الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Serious Incident

- Final Report -

AAIS Case Nº AIFN/0016/2021

Shallow Initial Climb After Takeoff

Operator:	Emirates
Aircraft Make and Model:	Boeing 777-300ER
Nationality and Registration:	The United Arab Emirates, A6-EQI
Place of Occurrence:	Dubai International Airport
State of Occurrence:	The United Arab Emirates
Date of Occurrence:	19 December 2021

This Investigation was conducted by the Air Accident Investigation Sector of the United Arab Emirates pursuant to Civil Aviation Law No. 20 of 1991, in compliance with Air Accident and Incident Investigation Regulation, and in conformance with the requirements of Annex 13 to the Convention on International Civil Aviation.

This Investigation was conducted independently and without prejudice. The sole objective of the investigation is to prevent future aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The Air Accident Investigation Sector issued this Final Report in accordance with the national and international standards and practices. Consultation with applicable stakeholders, and consideration of their comments, took place prior to the publication of this Report.

The Final Report is publicly available at:

https://www.gcaa.gov.ae/en/departments/airaccidentinvestigation/Pages/InvestigationReports.aspx

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Occurrence Brief

AAIS Report No.:	AIFN/0016/2021
Operator:	Emirates
Aircraft Type and Registration:	Boeing 777-300ER, A6-EQI
MSN:	42354
Number and Type of Engines:	Two, General Electric – GE90
Date and Time (UTC):	19 December 2021
Location:	Dubai International Airport
Type of Flight:	Commercial – Scheduled Passenger
People Onboard:	372
Injuries:	None

Investigation Objective

This investigation was conducted pursuant to the United Arab Emirates *Federal Act 20 of 1991*, promulgating the *Civil Aviation Law*, Chapter VII – *Aircraft Accidents*, Article 48. It is in compliance with the *Air Accident and Incident Investigation Regulation (AAIR)*, in conformity with *Annex 13 to the Convention on International Civil Aviation*, and in adherence to the *Air Accident and Incident Investigation Procedures*.

The sole objective of this investigation is to prevent aircraft accidents and incidents. It is not the intent of this activity to apportion blame or liability.

Investigation Process

The occurrence involved a Boeing 777-300ER, registration marks A6-EQI, and was notified to the Air Accident Investigation Sector (AAIS) of the United Arab Emirates by a phone call to the Duty Investigator (DI) Hotline Number +971 50 641 4667.

After the initial investigation phase, the occurrence was classified as a ‘serious incident’.

According to *Annex 13* obligations, and as the United Arab Emirates as of being the State of Occurrence, the AAIS formed an investigation team and appointed an investigator-in-charge (IIC) and members for the different investigation areas. The AAIS notified the National Transportation Safety Board (NTSB) of the United States as of being the authority of the State of Design and Manufacture of the aircraft. The NTSB designated an accredited representative supported by advisers from The Boeing Company.

Notes:

[1] Whenever the following words are mentioned in this Final Report with the first letter Capitalized, it shall mean the following:

- (Aircraft) – the aircraft involved in this serious incident
- (Commander) – the commander of the serious incident flight

- (Copilot) – the copilot of the serious incident flight
- (Incident) – this investigated serious incident
- (Investigation) – the investigation into this serious incident
- (Operator) – Emirates
- (Report) – this serious incident investigation Final Report.

2 Unless otherwise mentioned, all times in this Report are in coordinated universal times (UTC).

3 Photos and figures used in the text of this Report are taken from different sources and are adjusted from the original for the sole purpose to improve the clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast, or insertion of text boxes, arrows, or lines.

Abbreviations

AAIS	The Air Accident Investigation Sector of the United Arab Emirates
ACARS	Aircraft communications, addressing and reporting system
ADIRS	Air data initial reference system
ADF	Automatic direction finder
AFDS	Autopilot flight director system
AIFN	Accident/incident file number
ALT	Altitude
AOC	Air operator certificate
ATO	Approved training organization
ATPL	Air transport pilot license
°C	Celsius (degree)
COVID	Corona virus disease
CVR	Cockpit voice recorder
DME	Distance measuring equipment
EBT	Evidence-based training
EGPWS	Enhanced ground proximity warning system
EGT	Exhaust gas temperature
EICAS	Engine indicating and crew alerting system
EPR	Engine pressure ratio
ER	Extended Range
FCOM	Flight crew operations manual
FCTM	Flight crew training manual
FDM	Flight data monitoring
FDR	Flight data recorder
FFS	Full flight simulator
FMA	Flight mode annunciator
FMC	Flight management computer
FMS	Flight management system
GCAA	The General Civil Aviation Authority of the United Arab Emirates
GPS	Global positioning system
hPa	Hectopascal (pressure unit)
HPC	High-pressure compressor
IAS	Indicated airspeed

ICAO	The International Civil Aviation Organization
ILS	Instrument landing system
IPC	Intermediate pressure compressor
KIAD	Washington Dulles International Airport
LNAV	Lateral navigation
LPC	Low pressure compressor
MCP	Mode control panel
MFD	Multi-function display
MSA	Minimum sector altitude
MSN	Manufacturer serial number
MTOW	Maximum take-off weight
NTSB	The National Transportation Safety Board of the United States
OFP	Operational flight plan
OGS	Online grading system
OMDB	Dubai International Airport
OPC	Operator proficiency check
PAM	Pilot assessment marker
PF	Pilot flying
PFD	Primary flight display
PM	Pilot monitoring
SEP	Safety and emergency procedures
SID	Standard instrument departure
SSFDR	Solid state flight data recorder
TO/GA	Takeoff/go-around
TRE	Type rating examiner
UTC	Coordinated universal time
VDL	Distant visual acuity
V_{fe}	Maximum flap extended speed
VNAV	Vertical navigation
VOR	Very high frequency omni-directional range

Synopsis

On 19 December 2021, an Emirates Boeing 777-300ER (Extended Range), registration marks A6-EQI, operating a scheduled passenger flight number EK231, took off from runway 30R of Dubai International Airport (OMDB), the United Arab Emirates, at 23:10 UTC, for Washington Dulles International Airport (KIAD), the United States. There were 372 people onboard comprising of: 2 operating and 2 augmenting flight crewmembers; 14 cabin crewmembers; and 354 passengers.

The flight crew consisted of two sets: A and B. Each set consisted of a commander and copilot. The Commander of set A operated as the pilot flying (PF) and the Copilot operated as the pilot monitoring (PM). The augmenting commander and copilot occupied the observer seats.

During preflight preparation, the Copilot noticed that ALT pitch mode was engaged in the autopilot flight director system (AFDS) as indicated by the flight mode annunciator (FMA). In such conditions, and along with the selected zero runway elevation (00000 feet) altitude that was set sometime before the flight, the flight director (FD) would command a pitch that would target the selected zero runway elevation '00000 feet' instead of targeting climb speed normally of V2+15 to 25 knots.

The Copilot was aware of the inappropriate ALT pitch mode annunciated on the FMA, and he attempted to rectify it. The attempt of the Copilot was unsuccessful. Meanwhile, the Commander delegated the walkaround task to the augmenting captain.

The incorrect ALT pitch mode engagement went unnoticed by the Commander and augmenting flight crews throughout the taxi phase.

During initial climb, as the landing gear lever was moved to up, the pitch decreased causing the airspeed to increase and the rate of climb to decrease, resulting in the airspeed exceeding the allowable limits for the pre-selected flap setting (position 15). Consequently, the flap load relief function activated and started retracting the flaps to position 5.

The pitch continued to decrease passing through 3 degrees which remained for a few seconds. Thereafter, the Commander activated the TOGA switch, which resulted in a correct AFDS pitch mode activation, and the flight director pitch guidance was restored to guide a climb. However, the increased power combined with the low pitch attitude accelerated the Aircraft leading to another exceedance to the allowable extended flap airspeed.

Afterwards, the aircraft maintained an appropriate rate of climb and the flight proceeded towards its destination. Throughout this time, the Commander continued to fulfill the role of PF.

The Investigation concluded that the cause of the shallow climb serious incident was the pitch down below the required pitch attitude required for achieving a positive and safe rate of climb. Contributing factors to the Incident: The AFDS did not include any provisions to prevent a takeoff with incorrect AFDS pitch mode; the Commander did not identify the incorrect AFDS pitch mode and inappropriate altitude entry; the Copilot was aware of the incorrect AFDS pitch mode activation, however, he could not rectify it and did not bring it to the Commander's attention; and no explicit procedures were available on how to reset the flight directors in order to enable the crew to select the correct pitch mode.

Appropriate safety actions were taken by the Operator and Aircraft's manufacturer during the Investigation. The Air Accident Investigation Sector (AAIS) addressed one safety recommendation to the Operator.

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1. Factual Information

1.1 History of the Flight

On 19 December 2021, an Emirates Boeing 777-300ER (Extended Range), registration marks A6-EQI, operating a scheduled passenger flight number EK231, took off from runway 30R of Dubai International Airport (OMDB), the United Arab Emirates, at 23:10 UTC, for Washington Dulles International Airport (KIAD), the United States. There were 372 people onboard comprising of: 2 operating and 2 augmenting flight crewmembers; 14 cabin crewmembers; and 354 passengers.

The flight crew consisted of two sets: A and B. Each set was comprised of a commander and copilot. The Commander of set A operated as the pilot flying (PF) and the Copilot operated as the pilot monitoring (PM). The augmenting commander and copilot occupied the observer seats.

According to the Commander, she reported ten minutes late, but the briefings went normal, and the flight preparation checks were accomplished smoothly. The augmenting crew[1] also assisted in the flight preparation by checking the technical logbook.

The augmenting crew observed that the altitude window in the mode control panel (MCP) indicated zero '00000 feet', which was not the usual selection. Typically, this setting should either be the selected altitude for a missed approach in the previous sector or, in the event of a power reset, automatically default to '10000 feet'. At autopilot flight director system (AFDS) ALT pitch mode and with zero runway elevation selection on the MCP, the flight director (FD) would direct the Aircraft to descend, as if the sea level were the desired altitude, instead of climbing at a standard rate.

According to the Copilot's statement, after taking his cockpit seat, he performed the cockpit preparation duties as PM. He noticed that the flight mode annunciator (FMA) on his side was displaying TO/GA (roll Mode, engaged) ALT[2] (pitch mode, engaged), which was unusual. Despite that, he decided to continue with his tasks and address the FMA issue later. He attempted to reset the flight director on his side by toggling the switch 'off' and then 'on'. However, the reset attempt was unsuccessful and the FMA continued displaying TO/GA ALT. The Copilot intended to inform the Commander about the unusual FMA indication and his unsuccessful reset attempt. However, he forgot to communicate this information to the Commander attributing it to being distracted by the busy cockpit environment and describing it as slipping from his mind.

The pushback, taxi, and lining up procedures were routine, and speed calculations were initially performed for intersection Mike 13A. However, a request was made to change the clearance for takeoff to intersection Mike 14A, as it would allow for a longer distance for takeoff. As documented in the *operational flight plan (OFP)* and verified by the Investigation, the calculated

[1] Augmenting crew: comprises any pilot, carried to provide In-Flight relief for the operating crew for the purpose of extending a Flight Duty Period

[2] ALT is an AFDS mode that reflects that an aircraft will be leveling off at the altitude selected in the altitude selector

speeds for takeoff were as follows: V_1: 170, V_r (rotation speed): 177, V_2: 183[3] knots, and the flap selection for takeoff was flap 15[4].

At 2309:43 UTC, the Aircraft commenced the take-off roll.

At 2309:47, the FMA displayed THR REF (autothrottle mode), TO/GA (roll/lateral mode), and ALT (pitch/vertical mode). The THR REF started indicating at this time.

At 2310:02, the autothrottle mode changed to HOLD when the calibrated airspeed reached 80 knots.

At 2310:30, the Aircraft commenced rotating at 181 knots airspeed, about 2,280 meters on the runway from intersection Mike 14 A.

At 2310:34, the Aircraft lifted off. About two seconds thereafter, the pitch increased to 10.4 degrees nose-up. The calibrated airspeed was 197 knots, and the radio altitude[5] was about 30 feet. The pitch then started to decrease slowly. Once airborne during the initial climb, a maximum of about 5 knots tailwind was experienced.

As per the Copilot's statement, he attempted to confirm if the Aircraft was climbing by checking the increase of altitude in the altimeter and the pitch indication which was ten degrees. The Copilot stated to the Investigation, "I called positive climb and the Commander instructed gear up[6]."

At 2310:41, the landing gear lever was moved to 'UP' position when the Aircraft reached 101 feet radio altitude. The rate of climb was 880 feet per minute and started to reduce as the Commander pitched the nose down as a reaction towards the flight director indication.

As per the Commander's statement, she was aiming the pitch towards 15 degrees[7] up and to be adjusted as required. After passing 10 degrees, she noticed that the flight director was displaying a pitch attitude that was inconsistent with this phase of flight. In spite of this inconsistency that she was aware about, she opted to follow the flight director indication and accordingly lowered the pitch.

According to her statement, the Commander perceived the pitch higher than the flight director's indication (-6.9 degrees). Accordingly, she lowered the pitch attitude to approximately 5 to 7.7 degrees nose-up for about 15 seconds (between 2310:42 and 2310:56), even though the flight director indication still showing a lower pitch attitude. She maintained this pitch to "…make

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[3] V_1 is the maximum speed at which a rejected takeoff can be initiated in the event of an emergency. V_r is the speed at which the rotation of the aircraft should be initiated to take-off attitude. V_2 is the take-off safety speed which must be attained at the 35 feet height at the end of the required runway distance. [Source: Skybrary.com]

[4] The Boeing 777-300 ER has seven flap positions ranging from flap '0' (fully retracted), '1', '5', '15', '20', '25', and '30' (fully extended)

[5] Radio altimeter is an airborne electronic device capable of measuring the height of the aircraft above terrain immediately below the aircraft. It is an important tool to help minimize the risk of controlled flight into terrain (CFIT), because it provides an independent and unambiguous warning of proximity to the ground, regardless of any navigational uncertainty or error such as mis-setting of the barometric altimeter sub-scale. [Source: www.skybrary.com]

[6] 'Gear up' is a standard call-out in which the PF instructs the PM to retract the landing gear after confirmation that the aircraft is climbing by checking the altitude increase in the altimeter

[7] Standard pitch-up attitude to maintain the speed between V2+15 and V2+25 in accordance with the technique outlined in the *flight crew operations manual (FCOM)* and *flight crew training manual (FCTM)* to maintain a safe take-off profile

sense of what I [she] see[s].” The Commander also stated that upon observing the unusual indication, she became suspicious that the Aircraft calculated weight provided to the flight crew was incorrect.

According to his statement, after the Copilot moved the gear lever up, he checked outside and saw a different picture, the speed was increasing whereas the Aircraft was close to the ground. The Copilot added, “I got startled for a couple of seconds, then I shouted ‘climb’, and the augmenting commander shouted: ‘pitch up’.”

At 2310:49, the speedbrake lever was slightly moved shortly, however, the speedbrakes did not deploy.

Between 2310:49 and 2311:07, there were several significant roll control inputs of more than 15 degrees made by the Commander, six to the left with a maximum of 35.8 degrees and four to the right with a maximum of 23.3 degrees. However, the Aircraft’s roll angle remained below about 2.5 degrees. During this period, the heading was constant at 300 degrees and the Aircraft experienced a maximum of 4 knots tailwind with a small change.

At 2310:50, the airspeed was at 216 knots, and the Aircraft reached 160 feet radio altitude, while the rate of climb was about 255 feet per minute. The Commander manually advanced the thrust levers from 77 degrees (engine 1) and 79 degrees (engine 2) to 84 degrees for both engines over nine seconds.

At 2310:53, the speedbrake lever was slightly moved shortly, however, the speedbrakes did not deploy.

At 2310:54, as the airspeed was at 226 knots, the pitch attitude was at 7.7 degrees and lowered to about 3 degrees which was reached at 2310:59. Hence, the airspeed continued to increase and reached the V_{FE} flap 15, 230 knots, at 2310:56. This caused the activation of flap load relief that made the flaps automatically retracted to position ‘5’ without moving the flaps lever.

At 2311:00, the climb rate was about 64 feet per minute. The speedbrake lever was slightly moved shortly, however, the speedbrakes did not deploy. About one second later, the TO/GA switch was pressed causing the FMA immediately to change from HOLD | LNAV | ALT to THR REF | TO/GA | TO/GA, and the climb rate started to increase. The flight director's pitch bar started to move from nose-down to nose-up attitude. The Aircraft pitch attitude of 3 degrees started to increase slowly. There was no GPWS warning.

The Copilot stated that he thought to take control when he realized that the Aircraft was not climbing, based on external visual cues. However, shortly after, the Commander responded by activating the TO/GA switch on the thrust levers.

Between 2311:00 and 2311:16, the airspeed increased from 239 to 262 knots, causing a flap ‘5’ overspeed (245 knots) at 2311:03. During this period, the pitch increased from 3 to 14 degrees.

At 2311:06, the speedbrake lever was slightly moved shortly, however, the speedbrakes did not deploy.

At 2311:11, the autopilot was engaged, while the Aircraft climbed through 459 feet radio altitude and the rate of climb was about 2,610 feet per minute.

At 2311:19, the TO/GA mode was disengaged, and the Aircraft rate of climb was about4,900 feet per minute, with a pitch angle of 14.6 degrees. One second later, the flap lever was moved from 15 to 5 while the airspeed was 260 knots.

At 2312:27, the flaps lever was retracted from ‘5’ to ‘1’, while the airspeed was 239 knots.

At 2313:01, the flaps lever was retracted to ‘0’ while the airspeed was 249 knots.

At 2329:14, the Aircraft reached top of climb. The augmenting commander suggested to the Commander to take a ten-minutes break, but she responded that she was fine and had recovered from the “surprise” of the situation. The augmenting commander expressed “shock” about what had happened and asked the Commander how she was feeling. The Commander replied, “It is over, it is passed, carry on.” The augmenting commander then left the cockpit.

The augmenting commander stated that he returned to the cockpit due feeling “uncomfortable” and remained there for one hour. Afterwards, he needed to rest, so he checked with the operating crew about how do they feel after the Incident before leaving the cockpit. They confirmed that they were “okay”. Additionally, the augmenting commander informed that he asked the Commander to use the aircraft communications, addressing and reporting system (ACARS) to contact the Operator's head office and verify the accuracy of the load sheet calculations and ensure the Aircraft’s state following the overspeed.

At 1330:28 the Aircraft landed at KIAD uneventfully.

1.2 Injuries to Persons

There were no injuries to persons as a result of this Incident.

1.3 Damage to Aircraft

There was no damage to the Aircraft.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 General data

Table 1 illustrates the Commander and the Copilot data current at the time of the Incident.

Table 1. Operating flight crew data

	Commander	Copilot
Age	42	26
Type of license	ATPL*(A)	ATPL(A)
Valid to	7 June 2028	29 March 2025
Rating	IR/MPA/B777	IR/MPA/B777
Total flying time (hours)	10,849:15	4,644:35
Total on type (hours)	6,567:58	3,426:15
Total on type last 90 days (hours)	196:18:00	123:01
Total on type last 7 days (hours)	22:05	0
Total last 24 hours (hours)	0	0
Last recurrent Safety and emergency procedures (SEP) training	15 July 2021	5 July 2021
Last operator proficiency check (OPC)	15 July 2021	5 July 2021

Last line check	31 August 2020	19 July 2020
Medical class (valid to)	One (25 August 2022)	One (17 July 2022)
Medical limitation	NIL	VDL[8]
*ATPL: Air transport pilot license		

1.5.2 The Commander

The Investigation conducted two interviews with the Commander to assess her knowledge of the system, proficiency in flying the type, and any human factors considerations that could have influenced her performance during preflight preparation, takeoff, and initial climb.

The Commander stated that the take-off weight for the Incident flight was close to the maximum structural[9] take-off weight. In addition, she stated that during the threat-forward[10] briefing, she emphasized the need for the crew to utilize the entire length of the runway. The Commander further stated that she considered flying close to maximum take-off weight as a potential threat, as she had been previously operating lighter take-off weights mostly due to the effect the COVID-19 pandemic and had not flown an aircraft close to its maximum take-off weight for some time.

According to the Commander's flight records, she has operated a certain number of flights with relatively heavy take-off weights, as follows:

- Three flights to Melbourne, Australia, on the same aircraft type in January, February, and June 2021. The take-off weights for these flights were approximately 305, 309, and 309 tonnes, respectively.
- In April 2021, she operated a flight to Toronto, Canada, with a take-off weight of approximately 347 tonnes, which was close to the maximum take-off weight (351,534 kg)
- In May 2021, she operated a flight to Sao Paulo, Brazil, with a take-off weight of approximately 315 tonnes.

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[8] VDL limitation is correction for defective distant vision whilst exercising the privileges of the license, the license holder shall wear spectacles or contact lenses that correct for defective distant vision as examined and approved by the aeromedical examiner (AME). According to *CAR-Med* Regulations: the "Distant visual acuity", with or without correction, shall be in the case of Class 1 Pilot, 6/9 or better in each eye separately and visual acuity with both eyes shall be 6/6 or better. For Class 1 Pilots: A routine eye examination can be performed by an AME at each renewal of medical certificate. However, a comprehensive eye examination by an eye specialist (Ophthalmologist) is required at the initial GCAA examination. All abnormal and doubtful cases should be referred to an ophthalmologist during renewal or when clinically indicated

[8] The Commander was referring to the maximum takeoff weight of the Aircraft but used the term the maximum structural weight during the interview

[10] *Threat forward.* Following the law of primacy (that information presented first is better retained), crew departure and arrival briefings should first address the relevant threats to the flight and go on to discuss specific countermeasures that could be employed should any of those threats degrade safety margins. An additional benefit of a threat-forward briefing is that in identifying relevant threats early in the briefing, those threats tend to positively inform the subsequent departure or arrival plan. [Source: Flight Safety Foundation: www.flightsafety.org]

The Commander stated that she did not receive training for handling an aircraft with an incorrect flight director indication. She referred to the ALT pitch FMA indication and the flight director's command to decrease the pitch, which did not align with the typical initial climb attitude.

The augmented commander, who occupied the third occupant seat in the cockpit, described the Commander as, "Her demeanors were quite serious, structured and straight forward but it was fine."

1.5.3 The Copilot

The Investigation asked the Copilot about the cause of the ALT pitch mode being displayed on the FMA, and he explained that this occurred because the selected altitude on the MCP was within a 20-foot range from the barometric altitude.

The Copilot added that he intended to discuss with the Commander her thoughts on the FMA displayed modes and whether they were normal or required any action. On a later day, he found information in the "manual [*flight crew operations manual* (*FCOM)*]", which indicated that in order to reset the FMA modes to TO/GA TO/GA, a crewmember should do a reset of both flight directors.

1.5.4 Fatigue review

The Operator conducted a fatigue assessment by utilizing the Pulsar Psychomotor Vigilance Test (PVT)[11]. Additionally, the roster was examined and indicated that the Commander was in a two-day rest before operating the flight. It was also noted that the flight was the Copilot's first flight after returning from a leave.

The Investigation considered the Operator's assessment of fatigue, examination of the roster, and statements from the Commander and Copilot, and based on this information, fatigue was determined to not be a contributing factor to the Incident.

1.6 Aircraft Information

1.6.1 Aircraft general data

Table 2 illustrates the general Aircraft data.

Table 2. Aircraft data	
Manufacturer	The Boeing Company
Model	B777-300ER
Manufacturer serial number (MSN)	42354
Year of manufacture	2017
Nationality and registration	A6-EQI
Name of the owner	Credit Agricole Corporate and Investment Bank
Name of the operator	Emirates
Certificate of Airworthiness	

[11] According to the Operator, PVT measures changes in psychomotor speed, lapses of attention and instability of alertness

	Number: Issue date:	UAE-COA-0517 30 November 2017
Certificate of Registration		
	Number: Issue date:	UAE-COR-1038 30 November 2017
Date of delivery		30 November 2017
Time since new (TSN) (hours)		17,216
Cycles since new (CSN)		2,708
Cycles since last service check		11
Maximum taxi weight		352,441 kg
Maximum take-off weight		351,534 kg
Maximum landing weight		251,290 kg
Maximum zero fuel weight		237,682 kg

1.6.2 Boeing 777-300 ER cockpit layout

The Boeing 777-300 ER cockpit is configured with four seats, including two for observers.

The forward panel contains the flight display system, indicators, and some systems' controls. The landing gear lever is located on the forward panel.

Above the display units is the glare shield, where the MCP, red master warning, and amber caution lights are located. The MCP includes two autothrottle (A/T) arm switches and one A/T activation pushbutton switch.

The control columns are located forward of the pilots' seats. Each control wheel includes the pitch trim switches, autopilot disconnect switch, and a boom microphone push-to-talk switch. The control column design permits a clear view of all the flight instruments when the pilots adjust their seats to the eye reference point.

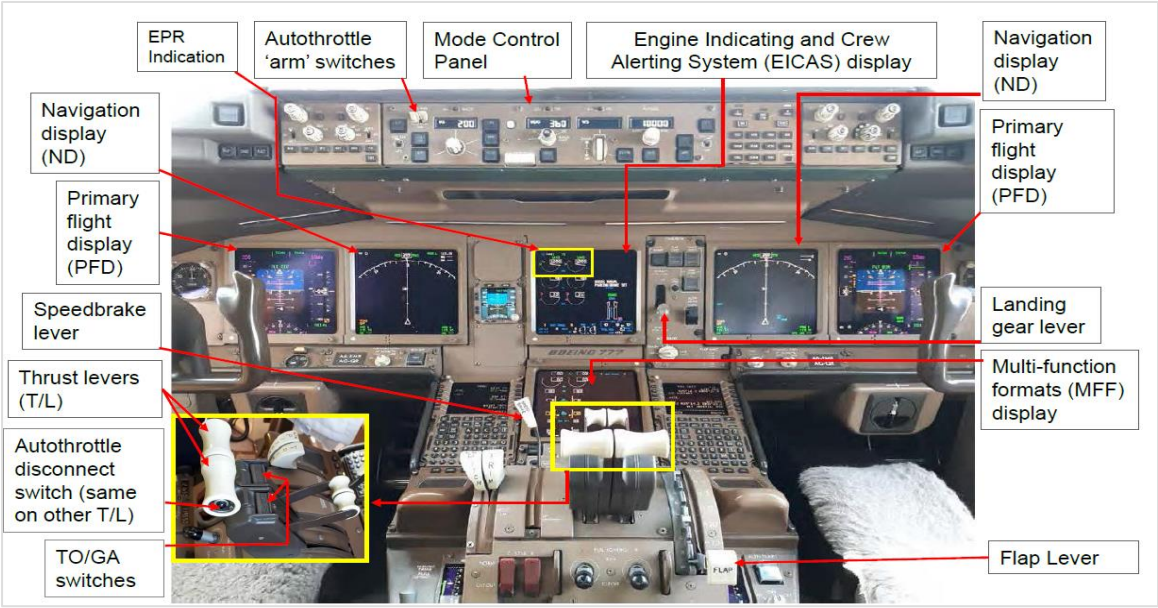


Figure 1. Boeing 777 cockpit layout

The control stand located at the center of the cockpit has provisions for easily reachable controls. Among these controls are the thrust levers, flap lever, and the speed-brake lever.

Both thrust levers can be manually moved by the pilots in addition to being automatically controlled by the A/T. There are no gates between the idle and maximum thrust lever positions. A TO/GA switch is located on the forward side of each thrust lever and an A/T disconnect switch is located on the side of each thrust lever. (Figure 1)

The flap lever (positions the slats and flaps) is located on the center control stand adjacent to the right thrust lever. There are seven selectable positions for the flap lever from 'up' to '30', with gated slots at positions '20' and '1'. The mechanical gate at the flaps 20 detent prevents inadvertent retraction of the flaps past the go-around flap setting. The mechanical gate at flaps 1 prevents inadvertent retraction of the slats past the midrange position.

1.6.3 Autopilot flight director system (AFDS) and the MCP

AFDS consists of three autopilot flight director computers and the MCP. The MCP provides control of the autopilot, 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.

The flight director information is displayed on the primary flight display (PFD). The AFDS does not have direct control of the flight control surfaces. The autopilot controls the elevators, ailerons, flaperons, and spoilers through the fly-by-wire flight control system.

1.6.4 AFDS pitch modes

There are several pitch annunciations presented on the FMA, two of these annunciations are: TO/GA; and ALT (active)[12]

On the ground, with both flight director switches OFF, TO/GA annunciations are activated by either positioning the flight director switch to 'ON', or by pressing either TO/GA switch while the airspeed is greater than 80 knots when MCP selected altitude differs more than 20 feet from displayed baro altitude. The flight director's PFD pitch bar indicates an initial pitch of eight degrees up. TO/GA pitch guidance becomes active at liftoff.

After liftoff, in TO/GA mode, the AFDS controls the pitch attitude to maintain:

- A target speed of V_2 plus 15 knots, or the airspeed[13] at rotation (pitch attitude greater than two degrees) plus 15 knots, whichever is greater;
- If the current airspeed exceeds the target speed for 5 seconds, the target speed is reset to the lesser of the current airspeed or to V_2 plus 25 knots; or
- The indicated airspeed (IAS)/MACH window speed if the window speed is changed to a speed greater than the target speed.

The Altitude hold (ALT) mode is engaged by:

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[12] Active: refers to the activation of ALT pitch mode which indicates that the Aircraft is levelling off at the altitude selected on the MCP

[13] The TO/GA pitch mode control law receives the V_2 speed target from the MCP speed window. The flight crew sets the V2 speed calculated by the FMC in the MCP speed window

- Pressing the MCP altitude HOLD switch; or
- Capturing the selected altitude from a vertical speed (V/S), flight path angle (FPA), or flight level change (FLCH) climb or descent.

1.6.5 The flight mode annunciator (FMA)

The FMA announces (figure 2):

- The authrottle (A/T) modes (1): one of five active modes is displayed in green: THR; THR REF; IDLE; HOLD; or SPD.
- The AFDS roll modes (2): one of nine engaged modes is displayed in green: LNAV; HDG HOLD; HDG SEL; TRK SEL; TRK HOLD; ATT; LOC; TO/GA; or ROLLOUT.
- The AFDS roll modes (3): one of three armed modes is displayed in white: LOC; LNAV; or ROLLOUT.
- The AFDS pitch modes (4): one of ten engaged modes is displayed in green: TO/GA; ALT; V/S; VNAV PTH; VNAV SPD; VNAV ALT; G/S; FLARE; FLCH SPD; or FPA.
- The AFDS pitch modes (5): one of three armed modes is displayed in white: G/S; FLARE; or VNAV.
- Autoflight status annunciation (6): The autoflight status will annunciate ‘A/P’ to indicate that the autopilot is engaged; or ‘FLT DIR’ when the flight director is selected ‘on’; or the autoland status.

The FMA displays the active modes in green color, while the armed modes are displayed in white color.

In addition, the Boeing 777-300 ER allows the arming/engagement of irrelevant FMA modes even if the mode can affect the performance of the aircraft’s safe flight path or performance. For example, ALT pitch mode can be active on the ground while at parking and before takeoff. Although the next phase of flight, which is takeoff, requires progressive climbing not levelling off to meet the safe climb gradient by maintaining V_2+15 or V_2+25 whichever is higher.

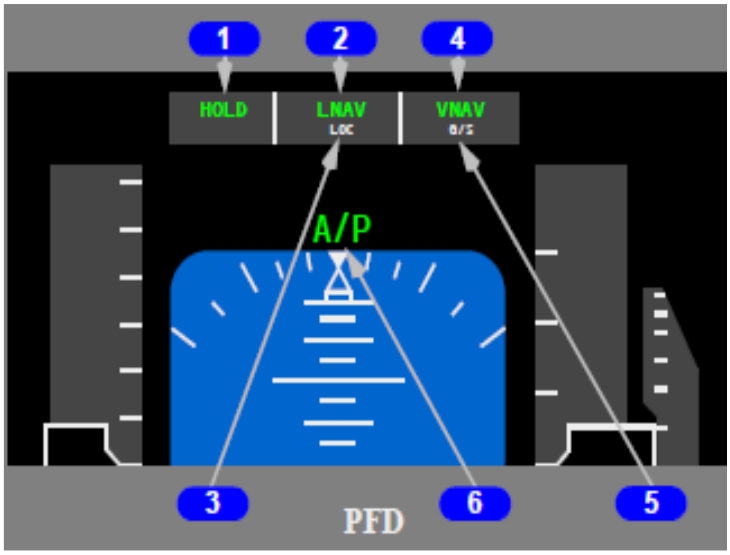


Figure 2. PFD flight mode annunciator (FMA)

Turning and ensuring that both flight director toggle switches are 'on' is part of the *SOP*. If done correctly, the FMA shall display TO/GA | TO/GA in both AFDS roll and pitch modes indicators. Engine 2 was the first engine that was started up, and both flight directors appeared ON. The FMA displayed TO/GA | ALT for the roll and pitch modes.

As observed by the augmenting crew, the MCP altitude indicated 00000 (within 20 feet of the displayed baro altitude) during the pre-flight preparation. Since OMDB elevation is close to sea level, the displayed ALT on the FMA was met.

1.6.6 Flight director and MCP interconnection

On the ground, with both flight director switches are 'off', switching either flight director (from either sides) to 'on' will:

- Activate the flight director TO/GA roll mode; and
- Activate the flight director TO/GA pitch mode when MCP selected altitude differs more than 20 feet from the displayed barometric altitude, or activate the flight director ALT pitch mode when the selected altitude is within 20 feet of the displayed barometric altitude in the PFD.

If ALT pitch mode engages, selecting an altitude more than 20 feet from displayed barometric altitude and recycling the first switch, activates the flight director in TO/GA roll and TO/GA pitch modes[14]. The flight mode annunciation appears on both PFDs. Positioning the second switch 'on' displays the flight director steering indications on the second PFD.

1.6.7 Typical PFD indication when TO/GA TO/GA are active on the FMA

According to the *FCOM*, the typical display of the PFD in preparation for takeoff is TO/GA TO/GA.

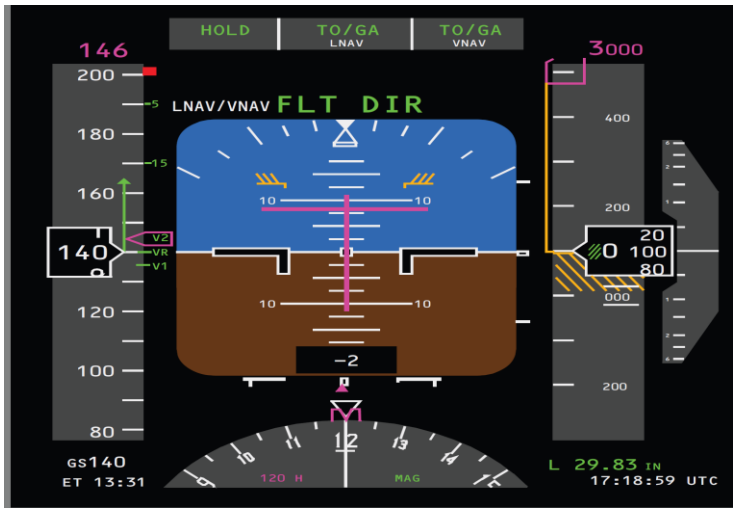


Figure 3. Typical PFD display for takeoff (note the flight director (the magenta cross) indicating climb prompt) [Source: *FCOM*]

[14] Reference: *FCOM*, Controls and Indicators, 4.10.1, AFDS System Controls

1.6.8 Flap/slat load relief

According to the *FCOM*, in the primary mode of flap and slat operation (by hydraulic power which is supplied by the center hydraulic system), the flap load relief system protects the flaps from excessive air loads. If flap airspeed placard limits are exceeded with the flaps in the 15 through the 30 positions, LOAD RELIEF is displayed and the flaps automatically retract to a position appropriate to the airspeed. Flaps start to retract when airspeed is 1 knot higher than the flap placard airspeed. Load relief retraction is limited to flaps '5'.

When a flap over-speed exists, load relief prevents flap extension beyond '5', '15', '20', or '25' positions until airspeed is sufficiently reduced. The flap display on the engine indicating and crew alerting system (EICAS) indicates an in-transit flap condition and shows actual flap position. The flap lever does not move during flap load relief operation. Load relief for slats is not required in the primary or alternate modes.

1.6.9 Flight instruments and displays

The flight instruments and displays provide information for all flight phases and include aircraft warnings and the status of aircraft systems, navigation data, flight plan data, the EICAS, and communication data, which is shown on six displays: two primary flight displays (PFD); two navigational displays (ND); one EICAS display; and one multi-function display (MFD). (Figure 1)

The PFD provides the flight crew with flight information including aircraft attitude, flight modes, airspeed, altitude, vertical speed, and other information.

The FMA annunciations are displayed just above the PFD AFDS status annunciations. The mode annunciations, from left to right are auto-throttle, roll, and pitch. In addition, the EICAS provides information to the flight crew about the primary engine parameters, flaps and flap lever position, landing gear status, and other messages.

The primary engine indications on EICAS are low pressure compressor (LPC) speed (N1% rpm) and exhaust gas temperature (EGT). The secondary engine indications on the MFD include the), high-pressure compressor (HPC) speed (N2% rpm), fuel flow, oil pressure, oil temperature, oil quantity, and engine vibration. Movement of the thrust levers will be indicated on the EICAS with a corresponding change in the engine indications.

In addition, when flap lever is out of the 'up' position, the combined flap and slat positions are indicated on EICAS when all surfaces are operating normally and control is in the primary mode. The indicator shows continuous motion. The indication is no longer displayed 10 seconds after slat retraction. The ND shows the wind speed and direction. Information is also available for the aircraft groundspeed, and the weather radar information.

1.6.10 Boeing 777 radio altimeter and main gear altitude

The radio altimeter measures the distance between the aircraft forward lower fuselage and terrain. Three transceivers and three antennas are installed on the lower fuselage, aft of the nose landing gear.

The system feeds the enhanced ground proximity warning system (EGPWS) with data about the measured distance which will be announced at certain predetermined radio altitudes. Radio altitudes are also used by the A/T system. Additionally, radio altitude is displayed at the bottom of the PFD attitude display.

1.6.11 Crew alerting and configuration warnings

Cockpit warnings are conveyed to the flight crew by visual and aural alerts. The warnings include take-off and landing configuration warnings. In addition, the take-off configuration warning

system warns the flight crew when the aircraft configuration is inconsistent with take-off requirements. A CONFIG message is displayed on the EICAS, together with a master warning (visual and aural). There are no warnings to alert the crew about incompatible FMA modes in relation to the flight phase such as the take-off phase.

A 'don't sink' cockpit alert is generated by the EGPWS system when there is an altitude loss after takeoff or during a go-around. The alert is a function of the height of the aircraft above the terrain. It is triggered by altitude loss with flaps and/or gear up after takeoff or go-around, and stays enabled until the EGPWS computer detects that the aircraft has gained sufficient altitude. The visual and aural alert annunciators remain active until a positive rate of climb is re-established.

No EGPWS warning was triggered during the Incident flight.

1.7 Meteorological Information

The METAR[15] of OMDB reported the following weather information at the time of the Incident:

OMDB 192300Z 18002KT CAVOK 21/15 Q1019 NOSIG

Wind was blowing from the south 180 degrees at a speed of 2 knots. Visibility was more than 10 kilometers. No Cumulonimbus or towering Cumulus clouds below 5,000 feet or minimum sector altitude (MSA), whichever was greater. Temperature was 21°C, and dewpoint at 15°C. The QNH[16] was 1019 hPa (hectopascals), with no significant change.

1.8 Aids to Navigation

The Aircraft was equipped with the required navigational equipment which consisted of global positioning system (GPS), air data inertial reference system (ADIRS), very high-frequency omnidirectional range (VOR) receivers, distance measuring equipment (DME) receivers, instrument landing system (ILS) receivers, transponder, weather radar, and flight management system (FMS) with two flight management computers (FMC), and two automatic direction finders (ADF). All ground and onboard navigation equipment were serviceable.

[15] METAR: Metrological Aerodrome Report, used to transmit weather observation periodically via a dedicated frequency

[16] QNH: The pressure set on the subscale of the altimeter so that the instrument indicates its height above sea level. The altimeter will read runway elevation when the aircraft is on the runway

As per the *OFP*, the standard instrument departure (SID) was SENPA 2F (figure 4), which was tracked by the flight crew for departure. As per the Commander's statement, the crew inserted the information of SENPA 2F SID in the FMC as planned.

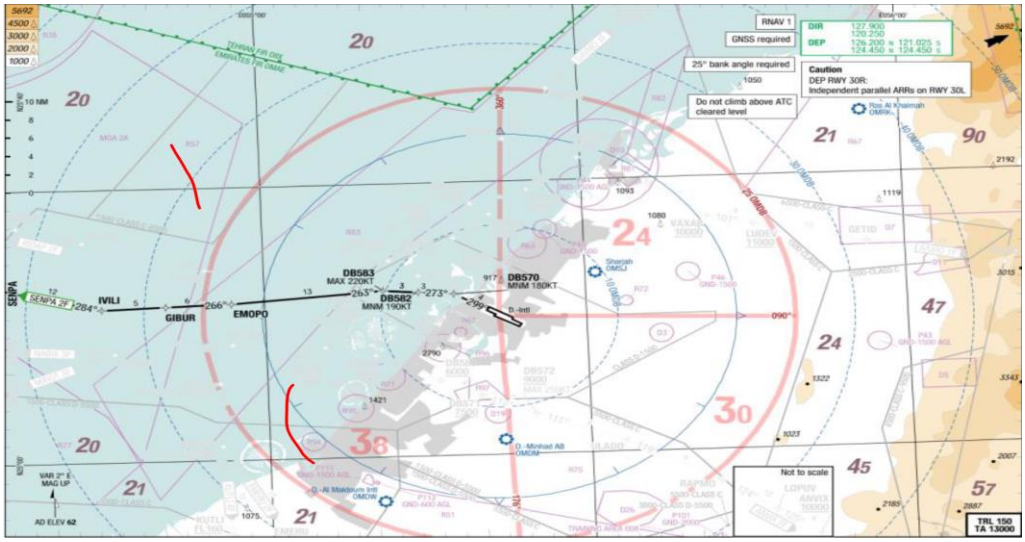


Figure 4. SENPA 2F SID chart

1.9 Communications

All communications between air traffic control and the flight crew were normal.

1.10 Aerodrome Information

Dubai International Airport was certificated by the General Civil Aviation Authority (GCAA) of the United Arab Emirates in accordance with Part IX – *Aerodromes*, of the *Civil Aviation Regulations (CAR)*. The airport is designated four letters code OMDB[17]. Its coordinates are 25°15'10"N 55°21'52"E, and it is located 4.6 kilometers east of Dubai city.

The airport elevation is 62 ft. It is equipped with two asphalt runways: 30R/12L; and 30L/12R. The runway 12L threshold is displaced by 450 meters and the runway 12R threshold is displaced by 715 meters. The runway 12R threshold is 1,880 meters ahead of the 12L threshold. From the centerlines, runways 12L and 12R are 385 meters apart.

Table 3 illustrates the airport general data.

Table 3. Airport general data	
Aerodrome code (ICAO/IATA)	OMDB/DXB
Airport name	Dubai International Airport
Airport class	CAT IIIB[18]
Airport authority	Dubai Airports Company
Airport service	ADC/APP
Type of traffic permitted	Visual flight rules (VFR)/Instrument flight rules (IFR)
Coordinates	251510N/0552152E
Elevation/reference temperature	62 ft/41 degrees centigrade
30R total take-off run available (TORA)	4,300 meters
30R accelerate-stop distance available (ASDA)	4,426 meters
30R take-off distance available (TODA)	4,360 meters
30R runway width 30R stopway	60 meters 126 meters
Category for rescue and firefighting service	10[19]

The color, intensity, dimensions, lateral and longitudinal spacing, and photometric characteristics of the airport lighting comply with the criteria of Part IX of the *Civil Aviation Regulations*, and conform with volume 1, appendix 2 to *Annex 14– Aerodromes*, to the Convention on International Civil Aviation.

1.11 Flight Recorders

The Aircraft was equipped with a solid-state flight data recorder (SSFDR) and a cockpit voice recorder (CVR) as described in table 4.

Table 4. Flight recorders data			
Recorder	Manufacturer	Part Number	Serial Number
SSFDR	Honeywell	980-4750-003	06216
CVR	Honeywell	980-6032-003	06933

[18] Category 3 B: is one category of precision approach categories. That are defined in accordance to Runway Visual Range and Decision Height. For Category 3B the Decision Height is lower than 50 feet or if there is no DH. For the Runway Visual Range, it shall be less than 175 meters and at or above 50 meters

The SSFDR and CVR were received by the AAIS Specialist in Abu Dhabi Flight Recorders Laboratory (AD-FRL) in good condition. The data from the SSFDR was successfully downloaded whereas the CVR was overwritten as more than two hours has passed since the event.

The graphs displayed in figure 5 depict various parameters including flap position, activation of flap load relief, pitch angle, engagement of roll TOGA, radio height, groundspeed, computed (calibrated) speed, flap handle position, engagement of pitch TOGA, and flight director pitch. All of these parameters were analyzed and converted into events that are described in the *History of the Flight*.

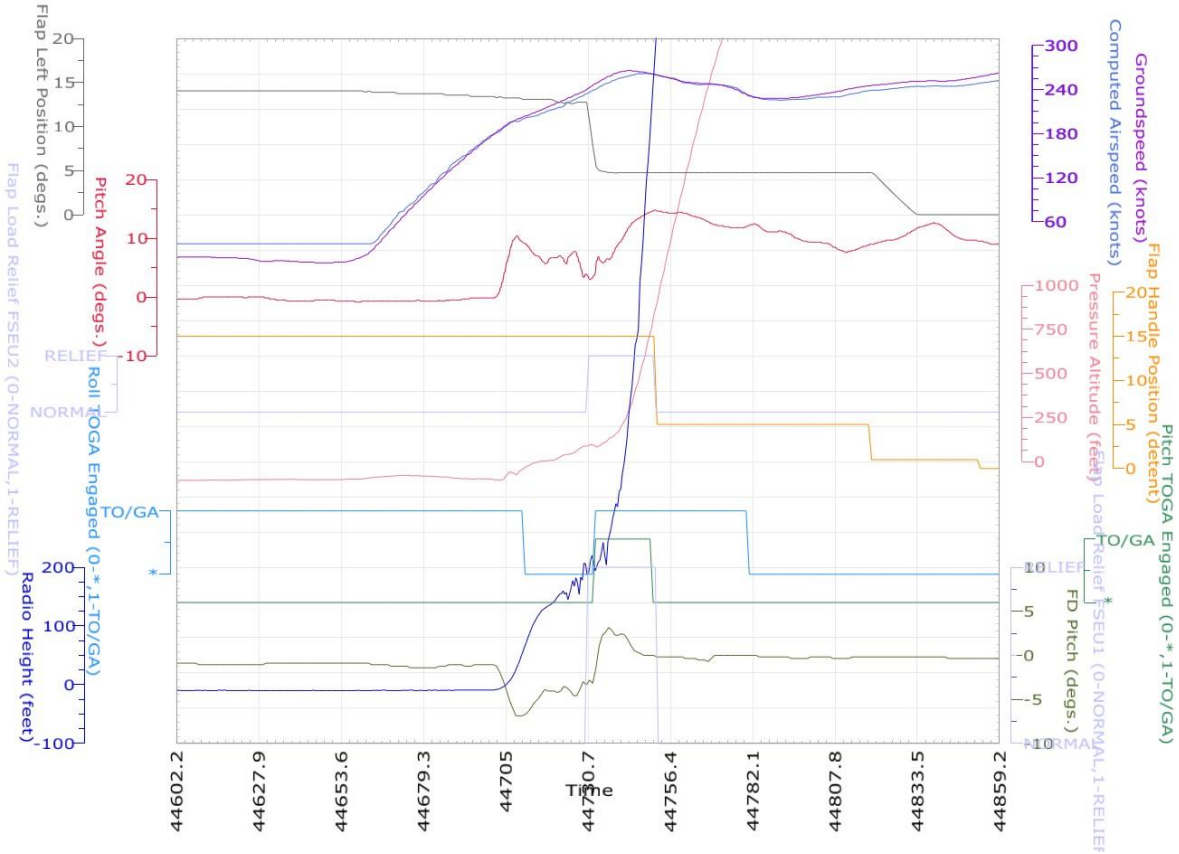


Figure 5. Plots derived from the FDR

1.12 Wreckage and Impact Information

The Aircraft was intact.

1.13 Medical and Pathological Information

There were no psychoactive materials found on the blood test.

1.14 Fire

There was no evidence of fire.

1.15 Survival Aspects

None of the passengers or the flight and cabin crew were injured.

1.16 Tests and Research

1.16.1 Simulator sessions at the Operator's flight simulator

The Investigation carried out a session at the Operator's full flight simulator (FFS)[20] using inputs identical to the Incident flight parameters as recorded by the FDR. The performance data of the Aircraft, along with information about the airfield including runway visual cues and the weather information at the time of the Incident, were utilized to simulate the flight. (Figure 6)

The objectives of the simulator session were to:

- Observe the result of switching one flight director to 'on' in the preflight phase with the altitude selector set to zero runway elevation given that the MCP selected altitude differs less than 20 feet from the displayed barometric altitude after takeoff.
- Confirm that the FMA modes are displaying TO/GA ALT instead of the normal TO/GA TO/GA for takeoff.
- Confirm if the flight director's prompt, when TO/GA ALT is armed, is different from the normal TO/GA TO/GA prompt on the ground.
- Visualize how the flight director prompted a level-off, and what would happen if the flight crew follows it.
- Confirm how the flight crew would exit an ALT pitch mode if it was undesirably engaged.
- Confirm whether an EGPWS warning is triggered during the climb/level-off or not.
- Confirm if the flap load relief is activated during the climb due to the flap over-speed.
- Capture the peripheral external view that the flight crew would have seen after the Commander pitched the Aircraft down based on the flight director's prompt after capturing the ALT pitch mode.
- Observe how the TO/GA power would have helped the Commander exit the situation and what were its consequences.

The simulated flight revealed the following events:

- At parking, the Investigation replicated the Copilot's flight director's reset by switching the Copilot's flight director to 'on', while the Commander's side remained

[20] A full-size replica of a specific type or make, model and series aeroplane flight deck, including the assemblage of all equipment and computer programs necessary to represent the aeroplane in ground and flight operations, a visual system providing an out of the flight deck view, and a force cueing motion system. It is in compliance with the minimum standards for FFS qualification [Source: www.skybrary.com]

'off', with altitude selector at zero runway elevation. The Investigation found that the FMA kept displaying TO/GA ALT.

- The Investigation resembled the Commander's control column inputs during the Incident flight climb[21]. At that time, the V/S was nearly zero and a slight descent was observed. However, the V/S indicator displayed a descent but without displaying a specific numeric value for the magnitude of descent.
- When the Investigation pushed the TO/GA switch, as executed by the Commander during the flight, the airspeed increased and the vertical speed reached 2,100 feet per minute during the climb, the ALT pitch mode of the FMA changed to TO/GA, and the roll mode remained on TO/GA. (Figure 6)
- The flap load relief activated, and master caution triggered aurally and visually. Subsequently, the flaps retracted due to reaching the maximum flap extended speed (V_{fe}) after applying TO/GA.
- There was no EGPWS warning triggered throughout the simulated flight.



Figure 6. Non-typical flight director display for takeoff which was shown during the taxi of the Incident flight

[21] The Commander stated explaining what she did after noticing the pitch down prompt: "I thought that my pitch is higher than the required. Therefore, I lowered the pitch attitude to approximately between five to seven degrees, the flight director indication was still lower than my pitch attitude. I held the pitch there to make sense of what I see"

1.17 Organizational and Management Information

1.17.1 The Operator - general

Emirates was established in March 1985, and was granted air operator certificate (AOC) No. AC-0001 issued by the GCAA.

At the time of the Incident, the Operator's fleet consisted of 253 aircraft comprising of Boeing 777 and Airbus A380 types.

1.17.2 The Flight Crew Training Department

According to the Operator's organizational structure, the conversion training is part of the Flight Training Department responsibilities under the *approved training organization (ATO) manual*. The *ATO manual* was issued in accordance with the organization requirements for aircrew incorporated in the *Civil Aviation Regulations*. The *ATO manual* complied with the *Flight Crew Licensing Regulations*, and with the terms of the AOC. The *ATO manual* is considered part of the *operations manual – part D* (*OM-D*).

1.17.3 Operations during COVID-19

The Operator's fleet activity during COVID-19

The Investigation was provided with the fleet activity during the time of COVID-19 pandemic. It is revealed that the Boeing 777 fleet was not affected by the COVID-19 restrictions enforced in most of the destinations.

The Operator's human factor articles to flight crew during COVID-19

The Human Factor Office of the Operator issued regular articles to the flight crew community during the time of COVID-19. The articles tackled several topics in which the flight crew were facing during that time. For example, it included tips on how to handle stress and maintain positive relationships with colleagues. Also, the articles contained tips on how to maintain an "up-to-date" status with the learning materials and the *SOP* of the Operator, especially for pilots who are grounded and are expected to be called to fly again when needed.

1.18 Additional Information

1.18.1 Preflight preparation

Task sharing in the preflight phase

According to *FCOM − Normal Procedure, Preflight Procedure,* both the commander and copilot are responsible for ensuring that the flight director toggle switch is switched to 'on' in the preflight phase.

FMA verification in the preflight phase

According to *FCOM − Normal Procedure − Preflight Procedure*, the following verification items need to be conducted by the flight crew during preflight to verify that the FMA modes are correctly armed, specifically (figures 2 and 7):

- Indication 1: Autothrottle mode is blank
- Indication 2: Roll mode is TO/GA
- Indication 4: Pitch mode is TO/GA

- AFDS status is FLT DIR.

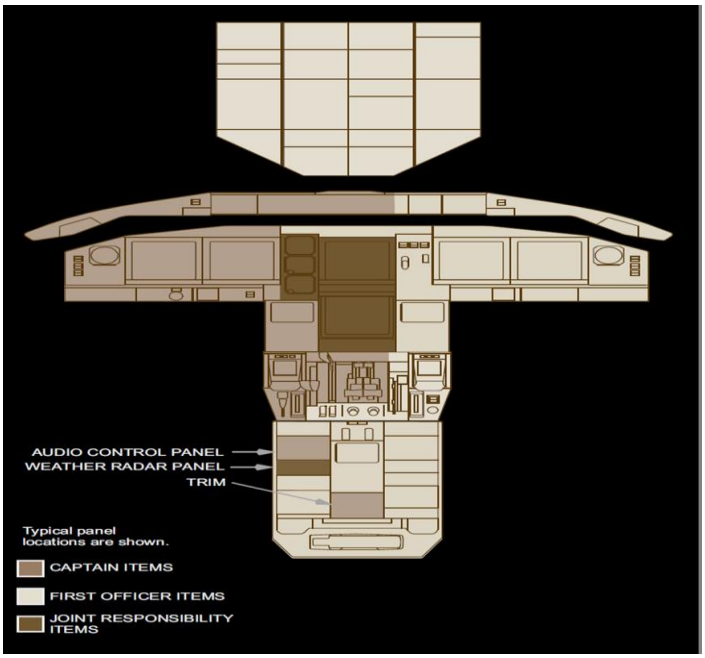


Figure 7. Areas of responsibility when the commander is the PF or the commander is taxiing

There was no requirement in the *FCOM* for the flight crew to announce the FMA modes, and all verifications are accomplished silently.

1.18.2 *Take-off review* procedure removal

Prior to 2019, the Operator's *SOP* included the *take-off review* procedure as part of *before take-off* procedures. The *take-off review* procedure served as a safety measure to verify and crosscheck any errors that could potentially affect performing the takeoff as planned and briefed during the taxi.

The removal of the *take-off review* procedure was an initiative taken by the Operator to align with the manufacturer's procedures and to reduce the flight crew workload during taxi Although a risk assessment was conducted by the Operator to support the decision of the *take-off review procedure* removal, the Investigation believes that the *take-off review* is still necessary if any changes to the departure or performance occur after the preflight procedures have been completed.

1.18.3 Evidence-based training (EBT)[22]

The Operator utilizes EBT to train and assess the pilots' competency. EBT is a modern approach used for training flight crew of turbo-jet aircraft of 50 seats or more, as well as turbo-propeller aircraft with 30 seats or more.

This new approach replaces the traditional method where pilots are required to repeat maneuvers if they are not able to meet the standard level. According to ICAO *Document 9995 − Manual of Evidence-Based Training*, the underlying philosophy of EBT focuses on identifying, developing, and assessing the flight crew based on a specific set of competencies, as follows:

"

- Application of procedures: described as the identification and application of procedures in accordance with published operating instructions and application of regulations using the appropriate knowledge.
- Communications: described as the ability to demonstrate effective oral, non-verbal, and written communications, in normal and non-normal situations.
- Aircraft, flight path management automation: described as the ability to control the aircraft flight path through automation including appropriate use of flight management system(s) and guidance.
- Aircraft, flight path management control: described as the ability to control the aircraft's flight path through manual flight including appropriate use of flight management systems and flight guidance systems.
- Leadership and team work: described as the demonstration of effective leadership and team work.
- Problem solving and decision making: described as the ability to accurately identify risks and resolves problems and by using the appropriate decision-making processes.
- Situation awareness: described as the ability to perceive and comprehend all of the relevant information available and anticipate what could happen that may affect the operation.
- Workload management: described as the ability to manage available resources efficiently to prioritize and perform tasks in a timely manner under all circumstances."

For each of the competencies above, there are behavioral indicators[23] that can be observed to determine the level of each competency as listed in table 5.

[22] Evidence-based training (EBT): Training and assessment based on operational data that is characterized by developing and assessing the overall capability of a trainee across a range of core competencies rather than by measuring the performance in individual events or maneuvers [Source: ICAO: doc 9995]

[23] Behavioral indicator: An overt action performed or statement made by any flight crew member that indicates how the crew is handling the event

Table 5. Competencies and behavioral indicators

Competency	Behavioral Indicators
Application of procedures (P)	– Identifies the source of operating instructions – Follows *SOP*s unless a higher degree of safety – Dictates an appropriate deviation – Identifies and follows all operating instructions in a timely manner – Correctly operates aircraft systems and associated equipment – Complies with applicable regulations – Applies relevant procedural knowledge
Aircraft flight path management, automation (A).	– Ensures the recipient is ready and able to receive the information – Selects appropriately what, when, how and with whom to communicate – Conveys messages clearly, accurately and concisely – Confirms that the recipient correctly understands important information – Listens actively and demonstrates understanding when receiving information – Asks relevant and effective questions – Adheres to standard radiotelephone phraseology and procedures – Accurately reads and interprets required company and flight documentation – Accurately reads, interprets, constructs and responds to datalink messages in English
Aircraft flight path management, manual control (H).	– Controls the aircraft manually with accuracy and smoothness as appropriate to the situation – Detects deviations from the desired aircraft trajectory and takes appropriate action – Contains the aircraft within the normal flight envelope – Controls the aircraft safely using only the relationship between aircraft attitude, speed and thrust – Manages the flight path to achieve optimum operational performance – Maintains the desired flight path during manual flight whilst managing other tasks and distractions – Selects appropriate level and mode of flight guidance systems in a timely manner considering phase of flight and workload – Effectively monitors flight guidance systems including engagement and automatic mode transitions
Communication (C)	– Ensures the recipient is ready and able to receive the information – Selects appropriately what, when, how and with whom to communicate – Conveys messages clearly, accurately and concisely – Confirms that the recipient correctly understands important information – Listens actively and demonstrates understanding when receiving information – Asks relevant and effective questions – Adheres to standard radiotelephone phraseology and procedures – Accurately reads and interprets required company and flight documentation – Accurately reads, interprets, constructs and responds to datalink messages in English
Leadership and Teamwork (L)	– Understands and agrees with the crew's roles and objectives. – Creates an atmosphere of open communication and encourages team participation – Uses initiative and gives directions when required Admits mistakes and takes responsibility – Anticipates and responds appropriately to other crew members' needs – Carries out instructions when directed – Communicates relevant concerns and intentions – Gives and receives feedback constructively – Confidently intervenes when important for safety – Demonstrates empathy and shows respect and tolerance for other people

	– Engages others in planning and allocates activities fairly and appropriately according to abilities. – Addresses and resolves conflicts and disagreements in a constructive manner. – Projects self-control in all situations.
Situation Awareness (S)	– Identifies and assesses accurately the state of the aircraft and its systems. – Identifies and assesses accurately the aircraft's vertical and lateral position, and its anticipated flight path. – Identifies and assesses accurately the general environment as it may affect the operation. – Keeps track of time and fuel. – Maintains awareness of the people involved in or affected by the operation and their capacity to perform as expected. – Anticipates accurately what could happen, plans and stays ahead of the situation. – Develops effective contingency plans based upon potential threats. – Identifies and manages threats to the safety of the aircraft and people. – Recognizes and effectively responds to indications of reduced situation awareness.
Workload Management (M)	– Maintains self-control in all situations Plans, – Prioritizes and schedules tasks effectively. – Manages time efficiently when carrying out tasks Offers and accepts assistance, delegates when necessary and asks for help early. – Reviews, monitors and cross-checks actions conscientiously. – Verifies that tasks are completed to the expected outcome. – Manages and recovers from interruptions, distractions, variations and failures effectively.

1.18.4 Flight crew training and checking forms

According to the Operator's *ATO manual,* the pilots' performance during training and assessment sessions were recorded using the electronic online grading system (OGS) forms. The OGS included both training and examining forms, which evaluators were required to complete after a simulator or a line check. Additionally, the OGS included the pilot assessment marker (PAM), which consisted of nine markers assessing technical and non-technical competencies.

The technical competencies were: knowledge; application of procedures; handling; and use of auto-flight. The non-technical competencies included: workload management; communication; problem solving/decision-making; situational awareness; and leadership/ teamwork/support. A letter identifier was used on the training and examining forms to reflect each competency[24] and was graded based on a five-scale performance grading system. The grades '3', '4', and '5' reflect 'acceptable' level of proficiency, and indicate that the pilot achieved a consistent standard of completion, while retaining an adequate margin of safety. The grades '1' and '2' indicate that the pilot did not meet the required performance standard necessitating remedial actions to be planned by the fleet training manager.

For manual handling simulator training sessions, and as per the *OM-D*, the evaluator was required to complete the OGS form after the completion of the session. However, there was no

requirement to grade the session except when the evaluator sees that the pilot performance is 'not acceptable'.

Upon reviewing the training records of the Commander and the Copilot, the Investigation found that the Commander had successfully completed two operator proficiency checks (OPC) successfully on 12 January 2021 and 14 July 2021. During the OPC conducted on 12 January 2021, the Commander received a grade of '4' in all the nine competencies. The type rating examiner (TRE) provided feedback on the session's form stating that the Commander was well-prepared, displayed a positive attitude, and demonstrated overall competent performance during the evaluation. The feedback also mentioned that the Commander showed knowledge of the fault and understood the potential implications of remaining in icing with flaps deployed, indicating good situation awareness and information management.

In the OPC of the 14 July 2021, the Commander received a grade of '4' in the following competencies: aircraft flight path management − automation (A); workload management (M); situation awareness (S); and problem solving and decision making (D). The Commander received a grade of '5' in the following competencies: knowledge (K); application of procedures (P); communication (C); and leadership and team work (L). The TRE provided a feedback on the session's form stating that objectives achieved. Engine failure after liftoff was very well flown. Elected to engage TO/GA thrust, and immediately ensured LNAV was re-selected. Wind shear escape was accurately and aggressively flown. Good rotation to 15 degrees pitch-up, and assertively advanced thrust levers to full forward. Instrument approaches were very well managed, and completely stable.

For the Copilot, the first OPC was conducted on 24 January 2021, and he received a grade of '4' on the following areas: knowledge (K); application of procedures (P); communication (C); workload management (M); situation awareness (S); problem solving and decision making (D); and leadership. The Copilot received a greed of '5' in aircraft flight path control automation (A) and aircraft flight path management − manual control (H).

The second OPC was conducted on 5 July 2021. The Investigation noticed that the Copilot's evaluation was unsuccessful. The areas in which the Copilot needed improvement were in (M) and (S) areas, in which he received grade '2' indicating that these areas were below the required proficiency standard. The TRE provided a feedback on the OGS form stating that some of the necessary behaviors (to allow prioritization and planning) were observed intermittently and did not meet the desired standard. The TRE provided examples in the feedback, such as allowing flight to progress towards the approach without intervention or considering the available time for setup, as well as instances of reactive rather than proactive behavior, including taking back control and flying the approach.

Furthermore, the Copilot received a grade of '3' in areas D and L. The TRE provided a feedback regarding area (D), acknowledging the Copilot's good decision to go-around when it became apparent that the required final profile could not be achieved. However, the TRE noted that accepting the clearance to start the approach was not the most ideal choice. In area (L), the TRE commented that the Copilot actively involved the other crewmember in all discussions, but there was inconsistency in leadership due to a decrease in the situation awareness (area 'S').

On 6 July 2021, the Copilot performed a reset OPC session with the same TRE. The session was completed successfully, and the TRE provided positive feedback, stating "A productive session with good improvement to an overall advanced exit standard observed." No items from this session needed to be carried forward for further action.

1.18.5 Take-off Performance calculations for the Incident flight

According to the load sheet, the maximum take-off weight (MTOW) was 351.53 tonnes, whereas the planned take-off weight for the flight was 350.579 tonnes (955 kilograms less than the MTOW).

The calculated actual take-off weight (using the manufacturer's calculation software on-board performance tool "OPT" 'figure 8') was 350.1 tonnes (1.4 tonnes less than the MTOW). The calculated take-off speeds were: V_1: 170, V_r:177, and V_2: 183 knots. These take-off performance calculations were correct.



Figure 8. Take-off performance calculation using OPT software

1.18.6 Flight data monitoring (FDM) historical data

The Operator provided the Investigation with a four-year historical data for takeoffs in ALT pitch mode. After reviewing the FDM data, the Investigation observed that there were 31 flights (from January 2018 to December 2021) where the flight director was set at ALT pitch mode.

1.18.7 *Flight crew training manual* (*FCTM*) − *Techniques for Takeoff and Initial Climb*

Initial climb (all engines) technique

The *FCTM* outlines the technique for the initial climb as,

> *"*After lift-off, use the attitude indicator as the primary pitch reference. The flight director, in conjunction with indicated airspeed and other flight instruments is used to maintain the proper vertical flight path. Pitch, airspeed, and airspeed trends must be crosschecked whether the flight director is used or not. After lift-off, the flight director commands pitch to maintain an airspeed of V_2 +15 to 25 knots until another pitch mode is engaged. V_2 + 15 is the optimum climb speed with takeoff flaps. It results in the maximum altitude gain in the shortest distance from takeoff. Acceleration to higher speeds reduces the altitude gain. If airspeed exceeds V_2 + 15 knots during the initial climb, stop the acceleration but do not attempt to reduce airspeed to V_2 + 15 knots. Any speed between V_2 + 15 and V_2 + 25 knots results in approximately the same take-off profile. Crosscheck indicated airspeed for proper initial climb speed."

V_2 is the minimum speed that needs to be maintained up to acceleration altitude in the event of an engine failure after V_1. Flight at V_2 ensures that the minimum required climb gradient is achieved, and that the aircraft is controllable. V_2 speed is always greater than V_{MCA}[25], and facilitates control of the aircraft in flight.

PF and PM task sharing in flight

As per the *FCOM*:

> "the general PM phase of flight responsibilities are:
>
> – Checklist reading;
> – Communications;
> – tasks asked for by the PF;
> – monitoring taxiing, flight path, airspeed, airplane configuration, and navigation.
>
> The mode control panel is the PF's responsibility. When flying manually, the PF directs the PM to make the changes on the mode control panel. The Captain is the final authority for all tasks directed and done."

Pitch attitude after takeoff

As per the *FCOM − Normal Procedure − Takeoff Procedure*, the following is the task sharing for the PF and the PM respectively:

For PF:

> "
> - At V_r, rotate toward 15 degrees' pitch attitude.
> - After lift-off, follow the flight director command."

For PM:

> "
> - At V_r call "ROTATE".
> - Monitor airspeed and vertical speed."

Standard call-out during excessive pitch

As per the *FCOM-Normal Procedure − Standard Callouts*, the standard call-out for excessively high or low pitch in relation to the flight phase is 'pitch'. This means that in case of excessive pitch in relation to flight phase, the phrase 'pitch' is used by the PM to alert the PF about the pitch attitude which would require correction.

1.19 Useful or Effective Investigation Techniques

This investigation is performed pursuant to the United Arab Emirates *Federal Act 20 of 1991*, promulgating the *Civil Aviation Law*, Chapter VII – *Aircraft Accidents*, Article 48. It is in

[25] VMCA: is defined as the minimum speed whilst in the air that directional control can be maintained with one engine inoperative (critical engine on two engine aeroplanes), operating engine(s) at takeoff power and a maximum of 5 degrees of bank towards the good engine(s) [source: www.skybrary.com]

compliance with the *Air Accident and Incident Investigation Regulation (AAIR)*, in conformity with *Annex 13 to the Convention on International Civil Aviation*, and in adherence to the *Air Accident and Incident Investigation Procedures*.

2. Analysis

2.1 General

In the general flight circumstances of the shallow climb Incident, the weather conditions were reported to be normal. There were no significant weather disturbances or adverse conditions that could have contributed to the Incident. The flight took place during the night, with conditions within the expected range for nighttime operations.

The airport marks and signage were found to be in normal condition during the Incident. This indicates that there were no issues with runway markings, taxiway signs, or other navigational or visual aids that could have caused confusion or contributed to the Incident. The crew would have had clear guidance and reference points to navigate the Aircraft safely on the ground.

The Aircraft's navigation systems were functioning normally. This suggests that there were no technical malfunctions or anomalies in the navigation equipment that could have affected the flight path during the initial climb. The crew would have had accurate and reliable information regarding the Aircraft's position, heading, and altitude, enabling them to make informed decisions during the flight.

Additionally, the communication between the crew and air traffic control was reported to be normal, indicating that there were no issues or misunderstandings in the exchange of information.

2.2 ALT Pitch Mode Engagement

The Boeing 777 flight mode annunciator (FMA) consists of three indications (1, 2, and 4 in figure 2): autothrottle mode; AFDS roll mode; and AFDS pitch mode. The typical AFDS pitch mode for takeoff is TO/GA, which ensures accurate pitch guidance from the flight director for takeoff and initial climb.

During the Incident flight, when the flight director on the Copilot's side was turned ‘on', the AFDS pitch mode set to ALT. This occurred because the altitude on the mode control panel (MCP) was set to zero, which is within 20 feet of the displayed barometric altitude. The Investigation did not carry out a detailed analysis of how the zero altitude (00000) was entered on the MCP. Hence, the Investigation could not determine who made that entry. Sometimes flight crewmembers use unconventional methods to remind themselves and the subsequent crews about certain actions[26]. The 777 *flight crew operations manual (FCOM)* states that the MCP altitude window is set to the 'initial altitude' *in the Normal Procedures − Amplified Procedures − Before Start Procedure.*

The AFDS design did not include any provisions to prevent a takeoff with incorrect AFDS pitch mode. As designed, the AFDS ALT pitch mode activates on the ground once either side flight director switch is switched ‘on’ while the MCP Altitude window is within 20 feet of the displayed barometric altitude. The Investigation did not examine whether the Aircraft manufacturer had performed a risk assessment for identifying the need for integrating a feature in the design of the

[26] Examples for such common non-standard practices in addition to pre-selecting MCP altitude to zero ‘00000 feet’ as a reminder to obtain the initial climb clearance, is the typing of the frequency in the so-called “scratch pad” of the flight management system (FMS) as a confirmation/reminder of the frequency digits

AFDS to detect the incorrect selection of AFDS pitch mode for takeoffs, and also enable the flight crew to take measures for rectification during the take-off roll or in the initial climb.

2.3 Flight Directors Reset Procedure

As per the design, if the altitude set on the MCP on the ground differs by more than 20 feet from the barometric altitude, the ALT pitch mode will not switch to TO/GA if both flight director switches are 'on' and only one flight director is reset. To activate the TO/GA pitch mode, the MCP altitude must be adjusted on the ground to differ by more than 20 feet from the current barometric altitude followed by a flight director reset. If both flight directors are 'on' then both flight director switches must be toggled to 'off'' prior to toggling either one or both flight director switches back to 'on' to complete the reset and activate TO/GA pitch mode.

The Investigation found that the *FCOM* provided information about the need to switch both flight directors, but it was only mentioned in the *FCOM, Controls and Indicators, 4.10.1 – AFDS System Controls,* and there were no clear instructions for the flight crew to follow. This lack of specific instructions likely led to the Copilot not realizing the need to reset the Commander's flight director after completing his own. The Copilot stated that this step slipped from his mind. Even if the Copilot realized the need to reset the Commander's flight director, the Copilot was likely not feeling empowered from the SOP point of view to change the altitude on the MCP altitude selector. In the context of two-crew operations, both pilots have individual and collective responsibilities. In this scenario, the Copilot could have adjusted the altitude selector if he sought agreement from the Commander.

2.4 *Before Taxi* Checklist

The *before taxi* checklist does not specify any steps to ensure that the correct take-off FMA indications are displayed.

The *before start* procedure *in the FCOM* states that the "initial altitude" needs to be set in the MCP[27] by the Commander, and the Copilot must verify it. While the 777 *FCOM − Preflight Procedure – Captain*, contains the ALTITUDE increment selector on the MCP, it also states, "The Captain normally does this procedure. The First Officer may do this procedure as needed." Verification of the correct FMA roll and pitch modes annunciation (TO/GA | TO/GA) is required to be made by the Commander and Copilot as per the preflight procedure in the *FCOM*.

Since calling out the FMA mode is not mandatory, it is possible that inconsistent settings go unnoticed by both flight crewmembers. Following the Incident, the Operator took safety measures by improving the *normal* procedure by including an FMA check that necessitates an announcement in addition to verification.

2.5 Removal of *Take-Off Review* Procedure

In the past, the Operator had a procedure for *take-off review* conducted during taxi out that included reviewing the AFDS modes to be used for departure. This procedure was not a Boeing procedure, and was eliminated on 18 July 2019 as part of a project to reduce the workload of the

[27] The MCP altitude is usually either the initial climb clearance outlined in the SID chart. This can be changed by the ATC instructions while obtaining the Departure Clearance which is mostly done at the parking stand

flight crew during the critical taxi phase and align with the manufacturer's procedure. According to the Operator's data for all variants of B777, there were a total of 12 from 214,224 takeoffs with the ALT pitch mode engaged between 1 January 2018 and 18 July 2019. After the removal of the *take-off review* procedure, this number increased to 19 from 244,135 takeoffs up to 31 December 2021. Based on the data, two statistical tests were carried out by the Operator, and confirmed by the Investigation.

The first test was made by comparing the two groups, group 1 from 1 January 2018 up to 18 July 2019, and group 2 from 19 July 2019 up to 31 December 2021. The P-value results were 0.3704 for group 1 and 0.3788 for group 2.

The second test was made by isolating the period to six months before and after the removal of the take-off review procedure. In this case, group 1 had a total of 3 takeoffs in ALT mode from 64,793 takeoffs between the period of 19 January 2019 and 18 July 2019. Group 2 had a total of 9 takeoffs in ALT mode from 69,247 takeoffs in the period from 19 July 2019 up to 18 January 2020. The P-value results were 0.1057 for group 1 and 0.1157 for group 2.

The results of both analyses revealed that the P-values are greater than 0.05, which is no statistically significant difference between the two rates of the groups. To determine whether the results were influenced by chance, each test evaluated their significance. Statistically, a significance level of 0.05 is the accepted norm to infer that a result is likely due to a hypothesized reason, like the removal of the take-off review procedure. If the level is above 0.05, it implies that chance cannot be discounted.

While in both tests, the probability values of incidents after the elimination of the take-off review procedure increased in comparison with the ones before the elimination, the important measure is whether the result is considered statistically significant. In this case, no significant difference was found in the probability of takeoffs in AFDS ALT pitch mode in either test. Hence, the Investigation is not possible to conclusively determine that the removal of the take-off review procedure caused the apparent increase in AFDS ALT mode take-off events' rate.

2.6 Flight Crew Performance

2.6.1 The Commander

The Commander noticed that the altitude selected on the MCP indicated zero (00000). The Commander did not identify the incorrect AFDS pitch mode, "TO/GA | ALT" instead of "TO/GA | TO/GA" on the FMA, instead, she recognized the green indications. Color recognition is not considered in the procedure when verifying the modes on the FMA. While green indicates active modes and white indicates armed modes, the flight crew is expected to note the title of the active mode as per the procedure rather than its color. This instance can be considered as inattentional blindness that could have been caused by distraction or expectation bias[28]. Inattentional blindness

[28] Expectation bias occurs when a pilot hears or sees something they expect to hear or see, rather than what actually may be occurring

is the failure to notice a fully visible, but unexpected object because attention was engaged on another task, event, or object[29].

Distraction is a significant hazard for flight crew, and managing it is a key skill taught in flight training. However, high levels of distraction during the pre-flight phase remain a threat. Despite efforts to reduce it, distraction still disrupts the completion of essential pre-departure checks. It prolongs tasks and increases the risk of tasks being left unfinished or completed with errors. Managing distractions requires practice and can result in undesirable long-term outcomes, such as crew workarounds and other compensatory behaviors. The need to save time may have caused the Commander to subconsciously automate the flight instruments check, resulting in less diligence. The flight crew statements indicate that high distraction levels, especially for the Commander, during the pre-flight phase may have negatively impacted her performance.

In addition to overlooking the incorrect AFDS pitch mode, the Commander did not notice the visual cues of the FD pitch bar being on the horizon instead of eight degrees nose-up. With pressure to achieve on-time performance and distractions in the flight deck, it's plausible that the Commander's focus was diluted, resulting in a shorter examination of the FMA and seeing what was expected rather than what was actually there. The FMA might have been observed but not properly noted. Therefore, the misinterpretation of the FMA was probably due to both factors and importantly, not unique to this flight.

Dealing with time pressure and managing distractions are seen as a regular part of the crew's duties. It is probable that, for the Commander, checking the flight instruments was an automatic action rather than a deliberate, rule-based check. Checking the flight instruments requires reading various display parts and interpreting the information in relation to the anticipated flight departure. Without a specific switch to press, dial to adjust, callout or crosscheck to perform, or awareness of the risks of not doing the check carefully, it's easy to fall into the habit of just glancing at the screen instead of reading it thoroughly. The habit of not reading the PFD carefully may have developed over time, strengthened by experiences where nothing went wrong. Therefore, this behavior was an unnoticed risk for the Commander. Since the exterior inspection was delegated, the Commander probably activated the FDs initially, although the Investigation could not confirm this. The inadequate check of the flight instruments by the Commander meant that the Copilot's subsequent check of the flight instruments and effort to resolve the ALT pitch mode issue did not yield success.

The Commander’s behavior suggests that checking the FMA mode was considered a ‘routine’ task that would not require careful attention to details. The Operator’s fatigue assessment for the Commander, the examination of the roster, and the statement provided by her indicated that fatigue was not a factor in her degraded situation awareness during the preflight phase.

Upon reviewing the Commander’s training records, no comments were found indicating a trend of errors. The type rating examiner (TRE) did not make any comments during the operator proficiency checks (OPC) conducted in January and July 2021. The grades received by the Commander during these checks indicated that she performed at a satisfactory level.

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[29] Daniel J. Simons, Melinda S. Jensen, ‘*The effects of individual differences and task difficulty on inattentional blindness*‘, Psychonomic Bulletin & Review, 2009, page 398-403

After the Aircraft took off, the FMA displayed a prompt to pitch down as result of the engagement of ALT pitch mode. The Commander was surprised by this unexpected indication and attributed that to the heavy take-off weight. She also had doubts about the validity of the indication. However, in order to achieve a more balanced solution, while the flight director indicated pitch-down command of 6.9 degrees, the Commander adjusted the pitch attitude when passing through 10.4 degrees pitch-up. She lowered the pitch to a level that she deemed reasonable (from her perspective) within the range of 5 to 7.7 degrees and maintained it for about 15 seconds in order to better understand the situation. This occurred despite the low rate of climb, increasing airspeed, and directive voice interventions from the Copilot and the augmenting pilots. Instead of disregarding the flight director's indication and setting a pitch attitude appropriate for takeoff (towards 15 degrees), the Commander became confused by the FD pitch bar, paused the rotation at 10.5 degrees nose-up, and then lowered the pitch, leading to the previously described events. The Commander's action could be classified as a skill-based error[30] and serves as an example of habit capture. Skill-based errors arise when actions are performed through automatic or well-rehearsed sensorimotor routines, which are mostly carried out without conscious awareness. The intention to rotate the Aircraft towards 15 degrees was disrupted by the habit-based inclination to follow the flight director. However, the flight director's indication was not normal, causing confusion.

The Commander reduced the pitch attitude abruptly from about 7.7 to 3 degrees nose-up. It was noted that the nose-down control inputs made by the Commander required a large amount of force on the control column. Following a normal rotation and liftoff, the primary flight computers (PFCs) adjust the horizontal stabilizer to maintain a trim reference speed of V2+15 to 25 knots. This trim reference speed represents the speed at which the Aircraft would eventually stabilize without any control column input. The Commander's efforts to pitch the nose down were counteracted by the pitch trim system, necessitating significant and escalating force to counteract. This Commander's action was an inappropriate (counter-intuitive) response related to approaching the red bar on the PFD speed scale (speed limit for flaps 15). The Commander would be expected to increase the pitch attitude to reduce the airspeed and therefore prevent an overspeed condition. However, raising the pitch attitude to slow down the airspeed could have appeared counter-intuitive to the Commander. When in a state of stress, the Commander might have instinctively thought that lowering the nose to reduce speed makes more sense. This situation is another instance of habit capture, where the instinctive response to pitch away from the red bar, as made during a TCAS Resolution Advisory maneuver, is incorrectly applied since in this case, the red bar represents an overspeed warning rather than a TCAS RA.

According to the standard operating procedure (*SOP*), it is necessary for the pilot flying (PF) to rotate toward 15° pitch attitude, at V_R. After liftoff, follow the F/D commands. Regarding the initial climb, the *FCTM* provides the following guidance: "V2+15 knots is the optimum climb speed with takeoff flaps. It results in the maximum altitude gain in the shortest distance from takeoff. Acceleration to higher speeds reduces the altitude gain. If airspeed exceeds V2+15 knots during the initial climb, stop the acceleration but do not attempt to reduce airspeed to V2+15 knots. Any speed between V2+15 and V2+25 knots results in approximately the same takeoff profile. Crosscheck indicated airspeed is required for proper initial climb speed. The attitude indicator is used as the primary pitch reference, after liftoff. The flight director, in conjunction with indicated

[30] Jens Rasmussen, '*Skill, Rules, and Knowledge: Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models*', 1983

airspeed and other flight instruments is used to maintain the proper vertical flight path. Pitch, airspeed, and vertical speed trends must be crosschecked whether the flight director is used or not. This is crucial to maintain a safe take-off profile.

According to the crew's statements, reaching the flap 15 limit speed likely coincided with directive interventions from the Copilot and the augmenting pilots, since the CVR was overwritten, the exact timing could not be determined. However, the crew's interventions, combined with the confusing FD pitch indications, could have startled the Commander and caused cognitive overload, potentially resulting in inappropriate Aircraft control and delayed corrective actions. The startle response is known to trigger involuntary physical reactions; therefore, the verbal interventions might have further exacerbated the nose-down pitch input. Shortly after the inappropriate nose-down inputs brought the Aircraft to its lowest pitch attitude of about 3 degrees up, the TO/GA switch was pushed which restored the FD pitch guidance in TO/GA mode, causing the pitch bar to indicate a climb. The Commander followed the pitch guidance and the autopilot was engaged.

Several roll (lateral) inputs of more than 15 degrees were made by the Commander, although, there were no significant tailwind changes. Thereafter, TO/GA thrust was selected leading to a valid AFDS pitch guidance, and the Commander followed the flight director pitch bar by applying the correct pitch control column input. The speedbrake lever was moved twice as the airspeed neared the flap 15-speed limit, and once during the overspeed event before the autopilot was engaged, however, the speedbrakes did not deploy. These speedbrake lever movements suggest instances of confused thinking where deploying the speedbrakes was considered necessary to resolve the speed issue, but the actions were not fully carried out. These two different actions, the roll inputs and the movements of speedbrake lever, were further indications of the Commander’s stress condition. The magnitude of over-controlling observed, likely influenced by acute stress, indicates that the Commander may have been operating beyond her capacity to manage the situation, resulting in impaired fine motor skills.

The Investigation examined the flying records of the Commander and noted that the last flight involving a takeoff close to maximum take-off weight occurred in May 2021. The Investigation determines that that a seven-month gap between two such takeoffs is not a contributing factor to the Incident. The Commander’s statement, “[I] have not flown an aircraft that is close-to-maximum-structural-weight for a while,” indicates a skill fade[31] of not flying a takeoff with a weight close to maximum take-off weight for an extended period of time.

From training perspective, after reviewing the training file of the Commander, the Investigation found that the Commander had not received any training on how to identify and handle an incorrect flight director indication after takeoff. Additionally, the manufacturer's manuals did not provide any specific procedures for responding to an invalid flight director indication.

2.6.2 The Copilot

The Copilot stated that he tried to reset the flight directors, but was unsuccessful because switching the flight director from 'off' to 'on' on one side does not reset the flight director. The Copilot planned to inform the Commander about this issue when she returned, but he “forgot” due to being occupied with other tasks in the cockpit. The Copilot's inability to remember the procedure

[31] Skill fade: is defined as the decay of ability or adeptness over a period of non-use

may be attributed to the busy environment in the cockpit. The absence of instructions regarding this procedure in the *FCOM* prevented the crew from recalling an important step during the preflight preparation, especially considering that a relevant caution in the checklists could have been easily noticed by the crew with a quick glance.

The Investigation believes that with a deeper understanding of the systems, the Copilot would have recognized that ALT mode was not appropriate for takeoff, potentially prompting him to prioritize informing the Commander despite other distractions. However, the exact cause, whether related to knowledge, distraction, or another factor, remains uncertain. Another possibility factor is automation complacency. Given the confidence gained from positive experiences with the automation systems on the aircraft type, it stands to reason that on a proven and reliable aircraft like the B777, the automation systems are designed to ensure that incorrect vertical guidance configurations, which could lead to unsafe conditions during takeoff, are not possible. Given this perspective and without a detailed understanding of the system, ALT mode might have been perceived as a mode of negligible significance.

The Copilot stated that he moved the landing gear lever to ‘up’ and then looked outside where he noticed a “different picture” than usual. He observed that the speed was increasing and the Aircraft was very close to the ground. He stated, “I got startled for a couple of seconds, then I shouted: climb, and the augmented captain shouted: pitch up.” According to him, he almost was about to take control from the Commander, but noticed that she had already activated the TO/GA switches, causing the flight director to revert to TO/GA TO/GA pitch mode as indicated by the FMA, and the Aircraft started to climb. According to the flight data recorder, at the time the TO/GA was activated, the vertical speed was +64 feet per minute, the height was 211 feet RA, and the calibrated airspeed was 240 knots.

The Investigation determines that the call-out made by the Copilot to alert the Commander about the excessively low pitch attitude during the initial climb did not adhere to the standard call-outs that should be used for this purpose. The Commander’s situational awareness degradation would not have been visible to the Copilot until the moment the flight deviation became apparent. At that moment, the Copilot could have experienced startle (as per his statement), which would have prevented a swift and assertive takeover.

In the case of the Copilot not being startled, there are other possibilities of the Copilot's non-assertiveness that could be the reason. In order to intervene and take over control, the Copilot must possess high situational awareness, expertise, and confidence in his ability to restore the situation. He must also be capable of overcoming cultural and societal obstacles, like respect for elders or higher-ranking individuals. He needs to feel empowered by the Commander to ensure he is not hindered by fear of repercussions. The most challenging one is that copilots (first officers) lack experience as flying instructors or captains (commanders) of multi-crew aircraft, and thus have never had to assume control from another pilot. All these factors differed from what is typically expected during simulator training, where pilot monitoring (PM) intervention is emphasized in such situations. In the simulator, there is a shared understanding of the training objective and a mindset that intervention will be necessary. However, in operational scenarios, intervention is not usually anticipated, and the mentioned various barriers may impede prompt action. As in this Incident, since the Commander did not properly control the Aircraft, the Copilot should have taken over, however, considering these factors, the delay can be seen as reasonable.

2.6.3 The augmenting crew

The presence of the augmenting crew in the cockpit contributes to the overall safety of the flight. According to the *operations manual – part A* (*OM-A)*, the augmenting crewmembers are expected to actively participate in flight deck briefings, closely monitor the flight path, ATC

communications, and the actions of the PF and PM. The preferred location for active monitoring is the first observer seat. Additionally, as stated in the *OM-A*, if any operationally relevant threats or errors are observed, the additional flight crewmembers are responsible for promptly bringing them to the attention of the operating crew. This allows the operating crew to take the necessary steps to mitigate or rectify the situation.

During normal operations, the augmenting crewmembers are expected to conduct the exterior walkaround and prepare the bunk for crew rest. However, during the preflight preparation of the Incident flight, the augmenting commander occupied the first observer seat behind the Commander's and Copilot's seats, which required him to frequently stand up and make room for the maintenance engineers and ground handling staff entering the cockpit. The augmenting crew's role is more active when they are seated. Consequently, it is less likely for the augmenting crew to provide feedback to the operating flight crew regarding the FMA during the preflight phase. This is because the augmenting crew's seat is located behind the operating flight crew, and their continuous movement to accommodate incoming personnel may cause them to easily miss important information displayed on the FMA.

The augmenting commander notified the Commander by saying, "pitch up" to alert her about the pitch attitude being excessively low during the initial climb. This call-out followed the standard call-out outlined in the *FCOM*.

3. Conclusions

3.1 General

From the available evidence, the following findings, causes, and contributing factors were determined with respect to this Incident. These shall not be read as apportioning blame or liability to any particular organization, or individual.

To serve the objective of this Investigation, the following sections are included in the Conclusions heading:

- **Findings.** Statements of all significant conditions, events or circumstances in this Incident. The findings are significant steps in the Incident sequence but they are not always causal nor do they indicate deficiencies.
- **Causes.** Actions, omissions, events, conditions, or a combination thereof, which led to the Incident.
- **Contributing factors.** Actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the Incident occurring, or mitigated the severity of the consequences of the Incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

(a) The Aircraft was certified, equipped, and maintained in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The Aircraft records indicated that it was airworthy when released for the flight.

(c) There were no technical malfunctions or anomalies in the Aircraft's navigation system that could have affected the initial climb profile.

(d) As designed, the AFDS did not include any provisions to prevent a takeoff with incorrect AFDS pitch mode. The ALT pitch mode activates on the ground if either side flight director switch is toggled to 'on' while the MCP selected altitude is within 20 feet of the displayed barometric altitude.

(e) To activate the correct AFDS TO/GA pitch mode, the mode control panel (MCP) altitude must be adjusted to be more than 20 feet different from the barometric altitude followed by resetting the flight director by toggling both flight director switches to "off" and setting either one or both flight director switches to 'on'.

(f) During the pre-flight preparation before the flight director was switched 'on', the selected altitude setting on the MCP indicated '00000' which is within 20 feet of the displayed barometric altitude.

(g) The cockpit voice recorder (CVR) was overwritten and could not be utilized for the Investigation.

(h) Following the Incident, the manufacturer took safety action by communicating this event to the affected fleets by publishing a *Fleet Team Digest (FTD)* article and by initiating the development of software updates.

3.2.2 Findings relevant to the flight crew

(a) The flight crewmembers were licensed and qualified for the flight in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) Both flight crewmembers were fit for the flight.

(c) The Commander acted as the pilot flying (PF) and the Copilot was the pilot monitoring (PM).

(d) The Commander's last flight before the Incident with heavy take-off weight, which was close to the maximum take-off weight, was before seven months from the Incident.

(e) The seven months elapsed time between the last heavy take-off weight flight and the Incident flight would not fade the Commander’s flying skill.

(f) The Operator’s fatigue assessment for the Commander, the examination of the roster, and the statement provided by her indicated that fatigue was not a factor in the degraded situation awareness during the preflight preparation or initial climb phases.

(g) Upon reviewing the training records of the Commander, no comments were found indicating a tendency for slip errors or any development of such errors.

(h) The Commander and the Copilot did not receive training on identifying and handling indications resulting from incorrect flight directors’ settings.

3.2.3 Findings relevant to the flight operations

(a) The weather conditions were normal. The flight took place during the night, with conditions within the expected range for nighttime operations.

(b) The airport's visual and navigational aids were functioning normally.

(c) The communication between the crew and air traffic control was normal indicating that there were no issues or misunderstandings in the exchange of information.

(d) The Commander did not carry out an effective check of the flight instruments and missed the incorrect AFDS pitch mode activation during the pre-flight checks.

(e) It is probable that the Commander did not identify the incorrect AFDS pitch mode and inappropriate altitude entry due to experiencing inattentional blindness that could have been caused by the pressure to achieve on-time performance and distractions.

(f) The Copilot noticed the incorrect AFDS pitch mode activation but could not rectify it and did not bring it to the Commander’s attention during the pre-flight checks.

(g) The ALT pitch mode was active from before engine start up to the initial climb, and the Commander followed the ALT pitch mode flight director pitch cue during the initial climb. She was surprised by this unexpected indication and attributed that to the heavy take-off weight.

(h) In order to achieve a more balanced solution, the Commander adjusted the pitch attitude to a level that she deemed reasonable, from her perspective.

(i) The Copilot got “startled” when he observed that the speed was increasing and the Aircraft was very close to the ground.

(j) The call-out made by the Copilot to alert the Commander about the excessively low pitch attitude during the initial climb did not adhere to the standard call-outs that should be used for this purpose.

(k) The Copilot’s involvement in the situation was minimal, and his response to taking controls was not assertive.

(l) The augmenting commander notified the Commander by saying, “pitch up” to alert her for the pitch attitude being excessively low.

(m) The Commander pushed the TO/GA switch on the throttle control stand to exit the ALT pitch mode, and the Aircraft responded as designed. However, during this process, a second occurrence of exceeding the maximum flap extended speed (V_{fe}) took place.

(n) The Commander continued the flight towards the destination as PF.

3.2.4 Findings relevant to the procedures

(a) The checklist for the Boeing 777-300 ER did not specify any steps to ensure that the correct take-off AFDS pitch mode will activate.

(b) The typical AFDS pitch mode for takeoff is TO/GA, which ensures accurate pitch guidance from the flight director for takeoff and initial climb.

(c) The *FCOM* did not contain explicit instructions on how to reset the flight directors in order to enable the crew to select the correct pitch mode. The *FCOM* only mentioned both pilots resetting the flight directors in the *Controls and Indicators* description (Volume 2 – *Systems Information*), not the procedures (Volume 1 – *Operational Limitations, Normal and Supplementary Procedures, and Dispatch Performance Data*).

(d) The *FCOM – Preflight Procedure* did not require the flight crew to announce and cross check the flight mode annunciator (FMA) mode status.

(e) The *flight crew training manual (FCTM)* provided guidelines for verifying the validity of the flight director’s data by *cross-checking* the pitch, airspeed, and vertical speed.

(f) Following the Incident, the Operator took safety measures by improving the normal procedure by including an FMA check that necessitates an announcement in addition to verification.

3.3 Causes

The Air Accident Investigation Sector of the United Arab Emirates (AAIS) determines that the cause of the shallow climb Incident was the pitch down below the required pitch attitude required for achieving a positive and safe rate of climb. The Commander followed flight director commands reflected in the flight mode annunciator (FMA) that were not appropriate for the takeoff flight phase. The inappropriate pitch flight director commands were a result of incorrect AFDS pitch mode setting in the flight director that went unnoticed by the flight crew.

3.4 Contributing Factors

The contributing factors to the Incident are:

(a) As designed, the AFDS did not include any provisions to prevent a takeoff with incorrect AFDS pitch mode. The ALT pitch mode activates on the ground once either side flight directors is switched 'on' and the selected altitude is within 20 feet of the displayed barometric altitude.

(b) The Commander did not identify the incorrect AFDS pitch mode and inappropriate altitude entry that could have been caused by the pressure to achieve on-time performance and distractions during preflight phase.

(c) The Copilot, as the pilot monitoring, was aware of the incorrect AFDS pitch mode activation, however, he could not rectify it and did not bring it to the Commander's attention.

(d) The *FCOM* did not contain explicit instructions on how to reset the flight directors in order to enable the crew to select the correct pitch mode. The *FCOM* only mentioned selecting an MCP altitude more than 20 feet from the displayed baro altitude and recycling the flight director switches in the Controls and Indicators description (Volume 2 – *Systems Information*), not the procedures (Volume 1 – *Operational Limitations, Normal and Supplementary Procedures, and Dispatch Performance Data*).

4. Safety Recommendations

4.1 General

The safety recommendations listed in this Report are proposed according to paragraph 6.8 of *Annex 13 to the Convention on International Civil Aviation*, and are based on the conclusions listed in part 3 of this Report. The Air Accident Investigation Sector of the United Arab Emirates (AAIS) expects that all safety issues identified by the Investigation will be addressed by the receiving States and organizations.

4.2 Safety Actions

The Operator took safety actions after the Incident as follows:

(a) Added a new FMA check in the *SOP* to allow the flight crew to capture errors in AFDS modes.

(b) Implemented a Flight Operation Data Monitoring (FODM) oversight to monitor errors in the AFDS and/or shallow angle of climb during the takeoff.

(c) Flight crew were communicated and reminded of the criticality of compliance with *SOP*.

(d) The current recurrent training has a full module dedicated to intervention.

The Manufacturer took safety actions after the Incident as follows:

(a) Released *Fleet Team Digest* articles 777-FTD-22-23001 and 787-FTD-22-23001 that inform operators' flight operations organizations of this event as well as ALT pitch mode engagement on the ground and the importance of following *FCOM/FCTM* guidance regarding TOGA/TOGA FMA indications prior to takeoff and rotation at VR towards 15 degrees of pitch attitude during takeoff.

(b) Initiated development of updates to 777 Flight Control Computer (FCC) and 787 Flight Control Electronics (FCE) software to inhibit transitions from takeoff pitch mode to other modes while on the ground.

(c) Initiated development of Alert Service Bulletins to implement the above software updates as part of expected FAA Airworthiness Directive (AD) actions that have yet to be released.

4.3 Safety Recommendations

4.3.1 Emirates

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The Investigation could not determine who set the MCP altitude window to '00000'. However, the *flight crew operations manual (FCOM)* does not specify any particular action to be taken on the MCP altitude window when the aircraft is on the ground.

Therefore, the Investigation recommends that the Operator issues a notice to the pilots not to set the altitude on the MCP at the runway elevation. This is to avoid the possibility of any errors committed by the next crew during departure, as they may unintentionally maintain the previously entered altitude.

This Report is issued by:

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