for the flight inspection aircraft to capture both RWY 25R Transmitters 1 and 2 LOC signals and the centreline reference was also correct. During the checks, the measured LOC deviations for both RWY 25R transmitters met the ICAO requirements.

4.1.2. Issue of Aeronautical Information Circular (AIC)

(1) The CAD issued AIC 28/19 "Coverage of ILS Facilities and Warning of False Capture and Signal Deviation at VHHH" on 14 November 2019 and this was superseded by AIC 12/20 dated 24 April 2020, which advised flight crew to confirm the validity of the LOC capture by cross-checking with other sources of navigation information.

(2) AIC 32/21 was issued by the CAD on 2 December 2021, which contained the same advisory information alerting air operators and flight crew of aircraft arriving at VHHH that they shall remain vigilant and adhere to the approach and descent procedures as promulgated in the Hong Kong AIPs. Raw data should be monitored as appropriate.

4.1.3. Issue of CAD Letter to Boeing 787 Operators

The CAD issued a letter on 15 April 2020 to remind all B787 operators and their flight crew flying into Hong Kong to be aware of the information in Boeing Operations Manual Bulletin TBC-106 and AIC 28/19.

4.1.4. Issue of Notice to Airmen (NOTAM)

The CAD issued NOTAM A0658-20 on 24 April 2020, drawing the attention of flight crew of arrival aircraft at VHHH to AIC 12/20 that was issued on the same date, with reference to Boeing Flight Crew Operations Manual Bulletin – LOC Capture Anomalies, in order to caution the possible AFDS anomaly upon

[5] The identity code of radio navigation aids with station name Tung Lung at Tung Lung Chau, an island located off the tip of the Clear Water Bay Peninsula in the New Territories of Hong Kong.

capturing LOC. When in doubt, the flight crew shall climb back to MSA, conduct missed approach and contact ATC.

4.1.5. Communication between the CAD and the FAA

In light of the potential safety risk of this event on a Boeing 787 aircraft, the CAD reported the event to the FAA, through the established working arrangement and requested the authority to coordinate with Boeing for the earliest release of the software upgrade and for providing further mitigation measures to operators before the software fix, and considered mandating the SB as AD. The FAA gave due consideration to the CAD and subsequently issued AD 2020-24-04 to mandate the change of the Operating Instructions in the Boeing 787 AFM and approved the certification of the software upgrade.

4.2. Proactive Safety Actions Taken by Boeing

Boeing implemented the following safety actions after the serious incident.

4.2.1. Issue of Flight Crew Operations Manual Bulletin

Boeing released a Flight Crew Operations Manual Bulletin TBC-106 on 18 December 2019 titled " LOC Capture Anomalies" to provide operating instructions to flight crew as a mitigation action.

4.2.2. Issue of Alert SB

Boeing has identified the root cause as the software issue of the FCMs. The company developed a software solution for the anomaly in FCE software CBP 5.1 and issued Boeing Alert SB B787-81205-SB270053-00 Issue 1 on 19 February 2021.

4.3. Proactive Safety Actions Taken by Ethiopian Airlines

Ethiopian Airlines implemented the following safety actions after the serious incident.

4.3.1. Distribution of Flight Safety Information

The operator distributed a Flight Operations Bulletin to all crew members on 2 September 2019 to increase crew awareness of such LOC deviation occurrence.

4.3.2. Incorporation of Alert SB

In March 2021, Boeing Alert SB B747-81205-SB-270053-00 was incorporated into all Ethiopian Airlines Boeing 787 aircraft.

5. AAIA Safety Recommendation Report

When a safety issue is identified at any stage of the investigation, AAIA issues Safety Recommendation Report to relevant organisation(s) to recommend preventative action that has to be taken promptly to enhance aviation safety.

5.1. Issue of Safety Recommendation Report

(1) With the efforts of Boeing, the aircraft manufacturer, the root cause of this incident had been identified as the software issue of the FCMs of the aircraft.

(2) The target date for the release of FCE software CBP 5.1 was initially scheduled for the fourth quarter of 2020, and was committed to take place in the first quarter of 2021.

(3) AAIA understood that other than the solution to the LOC capture anomalies, CBP 5.1 would also cover many other product improvements.

(4) Due to the rather high frequency of reoccurrence of B787 LOC deviation in Hong Kong, AAIA considered that there was a genuine need to suitably prioritize solutions to address the LOC Capture Anomalies happened on Boeing 787 A/P flight director system.

(5) On 12 June 2020, AAIA issued a Safety Recommendation Report 01-2020 to release Safety Recommendation 02-2020 to the FAA, as follows.

5.1.1. Safety Recommendation 02-2020

It is recommended that the Federal Aviation Administration to urge Boeing to suitably prioritize the development of a FCE software solution so as to achieve early rectification of the Boeing 787 localizer capture anomalies.

Safety Recommendation Owner: The Federal Aviation Administration

5.1.2. Response to Safety Recommendation 02-2020

The FAA advised the investigation team that the following safety actions had been taken to address the Safety Recommendations 02-2020.

5.1.2.1. Issue of AD

(1) As per the AD process stated in Part 39.5 of the Code of Federal Regulations (CFR) Title 14[6], the FAA identified an unsafe condition existed and subsequently mandated a corrective action by issuing an AD.

(2) Boeing changed the Operating Instructions in the Boeing 787 AFM as a mitigation action. The FAA mandated the incorporation of the AFM change via a correction to AD 2020-24-04 effective from 18 December 2020.

5.1.2.2. Issue of Software Approval

The FAA had approved the certification of Boeing 787 FCE CBP 5.1 software, which included changes that resolve the identified LOC capture anomalies in January 2021. Boeing subsequently published two iterations of Alert SB for installing FCE CBP 5.1 software with the compliance time of 6 months after the Issue 001 date:

(a) B787-81205-SB270053-00, Issue 001, was published on 19 February 2021, and

(b) B787-81205-SB270053-00, Issue 002, was published on 6 May 2021.

5.1.3. Closure of Safety Recommendation 02-2020

In consideration of the safety actions taken by Boeing and the FAA, the investigation team confirmed that there were no new discoveries of incomplete safety actions. Hence, Safety Recommendation 02-2020 was closed.

[6] The CFR Title 14 contains the codified Federal laws and regulations that are in effect as of the date of the publication pertaining to aeronautics, air transportation / aviation (including large and small aircraft, such as commercial airplanes, helicopters, balloons and gliders), and space exploration, including areas overseen by the FAA and National Aeronautics and Space Administration (NASA).

6. Safety Recommendation

In consideration of the proactive safety actions already taken by the CAD, FAA, Boeing and Ethiopian Airlines, the investigation team confirmed that there were no new discoveries of incomplete safety actions. Hence, no safety recommendation is proposed.

7. General Details

7.1. Occurrence Details

Date and time:	18 July 2019, 2351 hrs Local (1551 hrs UTC)
Occurrence category:	Serious Incident
Primary occurrence type:	Deviation from Intended Flightpath Inflight
Location:	Waypoint RIVER of Hong Kong
Position:	22° 24' 7.55" N, 114° 10' 54.23" E

7.2. Pilot Information

7.2.1. PF (Captain)

Age:	47
Licence:	Airline Transport Pilot's Licence (ATPL)
Aircraft ratings:	B777, B787
Date of first issue of aircraft rating on Boeing type:	07.1999
Medical certificate:	Class 1
ICAO Language Proficiency:	Level 5
Limitation:	Nil.
Flying Experience:	
Total all types:	5,302 hrs
Total on type (B787):	3,082 hrs

7.2.2. Pilot Monitoring (PM) (First Officer)

Age:	30
Licence:	ATPL
Aircraft ratings:	B777, B787
Date of first issue of aircraft rating on Boeing type:	04.2017
Medical certificate:	Class 1
ICAO Language Proficiency:	Level 4
Limitation:	Distant Vision
Flying Experience:	
Total all types:	3,082 hrs
Total on type (B787):	3,082 hrs

7.3. Aircraft Details

Manufacturer and model:	Boeing 787-8	
Registration:	Ethiopia, ET-ASG	
Serial number:	36111	
Year of Manufacture:	2015	
Engine:	Two General Electric GEnx-1B	
Operator:	Ethiopian Airlines	
Type of Operation:	Scheduled Passenger Service	
Certificate of Airworthiness	Issued on 30.01.2015	
Departure:	RPLL	
Destination:	VHHH	
Persons on board:	Crew – 10	Passengers – 225
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	Nil.	

7.4. Aerodrome Information

7.4.1. Aerodrome of Destination

Aerodrome Code	VHHH
Airport Name	VHHH
Airport Address	Chek Lap Kok, Lantau Island
Airport Authority	Airport Authority Hong Kong
Air Navigation Services	Approach Control, Aerodrome Control, Ground Movement Control, Zone Control, Flight Information Service, Clearance Delivery Control, Automatic Terminal Information Service
Type of Traffic Permitted	Instrument Flight Rules (IFR) / Visual Flight Rules (VFR)
Coordinates	22° 18' 32" N, 113° 54' 53" E
Elevation	28 ft
RWY Length	3,800 m
RWY Width	60 m
Stopway	Nil
RWY End Safety Area	240 m x 150 m
Azimuth	07L / 25R, 07R / 25L (At the time of the occurrence)
Category for Rescue and Fire Fighting Services	CAT 10

8. Abbreviations

A/P	Autopilot
AAIA	Air Accident Investigation Authority of Hong Kong
ACE	Actuator Control Electronics
AD	Airworthiness Directive
AFDS	Autopilot Flight Director System
AFF	Autoflight Function
AFM	Aircraft Flight Manual
AIC	Aeronautical Information Circular
AIP Hong Kong	Aeronautical Information Publication Hong Kong
Annex 13	Annex 13 to the Convention on International Civil Aviation
ATC	Air Traffic Control
ATPL	Airline Transport Pilot's Licence
CAAC	Civil Aviation Administration of China
CAD	Civil Aviation Department of Hong Kong
Cap. 448B	Hong Kong Civil Aviation (Investigation of Accidents) Regulations
CBP	Common Block Point
CFR	Code of Federal Regulations
CLC	Consistent Localizer Capture
CVR	Cockpit Voice Recorder
ECAA	Ethiopian Civil Aviation Authority
EAFR	Enhanced Airborne Flight Recorder
EAIB	Ethiopian Accident Investigation Bureau of Ethiopia

EGPWS	Enhanced Ground Proximity Warning System
FAA	Federal Aviation Administration
FCE	Flight Control Electronics
FCM	Flight Control Module
FDR	Flight Data Recorder
FIC	Flight Inspection Centre
FMA	Flight Mode Annunciator
ft	Feet
FTD	Fleet Team Digest
GBAS	Ground-Based Augmentation System
GLS	GBAS Landing System
GPS	Global Positioning System
HDG	Heading
hrs	Hours
HUD	Head-up Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LOC	Localizer
MCP	Mode Control Panel
METAR	Meteorological Aerodrome Report
MSA	Minimum Sector Altitude
NASA	National Aeronautics and Space Administration
ND	Navigation Display

NM	Nautical Miles
NOTAM	Notice to Airmen
NPRM	Notice of Proposed Rulemaking
NTSB	National Transportation Safety Board of the United States of America
O&M	Operations and Maintenance
PF	Pilot Flying
PFCF	Primary Flight Control Function
PFD	Primary Flight Display
PM	Pilot Monitoring
RPLL	Manila Ninoy Aquino International Airport
RWY	Runway
SB	Service Bulletin
TD	Station Identity Code of Radio Navigation Aids at Tung Lung
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
VHHH	Hong Kong International Airport

9. Table of Figure, Photo, Table